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Radiation Mayhem

An idle city-building exergame aiming to motivate players to be more physically active

Master's thesis in Computer Science / Informatics
Supervisor: Professor Alf Inge Wang
June 2023

NTNU
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Abstract

This master's thesis is part of the Game Technology for Health (GT4H) network at the Norwegian University of Science and Technology (NTNU). Due to the prevalence of sedentary lifestyles, global overweight and obesity rates have increased over the last 30 years, and prognoses show it will continue to increase in the upcoming years. Increasing people's levels of physical activity and exercise is essential to combat this trend. One way of achieving this can be through *exergames*, which are games that combine video game gameplay with physical activity.

This thesis aims to develop and evaluate an exergame that increases player motivation for and level of physical activity. The process started with a literature review with two objectives. The first was to explore the existing research on exergames to discover if there were any research gaps in the field. The second was to better understand relevant topics in physical health and motivation, game enjoyment and game engagement. We also investigated game genres, existing exergames, and technologies that could be used when creating exergames.

The findings in the literature review ended with creating the game concept *Radiation Mayhem*. Radiation Mayhem is an idle city-builder exergame for mobile where players must collect resources to build, expand, and protect a community against encroaching radiation. In many mobile games, players must pay for more resources and faster game progress through microtransactions. Radiation Mayhem replaces microtransactions with physical activity. While players get some resources from their community, they can get extra by completing quests. To complete quests, players must reach the quest's physical activity goals. When a quest is completed, players get extra resources, which enables faster game progress.

Radiation Mayhem was created using the Unity game engine with Firebase as the backend solution. It was developed for Android and iOS devices, enabling a larger test group. The test group consisted of 53 participants who tested the prototype over a two-week period, where the goal was to discover how playing the game impacted the participant's motivation and level of physical activity. Research data was collected through questionnaires, interviews and data generated by the game during the testing.

The results show that playing Radiation Mayhem positively affected the player's motivation for, and level of, physical activity regardless of their previous levels of motivation, physical activity, or experience with video games and gaming. Using physical activity as a replacement for microtransactions to get quicker in-game progress was a success, motivating players to be more physically active.

Sammendrag

Denne masteroppgaven er en del av Game Technology for Health (GT4H) nettverket ved Norges Teknisk-Naturvitenskapelige Universitet (NTNU). En mer stillesittende livsstil er en av grunnene til den globale økningen i overvekt og fedme de siste 30 årene, og prognoser viser at økningen vil fortsette i de kommende årene. For å snu denne trenden må befolkningen øke sitt daglige nivå av fysisk aktivitet, og en måte å gjøre dette på kan være via «exergames». «Exergames» er videospill som kombinerer vanlige videospill med fysisk aktivitet.

Denne masteroppgaven har som mål å utvikle og evaluere et «exergame» som prøver å øke spillerens motivasjon og nivå av fysisk aktivitet. Prosjektet startet med et litteratursøk som hadde to mål. Det første var å utforske den eksisterende forskningen som finnes på «exergames» og se om det var noen forskningsgap. Det andre var for å få en bedre forståelse av relevante temaer innenfor fysisk helse og motivasjon, spillglede og hva som gjør spill morsomme å spille. Vi undersøkte også videospill-sjangere, eksisterende «exergames», og hvilken teknologi som brukes når man skal lage et «exergame».

Funnene fra litteratursøket ble brukt til å lage et «exergame» konsept; Radiation Mayhem. Radiation Mayhem er et «idle» bybygger-mobilspill hvor spillerne må samle på ressurser for å kunne bygge, utvikle og forsvare en landsby mot radioaktiv stråling. I mange mobilspill må spillere betale for ekstra ressurser og raskere spillprogresjon gjennom mikrotransaksjoner. Radiation Mayhem bytter ut disse mikrotransaksjonene med fysisk aktivitet. Spillere får noen ressurser fra landsbyen, men for å få flere ressurser må de gjennomføre oppdrag. For å fullføre oppdrag må spillerne nå oppdragets aktivitetskrav. Ved å få flere ressurser kan spillerne oppnå raskere progresjon i spillet.

Radiation Mayhem ble laget i spillmotoren Unity med Firebase som backend-system. Spillet ble laget både for Android og iOS brukere, noe som gjorde det mulig å få en større testgruppe. Testgruppen bestod av 53 deltakere som testet spillprototypen i en to-ukers lang periode, hvor målet var å finne ut av hvordan spillet påvirket deltakernes motivasjon og fysiske aktivitetsnivå. Under testperioden ble det samlet inn data gjennom spørreundersøkelser, intervjuer, og data som spillet selv samlet inn.

Resultatene viser at å spille Radiation Mayhem vil ha en positiv effekt på både spillerens motivasjon for fysisk aktivitet og deres fysiske aktivitetsnivå. Dette er uavhengig av deres forhold til, eller nivå av, tidligere fysiske aktivitet eller erfaring med videospill. Det å bruke fysisk aktivitet som en erstatning for mikrotransaksjoner for å få raskere spillprogresjon, viste seg å være en suksess som motiverte spillere til å være mer fysisk aktive.

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Part I

Introduction

Part I introduces the project and how and why it was done. First, it describes the project task itself and the context behind it. Secondly, this part details the societal and personal motivations for doing the project. Then it presents the research goal, research questions, and project methodology. Lastly, there is a report outline and reader guides.

Chapter 1

Project Task and Context

This report is a Computer Science and Informatics master's thesis completed at the *Norwegian University of Science and Technology* (NTNU). It was a joint effort between a Computer Science student and an Informatics student. It was completed in the framework of the courses *TDT4900 - Computer Science, Master's Thesis*, and *IT3920 - Master Thesis for MSIT*.

This master's thesis is a continuation of a specialisation project conducted in the fall of 2022. The specialisation project served as a pre-project for this master's thesis. In the specialisation project, we conducted a literature review on different topics, such as exergames, worldwide overweight and obesity rates, and physical activity and exercise motivation. A draft concept of the exergame, *Radiation Mayhem*, was also designed. Part II, and to a lesser degree Part III, of this thesis is based on the findings from the specialisation project.

The project description for both the pre-project and this master's thesis is as follows:

[ExerGames] Play to get fit

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

The pre-project covers the first phase from the project description, whereas this master's thesis covers the second and third phases.

This project is a part of the Game Technology for Health (GT4H) Network at NTNU. GT4H is a network that gathers knowledge and expertise about "serious gaming" for health benefits from different research groups across the departments and faculties at NTNU [1]. The network aims to connect researchers and professionals that develop and use game technology for health to deliver high-quality research and advance their knowledge with the best value possible. GT4H believes game technology can be part of the solution for alleviating health problems associated with physical inactivity and sedentary behaviour.

Chapter 2

Motivation

The motivation for this project falls into two categories; societal and personal.

The societal motivation for the project is the growing worldwide health problem of overweight and obesity. Multiple studies have shown that the world population is getting increasingly unhealthy, as the proportion of the population that is overweight or obese has been increasing since the 1970s [2][3]. In Norway, the average adult is overweight or obese [4]. While there are many factors for why a person might be overweight or obese, a sedentary lifestyle is considered the main factor. Being overweight or obese increases the risk of health problems like cardiovascular diseases. As one of the main factors contributing to the problem is a lack of physical activity and exercise, the solution to counteract the problem is to motivate the population to be more active in their day-to-day life.

Studies have shown that the proportion of people playing organised sports has decreased while people, and especially children, spend more of their free time indoors playing video games, being on social media, and participating in other sedentary activities [5][6]. One way of increasing the population's physical activity level is to incorporate some form of physical activity and exercise into sedentary activities like video games. The video game will then motivate the player to be physically active, which can be especially helpful for those who find it challenging to stay motivated to be physically active. If the game increases the motivation needed for a person to be more physically active, it can help counteract the effect of sedentary activities and make the players healthier.

Our personal motivation for doing the project was that it combined research with game development. Both master students specialised in software development and wanted a project that included some development and not just research. The opportunity to research, develop, and test a game that could help increase the motivation for physical activity was fascinating, and the combination of the physical health, psychological, and technical aspect made the project both challenging and exciting.

Chapter 3

Research Goal and Questions

This report uses the Goal Question Metric (GQM) as the research approach [7]. The GQM is a goal-oriented method of identifying goals by breaking them down into three levels. The conceptual level is the overarching goal for the entire research. The operational level is a set of questions that breaks the goal into more detail by describing different aspects of it and highlighting potential challenges that need to be addressed to reach the goal. The quantitative level is the metrics and methods needed to answer the research questions.

Research goal: *Develop and evaluate an exergame that focuses on increasing the player's motivation for physical activity.*

After creating the research goal, it is necessary to identify the different challenges that must be solved to reach the goal. For this to be achieved, it is essential to understand the relevant fields related to health, exergame creation, and exergames, and then develop and test the exergame. The following research questions aim to do this by breaking the goal into more concrete tasks that are easier to identify, research, and solve.

RQ 1 - *How to create a new exergame that combines natural gameplay with physical activity?*

This research question explores topics related to public health, game enjoyment theories, game genres, existing exergames, and relevant technologies necessary to understand good game design, which is crucial to create an engaging exergame.

RQ 1.1 - *What existing technologies can be used to create an exergame?*

This research question explores technologies used in existing exergames and evaluates how the different technologies can work together to track player movement and physical activity.

RQ 1.2 - *How to create an exergame that is fun and engaging for the player?*

This research question explores existing game genres, exergames, and game enjoyment theories to see how a game dependent on the player doing physical activities can be fun and exciting for the player.

RQ 2 - *How does our exergame impact the player's motivation for physical activity?*

This research question explores how the player's motivation for doing physical activity is affected by playing the exergame. This research question includes whether or not players are willing to use physical activity to earn in-game resources and ensure faster game progress.

RQ 3 - *How does our exergame impact the player's physical activity level?*

This research question explores how the player's physical activity level is affected by playing the exergame.

RQ 4 - *How do different parts of our exergame motivate players to be physically active?*

This research question explores what in-game elements are most effective in motivating players to be physically active.

RQ 5 - How does our exergame affect the player's enjoyment and engagement?

This research question explores how the game affects the player's enjoyment and how they engage with the exergame.

Finding answers and solutions to the research questions makes it easier to reach the research goal by providing detailed information on how to optimise the game design process and evaluate the game's effects. While the overall goal is what this research project wants to achieve, the research questions are the topics the research project wants to investigate further. The research methodology used in this project is described in the next chapter.

Chapter 4

Research Methodology

The research performed in this master’s thesis is structured after the *research process model* presented by Briony J. Oates in her book *Researching Information Systems and Computing* [8]. Figure 4.1 shows a visualisation of Oates’ model with the elements used in this thesis highlighted in orange. This chapter will discuss the selected elements from the model and cover some of the theory behind them.

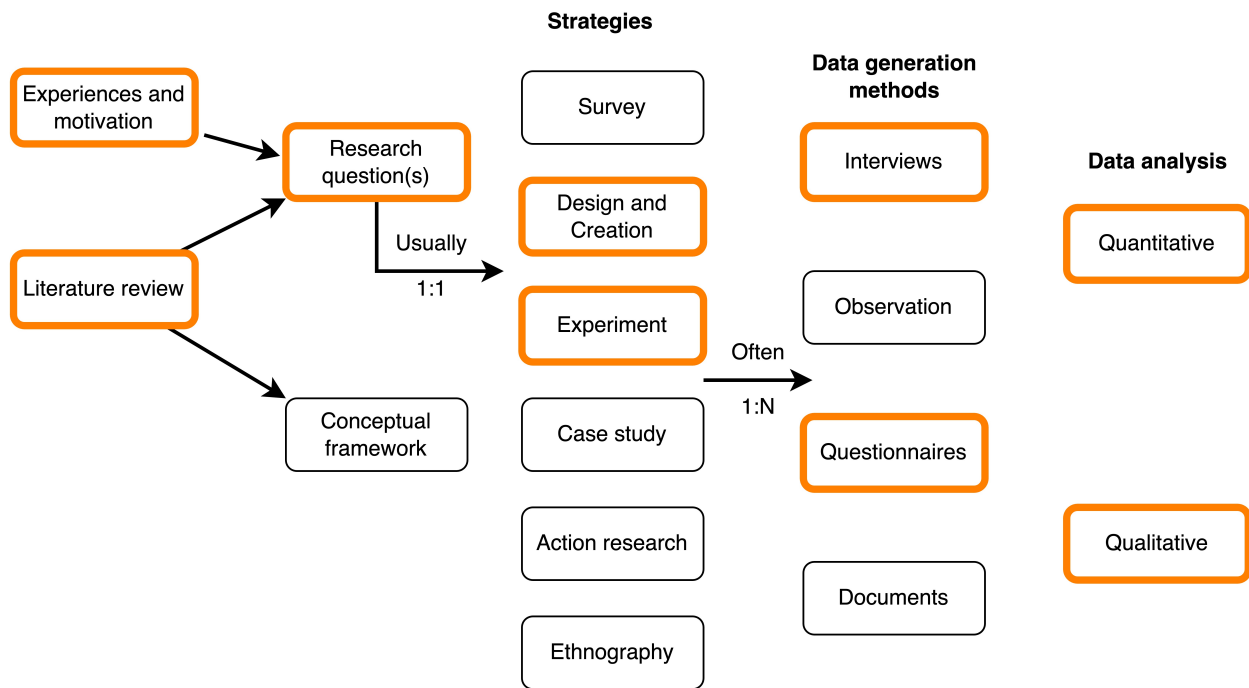


Figure 4.1: Research process (Oates’) model with relevant elements highlighted [8]

The “Play to Get Fit” project helped define the research goal for this thesis (see Chapter 3). To make fulfilling the research goal more manageable, the researchers broke it down into several research questions. The research questions were chosen based on the researchers’ motivation, experience, and the research gap discovered during the literature review. The motivation for this thesis was discussed in Chapter 2.

4.1 Personal Experiences and Motivation

Oates recommends using one's personal experiences, motivation, strengths, weaknesses, likes and dislikes as a guide when creating research questions [8]. Not only will it be easier to create research questions relevant to one's own experiences and traits, but it will also be easier for a team to stay motivated when working with material that inherently motivates them.

“Reminding yourself of why you are doing the research can also help keep you going through the difficult, boring or frustrating times - there will be some, guaranteed!” [8, p. 33]

4.2 Literature Review

The purpose of a literature review is twofold [8, p. 71-72]. The first is to explore the body of previous work on a subject. Here, the aim is to identify areas where more research is needed. These areas can be identified by looking at further work suggestions from the different papers, reports, and presentations or by finding gaps in the existing research that need to be better covered. The second purpose of a literature review is to gather evidence to support new research. Oates likens this second purpose to an attorney gathering evidence to support their case in court. A thesis must present new findings, but it also needs to be supported by existing research.

Oates states that a successful literature review will fulfil most of the objectives shown in the following list [8, p. 72].

- Show that the researcher is aware of existing work in the chosen topic area.
- Place the researcher's work in the context of what has already been published.
- Point to strengths, weaknesses, omissions or biases in the previous work.
- Identify key issues or crucial questions troubling the research community.
- Point to gaps that have not previously been identified or addressed by researchers.
- Identify theories that the researcher will test or explore by gathering data from the field.
- Suggest theories that might explain data the researcher has gathered from the field.
- Identify theories, genres, methods or algorithms that will be incorporated in the development of a computer application.
- Identify research methods or strategies that the researcher will use in the research.
- Enable subsequent researchers to understand the field and the researcher's work within that field.

During the literature review, we used services such as *Google Scholar*, *Web of Science*, *Scopus*, and *NTNU's Oria* for finding literary sources. Our supervisor also pointed us to valuable sources, especially concerning game enjoyment theory and previous exergames. Part II of this report contains the contents of our literature review.

4.3 Research Questions

The research questions are the fundamental questions that a piece of research is trying to answer. When combined, the research questions make up a research goal, with each question applying to a specific issue within the research goal. The research goal is motivated by the experiences and motivations of the research team and the literature review. Chapter 3 presents the complete list of research questions for this thesis.

Oates recommends two approaches to finding research questions [8, p. 34]. The first is finding research questions based on the kind of research the researcher would like to conduct based on their preferences and knowledge. The other approach is through the literature review, by finding other papers that call for more required research on various topics. This thesis uses both approaches.

4.4 Strategies

The research strategy is the approach a research project uses to answer their research questions [8]. This thesis uses two research strategies: *Design and Creation* and an *Experiment*.

4.4.1 Design and Creation

This strategy focuses on developing an *artefact*: a new technology, product, application, information system, or some other computer-based system [8, p. 109]. Design and Creation is a common strategy for IT and computing research projects. Research projects using this strategy offer an artefact as a contribution to knowledge, meaning that the artefact has to be innovative in some way. In the research project, the artefact needs to fulfil one of three roles: being the main focus of the research, being a vehicle to enable other research, or being a tangible end-product of a project where the focus and innovation is in the development process.

In this project, the artefact is the exergame we developed. Part III presents the concept and how it was developed. Part IV covers the development of the exergame and how it functions.

4.4.2 Experiment

This research strategy lies at the heart of the scientific method. Experiments investigate cause-and-effect relationships, aim to prove a hypothesis, or find a causal link between a factor and an outcome [8, p. 126-135]. Experiments are conducted with “before” and “after” measurements. It is essential to eliminate as many variables as possible to distil what impact the one factor the experiment is testing has.

The experiment in this thesis is a field experiment where our game is being tested “out in the field” rather than in a laboratory setting. Field experiments can never be as conclusive as true experiments [8, p. 133-135]. However, for many pieces of information systems research, true experiments will not be able to replicate the environment in which the information system needs to be tested. The experiment in this thesis follows the “*one group, pre-test and post-test*”

design. This thesis tests the developed game on real test subjects in a non-lab setting. This design measures the participants before and after some treatment is applied (for example, the testers testing a new exergame).

4.5 Data Generation Methods

Data generation methods are how a piece of research produces empirical data and evidence [8]. Data comes in two forms: *quantitative* and *qualitative*. Different data generation methods can produce different types of data, depending on how they are used. There is also a tendency for some data generation methods to go well with different research strategies, but these are not concrete rules. For this thesis, we have chosen *Interviews* and *Questionnaires* as our data generation methods.

4.5.1 Interviews

Interviews are a planned conversation between the researcher(s) and an interview subject [8, p. 186-201]. Interviews are suitable for obtaining detailed information, asking questions that are too complex or open-ended for questionnaires, or exploring emotions and sensitive issues. Interviews are good at generating qualitative data and are often used in collaboration with other, more quantitative methods to explore topics in more detail.

There are three main types of interviews: structured, semi-structured, and unstructured [8, p. 187-188]. This thesis uses semi-structured interviews. Here, the interview questions should be planned but open-ended, making the interview subject feel comfortable and encouraged to answer honestly and allowing for follow-up questions if the conversation drifts into an area that the researchers did not anticipate but that they think can be helpful for the research project.

4.5.2 Questionnaires

Questionnaires are pre-defined lists of questions that respondents are asked to answer [8, p. 219-220]. The questions usually have standardised answers, although some may allow for free-form responses. Questionnaires generate quantitative data, which is easier to analyse using statistical analysis due to their standardised answers. When creating a questionnaire, it is important to carefully design the questions to be clear and consistent for all participants. Usually, the researchers will not be present to assist or clarify any confusing parts of the questionnaire for the testers.

4.5.3 Triangulation

Using more than one data generation method allows the researchers to corroborate the findings from the different methods, which can lead to greater confidence in the research overall [8, p. 37]. This technique is called *method triangulation* and helps weed out erroneous findings and get to the bottom of the cause behind the observed effects.

4.6 Data Analysis

The data generated from the data generation methods will be either Quantitative or Qualitative [8, p. 38], and they vary in how they can be analysed.

4.6.1 Quantitative Data

Quantitative data is based on numbers [8, p. 245-249]. It allows statistical analysis to discover patterns and relationships (correlations) in the data. A typical way of displaying quantitative data is through tables, charts, and graphs. In this thesis, the quantitative data comes from the standardised questions in the questionnaires and the game data saved to the game's database.

4.6.2 Qualitative Data

Qualitative data is all non-numeric data (that cannot directly be converted to a numeric format) [8, p. 266-268]. Qualitative data analysis involves abstracting patterns and themes from the data. For example, researchers might look at how the interview subjects express themselves about different topics, depending on different criteria. In this thesis, the qualitative data comes from the semi-structured interviews and the long-form answers in the questionnaires.

4.7 Summary

This chapter discussed the methodology used in this master's thesis. This thesis used Oates' model (see Figure 4.1) as the basis for its research method. Oates model offers many possibilities within research strategies, data generation methods, and data analysis. Out of these, this thesis uses the researchers' *experiences and motivation*, as well as a *literature review*, to formulate several *research questions* that combine to form a research goal. To answer these research goals, the researchers employ the research strategies *Design and Creation* and *Experiment*. The exergame created as a part of this thesis is the artefact from the Design and Creation strategy. The experiment involves testing the exergame in a field experiment with a test group, with the results being compared pre and post-testing. The data generation methods for these strategies are *interviews* and *questionnaires*. These data generation methods produce both *quantitative* and *qualitative* data that need to be analysed differently. Statistical analysis is used to analyse the quantitative data, while abstraction and pattern recognition are used to analyse the qualitative data. Using various methods and types of data allows for *triangulation*, which helps to boost confidence by reaching conclusions from multiple sources. In the next chapter, the report's outline will be presented along with some guides for the readers.

Chapter 5

Report Outline

This chapter gives a summarised overview of the entire report and what the different parts contain. There are also reader's guides for different groups on which parts of the thesis might be more interesting and relevant for them.

5.1 Outline of Report

The report consists of eight parts.

Part I - Introduction

The introduction introduces the project and its context. It presents the project task, the motivations for doing the project, the research goal and research questions, the project methodology, the report outline, and reader's guides.

Part II - Prestudy

The prestudy is the project's literature review. First, it introduces relevant topics in health, overweight and obesity, physical activity, exercise, and motivation. Then it presents different theories of game enjoyment and what makes a game fun. Next, it describes different game genres, introduces the concept of exergames, and presents some existing exergames and how they affect the player's health. Lastly, it presents different technologies relevant to gaming and exergames. Most of the findings in this part are based on the findings in the specialisation project described in Chapter 1.

Part III - Concept

This part presents this project's new exergame. First, it presents the research gap discovered during the literature review. Second, many different game concepts are presented and rated following different criteria. Third, it presents the chosen game concept, and the different game mechanics and gameplay are described in detail. Then, the relevant game enjoyment theories are related to the game concept itself and how the exergame uses them to create player motivation. Lastly, it details how the different game aspects are designed to influence the player's activity and motivation. The concepts described in this chapter are based on the concept drafts created in the specialisation project described in Chapter 1.

Part IV - Development

This part explains the implementation process of the exergame. First, it describes the different technologies used to create the exergame and why these specific technologies were chosen. Next, the exergame's functional and quality attribute requirements are listed, and the exergame's software architecture is shown and described. Lastly, it explains how the exergame was tested and the evaluation of the development process.

Part V - Experiment

This part details the experiment process, from the preparation before the experiment could be held to the end of the testing period. First, it describes the preparation work necessary to complete the experiment. Then, it explains the experiment process itself from the start of the testing with the distribution of the game to the end of the test period. Lastly, it describes the different data generation methods and the data collected during the experiment.

Part VI - Results

This part presents the results from the data generated in the experiment. First, it introduces the demographics of the test population. Then, it presents the rest of the results from the questionnaires, interviews and the data, divided into different categories like physical activity, motivation and engagement, and game and enjoyment. Lastly, it presents some external influences on the results and discusses their impact on the results.

Part VII - Discussion

This part discusses the results presented in part VI and uses them to help answer the research questions. It also discusses some factors that could have affected the research results.

Part VIII - Conclusion and Further Work

The conclusion and further work concludes the report by summarising the project and its findings. Lastly, it discusses potential future work on the project. This discussion includes conducting additional research on testing the exergame, exploring the broader field of exergames, and making further improvements to the exergame.

5.2 Reader's Guides

Presented below are different reader's guides. While we recommend reading the whole report, as it gives a complete overview of the entire process, these chapters and parts are more relevant for specific topics.

Health workers

For someone interested in the health result of this thesis, we recommend focusing on the

chapters looking into physical health and motivation for physical activity from the prestudy (see Chapters 6 and 7). We also recommend focusing on the chapter describing how Radiation Mayhem is designed to influence motivation for physical activity (see Chapter 20). Lastly, we recommend reading Part VI-VIII, which covers this thesis' results, discussion, and conclusion.

Researchers

For someone interested in the research on exergames and exergame creation, we recommend focusing on the chapters looking into motivation for physical activity, game enjoyment theory, connecting motivation theory and game enjoyment theory, and game genres for exergames (see Chapters 7, 8, 9, and 13). We also recommend reading Part III and Parts V-VIII, which cover how Radiation Mayhem was designed, how the experiment was conducted, and this thesis' results, discussion, and conclusion.

Developers

For someone interested in the game and the development process, either because of further development or for tips related to the development of exergames, we recommend focusing on Parts III, IV, VII, and VIII. These parts cover how Radiation Mayhem was designed, how it was developed, as well as the thesis' discussion and conclusion. If you also are interested in the theory and reasoning behind the exergame concept, we recommend also reading Part II, the thesis' prestudy.

5.3 Summary

This chapter gave an overview of the report and the part it contains; each part having a short summary of what it contains. The chapter also contains reader's guides, with recommendations on the most relevant parts of this thesis depending on the reader's interest.

The next part will present this project's prestudy. It consists of a literature review investigating relevant topics for this project. The first chapter in the next part will look at physical health and global rates of overweight and obesity.

Part II

Prestudy

Part II is the literature review. First, it defines and presents relevant topics in health, physical activity, and motivation. Second, it explains different theories of game enjoyment and existing game genres. Then it introduces the concept of exergames, what they are, and presents some existing exergames and how they affect the player's health. Lastly, it presents hardware and software technologies often used in exergames and how they are used to track player movement. Most of the findings in this part are based on the research presented in the specialisation project done in the course TDT4501/IT3915 during the autumn of 2022.

Chapter 6

Health, Overweight, and Obesity

This chapter introduces relevant concepts related to physical health. First, it defines *Body Mass Index* (BMI) as it is the standard way of estimating the general health level of a person or population. Second, it defines the terms *overweight* and *obesity*, presents data on worldwide overweight and obesity rates, as well as some health risks and problems associated with overweight and obesity. As this thesis aims to help reduce overweight and obesity, it is important to understand what overweight and obesity are, how they are defined, and the worldwide situation and future prognosis of the problem.

6.1 Body Mass Index

Body mass index, or BMI, indicates the nutritional status in adults [9][10]. It was developed during the 19th century as a risk indicator for weight-related health problems. It gained traction during the 1970s fitness boom as a way of looking into the correlation between health problems and the weight and height of a person or population. BMI is calculated by dividing a person's weight (in kilograms) by their height (in metres) squared (shown in Equation 6.1). The results correlate to a category in a predetermined table, shown in Table 6.1, and can give insight into the person's or population's health status and the corresponding risk factors.

However, BMI is not a perfect measurement as it only considers the factors of weight and height [11]. BMI does not consider factors like age, sex, the level of physical activity, body build, or muscle mass; these factors are essential when evaluating a person's health risk [9]. Many have heard about BMI but do not necessarily know what it does and does not measure, which can lead to misuse. Healthy BMI can differ depending on ethnicity as some ethnic groups are more likely to have a higher body fat percentage at a given BMI than other groups [11].

$$\text{Body Mass Index (BMI)} = \frac{\text{weight}}{\text{height}^2} \quad (6.1)$$

BMI	Category
BMI \leq 18,5	Underweight
BMI 18,5-25	Normal weight
BMI \geq 25	Pre-obesity
BMI \geq 30	Obesity class I
BMI \geq 35	Obesity class II
BMI \geq 40	Obesity class III

Table 6.1: Body Mass Index scale for people above 20 years old from WHO [9]

6.2 Overweight and Obesity in the World

“Worldwide, at least 2.8 million people die each year as a result of being overweight or obese, and an estimated 35.8 million (2.3%) of global DALYs¹ are caused by overweight or obesity.” [12]

According to the World Health Organisation (WHO), worldwide obesity has almost tripled since 1975. WHO classifies overweight as having a BMI between 25 and 29.9 and obesity as a BMI above 30. They estimate that in 2016, 39% of the world population aged 18 years or older, which equates to about 1.9 billion people, had a BMI of over 25. Of these, 13% qualified as obese, which equals 650 million people. They also estimate that there were 340 million children that were overweight or obese in 2016 and that 39 million children under the age of 5 were overweight or obese in 2020 [2]. Figure 6.1 show the obesity trend in the US and Norway from 1975 to 2016.

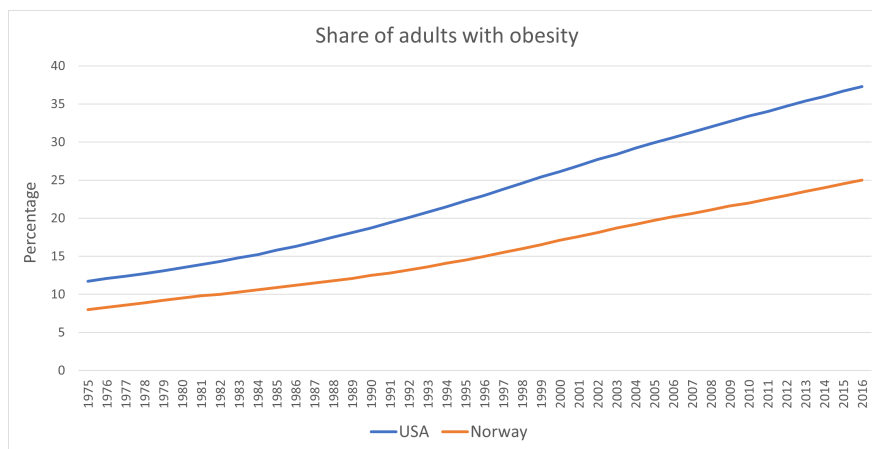


Figure 6.1: Obesity trends from 1975 to 2016 for the US and Norway [13]

In the US, the Centres for Disease Control and Prevention (CDC) estimated that, in 2017-2020, 41.9% of the adult US population was obese, which is an increase from 30.5% in 1999-2000. During the same period, the CDC estimated that severe obesity increased from 4.7% to 9.2% [14]. For children aged 2-19, the prevalence of obesity was 19.7%, about 14.7 million children, where the ages range 6-11 and 12-19-year-old were highest, with above 20% obesity [15].

In March 2023, the World Obesity Atlas published a report stating that over 2.6 billion people had a BMI over 25 in 2020, which equals 38% of the world population [16]. They estimate that in 2035 the number will increase to over 4 billion, or 50% of the world population. Of the 2.6 billion people with a BMI of over 25, 988 million were obese, equating to 14% of the population. This number is estimated to increase to 1.9 billion in 2035, which is 24% of the population. Figure 6.2 show the estimation of overweight and obesity trends from 2020 to 2035.

¹Disability-adjusted life years (DALYs) represent the loss of years due to premature mortality because of a disease or health condition. One DALY represents the loss of the equivalent of one year of full health.

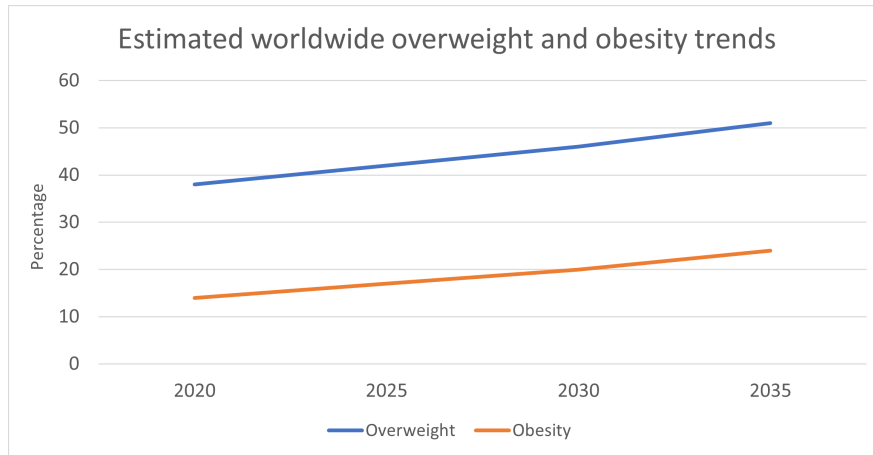


Figure 6.2: Predictions for worldwide overweight and obesity rates

While many factors can cause overweight and obesity, WHO says that the fundamental cause is the imbalance between calories, fats, sugars, and other energy-dense food we consume vs the amount of energy we expend. A more sedentary lifestyle and work environment, paired with eating more “unhealthy” foods (fast food, ultra-processed food), creates a calorie imbalance where we eat more food than our bodies use [2].

Being overweight or obese has been linked to several health problems and risks, such as [2][3]:

- Cardiovascular diseases like heart disease and strokes. Deaths related to heart diseases and strokes are among the leading causes of death worldwide.
- Musculoskeletal disorders like osteoarthritis, an aggressive degenerative disorder that breaks down and destroys joints.
- Some types of cancer (breast, kidney, prostate, liver)
- Diabetes type 2
- A variety of mental health problems like anxiety, depression and other psychoses

6.3 Summary

This chapter introduced relevant topics related to health, overweight, and obesity. These topics are relevant for exergame creation as the growing overweight and obesity problem is one of the things exergames are trying to solve. First, it explained the concept of Body Mass Index (BMI) and how it is used to estimate a person’s or population’s overall health. Then, it presented different data on the progression, current state, and future predictions on worldwide overweight and obesity. According to WHO, worldwide obesity and overweight have almost tripled from 1975 to 2016, and the World Obesity Atlas estimates that, in March 2023, over 2.6 billion people were overweight or obese, predicting that in 2035 it will increase to over 4 billion. The next chapter will discuss important factors for combating global obesity: physical activity, exercise, and motivation for physical activity.

Chapter 7

Physical Activity, Exercise, and Motivation

This chapter will define and discuss terms relevant to physical activity, exercise and motivation. First, it will define the term *physical activity* and present the World Health Organisations' recommendations for minimum physical activity levels. It will also present data from surveys reporting estimations of what proportion of the Norwegian population follows these recommendations. Second, the term *exercise* will be defined and described, and the difference between physical activity and exercise will be presented. Lastly, theories of motivation are presented and related to how motivation affects people's wish to be physically active or exercise. When creating an exergame, it is important to understand what *physical activity* and *exercise* are, as they are the core aspects of exergames. It is also important to understand how people get motivated for physical activity and exercise, as without motivation, the players will neither be active nor play the game.

7.1 Physical Activity

WHO defines physical activity as:

“Any bodily movement produced by skeletal muscles that requires energy expenditure.” [17]

Any activity done throughout the day, like walking around the house, doing household chores, or going for a short walk, is classified as physical activity. However, the amount of physical activity a person does throughout the day varies significantly from person to person depending on lifestyle. It will also differ for a single person from day to day [18].

To prevent and counteract the growing problem of overweight and obesity rates in the population, both WHO and different Norwegian health organisations have published a set of recommendations for the minimum physical activity level a person should do weekly, depending on age. Additional activity or exercise will give additional health benefits. For adults, WHO recommends [19]:

150–300 minutes of moderate-intensity aerobic physical activity or 75–150 minutes of vigorous-intensity aerobic physical activity as well as muscle-strengthening activities of all major muscle groups at a moderate or greater intensity at least two days a week. [19]

The difference between moderate and vigorous activity is defined by how strenuous the activity is [20][21]. *Moderate intensity activities* are defined as short instances of activity throughout the day that increases the person’s heart rate a small amount, like walking the dog, going to the store, household activities like vacuuming, mopping or mowing the lawn, or walking at a brisk pace (six km/h). *Vigorous intensity activities* are more strenuous activities like hiking, jogging or running at a pace of nine km/h or other high-intensity sports that increase the heart rate by a lot and makes the person really out of breath.

In 2014-2015, Helsedirektoratet (The Norwegian Directorate of Health) held a national survey about the physical activity level in the Norwegian population [22]. The goal was to map the Norwegian population’s daily activity level and changing trends. By comparing the data from 3020 participants, Helsedirektoratet found that only 32% of the participants satisfied the guidelines of 150 min of activity with moderate intensity or 75 min with high intensity per week. The results showed that overall, more females followed the guidelines than males in the same age group (34% of females, 29% of males). It is also worth noting that 37% of the participants in the age group of 50-64 satisfied the goals, which was the best result of the different age groups. Figure 7.1 shows the complete results sorted by age.

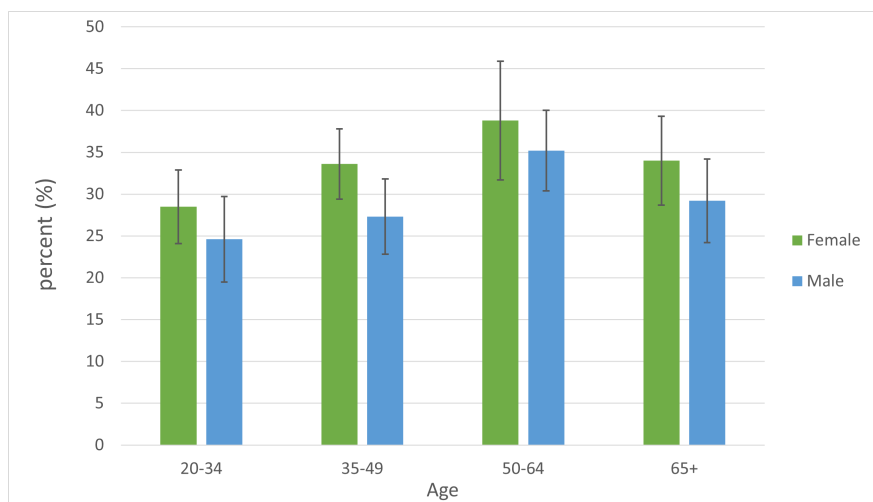


Figure 7.1: The percentage of age groups fulfilling the guidelines from Helsedirektoratet, 2014-2015 [22]

In the survey from 2014-2015, Helsedirektoratet used the same recommendations as WHO. However, in 2022, Folkehelseinstituttet (The Norwegian Institute of Public Health) released a new survey using revised recommendations (see Table 7.1) [23]. The reason for the revised recommendations is that Folkehelseinstituttet wanted a more complete and nuanced picture of the activity level of the participants. By splitting the original recommendation into two different recommendations, they could separate those who reach the lower level from those who reach the higher level, giving a more detailed insight into the activity level of the participants. In the 2020-2022 survey, they registered all activities the participants did, while in previous studies, they excluded activities that lasted shorter than ten minutes. This change was done because research suggests that any activity, regardless of duration, has benefits and should not be ignored; therefore, all activities were registered in the new study.

Recommendation 1	150 min/week of moderate-intensity activity, making it, on average, 21.4 minutes each day	or	75 minutes/week of vigorous-intensity activity, making it, on average, 10.7 minutes each day
Recommendation 2	300 min/week of moderate-intensity activity, making it, on average, 42.8 minutes each day	or	150 minutes/week of vigorous-intensity activity, making it, on average, 21.4 minutes each day
Recommendation 3	People who spend at least 8 hours sedentary per day should have 300 minutes/per week of moderate-intensity activity or 150 minutes/per week of high-intensity physical activity		

Table 7.1: Modified 2022 recommendations from Folkehelseinstituttet [23]

The 2020-2022 survey results for reaching the recommendations show that more than 70% of the participants reached the first recommendation, which is the same as reaching the recommendation in the 2014-2015 study [22][23]. At first glance, it looks like a drastic increase from the 2014-2015 survey, but it is hard to compare the two surveys. As mentioned, the 2014-2015 survey only registered activities lasting longer than ten minutes. Since this was excluded in the 2014-2015 study but included in the 2020-2022 study, it is impossible to have a direct comparison. Other results from the 2020-2022 study show that about 40% of the participants reached the second recommendation. This result indicates that most participants have a relatively low level of activity, as they reached the first recommendation but not the second. A critical part of the study is recommendation 3, targeting people who sit an average of eight hours or more during the day. With the increased sedentary lifestyle in the population, recommendation 3 most likely encompasses a large part of the population. The results show that only 30% of the participants that should follow recommendation 3 reach the goal. Graphs showing the full results of all three recommendations, divided into males and females, are shown in Figure 7.2 and Figure 7.3.

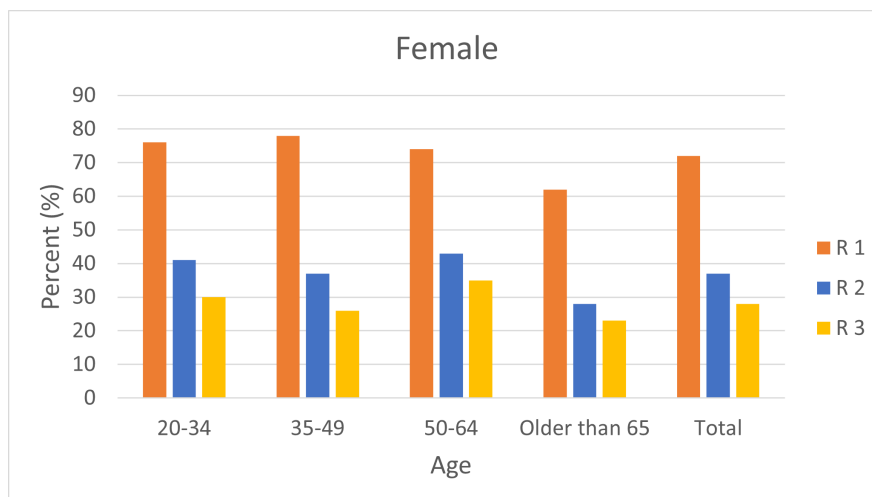


Figure 7.2: Percentage of females reaching the recommendations from Folkehelseinstituttet, 2020-2022 [23]

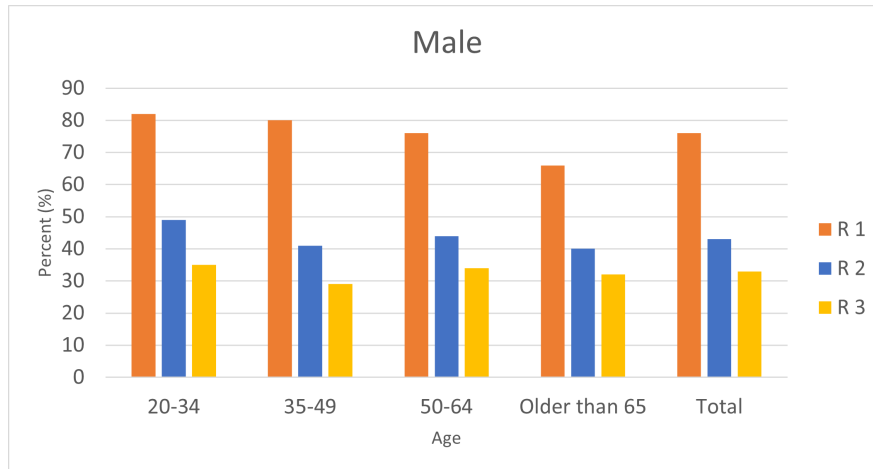


Figure 7.3: Percentage of males reaching the recommendations from Folkehelseinstituttet, 2020-2022 [23]

Overall, the results showed that the percentage of males reaching the goal was slightly higher than females across all ages. This result is the opposite of the result from the 2014-2015 study, where females were higher than males across all ages.

7.2 Exercise

The terms *exercise* and *physical activity* are often thrown around and used interchangeably. While the two definitions have many similarities and common elements, there are subtle but significant differences (see Table 7.2). Exercise is a subcategory of physical activity and can be defined as any physical activity that is “planned, structured, repetitive, and purposive in the sense that improvement or maintenance of one or more components of physical fitness is an objective” [18]. So, while both physical activity and exercise involve bodily movements that expend energy, *exercise* is seen as activities more dedicated to improving or maintaining the person’s physical fitness level.

Physical activity	Exercise
1. Bodily movement via skeletal muscles	1. Bodily movement via skeletal muscles
2. Results in energy expenditure	2. Results in energy expenditure
3. Energy expenditure (kilo-calories) varies continuously from low to high	3. Energy expenditure (kilo-calories) varies continuously from low to high
4. Positively correlated with physical fitness	4. Positively correlated with physical fitness
	5. Planned, structured, and repetitive bodily movement
	6. An objective is to improve or maintain physical fitness

Table 7.2: Difference between physical activity and exercise [18]

Physical fitness is defined as a set of attributes that makes a person able to function well in a normal everyday setting, which includes the ability to do everyday tasks with a good energy level while not becoming exhausted, and still having the energy to do emergency tasks if they arise. The attributes are cardio-respiratory endurance, muscular endurance, muscular strength, body composition, and flexibility [18].

7.3 Motivation

By its very definition, exercise is a strenuous activity, and the participant's motivation is vital for their ability to stick with an exercise plan [24]. When making an exergame where the goal is to motivate the players to be more physically active, it is important to understand how people are motivated to do activities.

7.3.1 Exercise Motivation

"*Autonomous self-regulation*" is when an individual is motivated to engage in an activity. Pedro J. Teixeira et al. concluded in an article that autonomous self-regulation is the most effective way of ensuring a participant will stick to an exercise plan [24]. There are two effective ways of developing autonomous self-regulation. The first is developing *autonomous (self-determined) extrinsic regulation* in the participant, and the other is enhancing the participant's *intrinsic motivation*.

Being *extrinsically motivated* means a participant will do something to achieve a specific outcome separate from the activity itself, for example, wanting to see the bodily results of the exercise or being able to do a specific task like running a marathon [25]. Extrinsic motivation works best for beginning and sticking with an exercise regime in the early stages [24]. Being *intrinsically motivated* means a participant does an activity because they find it inherently interesting or enjoyable; the process is its own reward [25]. Intrinsic motivation is vital for long-term participation in an exercise regime [24].

7.3.2 Self-Determination Theory

The article by Pedro J. Teixeira et al. is based on *Self-Determination Theory* (SDT). It discusses how SDT is essential for motivating people to exercise and be physically active [24]. The book *Handbook of Theories of Social Psychology: Volume 1*, Chapter 20, presents SDT as:

"[SDT] is an empirically derived theory of human motivation and personality in social contexts that differentiates motivation in terms of being autonomous and controlled." [26]

SDT started as research into the effects of extrinsic rewards on intrinsic motivation in 1971 [26]. Since then, it has evolved, with hundreds of studies confirming its findings. The basis of SDT is the belief that humans evolved to be inherently active, intrinsically motivated and oriented towards development. This quality is inherent to human nature, it does not need to be taught,

but the individual's social environment influences it. Since its inception, five additional "mini-theories" have been added to SDT. These are: *Cognitive Evaluation Theory* (CET), *Causality Orientations Theory* (COT), *Organismic Integration Theory* (OIT), *Basic Psychological Needs Theory* (BPNT), and *Goal Content Theory* (GCT). The first three were developed relatively early on in SDT's continued development. BPNT and GCT came later.

CET specifies external events that enhance and diminish intrinsic motivation, such as positive feedback versus tangible rewards [26]. COT explores *causality orientations*, which are facets of people's personalities that inform how they are motivated. OIT studies how external motivation can become internalised. There are two types of internalisation: controlled and autonomous. Controlled internalisation comes from external control and introjected regulation. Autonomous internalisation comes from intrinsic motivation and self-identified extrinsic motivation, which leads to wellness, engagement, competence, and deeper learning. Pedro J. Teixeira et al. use internalisation when discussing exercise motivation [24].

After these three initial mini-theories were developed, numerous studies were carried out, and many research papers were published on the topic [26]. This extensive research discovered that all three mini-theories emphasise the importance of fulfilling a person's three basic psychological needs. *Basic Psychological Needs Theory* was created to summarise these findings. GCT was developed later to explore how people develop life goals and what factors cause more intrinsic or extrinsic goals.

BPNT is the mini-theory that is most relevant to this thesis. The first three mini-theories all cumulate in BPNT [26]. The first three mini-theories all have elements that BPNT does not cover, but these are not directly relevant to this thesis. GCT covers topics that are outside of the thesis' scope.

7.3.3 Basic Psychological Needs Theory

BPNT states that fulfilling a person's basic psychological needs leads to both intrinsic and internalised autonomous extrinsic motivation [26]. This concept is particularly applicable to this thesis as the "situation" examined is the videogame prototype created by the authors.

The three basic psychological needs are [26]:

- Autonomy
- Competence
- Relatedness

BPNT describes how the satisfaction or frustration of each of these needs affects a person. A need being frustrated means that the need is actively being repressed rather than just not being fulfilled [27].

The need for *Autonomy* refers to the experience of willingness and using one's own will [27]. When satisfied, a person will experience a sense of integrity in their actions as they perceive them as self-endorsed and authentic. When frustrated, a person might experience social pressure and feel pushed in an unwanted direction.

The need for *Competence* is the need for effectiveness and mastery [27]. It is satisfied when a person gets to engage in activities or experience opportunities where they can use or improve their skills. If the need is satisfied, the person will feel competent and have a sense of mastery and validation of their skills. If frustrated, a person might feel a sense of ineffectiveness or helplessness.

The need for *Relatedness* is the experience of warmth, belonging, and connection with others [27]. The need is satisfied when a person can connect with others and feel significant in some way. This need can be satisfied in both competitive and cooperative settings. If frustrated, the person might experience the feeling of alienation, exclusion, or loneliness.

7.4 Summary

This chapter defined and discussed topics relevant to physical activity, exercise, and motivation. First, it defined the term *physical activity*, presenting WHO's recommendation for the minimum amount of physical activity for adults. It also presents the data from the 2014-2015 and 2020-2022 surveys from HelseDirektoratet and Folkehelseinstituttet, showing an estimation of the percentage of the population that follows the recommendations. Next, it defined the term *exercise* and discussed the difference between *physical activity* and *exercise*. While *physical activity* is defined as any body movement that requires energy usage, *exercise* is a more intense form of physical activity that is planned, structured and involves repetitive bodily movement. Lastly, it went through how to *motivate* a person to do physical activity or exercise. Research shows that *autonomous self-regulation* and *intrinsic motivation* are the most important factors when starting and maintaining an exercise schedule. The person will need to feel that they can achieve and master the goals they set for themselves and feel related to a group, community or organisation. The next chapter also discusses motivation, specifically how games can be designed to motivate and engage the player.

Chapter 8

Game Enjoyment Theory

This chapter will present game-enjoyment theories essential for making a game fun and exciting. First, it introduces the concept of *GameFlow* and *Dual flow*. Second, it details *Malone's challenge, fantasy, and curiosity model*. Then it explains the *Octalysis Framework*. Later, it presents Bartle's four *player types*, and lastly, some different *reward classifications and systems* are presented.

For an exergame, where the player's motivation already "starts at a negative" due to the player having to be physically active to play, the game must be so enjoyable that it outweighs the "negative" from being physically active. This thesis focuses on developing and testing an exergame; therefore, studying how to make that game enjoyable is very beneficial.

8.1 GameFlow

"Player enjoyment is the single most important goal for computer games. If players do not enjoy the game, they will not play the game." [28]

GameFlow is a model for evaluating enjoyment in games, developed and presented by Penelope Sweetser and Peta Wyeth in the article *GameFlow: A Model for Evaluating Player Enjoyment in Games* in 2005 [28]. GameFlow adapts the *flow* model to the domain of games. Mihaly Csikszentmihalyi created the flow model in 1990 [29]. The model states that flow is an enjoyable state that a person can enter. When a person experiences flow, they later usually describe experiencing one (or more) of the following phenomena [29]:

- The person acts with deep but effortless involvement, and the worries and frustrations of everyday life are removed.
- The person has a sense of control over their actions.
- The concern for the self disappears, and when the flow experience is over, the sense of self emerges stronger.
- The person's sense of time is altered.

The GameFlow model presents eight elements contributing to the feeling of flow in games [28]. These elements are *concentration, challenge, player skill, control, clear goals, feedback, immersion, and social interaction*. How these elements map to the original flow framework can be seen in Table 8.1.

GameFlow	Flow
The Game (Not an element)	A task that can be completed
Concentration	Ability to concentrate on the task
Challenge & Player skill	Perceived skills should match challenges, and both must exceed a certain threshold
Control	[The participant is] allowed to exercise a sense of control over actions
Clear goals	The task has clear goals
Feedback	The task provides immediate feedback
Immersion	Deep but effortless involvement & Reduced concerns for self and sense of time

Table 8.1: Mapping flow elements To GameFlow elements [28, p. 4]

8.1.1 Concentration

Concentration is one of the most directly translated elements from flow to GameFlow.

“The more concentration a task requires in terms of attention and workload, the more absorbing it will be. When all of a person’s relevant skills are needed to cope with the challenges of a situation, that person’s attention is completely absorbed by the activity, and no excess energy is left over to process anything other than the activity [...]” [28]

In order to get the player to concentrate, the game should provide something worth concentrating on [28]. This “something” comes in the form of graphics and content that is interesting and exciting to the player. The game should also increase the player’s workload as they progress but ensure that the load never exceeds their cognitive, memory, or physical limits. At the same time, the game should also avoid burdening the player with unimportant or non-game-related tasks and interactions, which will bore the player and make it easier to lose concentration.

8.1.2 Challenge

“Challenge is consistently identified as the most important aspect of good game design.” [28]

For flow to occur, the participant’s skill level and the activity’s challenge level must match, but both must be above a certain level [28]. If the challenge level is too high for the participant’s skill level, it can lead to anxiety, while the opposite can lead to apathy for the activity. Completing complex challenges (from the player’s point-of-view) in games can foster a great deal of extrinsic and intrinsic satisfaction. A game’s challenge level is often tied to rewards that the player gets for overcoming the challenges. The player can receive extrinsic rewards, such as points, virtual items, cinematics, or progression, for completing a challenge. They can also “receive” intrinsic rewards, such as a positive sense of self-satisfaction.

The game's challenges must also grow and keep pace with the player's growing skill level as the game progresses to avoid losing the prerequisite conditions for flow [28]. A game's difficulty should also be adjustable to offer the player the correct level of challenge. This variability can either be explicit, with the player choosing the game's challenge level themselves, or automatic, where the game automatically adjusts the difficulty level based on the player's performance.

8.1.3 Player Skill

For a player to experience flow, their skill level must match the game's challenge level. At the same time, skill and challenge must be above a certain level to achieve and maintain flow [28]. Therefore, the game should help the player develop the skills needed to play the game. The game should facilitate the player learning as they play, removing the need for explicit tutorials or lengthy reading material. Players should also be able to start playing the game without requiring them to read an instruction manual first. If there needs to be a tutorial, it should be well-designed, short, intuitive, and absorbing.

There are a few best practices that a game can follow to help the player develop their skills as they play [28]:

- The game should, where possible, adhere to platform standards. This adherence allows the game to benefit from any previous knowledge the player might have.
- Button prompts and hints should be contextual and explicit. They should not be mixed with in-game dialogue to prevent immersion breakage.
- Games should use interface metaphors and analogies to the real world to help players understand how to navigate through the environment.

8.1.4 Control

One of the reported effects of flow is the participant feeling a sense of absolute control of their actions [29]. Games and their interfaces (referred to as the "shell" by Sweetser and Wyeth [28]) are, by nature, an abstraction that sits between the player and what they imagine they are doing [28]. The game must be able to translate the player's inputs and intentions into actions in the game. If done correctly, the game's interface should "disappear", and the player feels they are directly controlling the actions on-screen. This feeling of control does not only apply to the player's minute-to-minute actions but also to the broader choices and decisions of the game. A well-designed game should allow players to feel as if their decisions matter and impact the game's progress. Games that are more free-form in their design and allow the player to experiment are more likely to make the player feel in control. Examples of these kinds of games are open-world games, non-linear games, and games that allow emergent gameplay. Nintendo's *The Legend of Zelda: Breath of the Wild* is a good example of a game that is open-world, non-linear, and that allows for emergent gameplay. More linear games should mask this linearity and make the player feel like they are in control of the game and not the other way around.

8.1.5 Clear goals

Flow requires clear goals for the participant to focus on [29]. Sweetser and Wyeth advocate that games should have *multiple layers of goals* for the player to focus on while they play [28]. An overarching goal should be established early on in the game. An example of an overarching goal is to “Defeat Calamity Ganon” in *The Legend of Zelda: Breath of the Wild*. Games should also have intermediate goals that keep the player’s attention minute-to-minute and second-to-second. The minute-to-minute goals are typically the goal of the current level in the game. These goals can be simple: “Get to the end of the level” or “Defeat all the enemies”. The second-to-second goals involve the challenges of the gameplay loop. These can, for example, be “defeat this enemy” or “jump over this chasm”. Having multiple levels of goals is also covered in Malone’s *outcome uncertainty* principle [30]. Malone’s model is presented in Section 8.3.

8.1.6 Feedback

Feedback is an essential element for sustaining flow. The participant must feel that their actions have tangible effects on what they interact with [28]. Games should give the player an idea of their progress towards their current objectives as frequently as possible and indicate whether they are “moving in the right direction”. The player should also receive immediate feedback on their actions. The feedback can be in the form of numbers flashing on the screen when the player hits an enemy, symbolising the damage the hit inflicted on the enemy.

8.1.7 Immersion

In his original paper on flow, Mihaly Csikszentmihalyi writes about “The Loss of Self-Consciousness” [29]. He discusses how a person experiencing flow will, through deep but effortless involvement in the activity, lose their concept of self for the duration of the activity. This loss of awareness is an enjoyable experience as the participant can let go of the worries of everyday life. When the experience is over, the participant sometimes feels like their boundaries have been expanded. Sweetser and Wyeth report that many players experience the same phenomena when playing games sometimes even devoting entire weekends to a single game [28]. For many, games act as escapism, allowing players to experience feelings and situations far removed from everyday life and its worries.

For games to have the best shot at achieving immersion, and by extension flow, in their players, they should use the following guidelines [28]. The interface should be as intuitive and “invisible” as possible to make the player forget that they are participating in an activity through a medium. Games should allow the player to linger and become immersed in the digital world “around” them. The world should be realised with well-crafted audio and visual elements. Audio is essential for drawing players into the game’s world. A well-crafted narrative can also help immerse the player and can help them connect with their avatars, making them feel like they are a part of the story.

8.1.8 Social Interaction

Social interaction is the only element in GameFlow that does not have a direct comparison to one of the elements from the original flow definition [28]. Social interaction can be antithetical to player immersion, but at the same time, social interaction is a big part of the enjoyment of games for many players [28]. Some players will even play games they usually would not enjoy for the social interaction they provide. This fact hints that different player types find enjoyment for different reasons in games; this will be discussed further in Section 8.5.

Games should encourage social interaction by providing opportunities for competition, cooperation, and connection between players [28]. These opportunities can take the form of in-game chat functions, leader boards, or tools for forming virtual communities such as the guilds in *World of Warcraft*. Adding tools for social interaction is not limited to multiplayer games. Single-player games can also add elements like global leaderboards, daily challenges (the same for all players), or secrets that are hard for a single player to figure out. These elements can encourage players to create out-of-game communities where they can discuss and bond over the game.

8.2 Dual Flow

Dual flow is an adaptation of GameFlow for use in exergames [31]. Specifically, the dual flow model (shown in Figure 8.1) is intended to be used with exergames that aim to provide moderate to intense aerobic workout sessions. The model does not work well for exergames aimed towards lower-intensity workouts or low to moderate physical activity. In such cases, the original GameFlow model might be a better fit.

Dual flow presents two success factors for achieving flow and a “proper” workout session in exergames [31]. The first factor is *attractiveness*, which describes the game’s ability to motivate players to start playing and keep playing the game over time. Attractiveness measures how well the game manages to keep the player in a normal flow state. A game must use the principles from GameFlow to achieve a good attractiveness score. *Effectiveness* is the second success factor; it describes the game’s ability to produce an effective workout.

“The most important outcome for exergaming systems is (arguably) to achieve health benefits” [31]

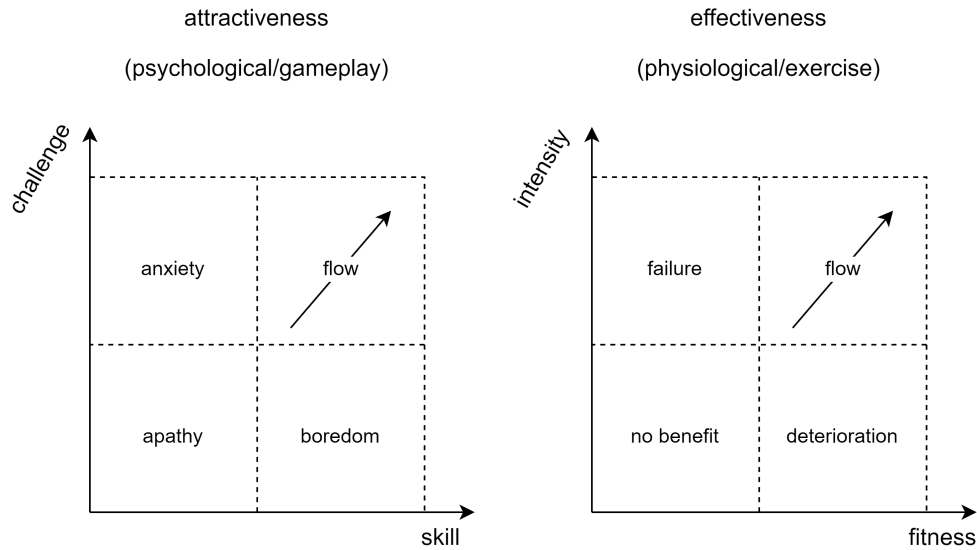


Figure 8.1: The dual flow model [32]

Looking at Figure 8.1, we can see that dual flow aims to achieve two flow states simultaneously, indicated by its two success criteria. The first is normal GameFlow through attractiveness. Section 8.1 describes in detail how to achieve this state. The other flow state dual flow aims to achieve is *physiological flow*, measured through effectiveness [31]. This physiological flow is met by matching the intensity of the physical activity the game tries to impose on the player with the player’s fitness level. If the game’s physical activity is too demanding, it will lead to failure, with the player unable to complete it. If the player is too fit for the activity the game provides, the activity will deteriorate. The physical activity requested by the game should match the player’s fitness level, or the physiological flow state will not be reached. Like matching a game’s difficulty to a player’s skill in “normal” games, an exergame should offer variability in its activity intensity, either through player choice or through analysis of how the player is performing.

8.3 Challenge, Fantasy, and Curiosity

One of the most influential papers in game enjoyment theory is Thomas W. Malone’s “*What Makes Things Fun to Learn? Heuristics for Designing Instructional Computer Games*” [30]. In this paper, Malone describes three essential characteristics of “intrinsically enjoyable situations” that he organises into three categories. These categories are *challenge*, *fantasy*, and *curiosity*. Malone recommends combining as many of the three categories as possible to create games that will be more engaging and intrinsically motivating. These categories can also be applied to activities other than games as a general theory on how to make activities intrinsically motivating.

“Though I will not emphasise the point in this paper, these same ideas can be applied to other educational environments and life situations. In a sense, these categories I

will describe constitute a general taxonomy of intrinsic motivation - of what makes an activity fun or rewarding for its own sake rather than for the sake of some external reward [...]” [30]

8.3.1 Challenge

A game works much better if it has a distinct goal; some might even argue that a game without a goal is no game at all [30]. The game’s goal should be something the player can identify with and intuitively understand. The goals should be well integrated into the game’s story and support its *intrinsic fantasy* (presented in Section 8.3.2). However, the game’s outcome should be uncertain, as the player will become bored if they know they are guaranteed to reach their goal. *Outcome uncertainty* ensures that the game gives the player a sense of challenge, making them uncertain if they will reach their goal. Malone presents four ways to introduce outcome uncertainty [30]: *Variable difficulty*, *Multiple level goals*, *Hidden information*, and *Randomness*.

Variable difficulty corresponds well with the main principle of *flow*, balancing an activity’s challenge versus the participant’s skill [30]. Games should facilitate this by having different difficulty levels. This variability can either be done automatically by the game detecting how well the player is doing and adjusting the difficulty accordingly or by allowing the player to adjust the game’s difficulty level manually.

Multiple level goals state that games should have several different levels of goals [30]. An overarching goal should typically be the centrepiece of a game’s story, like rescuing Princess Peach from Bowser’s castle in *Super Mario Bros*. In addition, games should include smaller goals the player can complete in a shorter time frame. Short-term goals are there to keep the player engaged on a minute-to-minute basis. Examples of short-term goals can be reaching the end of the current level or defeating the enemies the player is currently fighting. Malone also recommends including meta goals about how well or how fast a player can complete a task. Meta goals encourage replayability and allow players to compare themselves to others. Malone’s recommendation for multiple levels of goals corresponds well with GameFlow’s *clear goals* criteria (see Section 8.1.5).

To entice the player’s curiosity, game developers can hide and selectively reveal information to the player [30]. This *hidden information* can be in the form of hidden goals or twists and turns in the story that throws a wrench into the player’s plans and forces them to adapt.

The last way to introduce goal uncertainty is *randomness*. If the game runs the same way every time and is perfectly predictable, the player will eventually find one strategy that works every time and grow bored due to the lack of challenge [30]. Instead, suppose some of the parameters of a game, like enemy placement, are random each time. In that case, the player has to think on-the-fly and figure out strategies to deal with unfamiliar situations.

Malone argues that the challenge of a game connects tightly to the player’s self-esteem [30]. If the player is doing well and completing goals, they will get a boost to their self-esteem, and their desire to play the game will increase accordingly. Due to this phenomenon, the game must ensure that if the player fails to reach a goal, their desire to play the game does not decrease. Malone recommends adjusting the difficulty when players fail and giving performance

feedback that does not attack the player's self-esteem.

8.3.2 Fantasy

A game with a potent fantasy will be more interesting than a game with a weak or lacking fantasy [30]. Malone identifies two types of fantasies used in games: *extrinsic* and *intrinsic*.

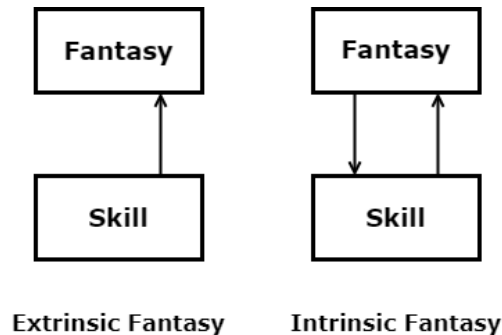


Figure 8.2: Extrinsic and intrinsic fantasy relate to skills in different ways [33]

In *extrinsic fantasy games*, the challenges and tasks the player faces are removed from the game's central fantasy [30]. Completing tasks feeds into the fantasy, but the fantasy does not inform the tasks themselves. An example of a challenge in an extrinsic fantasy game is guessing letters in the game *Hangman*. Guessing the letters will affect the fantasy as guessing the wrong letters will lead the prisoner closer to being hanged, but the fact that a prisoner is about to be hung does not influence what skills or kind of challenges the player faces.

In *Intrinsic fantasy games*, the game presents the player with situations where the challenges and fantasy inform each other [30]. An example of an intrinsic fantasy game is a simple dart game. Here, the fantasy is to hit the dart board, and the player's challenge is to aim and throw the arrow at the board.

Malone argues that intrinsic fantasy games are more engaging for the player and have greater potential for education and motivation [30].

8.3.3 Curiosity

"Curiosity is the motivation to learn, independent of any [goal-seeking] or fantasy-fulfilment]. Computer games can evoke a learner's curiosity by providing environments that have an optimal level of informational complexity [...]. In other words, the environments should be neither too complicated nor too simple with respect to the learner's existing knowledge. They should be novel and surprising, but not completely incomprehensible." [30]

Malone splits the curiosity category into two main types: *Sensory curiosity* and *cognitive curiosity* [30]. A game's *sensory curiosity* describes how well it can pull the player's attention with light, sound, and other stimuli. The curiosity comes from the player wanting to see what effect

will happen next. Sensory curiosity can be stimulated with techniques such as having a sound or graphic display as a reward when they reach a goal. *Cognitive curiosity* is the player’s drive to bring completeness to their knowledge of something. For example: in a murder mystery game, if the player is close to figuring out who the murderer is, their curiosity will drive them to solve the mystery. Malone recommends increasing cognitive curiosity in games by creating interestingly complex and responsive environments with surprising feedback.

8.4 Octalysis Framework

The Octalysis Framework is a gamification framework developed by Yu-kai Chou that highlights the different strategies games can use to make themselves enjoyable for players [34]. The framework takes its name from the eight “core drives of gamification” it presents. These eight drives are: *Epic Meaning & Calling, Development & Accomplishment, Empowerment of Creativity and Feedback, Ownership & Possession, Social Influence & Relatedness, Scarcity & Impatience, Unpredictability & Curiosity, and Loss & Avoidance*. The drivers are distributed around an octagonal figure, as shown in Figure 8.3. Note that the drivers’ names have been shortened in the figure.

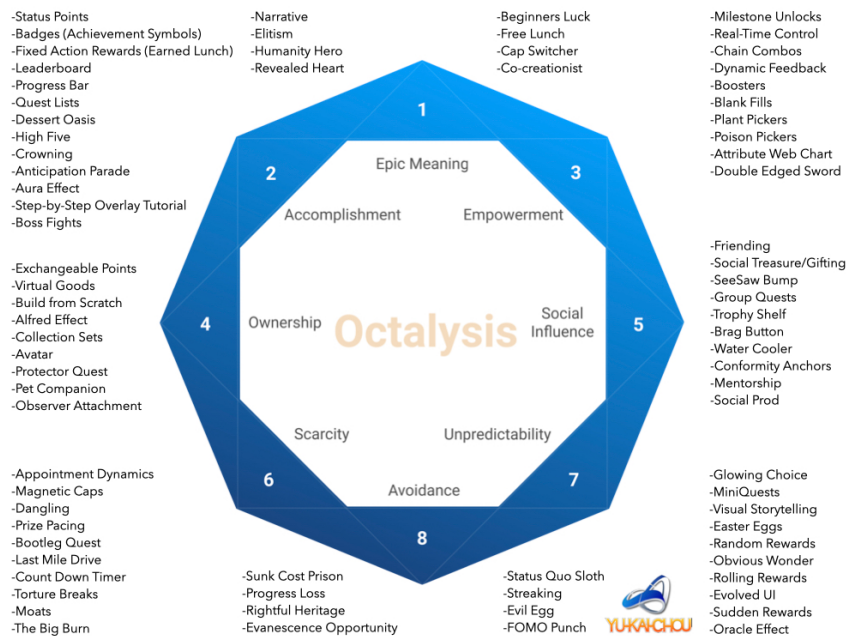


Figure 8.3: The Octalysis framework [35]

8.4.1 Epic Meaning & Calling

The Epic Meaning driver tries to get the player to believe they are part of something greater than themselves [34]. This belief can, for example, be developed through the game’s story, with the game presenting the player’s avatar as a “chosen one” with a just cause. This driver can also be found in places such as Wikipedia, where the different editors donate their time

because they believe it is the right thing to do.

8.4.2 Development & Accomplishment

This driver is the internal drive to progress, develop skills, and overcome challenges [34]. The driver relies on the player wanting to make progress, and games often try to encourage players by giving out points, badges, and other glory rewards, for overcoming challenges. Chou emphasises the importance of having challenges that match the rewards. If the challenges are too easy or hard compared to the given reward, the driver will not work.

8.4.3 Empowerment of Creativity & Feedback

This driver relies on engaging the player in creative processes [34]. The player should have a way of expressing their creativity, and the game needs to accommodate and respond to that. Chou recommends adding evergreen mechanics that are fun to interact with in-and-of themselves. Examples of such evergreen activities from the real world are building with Lego and painting.

8.4.4 Ownership & Possession

This drive tries to motivate players by making them feel ownership over something [34]. Chou postulates that when players feel ownership, they want to make what they own better and want to own more. In games, this mainly relates to virtual goods or currencies but can also be applied to situations where the player has spent a lot of time customising a part of the game (for example, their avatar) and now feels ownership over what they have created.

8.4.5 Social Influence & Relatedness

This drive incorporates all the different social elements that motivate people [34]. This drive is quite broad but also one of the best studied. Humans are inherently social animals that will form bonds through friendship, competition, envy, and many other means. Games can benefit from this drive by allowing for social interactions and appealing to bonds already established between the players. An example is games invoking a sense of nostalgia in the player by using imagery and sounds from previous eras. Another example is the game *World of Warcraft*, where players are encouraged to join large guilds to work together and be social with one another.

8.4.6 Scarcity & Impatience

This drive exploits the player wanting to have something because they cannot have it in their present state [34]. One common way games utilise this drive is with appointment dynamics (the player starts an activity and has to return later to see the result). These mechanics will cause the player to think about the game while waiting. Another use of this drive is through gatekeeping. If a game is invite-only or limited to a select audience, those who do not have access will want to get access just because they do not have it.

8.4.7 Unpredictability & Curiosity

This drive relies on the player's wanting to know what will happen next [34]. Generally, if a player does not know what will happen, they will think about the game more often. This drive is why many people watch movies or read novels; they want to know what will happen next. This phenomenon necessitates that the story in the game, movie, or novel is good enough for the player to pay attention to it. This drive is also behind gambling mechanics; the player returns to the game due to the possibility of something rare and great happening.

8.4.8 Loss & Avoidance

This driver is based upon the player's wanting to avoid something negative happening [34]. On a small scale, this can be the player trying their best to stay alive in a game to avoid losing progress. On a greater scale, this driver can keep players invested in a game because they do not want to lose everything they have built up in the game. This driver typically ties in closely with the *Ownership & Possession* driver.

The placement of the different drives in the Octalysis framework model (See Figure 8.3) is not random [34]. The drivers on the left appeal to the player's logic, calculations, and sense of ownership, whereas the drivers on the right appeal to the player's creativity, self-expression, and social aspects. The model can also be divided into top and bottom, with the top being called "white hat gamification" and the bottom "black hat gamification". The names refer to how positive or negative a driver is. The positive drivers motivate players by making them feel good through skills mastery, creativity and a higher sense of meaning. The negative drivers motivate the player by "pushing" them with techniques such as fear of loss, count-down timers, random rewards, and fear of missing out.

8.5 Player Types

Player types refer to the different kinds of players in a game. Different people find different types of games and game aspects interesting based on what they want to do and achieve in the game. One of the most referenced theories of player types is *Bartle's player types* [36]. Bartle's player types, shown in Figure 8.4, were originally based on observations of player behaviour in *Multi-user dungeons* (MUDs) but have since been adapted to fit different game genres [37]. The different axis on the figure describes what aspects of the game engage different kinds of players. The horizontal axis describes whether other players or the game world interests the player. The vertical axis describes if the player prefers to interact with what interests them or act upon it. The resulting four quadrants are: *Killers*, *Achievers*, *Socialisers*, and *Explorers*.

Achievers want to master the game and make the world do what they want it to do [37]. Finding new and more optimal ways of progressing compels them. Achievers want to rise through the levels, gather points, or get a high score, and their actions are all done with this as the end goal.

Explorers want to explore and be surprised by the world, and they feel a sense of wonder when they explore and interact with it [37]. They can appreciate other players in the game if they

add depth to the game or lets them explore new areas of the game. They explore different and creative ways to interact with the game, looking for different features and trying to figure out how things work.

Socialisers want to interact with other players. They want to learn about the people in the world, what they are doing, and why [37]. They see the world as a setting and the people living in it as the thing that makes the world feel alive. Socialisers value inter-player relationships through talking, joking and sympathising with other players.

Killers are interested in doing things to other people, usually without consent [37]. They want to show their superiority by dominating other players by abusing or killing their in-game characters. The killer finds joy in creating distress and chaos.

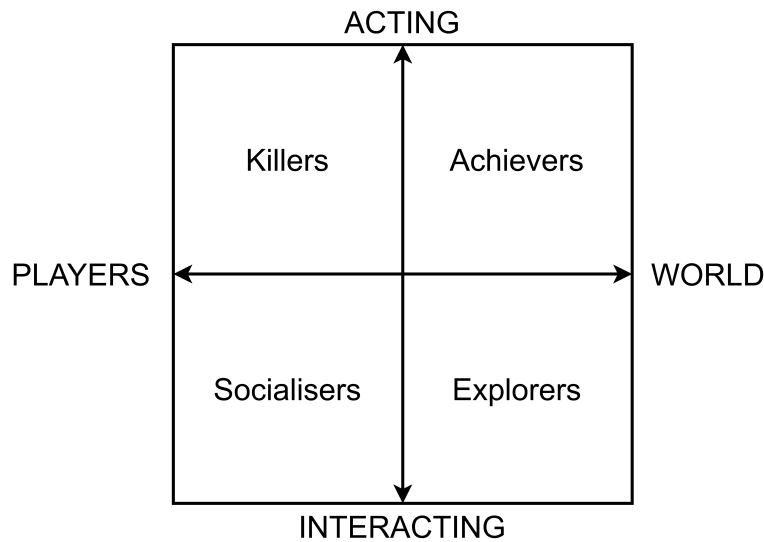


Figure 8.4: Bartle's player types [37]

Bartle's player types have received criticism for being too dichotomous and simplifying [36]. It is argued that while the categories can be suitable for design purposes, most players are a mix of player types, as they can have multiple motivations for doing something. Despite the criticism, Bartle's player types are still a useful lens for analysing player behaviour in games. Other researchers have continued researching player types while using Bartle's theory as a base/reference. There have also been other approaches to explaining possible player motivations that are not based on Bartle's theory. One example is Tseng, who looked at players' motivation based on two factors, the need for exploration and the need for conquering.

8.6 Reward Classifications and Systems

How a game rewards its players for playing the game is an essential factor in how the players will perceive that game. Using several ways of rewarding players correlates positively with overall player enjoyment [38]. Rewards are also an important factor for enabling several of the elements of GameFlow [28].

8.6.1 Reward Classifications

To better understand the various ways games can reward players, it is helpful to categorise these rewards based on their purposes and effects. In their book “*Swords & Circuitry: A Designer’s Guide to Computer Role Playing Games*”, Hallford and Hallford present four major classifications of rewards [39]:

- **Glory:** Rewards with no direct impact on the gameplay itself, but that can be used as a badge of honour for the player, like score, cosmetics, or literal badges.
- **Sustenance:** Rewards that maintain the player’s current state and achievement level. Examples of sustenance can be in-game consumables or values such as health, energy, or shields.
- **Access:** Rewards that allow the player to access new content in the game. For example, keys that unlock new parts of a level.
- **Facility:** Rewards that mechanically alter the player’s avatar. Either by unlocking new abilities or altering the avatar’s existing abilities. This type of reward can be combined with the access classification. A well-known use of this type of combination reward is in the *Metroid*-game franchise, where upgrades to the protagonist’s suit allow her to access new areas of the map.

These classifications were initially developed for Role-Playing Games but can also apply to most other types of games.

8.6.2 Reward Systems

The article “*Game Reward Systems: Gaming Experiences and Social Meanings*” by Hao Wang and Chuen-Tsai Sun expands further upon these major reward classifications by discussing the different forms of reward systems that exist and how they relate to the classifications [40]. The different forms of rewards systems presented are:

- **Score Systems:** Score systems are one of the simplest and earliest forms of reward systems. Most of the time, score systems will not directly impact gameplay; instead, they will be used to measure the player’s skill. The most common usages of score systems place them firmly in the *glory* category of rewards. In some cases, scores can be tied to unlocking in-game items or be used to match players of similar skill against each other in versus games. This usage of score systems means they can *touch upon elements from any of the four reward classifications*.
- **Experience Point Systems:** Experience points (XP) are common in all games where players control an avatar. The player’s avatar will gain experience points during play and typically “level up” when a predetermined amount of experience points are gathered. Levelling up will typically unlock or enhance the avatar’s abilities and directly impact gameplay. These types of reward systems belong in the *facility* category.
- **Item Granting Systems:** These systems award virtual items to player avatars, which can affect the avatar’s abilities or be purely cosmetic. These items can be rare, driving

some players to spend considerable time, effort, or money to acquire them. Obtaining these items can provide a competitive edge in gameplay or serve as a status symbol. These item-granting systems fall into one of two categories: *facility* or *glory*, depending on their implementation.

- **Resource Reward Systems:** Many games feature gatherable resources. These typically take a variety of shapes depending on a game's setting. Some examples are wood, stone, health potions, and energy spheres. At first glance, these might seem similar to the items granted by item granting systems, but they serve a very different purpose. Resources are mostly for practical in-game use, such as construction or maintenance. Resource reward systems correspond well with the *sustenance* category. Some games allow the player to use resources to create items; in these cases, a resource and an item-granting system work together.
- **Achievement Systems:** Achievements are titles and badges bound to avatars or players and are given to them as rewards for fulfilling specified conditions. These conditions encourage players to complete specific tasks, explore, or play in particularly challenging ways. Achievements do not directly impact gameplay and are typically viewable on a profile page outside the main game. Achievements land squarely in the *glory* category.
- **Feedback Messages:** Feedback messages are used to provide instant rewards to the player. Typical examples are the sparks and texts that show when the player hits a perfect note in a karaoke game or the comic-style pop-ups shown when landing hits in some fighting games. Feedback messages do not affect the gameplay directly; they only exist to evoke emotions in the player. Instant feedback is one of the key elements for sustaining flow (see Section 8.1.6), and feedback messages are a valuable tool in this regard. Feedback messages do not fit as neatly into one of the four major classification categories as the other systems. However, *glory* is the closest due to the messages having no direct impact on gameplay, and the accumulation of positive feedback messages can be seen as a badge of honour.
- **Plot Animations and Pictures:** These rewards are typically presented to the player after reaching important milestones or completing major tasks, commonly at the end of levels or the end of the game itself. The rewards can, for example, take the form of videos showing the player's avatar in a heroic pose after defeating a major enemy. These rewards are typically visually attractive and might be a reward in and of themselves. However, they also provide a sense of accomplishment as they signal that the player has reached a milestone. Plot animations and pictures are considered *glory* rewards.
- **Unlocking Mechanisms:** These give access to new game content. They can come in many forms and are often intertwined with other reward systems, such as scores, experience points, or items. For example, a new item might be unlocked after the player has reached a certain score limit. Unlocking mechanisms might also stir the player's curiosity. If the player knows what they need to do to unlock an item but do not know what the item does, their curiosity can incentivise them to try to unlock it as they want to discover what it does. Unlocking mechanisms align well with Malone's curiosity category (see Section 8.3.3) and are categorised as *access* rewards.

8.6.3 Reward Systems and Flow

In their article on reward systems, Wang and Sun also write about how reward systems feed into a player's sense of flow during gameplay [40]. They highlight three elements of flow where reward systems have the most impact: *challenge*, *clear goals*, and *feedback*. These elements are also some of the elements of flow that map most directly from flow to GameFlow (see Section 8.1). Reward systems can help players maintain flow by allowing them to see their progress, get a sense of accomplishment, and encourage them to set intermediate goals and break their records.

Flow requires clear goals and immediate feedback [29]. If the game correctly rewards player behaviour that leads towards the game's intended goals, it will be self-evident for the player what they need to do [40]. Reward systems like score systems and unlocking mechanisms allow players to set their own goals on the path to completing the game's overarching goals. For example, suppose the player needs to be more skilled to defeat a theoretical game's boss. In that case, they have two options: either keep trying, slowly improving their skills and seeing the boss' health bar tick closer and closer to the winning threshold. Alternatively, they can participate in other in-game activities and, for example, benefit from the game's unlocking mechanisms giving them items that will make their fight against the boss easier (proverbially known as loot grinding). Both approaches allow the player to set their own intermediary goals on their way to reaching their overarching goals.

According to the GameFlow model, without reward systems, the fight against the game's boss might feel tedious and even lead to anxiety [28]. The different reward systems are tools the developers can use to help the player stay in the flow state. In cases where the player's skill does not match the game's current challenge, the reward systems can help keep the player engaged with the game [40].

8.7 Summary

This chapter presented different theories of game enjoyment and how to make games fun and rewarding for the players. First, it presented the theory of *GameFlow* and its eight criteria contributing to achieving flow in games. These were presented along with the implications they have for game design. Second, it presented *Malone's model* of *challenge*, *fantasy*, and *curiosity*, meant for creating "intrinsically enjoyable situations". Third, it presented the *Octalysis framework* and its eight "core drivers of gamification" that can be used to motivate players by appealing to different facets of their personalities. Next, it presents *Bartle's Player Types* and discusses his four player types: *Killers*, *Achievers*, *Socialisers*, and *Explorers*. Lastly, it presents four different *reward classifications* along with the different types of *reward systems* often seen in games. These theories describe different ways games can reward their player and boost their enjoyment. One common through-line we can see in all the game enjoyment theories is the importance of balancing the game's challenge with the player's skill to keep the player engaged.

The next chapter will look at connecting the game enjoyment theory from this chapter with the motivation theory detailed in the previous chapter.

Chapter 9

Connecting Motivation Theory and Game Enjoyment Theory

This chapter connects the motivation theory from Section 7.3 and game enjoyment theory from Chapter 8.

Studies have shown that video games have great potential to fulfil the *basic psychological needs* [41]. Instances where players experience *flow* positively correlated with the game fulfilling the players' basic psychological needs (note: these studies refer to flow as "presence"). This correlation means that games have the potential to create both strong *intrinsic* and *internalised extrinsic motivation*, something that is confirmed by studies on game enjoyment [28][30]. Studies on exercise motivation have shown that *well-internalised extrinsic motivation* is vital for starting an exercise regime, and *intrinsic motivation* is essential for maintaining the regime over a longer period of time [24]. If the same connection could be found between exergames and SDT as with regular video games and SDT, it would mean that exergames can be a tool for helping people to start exercising and sticking with it long-term.

The three basic psychological needs from SDT are the need for *competence*, *autonomy*, and *relatedness*. There are several elements in the game enjoyment theories presented in Chapter 8 that map quite nicely onto the three basic psychological needs. For example, *Malone's Challenge* category, *GameFlow's challenge* and *player skill* categories, *Octalysis Framework's Epic Meaning & Calling*, and *glory* rewards align well with the need for *competence*. Almost every theory on game enjoyment states that a game's challenge and the player's skill level need to match; the player needs to feel a sense of competence. Other elements map to the need for *autonomy*. For example, one of the requirements for *Flow*, and by extension *GameFlow*, is that the player needs to feel in control of their actions; the player needs *autonomy*. The *immersion* category from *GameFlow* and the *fantasy* and *curiosity* categories from *Malone* also deal with player autonomy more directly. The last basic psychological need is the need for *relatedness*. Not all games directly fulfil the requirement of relatedness, but they can still improve a person's well-being and motivation by fulfilling the requirements of competence and autonomy [41]. The most direct way for games to fulfil the need for relatedness is through *social mechanics*. The *social interaction* category from *GameFlow* most directly covers this need.

The next chapter will introduce game genres that help define how different games are designed.

Chapter 10

Game Genres

This chapter will define and give examples of different game genres. Games are fantastically diverse in their designs. To an outside observer, it might be hard to classify games into distinct genres, especially with how multi-faceted modern high-budget triple-A games have become. An example of how multi-faceted modern games are is the game *Uncharted 4: A Thief's End*. Elements of this game can be split into many different genres, like action games, role-playing games, puzzle games, and shooter games. The genres presented are primarily based on the definitions by Ernest Adams in his book *Fundamentals of Game Design* [42], but with some additional genres from other sources. Understanding the context and design cues of different games is important when evaluating what makes other games good and when developing new game concepts.

“[Genres] are categories of games characterized by particular kinds of challenge, regardless of setting or game-world content.” [42]

10.1 Strategy Games

Strategy games aim to challenge the player with strategical, tactical, and sometimes logistical challenges [42]. The players overcome these challenges by planning a series of actions (laying a strategy) and executing them against other opponents' strategies, either human or computer-controlled. The resulting conflict might force the player to adapt their strategy while the game is underway. The conflict between different parties distinguishes strategy games from other genres, like puzzle games. Strategy games are traditionally turn-based, where one player does their turn and then waits for the opponent to respond. A sub-genre of strategy games is real-time strategy games. Figure 10.1 shows the turn-based strategy game Civilization 6.



Figure 10.1: Civilization 6

10.1.1 Real-Time Strategy Games

Real-time strategy (RTS) games are a sub-genre of strategy games [43]. The main difference is that in RTS games, in-game time progresses in real-time rather than in distinct increments. RTS present the players with the same challenges as strategy games but adds the challenge of reaction time due to their real-time nature. The gameplay loop typically consists of the opponents building structures and units to harvest resources and gather strength to fight each other. An example of an RTS is the game StarCraft 2: Wings of Liberty, shown in Figure 10.2.



Figure 10.2: StarCraft 2: Wings of Liberty

A notable sub-genre spawned from RTS games is the Multiplayer Online Battle Arena (MOBA) genre. Here, the maps and games are more regimented with a mirrored layout (see Figure 10.3), and players control a single character instead of an entire army.

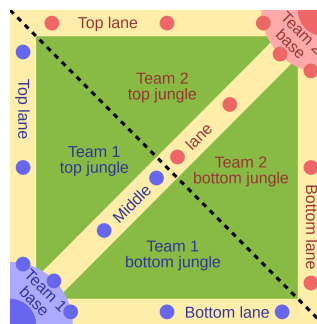


Figure 10.3: A common MOBA map layout

10.2 City-Builder Games

City-builder games, also known as construction and management simulations, try to simulate the work of a city planner [42][44]. The challenge of these games comes from designing the city and balancing resources. The player needs to consider the cost of their city's design, where the resources come from and how they are spent. Elements such as infrastructure and building compatibility are often mixed in to give interest and complexity to the experience. Usually, these games are viewed from a top-down angle to give the player a feeling of being in control, as if they are a "god" moving pieces on the ground.

City-builder games can have many different styles and themes, often denoted by the game setting. For example, *Farmville* (see Figure 10.4) is a farming-themed city-building game



Figure 10.4: Farmville

10.3 Role Playing Games

In role-playing games, the player takes control of a character and their actions [42]. The player can create the character from scratch, or it can be pre-generated. However, they differ from other more generic avatars as they have a set of defined character traits that can vary from character to character and could be affected by the player's choices. Through the game, the character will develop their skills and grow. The player gets to experience a sense of growth by going from an "ordinary" person and growing in power to becoming a superhero (or supervillain, depending on the game). *The Witcher 3* (see Figure 10.5) is a role-playing game where the player takes control of Geralt of Rivia.



Figure 10.5: The Witcher 3: Wild Hunt

The gameplay and associated challenges of role-playing games are diverse, but they all focus on two essential aspects: the story narrative and the character's development [42]. At first glance, role-playing games can appear quite similar to other genres. However, how the challenges are integrated into the narrative and character development sets the games apart from other genres.

10.4 Puzzle Games

Puzzle games offer conceptual and logic challenges where the player must recognise patterns, interpret clues, and make logical deductions to find the solution [42]. The games often consist of multiple levels, each with a new puzzle. The puzzles are generally similar or related to each other and get more challenging as the game progresses. These puzzles may occur as part of a story or otherwise strung together to reach a larger goal. Puzzle games exist in a wide variety of flavours, everything from hardcore brain twisters like *The Witness* to more causal experiences like *Angry Birds* (see Figure 10.6), *Candy Crush*, or *Cut the Rope*.

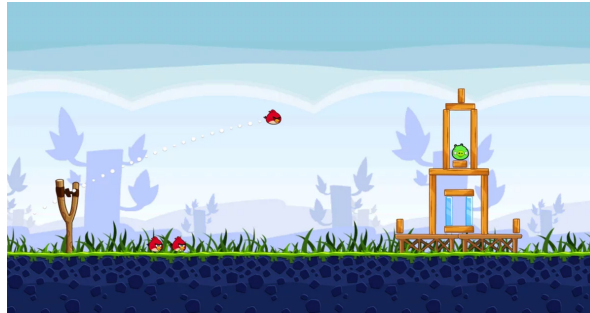


Figure 10.6: Angry Birds

10.5 Idle Games

Idle games, also known as incremental games, are games where the gameplay is straightforward, such as repeatedly clicking an object on the screen [45]. There are few challenges for the player in these games, as all they have to do is click different objects on the screen. In some cases, even these simple tasks become superfluous, as the players can buy in-game purchases to do the tasks for them. The enjoyment of these games comes from the progression, which plays on Malone’s concept of *curiosity* in games [30]. Many mobile games are a combination of idle games and other game genres, as mobile games are designed to be simple. For example, in the game *Cookie Clicker* (see Figure 10.7), the player starts out creating singular cookies by clicking on the image of a cookie but ends up ruling over a galaxy-spanning cookie empire.

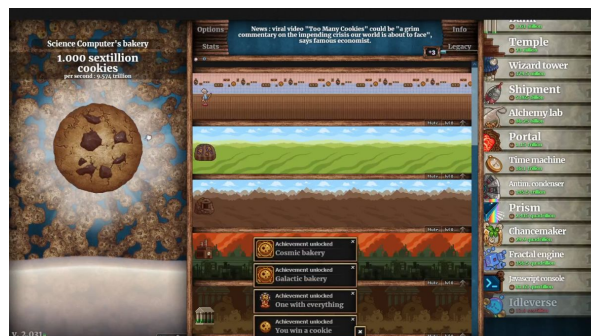


Figure 10.7: Cookie clicker

10.6 Party Games

Party games focus on the social and entertaining aspects of gaming. They typically lend themselves to more casual settings, like a group of friends playing against each other on multiple devices or a shared screen. The games typically consist of multiple easy “mini-games” that require a short time to complete and have a low skill barrier allowing players of all skill levels to participate. These “mini-games” vary a lot in terms of gameplay mechanics and challenge types, with the common factor defining them as party games being the game’s design intent. One of the most famous series of party games is the *Mario Party* series by Nintendo. Figure 10.8 shows the newest game in the series, *Mario Party Superstars*.



Figure 10.8: Mario Party Superstars

10.7 Sport Simulation Games

Sport simulation games aim to recreate the setting and feeling, if not the actual intricacies, of a sport [42]. The genre is very popular and has some unique design challenges. The main challenge comes from the players’ preconceptions; almost everyone has at least a surface-level understanding of how different sports work, so the developers need to be diligent when crafting the game’s rules so it does not break the player’s immersion. The challenge in sport simulation games is usually mechanical, with the player having to either control the actions of an individual athlete or a sports team. An example of the former is *Wii Sports* (see Figure 10.9), where the player has to perform the same movements as the athlete would do, and the game tracks the movement using a motion controller. The latter can be games like Electronic Arts’ *Fifa* series. Here, the controls are abstracted to button presses on a standard controller as the player controls an entire team of soccer players.

The games can also include strategic challenges, with the player dealing with the more managerial aspects of sports [42]. A sub-genre, occasionally called manager games, focuses mainly on the strategic challenges of sports instead of the mechanical ones.



Figure 10.9: Wii Sports

10.8 Action Games

Action games are one of the most loosely defined video game genres [42]. They come in a wide variety of flavours and only have one thing in common: physical challenge.

In *Fundamentals of Game Design*, Adams does not give a precise definition of *physical challenge* [42]. We have chosen to define *physical challenge* as a challenge that depends on the player's physical skills relating to their motor skills, coordination, timing, focus, and reaction time.

Action games typically have other, sometimes intentionally conflicting, challenges, such as puzzles, races, or economic challenges, but are less likely to include more complex strategic or conceptual challenges [42]. The only “pure” action games with nothing but physical challenges are early arcade games such as *Space Invaders*. An example of a more “modern” type of action game is the game *Metal Gear Rising*, shown in Figure 10.10.



Figure 10.10: Metal Gear Rising: Revengeance

As the genre of action games is so broad and unclear, many game genres are sub-genres of action games. However, some of these game genres have grown to be prominent game genres of their own, and while they technically fall under the action game umbrella, they are seen as independent genres. Some of the most prominent are mentioned in the following sections.

10.9 Platform Games

Platform games, also called platformers, are a subgenre of action games whose main goal is to get from one point in space to another [42]. The players control the avatar as they move through a vertically exaggerated environment containing different platforms at varying heights while avoiding hazards such as bottomless pits, traps, and enemies [46]. Most platform games are 2D games, like *Spelunky 2* (see Figure 10.11), but there are some 3D platform games, like *Super Mario 64*.

The main game mechanics for platform games are running and jumping, but many games include other manoeuvres such as swinging from vines or ropes, wall jumping, grappling hooks, gliding, and double jumping. There can also be environmental interactions, such as bounce pads or gusts of wind. The physics in platformers is unrealistic to the benefit of gameplay over realism.



Figure 10.11: Spelunky 2

10.10 Shooter Games

Shooter games are a subgenre of action games that challenge the player to react quickly to the gameplay and have a precise aim [42][47]. They are arguably one of the sub-genres of action games which focus most on physical challenges. In shooter games, fighting is conducted primarily with ranged weapons, and the player needs to focus on targets at long range while also staying aware of their surroundings in case they get snuck up on or flanked [42]. Shooter games tend to be 3D games and usually try to recreate relatable settings with realistic graphics and physics.



Figure 10.12: Rainbow Six Siege

Shooter games can be divided into two sub-genres: first-person shooter games and third-person shooter games, where the difference is the camera perspective, first-person and third-person [42]. There are also 2D shooter games that usually have more cartoon-like art styles and unrealistic physics, but these could also be classified as a sub-genre of platform games. Figure 10.12 shows *Rainbow Six Siege*, a competitive first-person shooter game.

10.11 Survival Games

Survival games are a subgenre of action games where the players try to survive for as long as possible in a hostile environment [48]. To accomplish this, the players must explore the environment to gather necessary resources while dealing with the different threats the environment presents [49]. By fighting off danger and their character's bodily needs (hunger, thirst, and fatigue), the player progresses until they either escape or succumb [50]. Figure 10.13 shows the survival game *Subnautica*.



Figure 10.13: *Subnautica*

Survival games typically rely heavily on resource reward and item granting systems (see Section 8.6). The player gathers the resources needed for their character to survive or to improve their ability to craft items that facilitate more efficient resource gathering or progression in the game. Similarly to horror games, survival games aim to make the player feel like their character is vulnerable.

10.12 Horror Games

Unlike other game genres, horror games are not defined by their activity level or challenge type but by the intention to scare or otherwise instil emotions of suspense, anxiety, or horror in the player [51]. Horror games typically use their visuals, audio design, and narrative to fulfil this intention. An example of a horror game is the game *Alien: Isolation*, shown in Figure 10.14.

Horror games have many sub-genres, arguably as many as there are classic game genres. Some of the most common are survival, action, psychological, and reverse horror (horror games where players try to scare each other) [51].



Figure 10.14: Alien: Isolation

10.13 Summary

This chapter has presented a selection of the game genres that exist. As gaming continues to grow in popularity and new games are created, the number of game genres also grows. As new, more advanced games are often a mix of different game genres, it becomes harder to define each category as the line between them starts to blur. An example of these hard-to-define games is the game *Uncharted 4: A Thief's End*, a game that includes elements from action games, role-playing games, puzzle games, and shooter games. The presented genres are a mix of genres often seen in combination with exergames and genres that have been popular and defining for the gaming industry for a long time. Some of the presented genres also consist of multiple sub-genres, but they are not detailed here.

The next chapter will introduce the concept of *Exergames*. Exergames are games requiring physical activity. They have been made in many of the genres presented in this chapter.

Chapter 11

Exergames

This chapter introduces the concept of *Exergames*. First, it discusses and defines what an exergame is. Second, it summarises the history of exergames and how exergames have evolved. Understanding how exergames have evolved reveals patterns and concepts that are tried, tested and shown to work. Many of the early exergames are motivational and engaging even today.

11.1 What is an Exergame?

The term *Exergame* is a portmanteau of the words “Exercise” and “Game”. Multiple researchers have defined the term in different ways, with the common factor being the combination of some level of physical activity and video games. In the paper *Defining exergames & exergaming*, Oh and Yang address the issue that the multiple definitions of the term *exergame* have led to an interchange of the terms *exercise* and *physical activity*, as many exergames only require physical activity and not exercise [52]. When the term has the word “exercise” in it, people will think of physical activity and exercise as the same thing. As mentioned in Chapter 7, the terms *exercise* and *physical activity* are often used as synonyms, but the definitions have subtle but significant differences, and exercise is a sub-category of physical activity. Because of the inconsistency of the term, researchers working in the health field sometimes avoid using the term *exergames* and instead use terms like *activity promoting* and *active video game*, which they regard as more representative term. While this might be a more terminologically correct use of words, this can also lead to misunderstandings. In their paper, Oh and Yang want to solve this by redefining the term exergame rather than changing it altogether [52]. They define an exergame as:

“A video game that promotes (either via using or requiring) player’s physical movement (exertion) that is generally more than sedentary and includes strength, balance, and flexibility activities” [52]

This definition is a good definition of exergames, but there is one detail we would change. In “... includes strength, balance, **and** flexibility activities”, we would like to change **and** to **or**. This change highlights that exergames do not necessarily need to contain activities that include all three categories, strength, balance, and flexibility. Games should still count as exergames even if they focus on only one or a combination of the categories.

Therefore, in this thesis, we will be using this amended definition to define the term *Exergame*:

A video game that promotes (either via using or requiring) a player’s physical move-

ment (exertion) that is generally more than sedentary and includes strength, balance, or flexibility activities.

11.2 The History of Exergames

The exergame genre has its roots back in the 1980s when Atari first released the *Atari Joyboard*, shown in Figure 11.1, in 1982 [53]. Atari also planned to release a bicycle game called *Atari Puffer*, but for different reasons, it never made it to the market. In 1988, Nintendo released the *Power pad* for the Nintendo Entertainment System (NES). The *Power pad* was a plastic mattress with 12 pressure sensors distributed around the mat, which would register where the player was standing. The *Power pad* was used for games like *Dance Aerobics*, which was released in 1989 and was an early example of a dance game before the genre took off with the dance game revolution of the late 1990s.



Figure 11.1: The Atari Joyboard is considered the first exergame

In the 1990s, VR games were introduced and mixed with the genre of exergames [53]. Gaming companies started creating games like *VR Bike* and *VR climber*, aimed at the fitness market as a response to the growing fitness trend and not only for the arcade or home market. However, the trend never took off because of the extensive cost of VR games. In 1998 the game *Dance Dance Revolution* (DDR) was released, kicking off the dance game trend along with the game *Pump It Up*. *Pump It Up* was an arcade game similar to DDR released in 1999 that used a five-arrow dance pad, unlike DDR, which used four arrows.

The turn of the millennium marked the introduction of exergames into the home market. Previous exergames had focused more on the arcade space as they required big machines and expensive technologies. However, this changed drastically as advanced technology became more readily available to the general public. *Geocaching* is a worldwide treasure hunt where treasures are hidden in public areas, and its GPS coordinates have been registered to a map. The players can find these hidden treasures using their GPS- or mobile devices [54]. The first

documented geocache was placed on May 3rd, 2000, and since then, an enormous amount has been placed worldwide. In 2005, *EyeToy: Kinetic* was released for the PlayStation 2 and was the first multi-function game to reach the home market. The game tracks the player's movement using an EyeToy camera, and the player can join different training groups known as Zones, where different Zones focus on different training styles [55]. In 2006, Nintendo released the *Wii* gaming console, which used a motion controller called the *Wii Remote* as the standard game controller. The remote had an accelerometer and detection sensors that tracked the controller's movement [56]. The introduction of the *Wii* led to a new wave of exergames that focused on motion tracking like *Wii Fit*, *Wii Sport* and *EA Sports Active*.

The 2010s showed the continuation of the introduction of exergames into the home market. Microsoft released the *Kinect* for the *Xbox* in 2010. The *Kinect* was a motion sensor device that used body motion tracking to track player movement for games like *Just Dance* and *Nike+ Kinetic Training*. The *Kinect* enabled the *Xbox* to track full-body movement instead of half-body or just controller movement that had been prevalent before [57]. After smartphones hit the market in 2007, the world was introduced to a new way of gaming; simple games that could be played everywhere and while on the move. As the smartphone market expanded and improved, with more advanced technology, mobile phone exergames rose in popularity during the 2010s [57]. One example of a mobile exergame is the game *Zombies, Run!*, where the player is chased by a group of zombies, indicated by sound effects through the headset. Other mobile exergames games, like *Ingress* and *Pokémon Go*, combined mobile exergames with augmented reality. Virtual reality was also reintroduced to the exergame market as the technology evolved, and the controllers became more compacted, cheaper, and more accessible for a home user to operate. VR headsets and controllers allow players to move around physically in games instead of sitting down and using a standard controller. With the reintroduction of VR, multiple popular games have been adapted to use VR headsets instead of the standard controller, and new games have been developed specifically for the use of VR.

The game *Ring Fit Adventure* was released for the *Nintendo Switch* in 2019 and quickly became one of the best-selling games for the console [58]. The game, shown in Figure 11.2, is a role-playing game where players connect the controllers to a Pilates ring and a leg strap so the game can track the player's movement. The outbreak of *Covid-19* further accelerated the game's popularity.

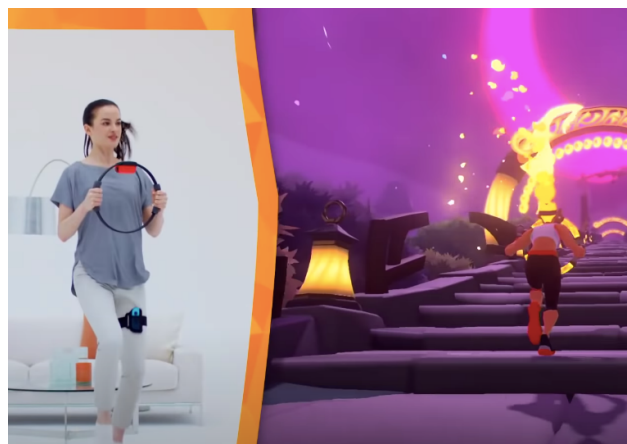


Figure 11.2: Ring Fit Adventure

Exergames have seen a surge in popularity in the last few years. After the explosion of *Pokémon Go* in 2016, most people became aware of exergames, and many other exergames have been created to capitalise on this. When the Covid-19 pandemic hit, exergames saw another surge in popularity as people had to find alternative exercise methods and start exercising from home [57].

Several exergames have also been developed as part of different research projects. Some examples of games in this category are *paperDude*, where the player is delivering papers, and *Fish'n'Steps*, where the player's steps help keep a virtual fish alive.

11.3 Summary

This chapter introduced the concept of exergames and gave a short summary of the history of exergames. *Exergames* are games that combine video games with some form of physical activity.

Exergames as a genre started in the 1980s with the *Atari Joyboard*. The 1990s began a new area for exergames with the dance game revolution. The 2000s introduced exergames into the home market. The Wii console started a new area of exergames that focused heavily on motion tracking. With the introduction and explosion of the smartphone market, exergames were introduced as mobile games that could be played almost anywhere. The most famous example is the game *Pokémon Go*. The 2010s also introduced the concepts of VR gaming to the home market, introducing a new form of exergames motion tracking was merged with VR technology to create more immersive experiences.

Having introduced what exergames are, the next chapter will present some existing exergames.

Chapter 12

Existing Exergames

This chapter describes a selection of different exergames in more detail. It will briefly describe the different exergames, how they implement physical activity into the gameplay, and how the games affect player health. The selected exergames are mostly mainstream and selected because of their impact on the exergame genre, either as a concept or by the technology used. While they were not necessarily the first in their category, they significantly impacted the gaming world and, in some cases, helped define a new era for exergames. Some of the exergames listed were created as part of a research project and were not released to the home market but were used to research their effect on the player's health. It is worth noting that the selected exergames come from the pool of exergames that have been popular in Europe and the US. Other parts of the world, like Asia and in particular countries like Japan and Korea, have a reputation for having many exclusive exergames, particularly arcade games. However, there is limited knowledge of these in the Western world, as they are limited to only specific countries. Looking into existing exergames and how they affect the player's health gives insight into which game elements are more enjoyable than others as they are re-used in other games. Exploring existing exergames also gives insight into how the different elements engage the player, making them want to play the game.

12.1 Dance Dance Revolution

Dance Dance Revolution (DDR) is a music, rhythm, and sport-simulation video game developed by the Japanese company Konami [59]. It was released in 1998 as an arcade game in Japan and released to the rest of the world in 1999. The game is considered a pioneer in the rhythm and music game category and consists of a "mat" or "platform" with four arrows pointing in different directions (see Figure 12.1). The goal is to step on the arrows in time with the music and the directional arrows shown on the screen (see Figure 12.2). The players get points based on if they are hitting the right arrows and how well-timed the hit is. DDR has since come out in many different versions and has been made compatible with different gaming consoles by having dedicated DDR pads that can connect to the different consoles.

There have been several studies on DDR and what effect the game has on a person's body and health. A study by Unnithan, Houser, and Fernhall found that a 12-minute DDR session raised the players' heart rate above the minimal ACSM (American College of Sports Medicine) recommended rate for developing and maintaining cardiorespiratory fitness [60]. Murphy et al. found that playing DDR significantly improved flow-mediated dilation, mean arterial pressure and peak VO_2 levels compared to a non-exercising control group [61]. Another study by Lanningham-Foster et al. showed that playing activity-promoting games like DDR increased the energy expenditure of 8 to 12-year-olds by 382 ± 181 kJ/hour above resting energy ex-



Figure 12.1: A DDR arcade machine with two arrow pads



Figure 12.2: DDR gameplay

penditure [62]. Zan Gao et al. study on Latino children in grade four found that playing DDR improved the children’s cardiorespiratory endurance compared to a test group [63].

Other research shows that playing DDR also has recreational benefits. Chuang et al. found that DDR could be a viable alternative for improving interference control, like reaction time, N2 latency, and P3 latency, in older females [64]. A study on exercise therapy for Huntington’s disease found that playing DDR helped reduce episodes of imbalance [65].

12.2 Wii Fit

Wii Fit is a sport-simulation game created for the Wii gaming console and released in 2007 [66]. The game was marketed as an easy way to exercise at home with the family. Later, the game has also been used for rehabilitation purposes. The game uses the standard “Wii Remote” as well as a “Wii Balance Board” (see Figure 12.3). The remote consists of a gyroscope, an accelerometer, an IR (infrared) sensor, and standard gaming controller hardware. Together, they register how the player moves the controller and whether there are any button presses. The balance board can track weight placement and the player’s centre of balance based on the pressure the player asserts on the board. By combining the input from the controller and the board, the game can track the movement and pose of the player and give the information as feedback to the game itself, which reacts accordingly. The gameplay consists of more than 40 activities in different categories, such as yoga, strength, aerobics, and balance (see Figure 12.4).

A study on the cardiovascular and metabolic responses in middle-aged and older adults when playing *Wii Fit* found that playing the game increased the player’s heart rate and energy expenditure [67]. They found that playing the game could be an alternative to traditional aerobic exercises for the tested age group and could make them fulfil the ACSM (American College of Sports Medicine) guidelines. Another study found that *Wii Fit* raised the player’s heart rate



Figure 12.3: Demonstration of Wii Fit

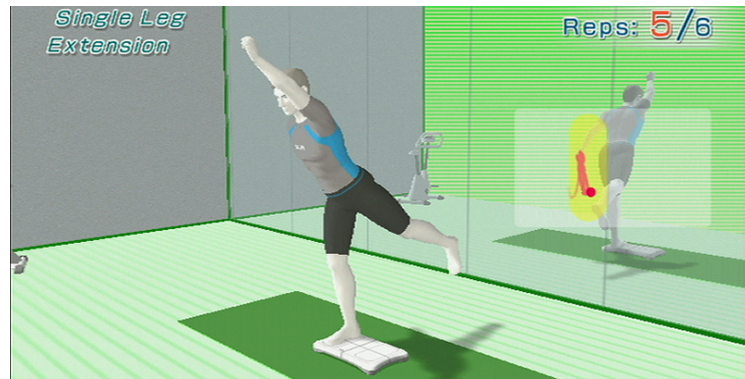


Figure 12.4: A Wii Fit exercise

more than playing sedentary video games but less than walking or jogging on a treadmill [68]. However, the level of enjoyment was higher when playing *Wii Fit* than when using the treadmill. Jennifer R. Worley, Sharon N. Rogers and Robert R Kramer measured the participant's O₂ levels between different game levels. They found that the intermediate level of hula, which was the game they tested, had an equivalent effect of walking at a speed of 5.63 km·h⁻¹ [69].

Studies have also tested how *Wii Fit* impacts balance. Vernadakis et al. found that playing *Wii Fit Plus* for 24 minutes, two times a week over eight weeks was effective on physical function related to balance competence in a test group of students compared to traditional methods [70]. Another study, using the Berg balance scale, found that patients with Parkinson's significantly improved their balance by doing exercises using *Wii Fit* [71].

12.3 Just Dance

Just Dance is a rhythm and sport-simulation game originally released in 2009 by Ubisoft for the Wii gaming console [72]. The game consists of different songs, each having its choreographed dance displayed on the screen using one or more avatars. The goal is to dance the dance by mirroring the avatar as closely as possible and in time with the music, and the better the player is, the more points they get (see Figure 12.5). The game supports both single- and multiplayer, where the players compete against previous high scores or each other. Ubisoft continually releases new versions of the game consisting of new and different songs. They have also released some Japan-exclusive and themed games in collaboration with other companies. As old gaming consoles fall out of favour and new consoles enter the market, the games are adapted for the new consoles, like the Xbox Kinect and the Nintendo Switch. Initially, when created for the Wii console, the game could only track the controller's movement. When the game was developed for other controllers, like the Xbox Kinect, it could track the player's entire body.

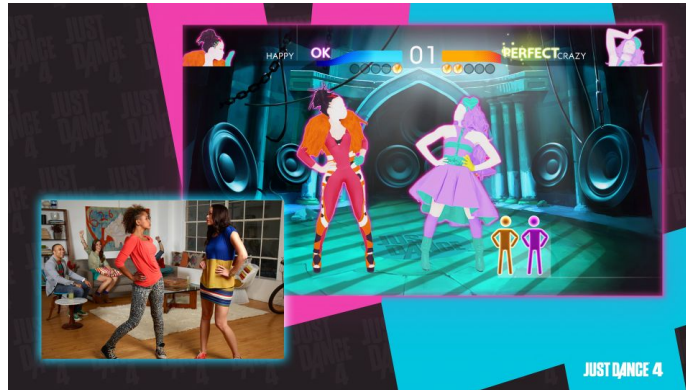


Figure 12.5: Just Dance

A study on exercise using Just Dance on Xbox Kinect investigated its effect on cardiovascular risk [73]. It showed that playing Just Dance had an intensity that was classified as “moderate”, according to the ACSM (American College of Sports Medicine). The study found that participation in one hour of exergames twice a week reduced cholesterol, triglycerides, and LDL levels and decreased TNF- α , CRP, resistin, leptin, and FFA. Jih-Hsuan Lin found that dancing dances from Just Dance gave participants an average heart rate of 109.23, with a standard deviation of 45.03 and a maximum heart rate of 160.66 ± 50.49 . The study found that following Just Dance videos will achieve moderate exercise intensity [74].

Quintas et al. found that gamified didactics in Physical Education improved the player’s Basic Psychological Needs and overall academic performance and motivation [75]. A study by McDonough et al. found that playing exergames instead of traditional treadmill exercises was significantly more enjoyable for the test subjects, and they reported a lower RPE (rating of perceived exertion) than when they did the treadmill exercises. However, the results also showed that playing exergames resulted in significantly lower metabolic equivalents (METs) than the treadmill [76].

12.4 Pedal Tanks

Pedal Tanks is an online multiplayer area action game based on the game Capture the Flag [77]. *Capture the Flag* is a game where two teams compete against each other to capture the opposing team’s flag (or another marker). In *Pedal Tanks*, the player controls the tanks with the help of an exercise bike and six controls on the bike’s handlebar (see Figure 12.6). The game has different types of tanks the players can select from, each having a different set of stats and abilities. Some tanks are slower but stronger and more defensive, while others are faster, more agile and easier to manoeuvre to capture the flag. A game consists of a pre-selected number of two-minute rounds, and the round is over when one of the teams captures the opponent teams flag or if the timer runs out.

When testing the game on a group of test subjects, the developers found that the average heart rate of a player during the game was 143 beats per minute (BPM) [77]. As a control, the participants walked at a moderate pace for 15 minutes on a treadmill. When walking on the treadmill, the participants had an average heart rate of 111 BPM. They also found that the

enjoyment level of the game was much higher than the enjoyment level of going on a walk. While the enjoyment level was between 34% and 45% during the walking, while playing the game, it was between 85% and 95%.



Figure 12.6: Pedal tanks [78]

Multiple research articles have been written about Pedal Tanks and the exercise bike system it was later paired with, PlayPulse [79][80]. In a 2022 article, the researchers found that using Pedal Tanks twice a week for eight weeks significantly improved the peak oxygen uptake of the participants compared to a control group [80].

12.5 Pokémon Go

Pokémon Go is a augmented reality adventure mobile game for iOS and Android [81]. It was created in 2016 by Niantic in collaboration with Nintendo and The Pokémon Company. The game is based on the popular gaming franchise “Pokémon”, where players explore a world and capture wild creatures called Pokémon. After capturing the Pokémon, the players train and battle them against other people’s Pokémon. In *Pokémon Go*, the player is a Pokémon trainer walking around in the real world catching different Pokémon, collecting equipment from “PokéStops”, evolving the Pokémon, and using them to battle against other teams at different gyms. The game uses augmented reality and the camera on the person’s phone to place the Pokémon in the real-life environment of the player (see Figure 12.7).



Figure 12.7: Pokémon Go

When *Pokémon Go* came out, it became a worldwide phenomenon, and many people started playing the game. Because of its wide popularity, there has been much research on the game and how it can help improve a person’s level of physical activity. A study by Nigg, Matero, and An found that playing *Pokémon Go* increased moderate to vigorous physical activity by about 50 min per week and decreased sedentary behaviour by 30 min each day [82]. Martínez-López et al. found that playing *Pokémon Go* led to decreased BMI and body fat percentage [83].

Althoff et al. found that playing *Pokémon Go* increased the average number of steps a person took per day, with an average increase of 1473 steps, equivalent to a 25% increase [84]. The study also noted that *Pokémon Go* was able to increase the physical activity level across all genders and ages regardless of their previous level of physical activity or weight. What made *Pokémon Go* so special was that it reached the part of the population that was considered “low activity” and not just the population that already was physically active. However, as was pointed out by the study, the study ran over a relatively short period, and the long-term motivation would have to be looked into further. Howe et al. raised the issue of long-term motivation and found that after the novelty of the game ran out, people returned to their previous level of physical activity and stopped playing the game [85].

Several other studies have found positive effects of playing *Pokémon Go*. A 2021 systematic literature review found that *Pokémon Go* had positive effects on the players’ physical, mental, and social health for as long as they were playing the game [86]. One of the largest studies of *Pokémon Go*, a survey with over 2000 respondents, found that 50% of players reported positive health benefits, including weight loss, loss in body fat, and gain in muscle mass [87]. This study also showed that *Pokémon Go* impacted different player groups differently. Player groups who were otherwise hard to motivate for physical and social activity benefited most from playing *Pokémon Go*. However, this positive effect only lasted as long as the players kept playing.

12.6 Exermon

Exermon is a mobile action game created by Torbjørn Høivik and Gaute Meek Olsen as part of the research for their master thesis in 2016 at NTNU [88]. The game combines the concepts of two well-known games, *Pokémon Go* and *Tamagotchi*, and combine them with strength exercises. The players get a pet monster called an “Exermon”, and the goal is to evolve the monster and battle it against other monsters (see Figure 12.8). The player can battle their monster against a computer-generated monster, or they can connect with other players by adding them as friends to battle their monster. To evolve the monster, the player has to do specific strength exercises registered using the different sensors on the phone. As the monster evolves, it can fight against higher-level monsters, which gives the players better rewards. If the player neglects the monster and does not do any exercises, the monster dies.

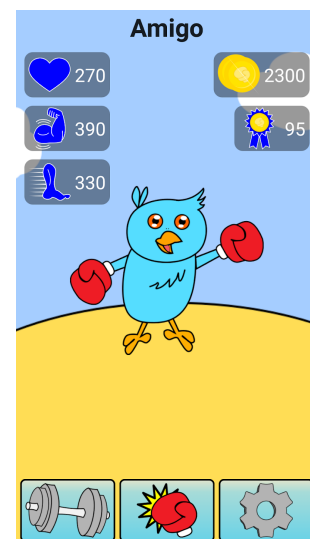


Figure 12.8: Exermon [89]

As part of the master's thesis, there was a two-week experiment on the use and effect of the game *Exermon* [88]. The results from the experiment found that 41.7% of the test subjects increased their level of exercise by using the app. The results also showed that 38% of the test subjects felt their strength had improved during the test period.

In 2017, an evaluation of *Exermon* was done for a conference paper [90]. This evaluation found that exergames for strength training have great potential, with 90% of the test subjects reporting the game to be engaging. The test subjects conducted an average of 1-2 extra exercise sessions per week during the test period compared to before. The evaluation also found that *Exermon* was great at encouraging test subjects already doing strength training to do more strength training. However, it was not too good at encouraging test subjects that were not already doing strength training to start doing strength training.

12.7 Beat Saber

Beat Saber is a virtual reality (VR) rhythm action game developed by Beat Games and released in 2019 for Play Station 4 and Microsoft Windows [91]. The player uses VR controllers to wield two lightsabers of different colours and use them to cut through different coloured boxes that fly towards the player in beat with the music (see Figure 12.9). While hitting the boxes, the players also have to avoid hitting bombs and avoid walls by ducking out of the way. By hitting the right boxes in the right direction, the player "fills up" a white bar on the side of the screen. If they miss a box or hit an obstacle, the bar's level reduces, and the level is lost if the bar is reduced to zero.



Figure 12.9: Beat Saber creates a virtual reality for the player

Polechoński et al. looked at how hand-held weights would affect the intensity of physical activity when playing VR. As VR mainly consist of upper-body movements, they decided to focus on the intensity of upper-body activity. They found that without using hand-held weights, the intensity of physical activity was low (mean 63.7% HR_{max} , SD 9.3% HR_{max}), but adding additional weights increased to moderate (mean 67.1% HR_{max} , SD 10.3% HR_{max}). Using hand-held weights also did not bring any discomfort to the player, meaning they could play as they usually would, but with the added health benefit [92]. A study on physical activity intensity, perceived exertion, and enjoyment when playing VR found that different VR games could elicit

varying degrees of activity. The games that scored highest in enjoyment were games that required mostly arm movements and had a perceived light exertion [93].

Another study examined a player's physiological and psychological data when playing Beat Saber vs following a treadmill exercise regime. One thing to note is that the study did not limit the time the participants spent on the tasks other than completing at least twenty minutes. The study found that the participants spent an average of 48.64 ± 8.26 minutes playing Beat Saber, while they only spent 23.24 ± 7.42 minutes on the treadmill, showing that the players found the exergame much more enjoyable. The measured overall mean heart rate data (beats per min) favoured the treadmill, with 144.41 ± 12.65 against 133.43 ± 15.23 with the exergame. However, when comparing the mean data of the most active twenty minutes, the results were almost identical, with 148.61 ± 15.91 for the exergame, and 148.17 ± 12.65 for the treadmill, showing that playing exergames can have similar results as more traditional forms of exercise. Other data, like RPE (Rated Perceived Exertion) and Intrinsic Motivation Inventory, except for interest, were almost equal [94].

12.8 Summary

This section has introduced some existing exergames and research on how they impact a player's physical health. The exergames range from pioneers like *Dance Dance Revolution* to more recent games that use newer technology, like *Beat saber*. Some of the games were wildly popular on release and helped introduce exergames to a broad audience, like *Pokémon Go*. Others were created predominantly for research purposes like *Pedal Tanks*. The exergames use various technologies and tracking methods, from dance pads to exercise bikes, motion detection, and GPS tracking, and have different gameplay stories and fantasies. From standard "hit the arrows" in *Dance Dance Revolution*, to driving tanks in *Pedal Tanks*, dancing a choreographed dance in *Just Dance* and evolving monsters in *Exermon*. The section also presents existing research on the different exergames that detail different ways playing the game impacts the player's physical health.

The next chapter will examine which game genres are best suited for exergames.

Chapter 13

Game Genres for Exergames

Regarding game genres for exergames, some genres are more widespread than others. Sport simulation games are probably the most well-known example and include games like *Wii Sport*, *Dance Dance Revolution*, and *Just Dance*. Other examples are adventuring games such as *Pokémon Go*, First-person shooters such as *Pistol Whip* and *Half-Life: Alyx*, and party games such as *Eye Toy: Play 3*.

If we look at the most popular exergames throughout the history of exergames, we can see that most games, while having different stories and fantasies, are all based on the same idea; combining player movement with gameplay and the game fantasy. Looking at the list of game genres in Chapter 10, it is clear that some game genres are easier to convert to exergames than others. In particular, games that mimic a sport or activity or have an avatar that moves a lot. In classic video games, players use standard controllers to move the avatar, so, unsurprisingly, when making an exergame, the natural next step is to map the player's movement directly to the avatar instead of using the input from the controller. These kinds of exergames will feel natural to the players as it reflects what they are used to and expect. Looking at *Wii Sport* and the game *Tennis*, it is much more natural for a person to “hit” the ball than to press a button.

However, exergames do not need to be constrained games that link movement directly to an avatar. As we see it, the only separating factor between exergames and regular video games is that exergames require some level of physical activity or exercise. Therefore, any game that integrates physical activity as part of the game, gameplay, or game progress could be considered an exergame.

Another way exergames can work is by indirectly implementing physical activity or exercise in the game and not as direct input to the gameplay or an avatar's movement. This implementation method makes it possible to create exergames in game genres that, at first glance, might not feel possible or fitting as exergames. As long as there is a way of having gameplay progress or earning in-game rewards, it should be possible to integrate some elements of physical activity or exercise into the game. *Exermon* is an example of a game where training indirectly affects the gameplay [88]. To evolve their monster, the player has to do strength exercises, which the phone registers and uses as input for the game. Instead of physical activity being a direct part of the gameplay, this method uses physical activity to get game progression.

By broadening the horizons on how physical activity and exercise can be implemented and affect a game and its gameplay, it is clear that exergames could be any game genre or a combination of multiple genres. As long as the exergame integrates player movement, physical activity, or exercise as a natural and necessary part of the gameplay, it does not matter what the game's fantasy or genre is.

The next chapter will present different hardware technologies often used in exergames.

Chapter 14

Hardware Technology

This chapter will present different hardware used in exergames and exergaming. Hardware is crucial for exergames, as, without it, the game cannot track any movement the player makes. If the game cannot access movement data and only depends on a sedentary button and joystick input, and is no longer an exergame. Knowing what hardware technologies exist and are often used for exergames helps limit the concept creation to games that are feasible with the existing technologies while at the same time also showing the vast possibilities that exist by using and combining the right technology.

14.1 Hardware Components

Many hardware components are often used when tracking player movement in exergames. Most of them are nowadays combined into smartphones, meaning that “everyone” has access to all of the following components.

14.1.1 Pedometer

A *pedometer* (see Figure 14.1), also known as a step counter, is a device that tracks a person’s steps using sensors and specialised software [95]. Simple variants of the pedometer consist of mechanical switches and a counter that registers steps when the switch is triggered. These pedometers are easily manipulated by moving them up and down, which triggers the switch. More advanced pedometers combine the traditional counting methods with software that can take various factors like step length and false steps into account when calculating steps. These factors make it harder to fake steps, as the software helps “calculate” whether the step was natural. Many modern step-counters use accelerometers instead of pedometers to calculate steps. Some examples are smartphone step-counters, smartwatches, and fitness watches such as Fitbits [96].



Figure 14.1: A pedometer

14.1.2 Accelerometer

An *accelerometer*, shown in Figure 14.2, is a device that measures its acceleration and vibration of itself based on its state [97]. Acceleration is calculated by the change in speed over a certain time. Accelerometers register changes in their velocity using an internal sensor or a set of sensors that keep track of their states and can calculate the rate of acceleration based on changes in those states. The difference between an accelerometer and a pedometer is that accelerometers can record total physical activity and time at different intensities, while pedometers only record total activity [98]. Accelerometers are used in game controllers to calculate the controller’s movement speed, which is used as input to the game. An example is the minigame *Baseball* in *Wii Sports*. The accelerometer, the optical sensor, and button presses work together to dictate how the player throws and hits the ball [99].

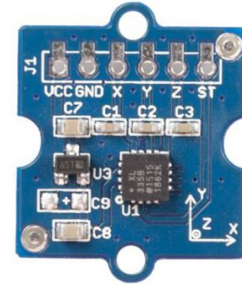


Figure 14.2: An accelerometer

14.1.3 Gyroscope

A *gyroscope* is a device mounted to a frame and can rotate freely on all axes inside the frame [100]. The gyroscope measures orientation, rotation, and angular velocity if the frame rotates. Changes to the gyroscope reflect changes to the object the gyroscope is mounted to and tracking. Figure 14.3 shows a traditional gyroscope. Micro-Electro-Mechanical System (MEMS) gyroscopes, shown in Figure 14.4, are used in electronics to calculate the angular motion of the device. MEMS can measure rotation around the axes (1-axis, 2-axis, and 3-axis) [100]. In smartphones, gyroscopes register the phone’s rotation, which can determine the screen’s layout from landscape to portrait mode.

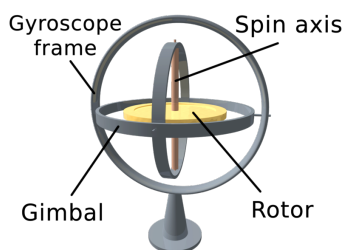


Figure 14.3: A classic gyroscope

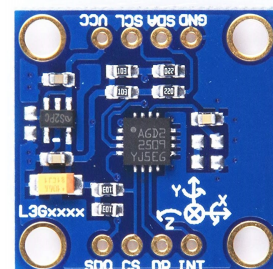


Figure 14.4: A digital gyroscope

14.1.4 Global Positioning System (GPS)

Global Positioning System, or *GPS*, was created by the U.S. government but made available and free to the public [101]. The GPS consists of three “components”; a set of satellites that orbits the earth, a receiver placed inside the device using GPS, and control segments placed around the world to ensure the satellites are working correctly. Figure 14.5 shows how the

three elements of GPS work together. The GPS can locate where the receiver is as long as there is a connection between a satellite and the receiver. The GPS can find the most efficient way to travel from A to B. As mentioned in Section 11.2, Geocaching uses GPS coordinates to mark where geocaches are hidden. The players use a map and GPS to find the hidden caches.

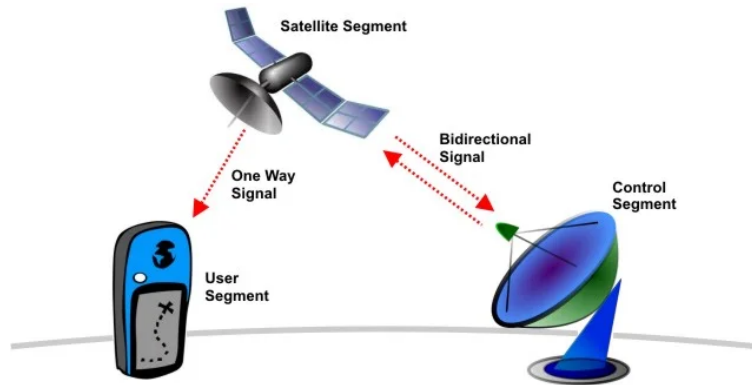


Figure 14.5: GPS works by sending signals between satellites, control segments, and a receiver inside the device

14.1.5 Camera

In their simplest form, *cameras* are optical instruments that capture 2D or 3D images [102]. Light is captured on a light-sensitive surface like a digital sensor or photographic film when the lens opens for a short time. Most cameras can take videos as well as still pictures. Video and digital cameras use an electronic image sensor to rapidly capture multiple images, which the camera processes into one video file. Figure 14.6 shows a digital camera on a smartphone. In this day and age, most people have a camera in their pocket.



Figure 14.6: A camera on a smartphone

14.1.6 Optical Sensor

An *optical sensor*, also known as an Electro-optical sensor, can detect its surroundings by turning light into electrical signals [103]. It can sense various frequencies and characteristics of light, such as intensity, wavelength, frequency, and polarisation. Figure 14.7 shows how an optical sensor uses light to detect its soundings.

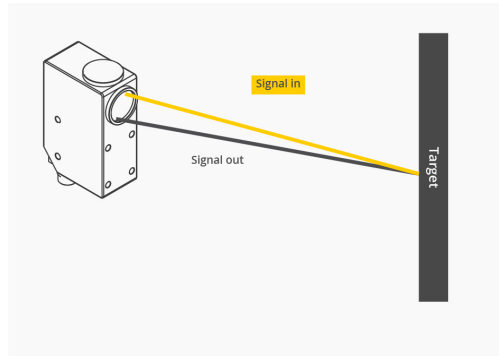


Figure 14.7: Optical sensors use light signals and detectors to detect the surroundings

14.2 Motion Tracking

Motion tracking in games has been done in many different ways, but the goal is mostly the same; to use motion tracking as a source of controller input so the game can react depending on the registered motion.

14.2.1 Remote Control Tracking

One way to do motion tracking is to track the movement of the game controller itself. The controller and console have sensors making it easy to collect and track the controller's position. By tracking where the controller is and how it moves and tilts, the sensors can give input to the game so it can react accordingly. However, this method only allows partial motion tracking, as only the controller is being tracked and not the user's entire body. This limitation opens for cheating in games that depend on the player doing a specific movement, like *Just Dance*. The game has to trust that the player completed the entire body movement and did not just wave their hand. The Wii console is an example of a gaming console that uses this tracking method. It uses an optical sensor and an accelerometer to track the controller's placement, direction, and tilt. Another example of this kind of motion tracking is VR. VR tracks the player's movement by tracking the position and rotation of the headset and the handheld controllers [104]. The tracking is done either by inside-out tracking or outside-in tracking. In inside-out tracking, the sensors are placed inside the headset and controllers and track movement directly through image tracking of the room around the player, inertial navigation, or a combination. Outside-in tracking uses cameras or sensors placed around a room and tracks the placement of the headset and controllers inside the monitored area.

14.2.2 Full-Body Tracking

Full-body tracking is where the player's entire body is tracked using an external camera or other optical sensors. This way, the game can track the player's movement directly and not rely on information from a handheld controller or headset. The EyeToy was a colour digital camera for PlayStation 2 and was one of the first introductions of body tracking into the home

market [105]. The EyeToy software uses the input from the camera and recognises changes using gesture recognition. Changes in the video due to a player's movement are recognised as gestures, and the game reacts accordingly, letting the players interact directly with the game and gameplay. The Xbox Kinect is a more modern system that uses a camera with depth-sensing to track movement. By creating a near-infrared pattern in the area in front of the camera and registering the reflected light, the software can calculate the perceived depth of the room pixel by pixel [106]. Using edge detection, it can separate things closer to the camera than the background, try to recognise human bodies in these shapes, and track that shape as it moves (see Figure 14.8) [107].



Figure 14.8: Kinect uses a depth-sensing and colour to register movement

14.3 Extended Reality (XR)

Extended reality, or XR, is an umbrella term encompassing many different technologies. These technologies are divided into the subcategories of augmented reality (AR), virtual reality (VR), and mixed reality (MR).

14.3.1 Virtual Reality (VR)

Virtual reality (VR) is the most well-known category of XR. It uses a head-mounted 3D display that blocks the view of the outside world as well as motion tracking to immerse the user in a virtual world (or “reality”) (see Section 14.2.1) [108]. Motion tracking is essential to simulate the player's movements in the virtual world based on their movements in the real world. By tracking the position and movement of the headset and any hand-held or wearable controllers, the players can interact with objects in the virtual world through real-life body movements.

14.3.2 Augmented Reality (AR)

Augmented reality (AR) adds virtual objects to real-life environments, making them appear as part of the real world [109]. However, interacting across the virtual and real world is impossible, unlike in MR. Mobile phones are the most common venue for AR, using the phone's camera and motion-tracking software and displaying the results on the screen. Mixing the real and virtual worlds can create scenarios that are impossible to experience in the real world. AR can, for example, be used to create a safe environment where students can test their abilities. This educational benefit has led to a breakthrough for AR in the educational space, as it provides a safe, risk-free environment where the students can get a “hands-on” experience.

14.3.3 Mixed Reality (MR)

Mixed reality (MR) is often seen as a combination of VR and AR [110]. Sometimes it is used interchangeably with the term augmented reality, but while the two have many similarities, there are some differences. As with AR, MR also aims to mix the real world with the virtual world, but it can cover more of the Reality-Virtuality (RV) Continuum [111]. In MR, it is possible to interact with objects in virtual reality using real-life objects. In contrast to AR, where the two realities cannot interact directly with each other [112]. MR often uses a tracked headset to display the mixed reality to the user. Examples of technology that uses MR are Microsoft’s HoloLens [113] and the newly announced Apple Vision Pro [114].²

14.4 Smartphone

In many ways, smartphones are a phone and a small computer combined with various sensors crammed together in a small form factor. There are several different “grades” of smartphones, most often categorised as “flagship”, “midrange”, or “budget”, where the flagship is seen as the top-tier phone while the “budget” is at the lower end in both cost and “specs”. Phones at a high “grade” might contain more sensors than phones at a lower “grade”, but most smartphones nowadays come with a set of “standard” sensors, including accelerometers, gyroscopes, ambient light sensors, barometers, and magnetometers [115]. Some “flagship” phones also have additional sensors like heart rate sensors, but more than that, they contain more advanced software that can use the sensor to their full capacity.

14.5 Wrist-Mounted Trackers

Wrist-mounted trackers are electrical devices worn on the wrist. In addition to displaying the time, it tracks different information about the wearer, like heart rate, steps taken, calories burned, and more. Standard analogue and digital watches are excluded as wrist-mounted trackers as they do not “track” user data and are only used to tell the time.

14.5.1 Fitness Trackers

Fitness trackers, or *fitness watches*, are electronic watches that also track other values and data from the user. One example of a fitness tracker is the Fitbit (see Figure 14.9). The Fitbit, and most other fitness trackers, includes a step counter, calculation of calories burned, heart rate, GPS, sleep tracking, and other ways of monitoring standard health values. This data is registered to a specific app, giving the user better access to the data [96].



Figure 14.9: FitBit

²Apple Vision Pro was announced on the 5th of June, 2023, with a planned release in early 2024. While this is far too late for this thesis, the technologies in the Apple Vision Pro make it ideal for body tracking and exergames

14.5.2 Smartwatches

Smartwatches are minicomputers optimised for a watch format. Essentially, they are a watch, a fitness tracker, and a phone combined and shrunk into a small format. An example is the Apple Watch (see Figure 14.10). This smartwatch can track movement, steps, heart rate, and meters above sea level. It also has a timer and compass, which is on par with most fitness trackers. However, smartwatches also have some phone functionalities like answering calls, messages and access to some apps. This functionality makes them almost like a second phone that can connect to the fitness apps on the person's phone [116].



Figure 14.10: Apple Watch

14.6 Game-Specific Controllers and Equipment

Several types of game controllers are specific to certain games or types of games. These gather input from the player in some other way than the typical handheld button- and joystick controllers. Several of these controllers are crafted to enable certain types of exergames, allowing the player to move around.

14.6.1 Pressure Pads and Dance Mats

An alternative to the handheld gaming controller is a floor mat or pad. The mat consists of several pressure sensors that register where the person is standing on the mat using feedback from the sensors. One of the first instances of a floor mat controller was the Nintendo Power Pad (see Figure 14.11) [53]. Another type of pad is the dance pad which was introduced in the 1990s as part of the dance game revolution and consisted of four or five arrows that the players had to step on in time with the music. The pads are made of different materials and are split into two categories: soft and hard, depending on their intended use [117]. Hard pads are standard for arcade machines, while at home, soft mats are more practical as they can be folded away after a game.

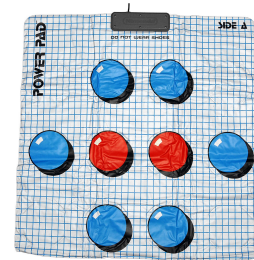


Figure 14.11: Side A of the double-sided Power Pad

14.6.2 Omni Treadmill

An Omni treadmill (see Figure 14.12) is a 360-degree treadmill that combines classic VR gaming with multi-directional player tracking. The Omni treadmill allows the player to walk in any direction and do other movements like jumping, kneeling, crouching, and crawling. The machine has multiple sensors on different parts of the machine that registers the movement and uses it as input for the game [118]. Still, in the early stages, the Omni treadmill is not integrated with many games, but the number is growing. The system is also costly, which only makes it interesting for people with niche interests, and is yet to reach the general market.



Figure 14.12: An Omni treadmill

14.7 Summary

This chapter introduced different hardware technologies often used in exergames. Exergames use a wide variety of controllers and equipment to track the player's body movement. The exergames rely on information and feedback from different hardware components, like gyroscopes, accelerometers, and cameras, to track the player's movements. The most well-known way of tracking body movement is motion tracking. Different exergames use different kinds of technology to track the person's moves, either through tracking the movement of a controller or tracking the whole body of the player. Some exergames use extended reality (XR) to combine body tracking with greater gameplay immersion by combining different levels of virtual reality and the real world. The explosion of smartphones and smartwatches in the last 15 years introduced a new way of tracking people's position, heart rate, movement distance, and steps. Some exergames also use hardware specifically designed for the game. Examples of this are dance mats and multidirectional VR treadmills.

Having looked at hardware technology for exergames, the next chapter will discuss what kinds of software technologies are suitable for exergames.

Chapter 15

Software Technology

This chapter will present different software technologies that are relevant to exergames. Specifically, it will go through some of the most standard fitness-tracking apps for smartphones and look at how the health APIs offered by Apple and Google work. Knowing what software technologies exist and are often used for exergames helps limit the concept creation to games that are feasible with the existing technologies.

15.1 Fitness Tracking Apps

Fitness tracking applications record a user's daily physical activity [119]. There are a lot of different fitness-tracking apps offering various features. However, they all track a few basic metrics and have some functionalities in common. The most commonly tracked metrics are:

- Steps taken
- Active minutes
- Calories burned
- Workouts (manually for some applications)

It is also common for these applications to offer expanded functionality if paired with a compatible smartwatch or other trackers [119]. They can also typically aggregate data from other apps, like the popular running app Strava [120]. Fitness tracking apps grew sharply in popularity around 2014 [119], and now, they often come pre-installed on smartphones and other devices.

Three of the most popular fitness tracking apps are *Samsung Health*, *Google Fit*, and *Apple Health*. They all cover the basic functionalities and metrics presented above but have some differences. Figure 15.1 shows the three fitness tracking apps. The following paragraphs will present the differences between these apps.

15.1.1 Samsung Health

In addition to the standard metrics, *Samsung Health* (see Figure 15.1a) allows its users to track food and water intake (manual), stress, periods, and sleep [120][124]. There is also the possibility of tracking metrics such as glucose levels, heart rate, oxygen levels (including sleep O₂ levels), snoring, and blood pressure as long as the users have a compatible device [124]. Samsung Health also supports a large number of both first-party and third-party devices [120].

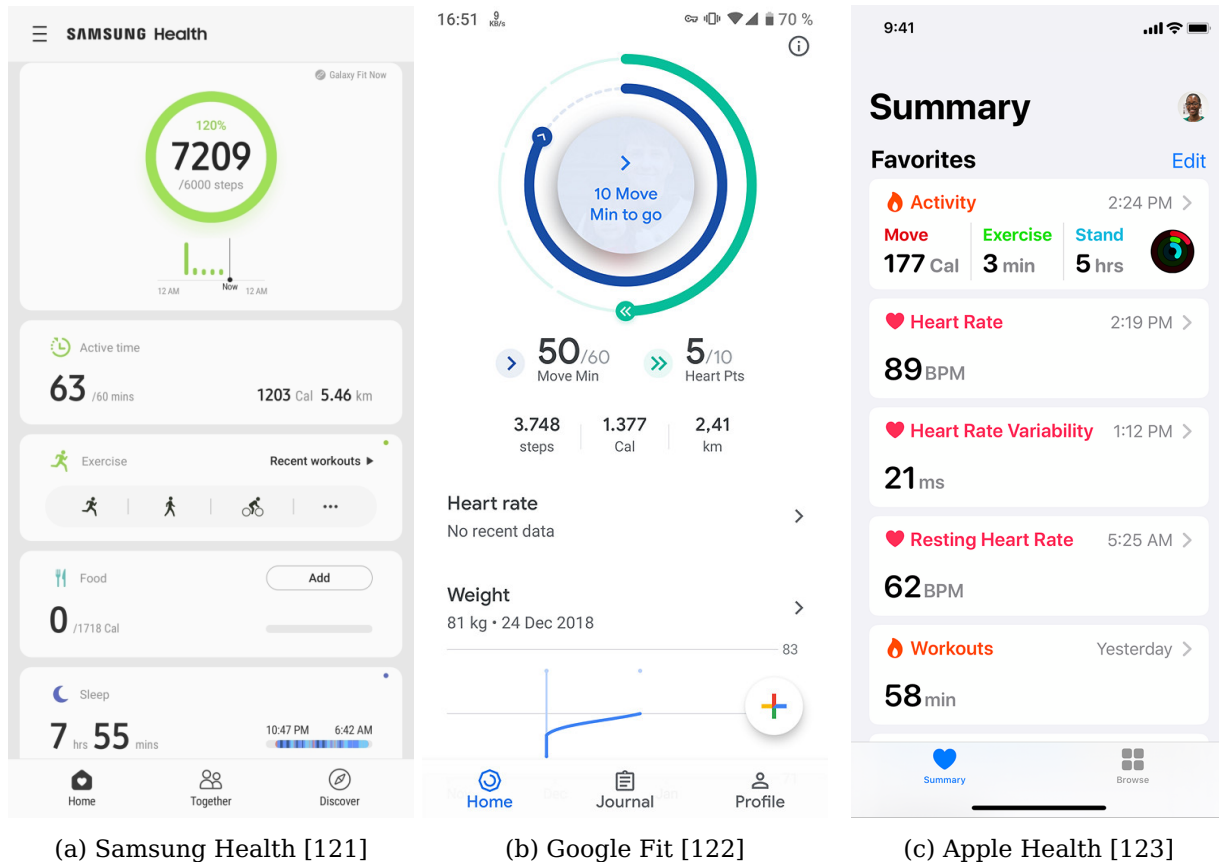


Figure 15.1: All three fitness tracking applications feature a home page summarising the data the application tracks.

Samsung Health features a system called *“Together”* which allows users to enter challenges and compare their data to other users, which can help them connect with friends and keep them motivated. Samsung Health also has workout videos and programs, sleep aids, and other exercise and wellness resources built-in [120].

15.1.2 Google Fit

Google Fit (see Figure 15.1b) expands on the standard metrics with elevation tracking, sleep, Move Minutes, and Heart Points [125]. Google Fit also has good support for the Google ecosystem. For example, Google’s Nest Hub can be used for sleep tracking, and Google has developed a version of their Android operating system, Wear OS, designed and optimised for smartwatches (as well as giving support to some other smartwatches), which can be used to track the user’s heart rate and blood pressure during exercise.

When Google developed Google Fit, they worked with the American Heart Association to create two metrics based on the association’s activity recommendations [125]. The metrics became *Move Minutes* and *Heart Points*. *Move Minutes* reflects the user’s “active time” and are registered any time the app detects that the user is moving. *Heart Points* require the user to perform activities of moderate or above intensity; anything at the level of a brisk walk or

above will count. One Heart Point equals one minute of moderate activity, and more strenuous activities give more Heart Points per minute. Google Fit also supports many third-party app integrations, which allows Google Fit to act as a hub for the different tracking apps users might use.

What Google Fit lacks compared to Samsung Health is social features and instructed workouts [125]. Google Fit has something it calls “*Stay Fit #WithMe*”, a series of YouTube Fitness playlists accessible through the app [126]. These videos offer the users instructed workouts, meditation, and mental wellness sessions, but the app does not directly track the sessions. However, Google Fit will automatically detect workouts and try to classify them based on the user’s movements [125].

15.1.3 Apple

Apple has split their health platform into two main applications, Apple Health and Apple Fitness.

Apple Health

Apple Health (see Figure 15.1c) acts as a fitness tracking app that, in addition to tracking the typical statics, aggregates data from all the other tracking apps the user might be using [127]. Apple Health is famed for its ability to analyse health data and displays trends and changes in user habits, customised based on the previous data the user has provided. Apple Health also allows users to share their health data with other users or health professionals.

Apple Fitness

Apple fitness is a fitness tracking app focused on the Apple Watch [127]. Similarly to Google Fit, the app has goal metrics, but instead of Move Minutes and Heart Points, it has *Stand*, *Exercise*, and *Move*. *Stand* represents how often the user has stood up. To complete the daily goal, the user must stand up at least once per hour for 12 hours daily. *Exercise* is similar to Google’s Heart Points, recording the number of minutes of moderate or higher activity for the user. *Move* records the estimated amount of active calories the users burn (not counting passive calorie burn from metabolism).

15.2 Health Data APIs

Apple and Google offer APIs (Application Programming Interfaces), allowing developers to access users’ health data. Apple offers one API, *HealthKit*, whereas Google offers two, *Health Connect* and *Google Fit*. The different APIs work differently, collect different kinds of data on the users, and allow developers access to different data.

15.2.1 HealthKit

Apple’s *HealthKit* allows iOS apps (with the user’s permission) to access all the health and fitness data stored on the user’s iPhone and Apple Watch [128]. The API comes with tools to help collect, store, analyse, visualise, and share user data.

HealthKit offers five kinds of data [129]:

- **Characteristic Data:** Typically immutable data about the user, such as their birth date, blood type, biological sex, skin type, and more.
- **Sample Data:** This encompasses most of the user's health data, stored in samples representing a data point at a particular time, for example, the user's heart rate exactly halfway through a workout.
- **Workout Data:** Samples that contain fitness and exercise data from a workout session.
- **Source Data:** Data that connects each sample to its source, showing the app or device that generated the sample.
- **Deleted Objects:** Placeholder objects for deleted data.

15.2.2 Health Connect

Health Connect is one of the two health APIs Google offers and is only available on Android. It is a Device-Centric service that stores the user's data on the device. [130]. Compared to Google Fit, there are some differences in how permissions are handled and what data processing services are available to the developers.

Health Connect offers six main data types [131]:

- **Activity:** Recorded data on user activities such as running, swimming, meditation, or sleep.
- **Body Measurement:** Common data related to the user's body, such as weight, height, and metabolic rate.
- **Cycle Tracking:** Menstrual cycle data, including binary results on ovulation tests.
- **Nutrition:** Data on the food and water intake the user has registered, including calorie count and macro and micronutrients.
- **Sleep:** Interval data related to a user's sleep pattern.
- **Vitals:** Essential vital information about the user, such as blood glucose levels, body temperature, and oxygen saturation.

15.2.3 Google Fit

The *Google Fit API* (not to be confused with the Google Fit App, see section 15.1) is the other health API from Google and is more of an ecosystem revolving around the Google Fit application [132]. It differs from the Health Connect API by being Account-Centric and storing the user's data on Google's servers and not only on the device itself [130]. It is available on Android and iOS, as well as web applications, and allows developers to upload and read health and wellness data about users from a central repository. The benefit of this is that all the activity a user records across different, unconnected devices can be accessed and aggregated.

Google Fit offers these six data types [133]:

- **Activity:** Any activity the user does, for example, running or weight lifting, as well as activities like meditation, gardening, sleep, and more.
- **Location:** Location data, such as the user's position and movement speed. From this, other data like cycling RPM (revolutions per minute) can be synthesised.
- **Nutrition:** Data on the food and water intake the user has registered, including calorie count and macro and micronutrients.
- **Health:** Data relating to the user's general health, such as blood glucose levels, blood pressure, body fat percentage, body temperature, menstruation, and many others.
- **Aggregate:** Data recorded over a period aggregated into a single data point—for example, sleep data collected over a week or the activity during a workout session.
- **Private Custom:** Custom data is defined by specific apps. Only the app that defines this data type can read and write it.

15.3 Summary

This chapter presented different software technologies relevant to exergames. Many fitness-tracking applications are built for tracking metrics like steps, calories burned, distance walked, and more, with some apps registering more metrics than others. Examples of fitness-tracking applications are *Samsung Health*, *Google Fit*, and *Apple Health*. These apps often come with different health data APIs, which allow exergame developers to access the fitness data collected by smartphones, smartwatches, or other fitness trackers.

The next part will dive into how the concept for our exergame was created. The findings from this prestudy were essential when developing the exergame concept. The first chapter in the next part will look at a research gap that was discovered during this prestudy.

Part III

Concept

Part III introduces the game concept for the new exergame developed in this project. First, it presents the research gap discovered during the prestudy and literature review. Second, it presents new potential exergame concepts and grades based on a set of criteria. Third, it presents the exergame concept selected for the thesis and describes the gameplay and mechanics in detail. Then, it describes how the exergame integrates game enjoyment theories into the game. Lastly, it describes the different methods the exergame uses to influence the players' activity level. The exergame concepts presented in this part are based on concepts first presented in the specialisation project.

Chapter 16

Research Gap

During the prestudy, we noticed a research gap. There is very little existing research investigating the use of “natural gameplay” and encouraging physical activity by replacing traditional microtransaction mechanics with requests for physical activity (see Chapter 12).

By “natural gameplay”, we mean gameplay similar to regular games without any exergame elements. The exergame we want to create to fill this research gap should be able to be played like any regular game without doing any physical activity. The game should encourage physical activity, not demand it. We believe that this gives the exergame a greater potential for reaching a user segment with very little innate motivation for physical activity. However, the game should rely on physical activity if the player wishes to achieve satisfying game progress.

As discussed in Chapter 13, some game genres are more widespread in the exergame genre as they are more suitable when converting traditional games to exergames. In the same chapter, we discussed the possibility of using any game genre as a base for exergames. We believe there is excellent potential for an exergame that is based on one of the more underrepresented game genres. For example, some of the most popular mobile games are idle games, a genre not well represented in exergames [134]. Utilising a genre less associated with exergames might also draw the interest of players that are less likely to be interested in exergames.

Chapter 17

Game Concept Ideas

This chapter describes several exergame concept ideas we came up with during the planning phase and pre-work of the project. It presents the idea behind the game concepts, what technologies they use, and the gameplay itself. The concepts are graded based on different criteria and evaluated against each other. Some of the concepts were created before the research gap was discovered. Therefore, some of the concepts do not quite fit the research gap, but they were part of the concept creation and brainstorming process.

17.1 Grading System

The different concepts will be graded in a set of categories, each giving a score from 1 to 5, with 5 being the highest score.

- **Technological Feasibility (TF):** How available the technology is to us as developers, how well we know the technology and how much experience we have with it.
 - 1 means that we think it will be very hard or impossible to access the technology needed for the exergame concept.
 - 5 means that the technology needed is readily available, and we have some experience using that technology.
- **Interest Reach (IR):** The proportion of the population that would find this exergame concept interesting and would want to try it out.
 - 1 means that we think only a small part of the population will be interested in the exergame concept and the resulting exergame.
 - 5 means that we think a large part of the population will be interested in the exergame.
- **Player Retention (PR):** How well we think the exergame concept will be able to keep its players' attention and interest.
 - 1 means that we think players will easily get bored of the exergame and stop playing.
 - 5 means that we think players will think the exergame is so fun that they might get addicted and constantly return to continue playing.
- **Accessibility for Player (AfP):** How accessible the chosen technologies are for the players. A measure of how easy it is for a potential player to access the exergame.

- 1 means that the exergame will be hard to access for the player. Either because the technology is not easily accessible or expensive.
- 5 means that the exergame is easily accessible to players and is not dependent on niche/costly technologies.
- **Physical Exertion (PE):** The level of physical activity the exergame demands from the player.
 - 1 means that the exergame has a low level of physical activity and could almost be seen as a sedentary exergame.
 - 5 means that the exergame demands a moderate to a high level of physical activity.
- **Personal Motivation (PM):** The level of motivation we as developers have for creating the exergame.
 - 1 means that we do not find the exergame concept exciting and do not think it will be interesting to create.
 - 5 means that we think the concept is exciting and something we would like to create.

17.2 Adventures and Abjurations (A&A)

Adventures and Abjurations (A&A) is a concept inspired by the fantasy role-playing game *Dungeons and Dragons (D&D)*, first published in 1974, where players create and control characters as they face different challenges (see Figure 17.1). *Adventures and Abjurations (A&A)* aims to take the leisurely activity of a tabletop game and convert it into a video game where the players can go on adventures “in real life”. As with the game of D&D, the players can select different races, classes, and skills, dictating what equipment is available for them and what they can do in the game. The players will play through pre-made stories, like exploring different dungeons to find hidden treasures, fighting monsters, solving puzzles, and avoiding traps. It is up to the player, using their avatar’s skills, to overcome these obstacles. The treasures they collect can be added to the player’s inventory or sold for gold. The dungeons will get more challenging as the player progresses and learn more advanced skills. The rewards will increase according to the skill of the player. The game should have a separate multiplayer mode where two or more players can work together and interact while exploring dungeons. The multiplayer aspect helps keep the important social aspect of D&D. The game concept uses VR technology in the form of a headset and handheld controllers, and an Omni treadmill to track the player’s movement and reflect it in the player’s avatar. The Omni treadmill allows the player to walk in any direction and conduct other movements like jumping, crouching, running, kneeling, and crawling. With the feedback from the buttons and joysticks, the game can represent the different player actions, like fighting with a sword, casting spells, or just interacting with the world around them.



Figure 17.1: Dungeons and Dragons, the inspiration for *Adventures and Abjurations*

17.2.1 Review

The following are the review scores in each category for *Adventures and Abjurations*.

Technological Feasibility: 2.5

NTNU does have an Omni treadmill, but to access it, the relevant institute must approve the project, which can be challenging. It can also be challenging to access the Omni treadmill if multiple groups are working on projects that use it.

Interest Reach: 2

The game is a hit-or-miss game, very motivating for more hard-core gamers that are very interested in D&D, first-person shooters, adventuring games, fantasy games, or role-playing games, as they get to act out the fantasy they are playing, but too nerdy and niche for most casual gamers.

Player Retention: 3.5

The game's retention will likely be high for the people that find the game interesting. The player can explore different areas, with some areas only accessible if the character has unlocked the required skills, ensuring there is always something interesting for the player to explore.

Accessibility for Player: 1

Omni-treadmills have only recently been introduced to the home market. With a cost of over a thousand dollars, they are for the enthusiasts rather than the mainstream market, which is not ideal for a game that wants to reach the general population.

Physical Exertion: 5

Using the Omni treadmill enables and forces the player to walk, sprint, jog, and do other high-intensity activities while playing the game.

Personal Motivation: 2.5

The game concept is interesting, but the lack of reach and accessibility makes it less appealing. Due to the limited time of the project, it is unlikely that there would be time to create a game of such high complexity.

17.3 80 Days of Exercise

80 Days of Exercise is an adventure/puzzle exergame inspired by the indie game *80 Days* (see Figure 17.2) [135], which again is based on the book *Around the World in Eighty Days* by Jules Verne. In *80 Days of Exercise*, players compete against each other to travel around the world as fast as possible within 80 days. Players register for a race with a set start date, and once the race starts, the game proper begins. This game has two states: spending time in cities and travelling between them. To afford to travel around the world, the player needs tokens. Players can buy and sell goods or complete tasks and challenges to earn tokens. These activities are mostly found in cities and are designed to help players earn tokens for their next travel route. The cost of travel between cities varies depending on the route. While travelling, players can do smaller challenges to shorten the travel time. As the game progresses, the players face different obstacles, some more critical than others. A planned route might suddenly be cancelled, or the plane they are on might have to do an emergency landing. The obstacles will give the game an extra level of challenge and randomness and ensure that every game run differs from the last. The game is a smartphone game that mostly runs in the background of the user's phone. The user has to check in throughout the day to select what routes to travel and what tasks they have to do. The player will be notified by the game when they finish a task or arrive at a destination. The tasks and challenges in the game collect activity data registered by the phone. Since phones are best at tracking aerobic exercises like walking, running, jogging, and biking, the tasks and challenges consist of those kinds of activities.



Figure 17.2: *80 Days*, the inspiration for *80 Days of Exercise*

17.3.1 Review

The following are the review scores in each category for *80 Days of Exercise*.

Technological Feasibility: 3.5

The technology needed is very accessible for the developers. However, the large scope of the game, together with the multiplayer aspect, would make it challenging to create a satisfying prototype within the given time frame. The game concept would have to be downscaled, possibly removing what made the game enticing in the first place.

Interest Reach: 3

Players motivated by the adventure and curiosity to explore will likely find the game inter-

esting. However, the competitive aspect could be less appealing for people who enjoy more casual gaming, and if they think there is no chance of winning, it is unlikely that they will try the game.

Player Retention: 2

The competitiveness and longevity of each race means that the game will mostly appeal to the few people with a chance of winning, while those who fall behind might lose interest. While falling behind could push some players to become more active, it is more likely that they will stop playing.

Accessibility for Player: 5

Most people own a smartphone, which makes the game easily accessible for most people. There is the issue of compatibility for different OS, but one solution is to develop the game as a web app, making it accessible on any device.

Physical Exertion: 3

The exertion will be of a light to moderate nature. The activity and exercise consist of walking, jogging, running, or cycling, as they are the easiest to track using smartphones.

Personal Motivation: 2.5

While the game concept sounds fun and exciting, it would have to be downscaled to fit in the short time frame, making it lose many of the most exciting aspects and making it much less appealing.

17.4 Treasure Hunters

Treasure Hunters is a concept inspired by existing games like *Pokémon Go* (see Figure 17.3) and the outdoor multiplayer game *Treasure* [136]. The game takes the hidden treasure aspects from *Treasure* and combines it with the collection aspect from *Pokémon Go*. The game will generate different walking routes, or “treasure maps”, of different lengths, depending on the player’s preferences. Hidden treasures are generated at random places along the route and trigger when the player approaches the spot, allowing them to collect the treasure. The treasure consists of different items the player collects, and the goal is to collect as many items as possible. Some items are rarer than others and, therefore, harder to find. If the player gets an item they already have, they can sell it and use the money to buy boosters, increasing their chance of getting rare items. When the game generates a route, it also calculates how long it will take to reach the treasures if the player walks at an average speed. The treasure will be bigger if the player reaches the location faster than the calculated time by running or jogging. Throughout the week, the game adds up the player’s activity. If the player reaches the recommendation from WHO, they get a reward, and if they reach it multiple weeks in a row, the reward grows. The game will also give a higher chance of rare items if the player is taking a walk outside in bad weather like rain or snow, which could motivate the player to go for a walk despite the weather. There should also be some items only available for a limited time, incentivising the player to play extra during those periods to ensure they get the exclusive items. The concept is intended for mobile devices and will use GPS and the fitness data collected on the phone. By tracking the player’s location and number of steps, the game ensures that the player is actually walking, running or jogging and not, for instance, driving

slowly in a car. Once the GPS tells the game that the player is close enough to the treasure, the game alerts the player so they can collect the treasure. The game will run in the background so players can enjoy the walk without constantly looking at their phones, as they only need to glance at it briefly to check the map.



Figure 17.3: Pokémon Go, the inspiration for Treasure Hunters

17.4.1 Review

The following are the review scores in each category for *Treasure Hunters*.

Technological Feasibility: 3

The random generation of set routes and treasures is the biggest technological challenge, as the map must be up to date on all roads and traffic. If a road is closed or the map shows a road that is not there, the entire route could fall apart, making it impossible to complete as the players are unable to reach their treasures.

Interest Reach: 4

The game is primarily for players who want a relaxed gaming experience, as they can go on a casual walk with friends while still being able to play the game.

Player Retention: 3

The idea of collecting many different items can appeal to the player as they want to complete the game, but the game could start to feel repetitive and boring, making people stop playing.

Accessibility for Player: 5

The game is accessible to anyone who owns a smartphone as long as it is available on their OS. The game might not be as accessible in early development, but it would be more accessible if it were to go public.

Physical Exertion: 3

The game focuses on cardiovascular activities and exercise as it only tracks walking, running or jogging. However, it only works for walking or running outdoors, as the player has to walk a physical route.

Personal Motivation: 4

The most appealing part of this concept is all the different ideas for incentivising the player to be physically active and continue playing. The different ideas sound interesting to test, and they have a large potential. The game concept itself would be feasible to complete within the time, but the gameplay could become repetitive for the players.

17.5 Real Life Pac-Man

Real Life Pac-Man is based on the old arcade game *Pac-Man* (see Figure 17.4), from 1980. In the original game, the player guides Pac-Man around a maze, eating the yellow dots and trying to avoid the ghosts. *Real Life Pac-Man* is a multiplayer game for 3-5 players. Instead of a digital maze, the game converts the surrounding roads and buildings into the play area. The players get specific roles as well as a starting location. Once everyone is in position, the game starts. The player playing Pac-Man will have a complete map of all the dots they have to collect and the locations of the ghosts, while the ghost only gets an indication of the direction where Pac-Man is. The game automatically collects the dots for Pac-Man as they move through the maze. The game stops either when a ghost catches Pac-Man or Pac-Man has collected all the dots. The game then generates a new map, and the game starts again. Once the Pac-Man player has lost all their lives, the game redistributes the roles and chooses a new Pac-Man. Each player has a profile where the game shows their accumulated score as Pac-Man, how many levels they have completed as Pac-Man, and how many Pac-Mans they have caught. The game is a mobile party exergame that uses GPS to locate the different players' positions. The challenge is that the player's position has to be very accurate. If a ghost can catch Pac-Man too early or not fast enough, the game's entire concept falls apart. The game also needs access to an updated map so it does not generate a play area using inaccessible or highly trafficked roads, as it is not safe to sprint through dense traffic while staring at a phone.

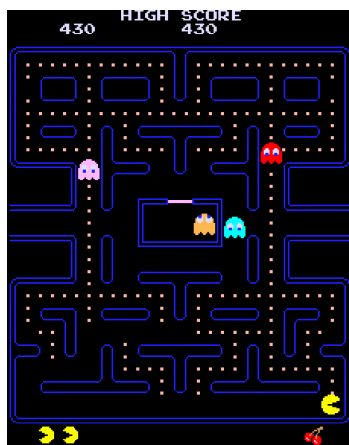


Figure 17.4: Pac-Man, the inspiration for Real Life Pac-Man

17.5.1 Review

The following are the review scores in each category for *Real Life Pac-Man*.

Technological Feasibility: 2.5

As the players constantly move around, it would be a challenge to have accurate GPS data, which is crucial for the game to work. Inaccurate GPS data can lead to Pac-Man wrongfully being captured or escaping, which will ruin the game. The issue with updated maps and road safety also makes this concept challenging.

Interest Reach: 2

The reach is limited as it can be hard to find suitable areas to play in if the player does not live in a town or city centre where it is easy to generate a map. The fact that it is a multiplayer game makes it harder to do a “quick game” when the player has time, as it requires coordination and planning between players, raising the barrier to entry.

Player Retention: 2

The players would constantly have to gather multiple players to play, which could quickly become challenging due to scheduling conflicts. If they never find a suitable time to play, they would quickly lose interest.

Accessibility for Player: 5

The only piece of equipment the player needs is a smartphone which makes the game accessible as long as the game works on the player’s OS.

Physical Exertion: 4

The exercise intensity can vary depending on the people playing. The game can get intense, with stretches of walking and jogging combined with bursts of sprints if the competitive instincts kick in or the ghost is close to catching Pac-Man, facilitating high-intensity exercise.

Personal Motivation: 2

The concept has more challenges than interest points, making it less attractive than other concepts. With the GPS and safety challenge, the game will likely be severely limited.

17.6 DigiDoggo

DigiDoggo is a concept inspired by the game *Nintendogs* (see Figure 17.6) and *Tamagotchi* (see Figure 17.5). *DigiDoggo* is a digital dog that the player has to take care of throughout the day. The dog needs fresh water, food, walks, and daily care like petting and grooming. To take the dog for a walk, the player has to go for a walk themselves. Some dogs would need more frequent and longer walks than others so the player can choose a dog depending on their activity level. The player can register other players as friends and meet up to let the dogs interact and play with each other. If the player neglects the dog over a long period, they will get a warning; if they keep neglecting it, they will lose the dog and have to start again. However, the game knows that there are days when the dog might get less attention due to schedule problems and will not take the dog away if the player loses a day or two. The game is for smartphones and uses the phone’s integrated step and distance counter to determine how far the player has walked. If the game registers that the player has walked for a distance and

time equal to or longer than the exercise required by the dog, the game will register the walk. The player does not need to register that they are going for a walk or continuously interact with the game throughout the walk. By having the phone in their pocket and just going for a walk, people might appreciate the walk itself, and the phone does not need an extensive mobile network connection and a full battery.



Figure 17.5: Tamagotchi, one of the inspirations for DigiDoggo



Figure 17.6: Nintendogs, one of the inspirations for DigiDoggo

17.6.1 Review

The following are the review scores in each category for *DigiDoggo*.

Technological Feasibility: 3.5

For this game concept to work, the visuals must resemble different dog breeds and be appealing to the player, which can be a challenge in the project's short development period. The multiplayer aspect is also a challenge, as it needs to synchronise live across multiple devices.

Interest Reach: 4

The game concept is simple and can appeal to many players as a game they can play throughout the day when it fits them. However, the game can appear one-dimensional for players who want a more intense and action-filled gaming experience.

Player Retention: 3

If the players bond with their dogs, they get a feeling of responsibility and will want to take care of the dog to ensure it is happy. However, similar games show that people can find the game repetitive and lose interest.

Accessibility for Player: 5

The players only need a smartphone that is capable of running the game. In the prototype phase, it will most likely only work on Android phones, but it should be available on all OS if it goes public.

Physical Exertion: 2

The game's simplicity makes it more accessible for people not interested in strenuous activities. However, the game has no way of motivating the player to push themselves to do higher-intensity activity than walking.

Personal Motivation: 3.5

The concept sounds fun, but the main part of the motivation comes mainly from missing having a pet. Adding together the problems of the visuals having to be perfect for the game to be attractive, the fact that many similar games already exist, and the problem with player retention, reduce the score.

17.7 Exercise Empire

Exercise Empire is a mix of an idle game, a real-time strategy game, and a city-builder game inspired by games like *Black & White* and the game series *Age of Empires* (see Figure 17.7). In *Exercise Empire*, the player is a deity or god-like figure that helps a civilisation grow into a large empire. In order to grow, the community needs to gather different resources spread across the map. The resources are needed to clear land areas that can be used for building different types of buildings for the empire, including defences to protect from wild animals and raiders. The player has to continuously make sure that no one breaks through their defences, adding a feeling of urgency to the game. Collecting resources and building buildings takes time, but the player can get energy points that can be used to speed up the process. If a player is active, they will get some energy points to use in the game. The game will register the person's activity throughout the week by looking at the health data from the phone, and if they reach the recommendations from WHO, they will get an extra boost of energy in the game. As the empire grows, it will get access to new, more advanced technology that will improve the empire. However, building advanced things will cost more resources, and the strength of the enemies will also increase as surrounding civilisations grow in strength. As the empire develops, it will evolve through different ages. *Exercise Empire* is played on the user's phone and utilises a health API to track and register the user's activity. The exercise will be light to moderate aerobic activity, like walking, jogging, and running, as this is the easiest type of activity to track with health APIs. The game will register activity even if it is inactive, meaning that the player only needs to check in when they want to collect new resources, build something or stop an impending attack.



Figure 17.7: Ages of Empires, the inspiration for Exercise Empire

17.7.1 Review

The following are the review scores in each category for *Exercise Empire*.

Technological Feasibility: 3.5

The problem with this game is the scope. The number of resources, buildings, technologies, mechanics, and enemies needed for different ages is a lot for the limited development period. To create this concept, it would have to be scaled down significantly, which makes the game lose much of what makes it unique in the first place.

Interest Reach: 3

Real-time strategy (RTS) is a tried and tested game genre used by many popular games. At the same time, the game genre might be too complex for more casual gamers who are not used to the complex control schemes and planning skills required of RTS games.

Player Retention: 4

Player retention will be pretty high due to the competitive environment with persistent incentives to return to the game. Having a unique civilisation for each player gives a sense of ownership, making players want to defend their civilisation.

Accessibility for Player: 5

All that is required to play the game is a smartphone with an OS that supports the game. Which OSes the game is available on will be up to the developers, but if the concept were to be released, it should support most OSes.

Physical Exertion: 3

The game focuses on aerobic and low to moderate-intensity activities such as running, jogging, and biking registered by the health API. Whether the game is able to increase player activity depends on if the player wants to gather extra resources.

Personal Motivation: 3.5

The concept in itself is exciting, but due to the game's complexity, it would not be possible to get a complete prototype within the limited time frame of the project, and it would have to be scaled down, which would remove a lot of the more fun aspects of the game.

17.8 House Designer

House Designer is a game concept based on house building and interior design games like *The Sims* (see Figure 17.8) and *Homescapes*. *House Designer* revolves around designing and furnishing a house for an avatar that has just moved into the area. The player can select different furniture and colours to make the house personal. Buying the furniture cost money, which the players have to earn, either through the gameplay itself or by completing tasks. The tasks will be connected to physical activity or exercises, for example, "Take a 15 min walk", forcing the player to be active if they want the reward. The players can also buy new rooms to expand the house. As the house expands, the cost of further expansions will increase, increasing the game's challenge as the game progresses. There will also be some furniture only available for a limited period, which creates an incentive for the player to return to the game and make sure that they have enough money to get the furniture they want. Exclusive

tasks like “take a walk with an elevation difference of 200m” or “walk a minimum of X minutes over the next 14 days” will unlock themed furniture that the players can use. As with the game concept *Treasure Hunters* (see Section 17.4), the player can get extra bonuses if they can reach WHO’s recommendations multiple weeks in a row (maintaining the streak). This concept is an idle smartphone game, where the physical activity aspects do not directly impact the game’s outcome in real-time. Instead, when a player opens the game app, the game checks if the health data app has registered any new activity and if so, the game calculates if the players have earned any bonuses. Another aspect similar to *Treasure Hunters* is that the health data should register if the person is walking outside or inside a building, which could give bigger activity bonuses depending on the weather.



Figure 17.8: The Sims, the inspiration for House Designer

17.8.1 Review

The following are the review scores in each category for *House Designer*.

Technological Feasibility: 4.5

The game concept is relatively small and straightforward, making it ideal for a short project. The biggest challenge is to calculate how much the player has moved and if they are moving outside or inside.

Interest Reach: 4

This game can appeal to a broad audience, regardless of their gaming background. Its customisation options, cosy atmosphere, and easy-to-play nature make it a great choice for those looking for a quick distraction while on the go.

Player Retention: 3

While the players can easily feel some ownership of their house, the game has no real urgency other than time-limited exclusive tasks for unique furniture. When a player is happy with their house, there is no reason for them to continue playing.

Accessibility for Player: 5

The game is accessible to everyone with a smartphone with an OS that can run the game. A prototype would likely only work on one or two operating systems, but a published game should work on as many as possible.

Physical Exertion: 3

The game facilitates different cardio levels, which is good, as higher-intensity activity benefits the player. However, there is no direct incentive for getting the player to increase intensity.

Personal Motivation: 4

The easiness and simplicity of the game, combined with the ability to personalise as part of the gameplay, ticks many of the boxes of an engaging game. Taking the “pay-to-win” aspect of games and replacing it with physical activity is worth exploring. Many idle games rely heavily on microtransactions, and replacing those with activity would be the extrinsic motivation a person needs.

17.9 Evaluation of Game Concepts

Concept	TF	IR	PR	AfP	PE	PM	Sum
Adventures and Abjurations	2.5	2	3.5	1	5	2.5	16.5
80 Days of Exercise	3.5	3	2	5	3	2.5	19
Treasure Hunters	3	4	3	5	3	4	22
Real Life Packman	2.5	2	2	5	4	2	17.5
DigiDoggo	3.5	4	3	5	2	3.5	21
Exercise Empire	3.5	3	4	5	3	3.5	22
House Designer	4.5	4	3	5	3	4	23.5

Legend: **TF** = Technological Feasibility, **IR** = Interest Reach, **PR** = Player Retention, **AfP** = Accessibility for Player, **PE** = Physical Exertion, **PM** = Personal Motivation.

Table 17.1: Evaluation of the game concepts

Table 17.1 shows the evaluation scores for the presented game concepts. It shows that several possible contenders could be the concept we would want to develop, but none felt perfect. Due to the limited development time, we wanted to find an idea with a relatively simple MVP while still having aspects that would increase motivation and player retention. When developing the different concepts, some aspects were introduced in multiple game concepts as they took inspiration from one another. Some examples are giving extra bonuses as rewards for being outside in bad weather and trying to replace microtransactions with physical activity, which is repeated in multiple of the presented concepts.

The results from the review showed that four concepts stood out above the others. *Treasure Hunters* (sum 22), *Exercise Empire* (sum 22), *DigiDoggo* (sum 21), and *House Designer* (sum 24.5). All these concepts had the advantage of being readily available for the players, having high *Interest Reach*, and *Personal Motivation* scores. *Treasure Hunters* and *DigiDoggo* aim to make the player’s physical activity more directly impact the gameplay. In contrast, *Exercise Empire* and *House Designer* had the player’s physical activity affect the game more indirectly. We found that we liked the second approach better, so we started looking into those games more closely.

House Designer was appealing because of its simplicity. It is a simple concept, and something we knew would most likely be achievable in our limited time, but the lack of urgency made

it feel like a game that would be easily forgotten. On the other hand, the urgency of the *Exercise Empire* was more on the level of what we wanted, but the game's scale was overly big. Therefore, we concluded that the best solution would be to combine the two concepts by taking the best aspects from each game and meeting somewhere in the middle. The new concept is described in the next chapter.

17.10 Summary

This chapter presented several new potential exergame concepts. Each concept presented where the inspiration for the concept came from, how the game and gameplay would work, and what technologies the game would use. The concepts were graded using a grading system. Lastly, the concepts were evaluated against each other, and the conclusion was that none of the concepts felt perfect, so the best solution was to combine the best elements from two different concepts: *House Designer* and *Exercise Empire*. How these were combined and further developed into the exergame concept called *Radiation Mayhem* is detailed in the next chapter.

Chapter 18

Radiation Mayhem

In this chapter, we will discuss the details of the exergame concept selected for the project. As mentioned in Section 17.9, none of the earlier concepts felt perfect, but many had exciting aspects that could be explored in more detail. As a result, we decided to combine two concepts, *House Designer* and *Exercise Empire*. Both were exciting concepts but had some problems, making them less ideal for the project. By combining the two, the new concept could keep the best parts of these two exergames while eliminating the problematic ones. The result is the new mobile exergame concept *Radiation Mayhem*.

18.1 Game Synopsis

In the future, after a nuclear catastrophe: the player has discovered one of the last liveable areas on earth and has to preserve it by fighting against the encroaching radiation. Radiation Mayhem is a grid-based idle city-building exergame where players must expand their community by cleaning irradiated areas and placing tiles that provide living space and resources, and generate renewable energy for the community. This task will be challenging as the radiation is ever-expanding and threatens to envelop the community. Luckily the player has an RCM (Radiation Clean-up Machine), which allows them to use energy to eliminate radiation.

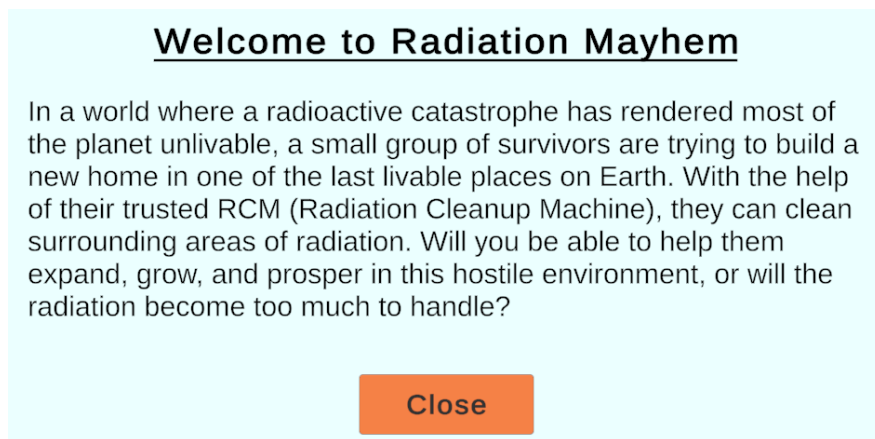


Figure 18.1: The intro text for the exergame tells the story and in-game fantasy of the exergame.

The first time the exergame starts, it shows a short synopsis of the exergame's in-game story for the players (see Figure 18.1). The text also introduces the exergame's goals to the players and lets them know the basics of how the exergame works. Without any introduction, it could

be hard for the player to know the exergame's goal, which could lead to confusion.

The player needs to collect different resources to continue expanding their community. The community can generate some resources by themselves, working in the fields and forests and collecting renewable energy. However, the most efficient way to gather resources is for the player to be physically active. The exergame gives in-game rewards based on how physically active the player is by using activity data like active minutes and steps. The players can also get resources through quests they complete by reaching their activity goal.

18.1.1 Characters

There are two characters in Radiation Mayhem: the radiation and the community.

The Radiation

The radiation is what the players are fighting. If the player does not care for the community by expanding and maintaining it, the radiation will spread and make areas in the community unlivable. Areas that start to get corrupted will get desaturated as nature decomposes.

The Community

The community is what the player is trying to protect and grow throughout the exergame. Starting out pretty small, its ability to grow depends on the player's skills and actions. If the player keeps the radiation at bay and places tiles that improve the community, such as forests, fields, and houses, the community will be happy and safe. However, if the player cannot keep up or neglects the community, the radiation will spread, and the community will decay.

18.2 Gameplay

The core of any game lies in its gameplay. The game's goals, and the skills required to reach them, will be at the forefront of the player's minds as they play the game. As a game progresses, its challenges will evolve as the player's skills improve. In Appendix K, there is a link to a video demonstrating Radiation Mayhem's gameplay. There is also a help guide to the game in Appendix L. This guide is the same that is accessible to the players via the in-game settings.

18.2.1 Goals

The exergame has one main goal that can be broken down into multiple sub-goals. The main goal is the overarching goal of the entire exergame, while the sub-goals are smaller goals that can be achieved on a relatively short timescale and can aid the player in making progress in the exergame. By achieving the sub-goals to a satisfactory level, the players will find it easier to achieve the main goal.

Main Goal

- Build, maintain and expand a community while cleaning the nuclear radiation from the surrounding areas and defending the community against the encroaching radiation.

Sub-Goals

- Collect energy generated by the player being physically active.
- Collect money generated by the community.
- Collect energy generated by energy tiles.
- Use available resources to grow the community by cleaning areas of radiation.
- Use resources to build the tiles the community needs to thrive.
- Defend the community from the encroaching radiation by removing traces of radiation that has seeped into the community.
- Complete quests and daily streaks to get extra rewards in the form of resources to the community.
- Increasing the player score by interacting with the community.

18.2.2 User Skills

User skills are the skills the player has to learn and master to get the most out of the exergame. By perfecting these skills, the player can make better progress in the exergame through feedback and reward systems. If the player does not master these skills, they will be unable to make good progress in the exergame and could risk losing altogether. The most important skills to master for the exergame are:

- Maintaining a balanced community with all the community tiles needed to thrive.
- Maintaining the cleaned areas and removing any radiation that might seep in from the outside.
- Collect resources (energy and money) from the community.
- Completing quests and maintaining streaks to collect additional resources for the community.

18.2.3 Exergame Progression

The player progresses in the exergame by maintaining and growing the community. It is up to the player to use their limited resources to optimise the community and make it independent and efficient. However, as the player expands the community, the exergame increases in difficulty. As the community grows, it will need more resources to continue to grow and prosper. However, the community will also generate more money that the player can collect.

Challenge

As the player continues to grow their community and move further away from the centre, the cost of cleaning tiles will increase. The increase in cost is also the case when it comes to saving tiles that have become corrupted. The tiles distance from the centre, combined with the stage of their corruption, dictates how much it costs to save them.

There is also the challenge of keeping the community balanced as it expands. The community must meet the resource goal to thrive, and as the area expands, the goal grows. Finding the right balance between expanding the buildable area while still having enough money to build

the community tiles needed is challenging. Growing the community adds many points to the player's score, but growing it too fast will result in smaller rewards.

Losing

If the player does not maintain their community, the radiation will start seeping into the community's edges, making the tiles corrupt. If the player does not remove this radiation, the tiles will be lost and must be cleaned and rebuilt. If the player loses all their tiles to radiation, the exergame shows the game over screen, shown in Figure 18.2, and the player must start again.



Figure 18.2: The exergame's "Game over" screen

18.3 Game Mechanics

The exergame consists of different game mechanics, making the game fun and exciting for the player. These mechanics are crucial for the exergame as they work together to create a story and provides the player with different challenges and things they can do in the exergame. The game layout is shown in Figure 18.3. The game map is displayed in the centre, while different information and buttons important for the player are placed around the edge.



Figure 18.3: The game's main screen displays the map and other important information the player needs.

18.3.1 Tiles

The map of hexagonal tiles is at the exergame's core, serving as the foundation for the entire concept. The player interacts with the exergame by clicking on the tiles, and different tiles have different actions the player can do. Most tiles can be placed and moved without restrictions, giving the player creative freedom to build, expand, and create a unique and personal community. The different tiles and tile states (clean or corrupted) impact the community positively or negatively, and the community has to react accordingly. All the different tile types are listed below. For pictures of the tile design, see Figure 18.7.

Clean Tiles

"Clean tiles" is an umbrella term for all tiles the player has cleaned from radiation and is the only area where the community can live.

- **Cleared Tile:** Cleared tiles are tiles cleaned from radiation that has not been developed yet. Players can build these into community or energy tiles or move existing tiles there.
- **Centre Tile:** The Centre tile is unique and placed at the centre of the grid. It is the community's only water source, and if the player loses this tile to corruption, they lose the game. The centre tile is bound to its position and can not be moved or deleted.
- **Construction Tile:** Construction tiles are where the community is building something. The timer over the tile shows the time left in the building process. The player can shorten the construction time by using energy to speed up the process. When the building process is completed, the tile automatically changes, showing the newly developed tile (see community and energy tiles below).
- **Community Tiles:** Community tiles help the community gather the resources they need to survive and thrive. The community earns resources in the form of money from working at the community tiles, and the player can collect the money and use it to buy other tiles. If the community has too few community tiles, they become unhappy, cannot work efficiently, and earns the player less money. There is also a synergy-mechanic in the exergame; community tiles of the same type placed together are more efficient and will generate more money for the player.
 - **Field Tile:** Fields are where the community grow the food needed to feed the inhabitants.
 - **Forest Tile:** Forests are where the community gather wood, stone and other natural resources necessary for expanding and building their community.
 - **House Tile:** Houses are where the community inhabitants live. They are a safe space where they can sleep, rest, and socialise while being protected from the environment.
- **Energy Tiles:** Energy tiles are where the community generate renewable energy by charging batteries. The player can collect the energy by clicking on the energy bar above the tile. Each battery has a maximum capacity and cannot be charged over this capacity.
 - **Windmill Tile:** The windmill charges its battery throughout the day by collecting power from the wind. It is a slow but steady process, making it a reliable resource for the community.

Any clean tile can become *corrupted*. A corrupted tile is still part of the community but has started to get saturated with radiation from the dirty tiles. The radiation renders the tile useless until the player saves it by removing the radiation from the tile, restoring it to its former use. The radiation will increase over time, making the tile increasingly more corrupted, and if the player does not save it in time, they will lose it, and it will turn into a dirty tile.

Dirty Tiles

Dirty tiles are tiles the player has not cleaned, and they are saturated with radiation, making them unlivable. The player can clean the radiation from the tile by using their collected energy, and thereby continue to expand their community.

18.3.2 Resources

The game consists of two in-game resources (or currencies); *money* and *energy*. Players can easily keep track of their resources as they are displayed in the top right corner of the screen (see Figure 18.3). The two resources are necessary for the player to continue to expand and maintain their community. They are needed for different tasks in the game. The player can collect money and energy in various ways.

- **Money:** Money is generated through community tiles and certain quests. A well-balanced community is more effective and can efficiently use its limited resources. By growing, the community can generate more money. The money collected can be used to develop cleared tiles in order to grow the community.
- **Energy:** Energy is what the community needs to expand and run efficiently. The player can collect energy from energy tiles, certain quests, and by being physically active. The Radiation Clean-up Machine, used for cleaning dirty tiles of radiation, needs energy to work and protect the community from radiation. However, energy can also be used to speed up the building process of community and energy tiles.

Streak

The streak is a short task which, like daily quests, repeats daily. The reward for claiming a streak is a small amount of money that increases every day as long as the player continues to complete and claim their streak goal. The goal is relatively easy to reach, but the challenge is that the player must complete it daily. If they lose one day, the streak resets and the reward reduces to the starting reward.

18.3.3 Quests

Another way to get access to resources is to complete quests. To see the quests, the players can click on the paper scroll in the top left corner of the main screen (see Figure 18.3). Quests are small tasks or challenges for players that they can complete to get rewards like money, energy, and points. Different types of quests give different rewards depending on the type and challenge level of the quest. The quest goals are related to physical activity or exercise goals the player must complete in the real world.

- **Daily Quests:** Daily quests are repeated every day and are relatively small and easy to complete. The different quests in this category aim to motivate the player to “just go a little further” to get a bigger reward. They aim to give the players a sense of achievement and a small game boost. Unlike with streaks, the reward amount for quests does not increase if the player has reached it multiple days in a row. In our exergame, there are three daily quests, with goals of 60, 120, and 240 active minutes, respectively.
- **Weekly Quests:** The two weekly quests are repeated every week. They are more challenging than the daily quests, thus giving the player a bigger reward. They coincide with recommendations one and two from the FHI’s 2022 revised recommendation (see Table 7.1) [23]. They are a way for the player to track their weekly progress against the FHI recommendations while still playing the game.
- **Non-Repeating Quests:** These are one-time quests that are more challenging to complete. In addition to being a greater challenge, they are more time-consuming and require the player to make a conscious effort to reach them. However, as a reward for completing them, the player gets more resources and points than the other quests. For this project, the goals are calculated based on the duration of the test period, making them challenging but not impossible to reach in time. There are four non-repeating quests in the game. To reach the quest goals, the player must walk an average of more than 3000, 6000, 10 000, and 12 500, steps per day during the two-week test period, respectively. The non-repeating quests were particularly designed with the *achiever* player type in mind (see Section 8.5).

Figure 18.4 shows the game’s quest screen. Each quest card displays the quest’s name, a short description of how to complete the quest, what kind of reward it gives (money or energy), and how much of that reward the player gets for completing the quest. It also shows the player’s progress and how far they are from their goal. If they have reached a quest goal but have not claimed it, an orange circle will appear on the top right of the paper scroll, and the player can collect their reward by clicking the “Collect” button.

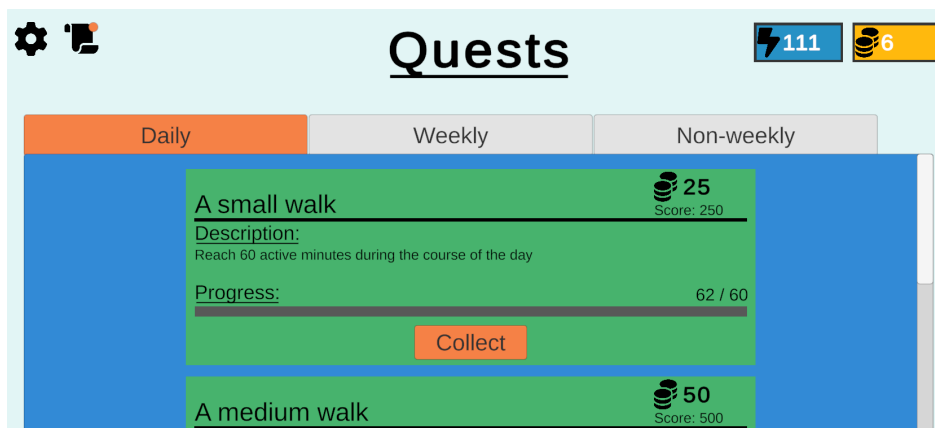


Figure 18.4: The quest screen, displaying the player’s daily quests

18.3.4 Resource Goals

As the community grows, it needs more resources to maintain itself. If the community lacks resources, it will have to spend more time trying to survive and will not be as effective. If the community only lacks a few resources, say, they have three fields but need four, they would still be able to work somewhat efficiently. However, if they lack many different kinds of resources or are missing a type of resource altogether, the community will work less and less efficiently or not be able to work at all. The resource goals are displayed in the lower-left corner of the game's main screen (see Figure 18.3). The three symbols indicate how many forest, field, and house tiles the community has versus how many they need.

18.3.5 Score

Actions in the game will impact a total player score by adding or subtracting points. Most actions will add to the score, but some will deduct points. The player's score is measured against other players, letting the player know how close they are to the next person's score. The score is displayed in the lower right corner of the main page (see Figure 18.3). The large number displays the player's score, and the smaller number beneath shows the points needed to surpass the player just above them on the scoreboard. As part of the experiment, during the test period, a scoreboard displaying the scores of all players was sent out every three days. Although the intention was to integrate this scoreboard into the game, this was not possible within the project's time frame.

18.4 Audio

For players to feel fully engaged and immersed in a game, the game must offer both pleasant audio and tactile interactions. Therefore, the exergame needs to give the players audible feedback when interacting with the exergame. However, some players might find the sound distracting. Therefore the option to turn the sound volume down or completely off has been included in the settings (see Figure 18.5).

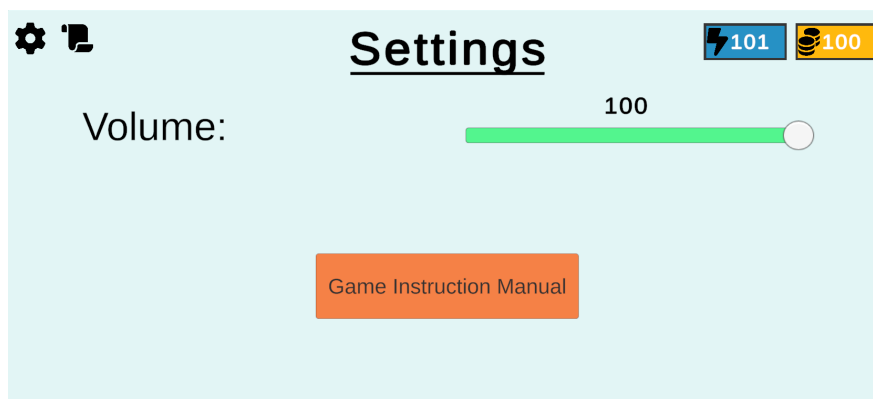


Figure 18.5: Radiation Mayhem's settings screen

18.4.1 Music

The background music is low-fi and relatively unobtrusive. Its calm but upbeat vibes invoke positive feelings in the player as they tend to their community, telling the player that they are doing good work. Invoking positive feelings in the players will make them enjoy the exergame and want to return to it.

18.4.2 Sound Effects

Different feedback sounds in the exergame add a sense of tactility whenever the player interacts with the exergame. The different sounds include clicks when the player presses buttons, coins clinking when the player collects or uses money, as well as other sounds connected to different actions in the exergame.

Some sounds are used as positive feedback when the player does something that helps the community. These are used as *glory rewards* to enhance the player's motivation and enthusiasm for the exergame (see Section 8.6). Some of these sounds serve a dual purpose by also helping to deepen and reinforce the exergame's *fantasy*, like the sound of money whenever the player uses or collects money.

There are also sounds for negative situations in the exergame. If a player does not save a tile, there will be an empty popping sound as it is lost and returns to being a dirty tile.

18.5 Visual Design

The exergame consists of a single map displayed on an invisible hexagonal grid. The map shows the player's cleaned area, surrounded by the dirty area still saturated by radiation. The exergame's visuals create a contrast between the clean tiles and the surrounding area still full of radiation. The cleaned areas consist of bright and clear colours that make the area stand out from their surroundings, which are subdued and have more desaturated colours symbolising pollution. The main inspiration for the design was the puzzle game *Dorfromantik* (see Figure 18.6) with its radiating tile placement, its soft colours, and some of its tile types.

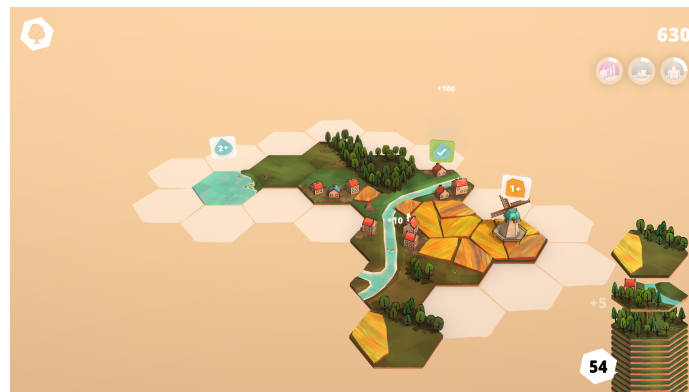


Figure 18.6: *Dorfromantik*, one of the main inspirations for Radiations Mayhem's visuals and grid system

18.5.1 Tile Design

The tiles in the exergame are three-dimensional hexagons that create a grid. The clean tiles are distinguishable from the dirty ones because of their bright green, saturated colours. Additionally, each tile has a unique layout that represents its function. For instance, the central tile contains water essential for life. Another example: the windmill tile collects energy through renewable energy methods and therefore has a windmill on top of it, invoking the feeling of clean energy. The tiles are also shaded to be relatively glossy, imitating the look of plastic pieces on real-life playing boards. All the tiles can be viewed in Figure 18.7. For information about the different tile types, see Section 18.3.1.

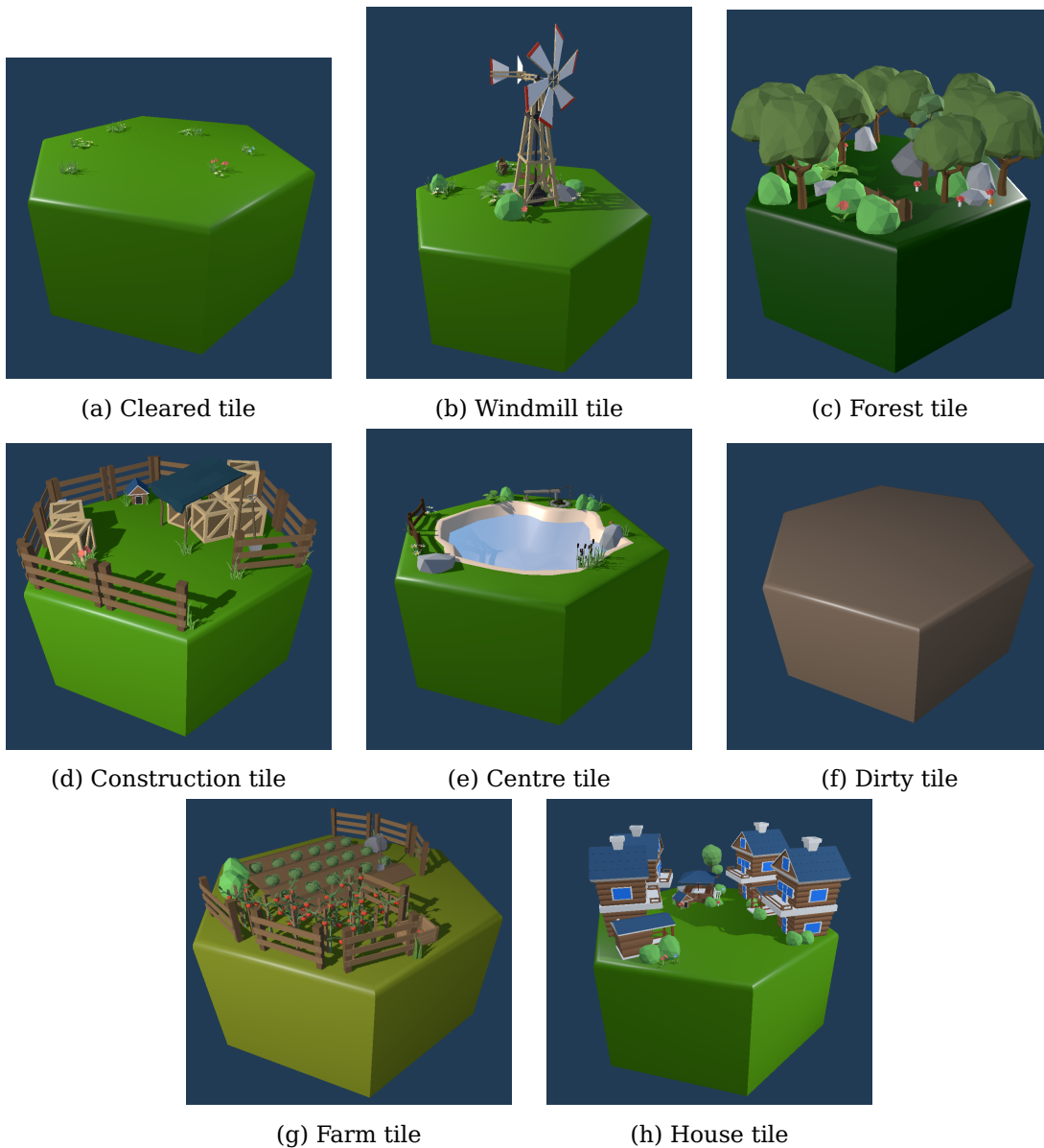


Figure 18.7: All the tiles in Radiation Mayhem

The tiles themselves were designed and created by the master students. Most of the models used when creating the tiles were collected from various free asset packs downloaded from the internet, primarily from Unity's Asset Store. The external assets used to create the exergame are summarised in Appendix J. The two assets created entirely by the master students were the windmill and the base model for the centre tile. These were modelled in the 3D modelling program *Blender* and textured using Unity's internal shader system. The windmill design is inspired by different existing windmill models from asset packs that had a similar style to the other packs used when creating the tiles. The windmill was also animated to spin, indicating that it was producing electricity.

18.5.2 Colours

When selecting colours for the tiles, it was important that they felt natural to the players, meaning they were colours the players would associate with the tile types. Open grass areas are green, forest trees are a darker green, and fields for planting food are green with a brown-yellow tinge often associated with farmed areas.

The colours used on the UI were selected to give the exergame a specific vibe. The pastel colours give the exergame a light, carefree, and calm feeling. The buttons were coloured orange to create a contrast between the background. Some buttons were red as a way of warning the players. An example is shown in Figure 18.8, where pressing the red "Delete" button would delete the selected tile.

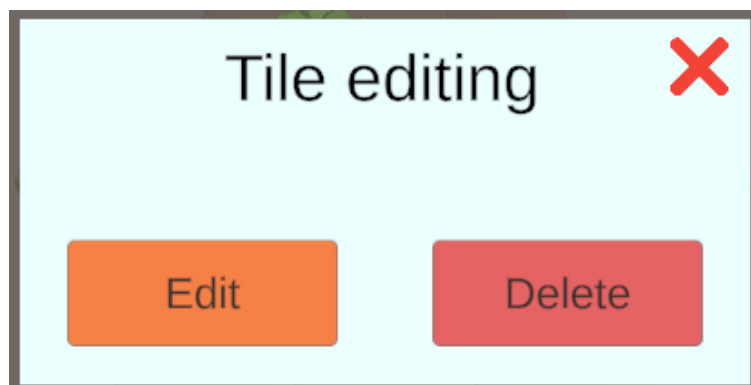


Figure 18.8: The popup for editing the tile layout.

18.5.3 Animations

The exergame has some animations making the exergame feel alive and not just like static pixels on a screen. Small things, like the spinning of the windmill blades, give the illusion of wind that blows through the community. Other animations are the tiles gradually changing colour when cleaned or corrupted, text popping up for a short time to display the number of resources collected, surrounding dirty tiles popping up when a new tile is cleared of radiation, and the resource trackers and score counting up or down when their values change.

18.5.4 Accessibility

Other than being able to change the in-game sound volume in the settings screen, there is little a player can do to change the settings in the exergame. A fully developed game should include different settings and accessibility options to be more inclusive. Things like different colour schemes for people with colour blindness, changing text and icon size, and the ability to use text-to-speech can be necessary if the app should become as accessible as possible. These features were not implemented in the prototype, as they were not features critical for testing.

18.6 Summary

This chapter introduced the exergame concept *Radiation Mayhem*. *Radiation Mayhem* aims to implement a type of gameplay often seen in *idle* and *city-builder* games, and combine it with physical activity. The fantasy in *Radiation Mayhem* is that the player is trying to build a community after a nuclear catastrophe that has rendered most of the world unlivable. To accomplish this, they need to use the Radiation Clean-up Machine to remove radiation from the ground where they want to build their community. The radiation is always trying to spread back into the community, so the players should not only grow their community but also maintain the area they already have.

The exergame is tile-based. The player decides where they want to place tiles, and depending on which tile they place, it affects the community differently. Community tiles are necessary for the community to live and thrive. In contrast, energy tiles generate energy that the community can use to clean the radiation from surrounding areas and continue to expand. The players will have to balance having enough community tiles for the community to prosper and enough energy to keep maintaining and expanding their community.

Radiation Mayhem is a mobile exergame which makes it more accessible to players. With a minimal and intuitive interface, it is easy for the player to learn the different functionalities and abilities of the exergame. Other aspects of the exergame, like the art style, music and sound effect, will make the exergame more immersive and enjoyable.

In the next chapter, we will discuss the use of game enjoyment theory in *Radiation Mayhem*.

Chapter 19

Use of Game Enjoyment Theory

This chapter discusses the theories and frameworks used to design Radiation Mayhem as an enjoyable gaming experience. First, it will explain how the exergame integrates the concepts of GameFlow [28] and Malone’s model of Challenge, Fantasy, and Curiosity [30]. Then, it will describe the different reward systems the exergame uses. Lastly, it will go through the drivers used from the Octalysis framework. More detail on these theories and frameworks are in Chapter 8.

19.1 Use of GameFlow

Flow is crucial for maintaining a player’s interest and motivation for an activity [29]. To ensure the player experience flow, Radiation Mayhem consisted of several features and elements that aim to meet the GameFlow criteria. The theory of GameFlow is presented in Section 8.1.

19.1.1 Concentration

The exergame provides a lot of stimuli worth concentrating on from audio and visual sources. When the player opens the game, they will be met with a pleasant visual of their little community surviving despite the surrounding radiation. These visuals are accompanied by calm music and ambience. The calm visual and auditory design will create a calm atmosphere that enables the player to take a break from what they are doing and enjoy playing the game.

Another element that helps the player’s concentration is the constant danger of the radiation eating up their community. If the player is not physically active and plays the exergame often enough, their community will suffer the consequences. Though this sounds quite grim, in practice, the players will find great motivation in protecting a community they have built themselves.

The exergame will refrain from having too many pop-ups and other disparate elements to prevent the player from being cognitively overloaded with too many things fighting for their attention. The spread of the radiation will not be so fast that the player cannot keep up. The challenge in the exergame should motivate the player, not crush them.

19.1.2 Challenge

A crucial component for flow to occur is the balance between the participant’s skill and the activity’s challenge level (more on this in Section 8.1) [29]. In our game, the challenge comes from the radiation trying to spread and consume the player’s community. The exergame has a

built-in balancing factor; the cost of cleaning tiles is tied to their distance from the centre of the grid. This balancing factor means that the more the player expands, the more challenging the exergame will get. The player can avoid radiation spreading to their tiles by continuously maintaining and expanding their community. This balance will motivate the player to want to be more active and get better at the exergame in order to expand the community as much as possible.

19.1.3 Player Skill

The exergame should suit players of all skill and physical activity levels by balancing the game's challenge level; the more the player expands their community, the more expensive cleaning new tiles will become. This mechanism means that the player's skill and the game's challenge will be closely matched, even as the player gets more proficient with the game's mechanics and physical activity. The controls themselves will also be pretty straightforward and adhere to mobile platform standards.

19.1.4 Control

With the minimal and intuitive interface, the player should feel like they can easily control the game. With the main objective being to fight against the ever-encroaching radiation, the player should also feel like they have the control they need to affect it. There is a direct correlation between the amount of physical activity the player does and how many dirty tiles they can afford to clean. This fact should make the player feel in control of how much radiation gets cleaned up. The player also has complete control of where to place the different tiles in order to grow their community. Which tiles the radiation "eats" is, from the player's perspective, random, but the player can use energy to stop the radiation from expanding.

19.1.5 Clear Goals

The game's primary goal is to keep the community alive and happy by clearing out the surrounding radiation and building the facilities they need to survive and thrive. This goal is presented early in the exergame as a tutorial message. The exergame also has several sub-goals in the form of quests that allow the player to gain resources by completing them. These quests come in a wide variety, from different daily and weekly quests to more long-term quests that give more significant rewards. To remind the player of the quests, an orange notification mark will appear in the top left of the screen when a quest goal has been reached, and the reward can be collected. There are also short-term goals, with the player having to gather and spend energy cleaning tiles that are in danger of being consumed by radiation. The short-term goals are very visible to the player; tiles in danger will have a warning symbol above them and slowly change colour to that of the dirty tiles. For gathering energy, the energy tiles all have bars that indicate how full they are. By clicking on the bar, the player collects the energy. A push notification will be sent to the player's phone when all the energy tiles are full, reminding the player of their current short-term goal. An element in the exergame that works as both a short-term and long-term goal is the points system. Helping the community, gathering re-

sources, and completing quests all give the player points. These are added to an on-screen count of the player's current score. The points required to pass the next player are also displayed. They can strive to pass the next player as a short-term goal and even aim to be at the top of the scoreboard in the long run.

19.1.6 Feedback

The exergame concept has several ways of providing feedback to the player. When the exergame runs in the background, it can send push notifications to the player, informing them that there is energy to harvest from the energy tiles or give them a gentle reminder if it has been a while since they have opened the game. When the player is in the game, there will be visual and auditory feedback messages informing the player of what they are doing and what is happening in the game. For example, when the player cleans a dirty or corrupted tile, there will be a visual effect of the tile being cleaned to become part of the community. This transition is accompanied by a pleasant and situation-appropriate audio queue telling the player they have accomplished something positive, immersing them in the fantasy. Another form of feedback the exergame gives is the player's progress on the different quests. Each quest has a progress bar that fills up as the player approaches the goal.

19.1.7 Immersion

The exergame concept has several considerations to help with player immersion. We intended to keep the game's interface as "invisible" as possible. To achieve this "invisibility", the interface is simple and stays mostly out of the way. The cohesive visual and audio design will allow the player to feel like it is all part of a world they can influence. The exergame will also allow itself to "breathe" and let the player immerse themselves without constantly trying to pull on and distract them.

19.1.8 Social Interaction

The exergame is primarily a single-player experience and, as such, draws only a little on the social interaction criteria. However, the exergame does include a scoring system where the player can see the number of points needed to reach the player above them. The original intention was to have a high-score list as an in-game feature, but during the test period, this list was sent out to the testers as an email every three days. This list allows the players to compare their scores to the rest of the testers. This system allows the players to form competitive relationships with the other players, which can lead to extra engagement [28].

19.1.9 Dual Flow

Although the dual flow framework is often used to evaluate exergames [31], it does not apply to our concept. As detailed in Section 8.2, dual flow is designed for exergames that aim to achieve both attractiveness through normal GameFlow, and effective exercise as part of the gameplay. Radiation Mayhem focuses mostly on general activation and physical activity with

low to intermediate intensity, which is too low for dual flow. The physical activity and game-play are done separately, with the player exercising to gather resources they can use in the exergame later. The dual flow framework assumes that the exercise is conducted while the player plays the game.

19.2 Use of Challenge, Fantasy, and Curiosity

Malone presents several elements that help make “intrinsically enjoyable situations” [30]. These elements, *Challenge*, *Fantasy*, and *Curiosity*, were used when designing Radiation Mayhem. More details on each of these categories can be found in Section 8.3.

19.2.1 Challenge

Radiation Mayhem presents the player with a clear goal: Keep the community alive and happy by expanding and fighting against the encroaching radiation. The challenge to this goal is the ever-expanding radiation and the balance of tiles needed to keep the community happy. The player has to be physically active and complete quests to get the energy needed to clean up the radiation. Physical activity and exercise are in and of themselves challenging, but the exergame adding a goal to this challenge should make it more exciting.

To keep things exciting, Radiation Mayhem also uses Malone’s principle of *outcome uncertainty* [30]. As the player grows their community, the cost of growing and maintaining the community will rise, and the exergame will become more difficult. There is also some *randomness* involved; the areas bordering the radiation are all at risk of getting swallowed, but which one will fall next appears random to the player. Actually, the tiles picked by the radiation are weighted towards tiles that are surrounded by many dirty tiles. This is to make the exergame feel less cruel.

Radiation Mayhem also uses *multiple level goals*, with the long-term goals being to clear all the radiation and keep the community alive and happy [30]. The shorter-term goals are the exergame’s different quests (see Section 18.2). This setup means that the player will always have many small goals they can complete in the short term that are not too challenging, as well as having more long-term goals they can strive for. Along with these long-term and short-term goals, there is also the player’s score. The exergame does not explicitly encourage the player to get as high a score as possible, but it opens up the possibility for the player to set their own goals. With competitive nature being what it is, it is easy to foresee that some players will play extra hard to get more points than the next player on the scoreboard.

The exergame’s challenge is fairly well integrated into the exergame’s fantasy, which will be discussed more in the “fantasy” category.

19.2.2 Fantasy

In the fantasy of our exergame, there is a machine called the RCM (Radiation Clean-up Machine). This machine converts physical activity into energy. This narrative construct allows the

player to feel like the physical activity they are doing day-to-day is being fed into, and affecting, the exergame and its fantasy. There is also a nice parallel between the player cleaning up radiation and improving the community in-game while at the same time improving themselves by being more physically active in real life.

We would classify the fantasy in our exergame as both *intrinsic* and *extrinsic*. The elements where the player is building buildings and organising their community are pretty tied in with the actions the payer is doing. The player assumes the role of a city planner and decides which areas should contain specific types of buildings. For these elements, the exergame's fantasy is intrinsic. For the elements where the player converts physical activity into energy or money (through the streak, quests, and the conversion feature), the fantasy is more *extrinsic*. Most players may find it easy to believe in the possibility of transforming physical activity into energy. Technology that converts activity directly into energy already exists in the real world, such as exercise bikes equipped with generators. However, the technology for converting physical activity directly into money does not exist yet.

19.2.3 Curiosity

Radiation Mayhem employs both *sensory* and cognitive *curiosity*. The sensory curiosity comes from the different feedback messages and the overall visual and auditory design. The community is friendly, peaceful, and saturated, whereas the radiation is bleak and desaturated, making the community seem like an island in the middle of a desaturated sea. This contrast will make the player want, through sensory curiosity, to expand the community to create a more pleasing image [30]. Cognitive curiosity comes from several places. At the beginning of the exergame, radiation covers almost the entire map. The player does not know what is out there and needs to clean areas to find out.

19.3 Use of Reward systems

Radiation Mayhem utilises several types of reward systems in its gameplay. Using several affordances, such as reward systems, correlates with greater game enjoyment [38]. The definitions for each of these reward systems can be found in Section 8.6.

19.3.1 Score system

In Radiation Mayhem, the player can earn points from almost every action they take. These points contribute to their overall score, which is displayed in the bottom-right corner of the game screen. The points required to surpass the next player are shown just below. Every three days during the test period, a high-score list was sent out, allowing players to compare their scores to others.

The scoring system does not directly affect the gameplay and is there for the *glory* of the player [39]. The players who reach the top of the scoreboard will feel gratified for reaching that milestone. They will also be engaged in the exergame by trying to keep their top spot. Those players who are further down on the board will likely focus on climbing the scoreboard

or passing the player right above them. Here they will feel a sense of accomplishment as the number of points to the next player decreases, and they eventually surpass them.

19.3.2 Resource Reward Systems

The resource reward system is the reward system the player will be interacting with the most. This system consists of four main elements: the energy the player gets by being physically active, the energy the player gets from the different energy tiles they have placed, the money the player gets from the community tiles, and the energy and money collected from completing quests and streaks.

Whenever the player opens the game, whatever physical activity they have done since they last entered the exergame will be tallied up and converted into energy. The energy can be collected by clicking on a pop-up that appears over the central tile. Clicking it gives a positive feedback message displaying how much energy they have collected. The conversion relies on the active minutes metric from Google Fit or steps counted from Apple Health, depending on the OS.

The energy from energy tiles can be collected by the player clicking the bar above the different energy tiles. This element incentivizes the player to regularly check in on the exergame, as each energy tile can only hold a specified amount of energy. If the tile's capacity is filled up, the tile will not produce any more energy before the player collects the stored energy.

Money is collected from community tiles. Unlike the energy collected from energy tiles, there is no limit to how much money can accumulate before the player collects it. However, the rate at which money is produced depends on the number of community tiles the community has compared to the community's needs.

Quests have different rewards depending on the difficulty and type of quest. The reward is an amount of energy or money, depending on how challenging the quest is. The quests also have points that are added to a player's score when they complete it.

19.3.3 Achievement Systems

Radiation Mayhem does not have a distinct achievement system, but the non-repeating quests are intended to serve that purpose. With varying degrees of challenge, some of the quests are challenging enough to complete that the players must dedicate some effort. They can only complete these quests once; therefore, a completed, non-repeating quest serves as a badge of honour.

19.3.4 Feedback Messages

Both sound and visuals are used as feedback messages, which will be activated whenever something significant happens in the game. The feedback messages can be both positive and negative.

Positive messages play when the player does beneficial actions, such as cleaning areas of radiation and picking up money and energy from tiles. When the player cleans areas, there is a satisfying sound and a nice transition from the desaturated and dirty tile to a saturated and

clean tile. When picking up energy and money, there is animated, hovering text that pops up, displaying how much they have gathered, along with a satisfying ticking sound, and the display of resources counts up to display the new number.

Negative messages play when something bad happens to the player. These situations are primarily when the radiation consumes a tile. When this occurs, a popping sound plays, and the tile returns to a dirty tile.

19.4 Use of the Octalysis framework

We used several of the core drivers from the Octalysis framework in our exergame concept, a good mix of *white hat* and *black hat* drivers from the left and right side of the framework [34]. A more detailed description of the Octalysis framework can be found in Section 8.4, including a model of the Octalysis framework (see Figure 8.3). The drivers used in Radiation Mayhem are:

- **Epic Meaning & Calling**

This driver fits well with the concept as the community needs saving, and the player's actions are the only thing that can achieve that goal.

- **Development & Accomplishment**

This driver plays on the player's internal drive to progress through a challenging scenario. The different quests and steaks are meant to utilise this driver. As the player feels a sense of accomplishment for completing them.

- **Empowerment of Creativity & Feedback**

The exergame is, at heart, a city- or community-builder, allowing the player to express themselves through how they build their community. Other elements that use this driver are the myriad of feedback messages the player gets when they complete different tasks and actions in the game.

- **Ownership & Possession**

Several parts of the concept play on the ownership driver. The player will want to collect resources in the form of money and energy, as well as gathering points. The player is also building a unique community they have to protect, which could help foster a sense of ownership in the player.

- **Scarcity & Impatience**

One of the more black hat gamification approaches used is *countdown timers*. If the player wants to place a tile, that tile takes time to build. The countdown can be shortened or skipped if the player is willing to use energy to pay. See Section 20.2 for more on the use of this driver.

- **Unpredictability & Curiosity**

The radiation is ever-encroaching; which tiles the radiation will strike next is determined, from the player's view, at random, leaving them to wonder.

- **Loss & Avoidance**

The encroaching radiation will eat up tiles at a steady pace, and the only thing that can

stop it is the player. To avoid losing their unique community, they must be physically active and play the game.

These different drivers keep players engaged and motivated to be physically active. Of these drivers, Radiation Mayhem relies most on *Development & Accomplishment*, *Ownership & Possession*, **Scarcity & Impatience**, and *Loss & Avoidance*. The main objective of the exergame is to create and protect a community. However, the players lack sufficient resources to do this and depend on completing quests to get the resources they need.

19.5 Summary

This chapter described in detail the different game enjoyment theories and frameworks utilised when creating Radiation Mayhem. It highlighted and discussed the relevant elements from each theory and framework, including all criteria from GameFlow and seven out of eight drivers from the Octalysis framework. The game's design focuses on integrating several different types of *reward systems*, as studies show that it leads to greater game enjoyment. The reward systems used are *Item granting systems*, *Resource reward systems*, *Achievement systems*, and *Feedback messages*.

The use of game enjoyment theory is essential when creating motivation, engagement, and enjoyment for the player. The next chapter will discuss the specific game elements in Radiation Mayhem that will influence the player's physical activity and motivation for physical activity.

Chapter 20

Influence on Physical Activity and Motivation

This chapter discusses how Radiation Mayhem and its different game elements and mechanics influence the player's level of physical activity and motivation. First, it explains how Radiation Mayhem registers user activity and how it impacts the game. Second, it introduces the concept of "Train-to-Win" and how it is implemented and affects the game. Then, it explains how the exergame uses urgency and repeats rewards to entice the player to return to the exergame and continue playing. Lastly, it presents how the exergame uses existing motivation theories to increase player motivation.

20.1 Registering Activity Data

Radiation Mayhem does not register player activity as part of the gameplay itself. Rather, the activity will indirectly affect the gameplay. The fact that the exergame does not need to be active to capture activity data might motivate more social walking, like taking a walk with friends or walking a dog. It also prevents running down the battery on the phone or forcing the player to use a mobile network to stay connected. Most, if not all, smartphones have ways of tracking user movements, and this data is what the exergame will use as input. There are many specialised apps for tracking a person's movement and activity. Using these apps is more efficient than implementing a self-developed method of tracing the player's movement and activity in the game.

20.2 Train-to-Win

Train-to-win is a concept created by us and is the main idea for how to make the players more active. Radiation Mayhem is a *free-to-play* (F2P) exergame that is free for anyone (within the test group) to download and play. Most mobile games are free-to-play games; however, most are also known as *pay-to-win* games. *Pay-to-win* is where players are encouraged to pay *microtransactions* to get faster game progress. The microtransactions can unlock different loot boxes, buy extra resources, or reduce cooldown times. There are also ways of using microtransactions without directly affecting gameplay, like paying to unlock cosmetics or "skins" for characters.

Games that rely on *microtransactions* are often designed so they are easy to start playing and are enjoyable for the players. Initially, game progress happens fast, but as the exergame pro-

gresses, progression stalls and the players must either accept the slowing game progression or buy microtransactions to continually improve at a higher rate. If people find the game fun and engaging, they are more willing to spend small amounts of money to continue the game experience. The small transactions might feel insignificant, but by adding them together, the total sum can end up very high.

The idea behind *train-to-win* is to replace microtransactions with data from the fitness tracking apps on the phone. Phones can track things like steps, active minutes, elevation, and in some instances, activity levels. This data can be collected by the app and used as “payment” to get bonuses. Instead of paying a small amount of real-world money, the exergame will encourage the players to take a walk to get the bonuses microtransactions usually would give. The motivation of earning bonuses and benefits in the game without having to pay money might lower the threshold for going on walks. The players get the rewards by completing the streak and different quests. The motivation of getting extra bonuses might also encourage the players to continue being active over long periods.

20.3 Urgency

To make people return to the exergame, it needs an element of urgency, which will make the player “fear” missing out on something and motivate them to return. If the exergame gives them a feeling of having to keep up with the exergame or lose their progress, it can motivate them to be active to get the bonuses that can help with this task. The element of urgency and probability of loss plays on the *Scarcity & Impatience*, and *Unpredictability & Curiosity* drivers from the Octalysis framework (see Section 19.4) [34].

In Radiation Mayhem, urgency is created by the radiation that tries to spread and infuse all areas, making them unliveable. The player has to stop the radiation by expanding and maintaining their community. This race against the spread of radiation is the main urgency factor in the exergame, as the radiation will corrupt the player’s clean tiles if they do not keep up with the exergame. There will also be a smaller urgency factor from the streaks that must be achieved and collected every day, and if not, it is lost.

20.4 Repeat Rewards

One way of motivating people to return to the exergame and be physically active is to entice them with repeat rewards. Repeat rewards that increase over time, like the exergame’s daily streaks, will encourage the player to reach their goal in fear of losing their streak and all the previous work. The daily streaks utilise the *Loss & Avoidance* driver from the *Octalysis Framework* [34]. Figure 20.1 shows how streaks are shown to the player. The player must be physically active if they want to reach the streak goal, which could encourage them to get in a few more minutes of activity every day. The amount of activity needed to reach the goal is relatively low, making it more obtainable and will likely lower the threshold for being active. This design is backed up by the *Challenge* and *Clear goals* criteria from *GameFlow* [28], and the *Multiple level goals* from *Malone’s model* [30]. The streaks act as clear short-term goals that are more in line with the player’s skill. The player can focus on these short-term goals

while working towards bigger goals, such as the non-repeating quests.



Figure 20.1: The players will be reminded of their streak progress when they access the exergame

As the player will have to complete a specific task to collect their streak, it would be more optimal if the streak task was more challenging but could span over a longer time, like a week. Sometimes players cannot play the exergame one day due to scheduling conflicts, illness, or other factors, and losing the streak so quickly can be disheartening. Weekly streaks are easier to reach, as missing a day or two is not catastrophic, and the player can catch up by doing extra work another day. However, due to the limited time for this project and the two-week test period, weekly streaks would not work, as there is not enough time to reach a streak “level” that would impact the players enough that they would be afraid of losing their streak.

Radiation Mayhem also has other repeat rewards in daily and weekly quests. They are not tracked the same way as streaks, and their reward does not increase over time, but they are quests that repeat every day or week, giving the player a set of reliable tasks they know will be available for them and can be used to get a steady stream of resources.

20.5 Use of Motivation Theory

The primary motivation theory used for the exergame is *self-determination theory* (STD) [24]. Ideally, for people to be active over a long period, they need autonomous self-regulation for physical activity. Autonomous self-regulation is when a person has an internal motivation for doing something and does not need any external influences or “push”. For many people, when it comes to physical activity and exercise, this is not the case, and they need to increase their *intrinsic motivation* or have some *extrinsic motivation*. STD and the other relevant motivation theories for this thesis are covered in more detail in Section 7.3.

Radiation Mayhem can potentially increase the player’s intrinsic and extrinsic motivation as games can generate both strong extrinsic and intrinsic motivation [28][30]. The goal of **RQ2** and **RQ4** is to investigate if the motivation generated from games and gaming can influence motivation for physical activity and exercise. They also look at if players will get motivated to be physically active with the promise of faster game progress because of it. Since extrinsic motivation is essential for people who want to start being active, the exergame must incentivise the player to be physically active. The exergame does this through streaks, quests, and the consequences of not protecting the community from radiation. As the players continue to play the exergame, the motivation for playing the exergame could carry over as intrinsic motivation

for physical activity due to the player associating the fun of playing the exergame with physical activity.

20.6 Use of Basic Psychological Needs theory

One of the mini-theories that comprises SDT is the *Basic Psychological Needs theory*. BPNT states that a person will feel a better sense of well-being and foster intrinsic motivation for an activity if that activity satisfies the three basic needs: *autonomy*, *competence*, and *relatedness* [27].

The exergame and the gameplay fulfil these needs. The players make an *autonomous* decision on if they want to download and play the exergame, and they are in control of their community and are the only ones that can help it grow. The relative easiness of the exergame will give the players a sense of *competence* as they complete quests and clear out radiation. The exergame also grows more difficult as the player expands their community, meaning that the exergame will challenge the player through to the end. The players can also get a sense of *relatedness* to the exergame, either by getting a sense of ownership over the community they have built, through the competitiveness of the scores, the goal of catching up to the next player or getting as high on the scoreboard as possible.

20.7 Summary

This chapter explained some of the concepts and strategies Radiation Mayhem uses to motivate players to be more physically active. The most important of these elements is what we have called “train-to-win”. It uses the same concept as “pay-to-win”, where players must buy microtransactions to progress in the game. However, in Radiation Mayhem, the payments are exchanged for tasks that require physical activity. Another way to motivate players to be active is to give the exergame a feeling of urgency, which makes them want to return to the game. The urgency aspect is achieved by introducing the risk of losing areas to radiation if the players do not continue playing and cleaning up the radiation. Repeat rewards like streaks and daily and weekly quests that the players can achieve to get rewards will also help motivate players to be physically active and return to the game. The risk of losing a streak can incentivise players to take extra walks to reach a goal. Furthermore, the rewards for completing different quests increase with the difficulty level, which can motivate players to complete more challenging tasks to earn a larger reward.

This part introduced the Radiation Mayhem exergame concept. The following part will focus on the development of a prototype. The initial chapter of the next part will cover the selection of technologies used to create Radiation Mayhem.

Part IV

Development

Part IV is about the development of the exergame Radiation Mayhem. First, it presents the technologies chosen to use in the project. Second, it presents the functional and quality attribute requirements. Then it presents the system architecture of the exergame. Lastly, it describes the testing of the exergame before the experiment and evaluates the development process as a whole.

Chapter 21

Chosen Technologies

This chapter will present the different technologies used to develop Radiation Mayhem. First, it explains the choices of developing the exergame as a mobile application, the choices of mobile platforms, and how it affects the exergame. Second, it describes how the exergame collects users' activity data. Then, it presents the game engine used in the project and explains why it was selected for this project. Lastly, it explains the choice of using Firebase as the exergame's backend solution and how it integrates with the rest of the exergame's system.

21.1 Mobile Application

Radiation Mayhem was developed as a mobile application for smartphones for several reasons. Firstly, almost everyone has a smartphone capable of running games, which means that a lack of equipment availability does not hamper the game's reach. Also, the exergame is designed to be played in short bursts, which lends itself well to being on mobile, where there is close to no setup required for the user to launch the game.

One of the earliest decisions that had to be made was whether to develop the exergame as a *native application* or *web app*. While the master students had more experience developing web apps, the benefits of a native application were too great to pass up. Native applications are usually more performant than equivalent web apps and tend to integrate better with platform-specific SDKs and functions. For example, the native Google Fit SDK allows applications to read exercise data directly from the device's local Google Fit installation instead of waiting for the data to sync with Google Cloud. Therefore, the exergame was developed as a native application.

21.2 Mobile Platform

During the development period, the main emphasis was on creating the Android version of the exergame, while the iOS version was more of a stretch goal.

In Norway, iOS is the mobile platform with the largest market share, with 63.66% share. Android is the second largest mobile platform with 35.82% market share. Norway diverges from the global statistic where Android has a more dominant market share of 71.55% against iOS's 27.8%. These numbers are as of September 2022 [137].

The reason for primarily developing for Android was that *Android* is a more accessible environment to develop and test in. Both team members were familiar with the platform and owned Android devices. Android is also an easier environment for distributing applications for test-

ing. Android apps can also be developed on Windows and Linux machines, which the master students usually use. *iOS* applications must be exported using a program called Xcode, which is only available on macOS. Luckily, we got access to a macOS machine late in development and got an *iOS* version ready in time. The result was that we managed to build the exergame to both *Android* and *iOS*.

Nearly half of our testers were *iOS* users, which meant that developing an *iOS* version of our exergame would significantly affect the amount of data we could gather during our test period. The original intention was to use Apple's *Testflight* service to install the *iOS* version of our exergame remotely. Unfortunately, due to account issues, *Testflight* was unavailable for the test period, and the *iOS* version had to be installed by manual side-loading instead. This setback meant that only the *iOS* users who could physically meet with the researchers (19 in total) could get *Radiation Mayhem* installed.

21.3 Activity Data

For the exergame to work as intended, it needs access to the player's activity level. On *Android*, the exergame accesses the data from the *Google Fit* app through the *Google Fit API*. On *iOS*, the data comes from *Apple Health* through a Unity plugin called *BEHealthKit*. One thing to note is that the *Google Fit* API requires that the players have the *Google Fit* app installed on their phones to track their activity. *HealthKit* also has this requirement for *Apple Health*, but unlike *Google Fit*, *Apple Health* comes pre-installed on *iOS* devices.

The original plan was for the exergame's *Android* and *iOS* versions to use *Google Fit*, as it registers both active minutes and steps. Late in the development period, we encountered a problem that prevented us from authenticating the users with *Google Fit* on *iOS*. As a result, we opted to switch to using *Apple Health* on *iOS*. This switch meant we had to change what kind of activity data the *iOS* version of the exergame relies on. *Apple HealthKit* does not provide active minutes by default. Therefore, all the elements in our exergame using active minutes got translated to steps on the *iOS* version. The translation was done by comparing the active minutes and steps of the two researchers in the weeks before the test period. It is impossible to convert active minutes into steps accurately, which means that some of the physical activity requirements in the *iOS* version of our exergame may be more challenging or easier than intended.

Using *Google Fit* for *Android* and *iOS* would still be the best choice for the exergame. *Google Fit* being cross-platform, allows the exergame to access the same types of activity data no matter the platform. The *Google Fit* API is also part of the *Google Cloud* ecosystem, meaning that it integrates neatly with *Firebase*, our backend solution (see Section 21.5).

To allow developers access to *Apple Health* data, *Apple* has developed an SDK called *HealthKit*. Unity does not support fetching data through *HealthKit* out-of-the-box. Luckily, the developers at *BeliefEngine* have created a plugin for Unity called *BEHealthKit* that fixes that problem [138]. This plugin costs money, but the developers graciously allowed us to use it for free.

Google Fit has a metric called *heart points* that is meant to correspond with WHO's weekly recommendations (for more details, see Chapter 15) [125]. This metric is not available through the *Google Fit* API, which is why *Radiation Mayhem* uses active minutes instead. In a future

implementation, active minutes can be converted into heart points by analysing the activity level during those minutes. This translation will improve the exergame’s ability to monitor whether a player has achieved their weekly WHO goals.

21.4 Unity

The game engine used for the project is Unity [139]. Unity is a cross-platform development platform and game engine that allows users to create 2D, 3D, and VR games. The editor supports a wide range of platforms, from desktops running the major operating systems to consoles, WebGL, and the major mobile platforms. Unity is known for its ease of use and thriving community. Due to its large community of mostly novice game developers, Unity has a reputation for only being capable of creating small, low-grade games. However, this is disputed by the fact that one of the games that inspired our game, *Dorfromantik* and other large games, such as *Cities: Skylines*, are made with Unity.

Unity uses the programming language C#. C# is a programming language that both team members had little experience using. However, C# is known for its similarity to Java, a programming language both team members have a lot of experience with using. The similarity of C# to Java made Unity a better alternative as the gaming engine to the alternative Unreal Engine, which uses C++.

There were several other benefits to selecting Unity as our development platform. Unity has a huge asset store containing free and premium assets that could be used in the project. Unity also offers many different learning courses and resources for game development created by the Unity team. As both team members had little experience in game development, these lessons and resources were essential when starting the project. In addition to the official resources, Unity’s expansive community has created other resources and help guides. Another appeal was Unity’s student program which provides premium training materials and assets for students over 16 for free. As the project ran over a limited time, the time needed to be used efficiently and not wasted on unnecessary tasks; Unity’s asset store and resources helped save time through its free tutorials and assets.

One disadvantage of Unity is that it is known to create issues with version control systems such as GitHub. This problem was mitigated using Unity’s version control system, *Plastic SCM*. While Plastic is far less known than GitHub and lacks a lot of the features GitHub has, it is made specifically for Unity and interacts a lot smoother with Unity than GitHub does.

21.5 Firebase and Cloud Firestore

Firebase is a backend-as-a-service (BaaS) and hosting service provided by Google. It offers various forms of NoSQL and real-time databases, as well as authentication, hosting, communication, and analytics services [140]. It is regarded as a “one-stop shop” for everything needed to get a project up and running and hosted on the Internet. Firebase has a payment plan, but it also comes with a generous free plan with up to one gigabyte of storage and enough daily traffic allowances to accommodate this project’s needs.

Firestore was selected because of its ease of use and because one of the team members had previous experience with the service. Another reason was that Firestore is part of the Google ecosystem, making it easily compatible with Google's other services, like the Google Fit API and the Google Fit application.

We selected Cloud Firestore from Firestore's database options. Cloud Firestore is a Database-as-a-Service (DBaaS) and is one of many available services from Firestore. It is a scalable NoSQL database that can sync data across different client applications [141]. Additionally, it includes an SDK that can be integrated with Unity. This SDK has some nice features, like offline caching, where the user's requests are cached locally on the user's device if there is no connectivity.

21.6 Summary

This chapter detailed the technology stack that was used to create Radiation Mayhem. The exergame was developed as a *mobile application* using the *Unity game engine*. The choice to make Radiation Mayhem a mobile exergame was due to greater access to testers and mobile applications being a familiar platform for idle games. The Unity game engine was chosen due to the large number of free assets, the ease of use, and the available learning materials. For gathering health data, we chose to use *Google Fit* for the Android version of the exergame and *Apple Health* for the iOS version. The original idea was to use Google Fit for both versions of the exergame, but due to issues with Google authentication on iOS, we settled for using Apple Health on iOS. *Firestore*, and the database solution Cloud Firestore, was used as the backend and database solution due to ease of use and the researcher's familiarity with the platform.

The next chapter will present the functional requirements of Radiation Mayhem.

Chapter 22

Functional Requirements

This chapter presents the functional requirements for Radiation Mayhem. The functional requirements are divided into three categories, depending on the importance of the implementation:

- **High:** High means that it is an essential part of the exergame and will not work as intended without it.
- **Medium:** Medium means that the functionality will significantly improve the players game enjoyment and immersion of the exergame, but they are not crucial for the game to work
- **Low:** Low means that the function has no significant impact on the game but is nice to have and will help increase the player’s immersion and game enjoyment.

The functional requirements for Radiation Mayhem are presented in Table 22.1.

ID	Description	Priority
FR 1	A player should be able to play the game on their mobile device.	H
FR 1.1	A player should be able to play the game on an Android phone.	H
FR 1.2	A player should be able to play the game on an iOS phone.	M
FR 2	A player should be able to click on a dirty tile and clean it up.	H
FR 3	A player should be able to click on a cleared tile to build a community tile there.	H
FR 4	A player should be able to use resources to speed up the building process of a tile.	H
FR 5	A player should be able to edit the layout of the community.	M
FR 5.1	A player should be able to move a community tile to a cleared tile.	L
FR 5.2	A player should be able to delete a tile.	M
FR 6	A player should be able to keep track of their resources.	H
FR 7	A player should be able to collect their accumulated rewards	H
FR 7.1	A player should be able to collect energy generated by the player’s movement.	H
FR 7.2	A player should be able to collect money generated by the community tiles	H
FR 8	A player should be able to collect energy generated by the windmill.	H
FR 9	A player should be able to track their game score	M
FR 10	A player should be able to see how their score compares to other players.	M
Continues on the next page		

ID	Description	Priority
FR 10.1	A player should be able to see how many points there are to the next player.	M
FR 10.2	A player should be able to see how they are ranked in the overall stands.	L
FR 11	A player should be able to keep track of the resource goals of their community.	H
FR 12	A player should be able to access a help guide	M
FR 13	A player should be able to see the different quests they can complete	H
FR 14	A player should be able to collect the reward from the quests they have completed.	H
FR 15	A player should be able to save a corrupted tile by clicking on it	H
FR 16	A player should be able to see how long their current streak is	H
FR 17	A player should be able to collect today's streak if the streak goal is completed.	H
FR 18	The game should save the player's progress when the game is paused and reload it when the game continues	H
FR 19	The game should keep track of the player's data using a player ID.	H
FR 20	The game should calculate money rewards based on how the players fulfil their community's resource goals.	H
FR 21	The game should store the players score in the database	M
FR 22	The game should calculate if any tiles have become corrupted, and if they have, display it to the player	H
FR 23	The game should increase the streak reward as the streak length increases	M
FR 24	The game should have different types of quests, with varying levels of challenge	M
FR 25	The game should keep track of the player's progress on the different quests	H
FR 26	The game should have low-fi music and sound effects	L
FR 27	The game should calculate reward bonuses for the player depending on the layout of the community	L
FR 28	The game should show the player changes to their resources and score by adding a counting animation.	L
FR 29	The game should be able to collect the player's movement data even from periods when the game is not running.	H
FR 30	The game should send notifications to the player, reminding them about the game.	L

Table 22.1: Functional requirements

Chapter 23

Quality Attribute Requirements

Quality attribute requirements are non-functional requirements used to evaluate software systems. The list of possible quality attributes is long, with many categories that overlap each other. For this project, the focus is on a selected number of attributes: *performance*, *modifiability*, and *usability*. The attributes are measured through different scenarios. Each quality attribute scenario will be presented using the descriptors:

- **Source:** The entity creating the stimulus
- **Stimulus:** A condition that requires the system to respond.
- **Artefact:** The part of the system that receives the stimulus.
- **Environment:** The condition of the system when the stimulus occurs.
- **Response:** How the system reacts to the stimulus.
- **Response Measure:** How the response is measured to test if the requirement is well implemented. In this project, the response measure is always measured in terms of how long it takes to complete each scenario at a maximum.

Performance

The performance attribute measures how the system performs. A system's performance is measured in different ways, like response time, server downtime, throughput and latency. The performance of a system relies heavily on the software architecture and how it communicates both inside itself and with external sources. The performance scenarios can be seen in Table 23.1, Table 23.2, and Table 23.3.

ID	P1
Source	User
Stimulus	User opens the exergame
Artifact	The exergame
Environment	Normal
Response	The exergame loads and starts as expected
Response Measure	10 seconds

Table 23.1: Quality Attribute Scenario P1

ID	P2
Source	Game client
Stimulus	The exergame saves the required data
Artifact	The exergame
Environment	Normal
Response	The client stores the required data to the database
Response Measure	< 1 seconds

Table 23.2: Quality Attribute Scenario P2

ID	P3
Source	Game client
Stimulus	The exergame needs to load data from the database
Artifact	The exergame
Environment	Normal
Response	The client asks for the necessary data and receives it from the database
Response Measure	< 5 seconds

Table 23.3: Quality Attribute Scenario P3

Modifiability

The modifiability attribute measures how easy it is to modify, change, and expand a system. A system's modifiability depends on how easy it is to change or add parts to the application. The modification should be time- and resource-efficient, and the change should not negatively affect any other part of the system. The modifiability scenarios can be seen in Table 23.4 and Table 23.5.

ID	M1
Source	Developer
Stimulus	Wishes to add a new type of tile to the exergame
Artifact	Client source code
Environment	Design
Response	The new tile is implemented into the exergame
Response Measure	3 hours

Table 23.4: Quality Attribute Scenario M1

ID	M2
Source	Developer
Stimulus	Wishes to add a new quest to the exergame
Artifact	Client source code
Environment	Design
Response	The new quest is implemented into the exergame
Response Measure	10 minutes

Table 23.5: Quality Attribute Scenario M2

Usability

The usability attribute measures how user-friendly the system is. A system with good usability should be easy and intuitive to navigate and let the user achieve the desired task without problems. A simple user interface is one of the most important usability factors, as it is the only way for the user to communicate with the system. The usability scenario can be seen in Table 23.6.

ID	U1
Source	User
Stimulus	User plays the exergame for the first time
Artifact	The exergame
Environment	Normal
Response	The user explores the exergame and learns how to play it
Response Measure	5 minutes

Table 23.6: Quality Attribute Scenario U1

Chapter 24

Software Architecture

This chapter describes the software architecture of Radiation Mayhem. As there are two versions of the game, one for Android and one for iOS, both will be described. First, it will detail the parts of the software architecture that are similar between the two versions. Then, it will describe the differences between the two versions and how it affects them. The reasoning behind the choices of technology is in Chapter 21.

24.1 Shared Architecture

The software architecture of the exergame is relatively simple, as the exergame itself is relatively simple. Figure 24.1 shows the architecture of the Android version, and Figure 24.2 shows the architecture of the iOS version.

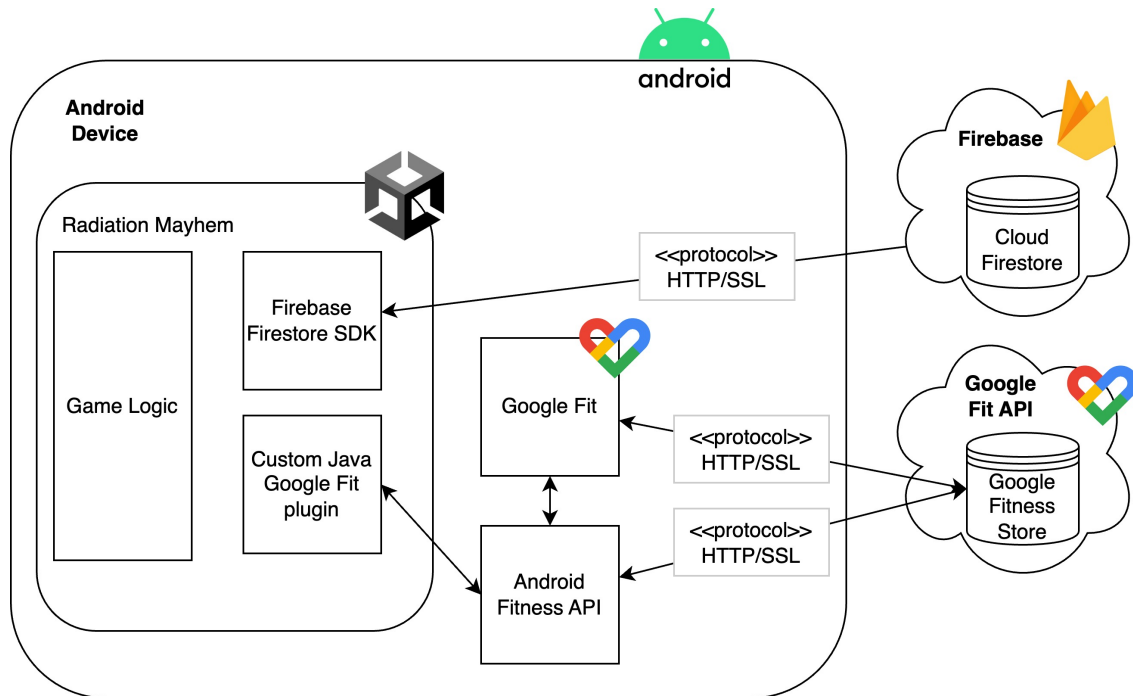


Figure 24.1: The Physical View of the Architecture of the Android Application

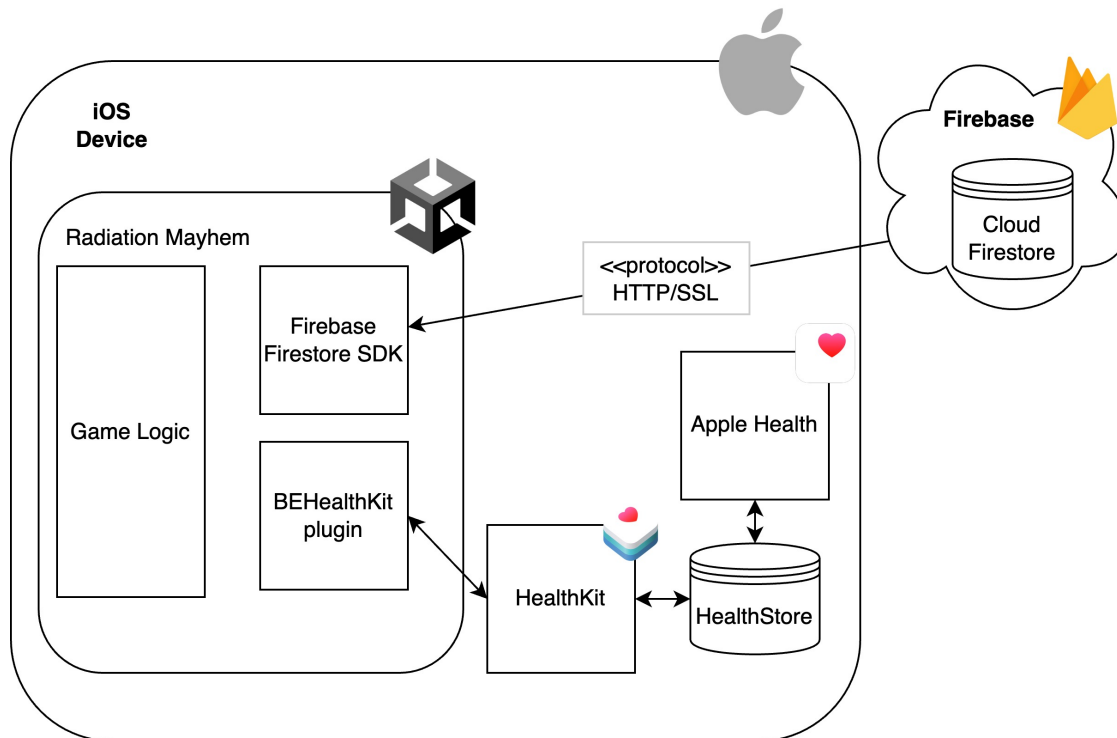


Figure 24.2: The Physical View of the Architecture of the iOS Application

As the figures show, the core parts of the exergame are identical between the two versions. The main part of the exergame is the game logic. It takes care of all the player interactions with the exergame, the visuals, the logic and interaction between the different game elements, and the communication between different parts of the software architecture. The database solution is also identical. Both versions use Cloud Firestore, a cloud database solution from Firebase, to store different game data.

24.1.1 Game Logic

The game logic is the most essential part of the exergame, as without it, there would be no exergame. Every time a player opens the exergame or interacts with it in any way, they interact with the game's logic. When the exergame starts, the game logic is responsible for fetching the saved game state and rendering the screen with all the different game elements. Whenever a player interacts with different elements in the exergame, the game logic ensures communication between the connected game elements and that the exergame tracks the changes done by the player. The exergame needs to keep track of all changes so it does not lose any of the player's progress, and it needs to show the changes to the player through visual changes and audible feedback. The game logic is also responsible for storing the game state on a local file when a player exits the exergame and for communication between the exergame itself and its various SDKs and plugins. For example, the game logic asks for the necessary database through the Firebase Firestore SDK. It also returns the relevant data to the database through the same SDK when the player exits the exergame.

24.1.2 Firebase and Cloud Firestore

The exergame uses Firebase as its backend solution and its service Cloud Firestore as the database. It sends and receives information to the game logic through the Firebase Firestore SDK. Firebase is mainly used for hosting the Cloud Firestore database and communicating with it. Firebase also tracks the number of reads and writes to the backend service, tracking how much players interact with the exergame. The exergame stores player information in the database by connecting it to the Player ID the player must enter the first time they start the exergame. The information stored in the player's score, the number of times they have visited, and which quests they have completed and when. The player's score is also stored locally on the player's device, but it is also necessary to store the score in the database, as the exergame needs to know other players' scores for the high-score lists and to display the points to the nearest player.

24.2 Differences Between Android and iOS

The differences between the two versions of the game are primarily in how and from where they fetch the user's fitness data. Ideally, it would be the same for Android and iOS, but due to the issues with Google authentication on iOS, Radiation Mayhem uses Apple Health for fetching fitness data. The differences between the two versions are shown in Figure 24.1 and Figure 24.2.

24.2.1 Android

The Android version of the game uses *Google Fit* to access the user's fitness data. In order to access data from Google Fit, the game uses a *custom Java plugin* that communicates with Android's Fitness API. The Android Fitness API accesses data directly from the local installation of Google Fit but also communicates with Google Fitness Store, the cloud storage solution for Google Fit.

Java Plugin

The custom Java plugin we made acts as a middleman and enables Unity to communicate with Google Fit using Google Play Services. Google Play Services is a collection of Android background services and libraries that allow Android apps to communicate with different Google apps and services, including Google Fit [142]. Unity can utilise many functionalities from Google Play Services through an official plugin called Google Play Games. Unfortunately, this plugin does not include support for Google Fit, which necessitated creating a custom plugin. Therefore, we had to create a custom Java plugin.

24.2.2 iOS

The iOS version of the game uses Apple Health to access the user's fitness data. Like Google's Android Fitness API, Apple has developed a framework that allows apps to communicate

with services such as Apple Health. This framework is called HealthKit [129]. It functions slightly differently from Google's Fitness API, communicating with a local storage solution called HealthStore instead of directly with the Apple Health app.

Unity has no official plugins that allow it to communicate with HealthKit. As mentioned in Section 21.3, Belief Engine has developed a plugin that implements this functionality, and Radiation Mayhem uses this plugin to communicate with HealthKit.

24.3 Summary

This chapter described the software architecture behind Radiation Mayhem. The architecture differs slightly depending on if it is the Android or the iOS version. The elements shared between the versions are the *Game Logic* and the *database solution*. Together, they are responsible for the main part of the exergame, including all gameplay, game logic, and storing of the game state. The difference between the two versions is how they gather health data, as the Android version uses *Google Fit*, communicating through a *custom Java plugin*, and the iOS version uses *Apple Health*, communicating through a plugin called *BEHealthKit*.

The next chapter will look at the pre-testing stage of the development.

Chapter 25

Pre-testing

Prior to the official test period, we conducted a two-week pretest. The pretesting was an important step, as it aimed to uncover critical errors or bugs that needed to be fixed before the testers could start playing the exergame. Not testing the exergame before the official experiment started could have severely damaged the results, as the exergame would not work as intended for the testers.

While all the game features and elements were tested during development, both alone and with the game as a whole, it was important to test the exergame over an extended period. While we had tried to test everything as thoroughly as possible throughout the development process, we knew there most likely were edge cases we had forgotten to account for in the implementation. There could also be features and elements that impacted each other in unexpected ways, creating situations that should not happen. By testing the exergame as if we were official testers, we would be able to discover if there were any bugs that could break the exergame and destroy the gaming experience for our testers.

When conducting the pretest, we played the exergame as if we were testers, making it the first time we played the exergame “for real”. While we had tested the exergame on our phones during development, we often changed the code or used “cheating” buttons to force certain situations or get extra resources. This type of “cheating” was not applicable during the pretesting period as it would not reflect the tester’s experience. It was also important to check if the exergame gave a balanced amount of resources. If the exergame was unbalanced, it would limit the player’s enjoyment and could lead to testers not finishing the test period.

The pre-testing did uncover some bugs and discovered some missing features we had forgotten to implement. All bugs and discovered features were fixed or implemented before the experiment began. The pre-testing also uncovered that there was an imbalance between the amount of money and energy the exergame provided. While we attempted to fix this issue, it was hard to calculate how many resources the players should get. After all, an imbalance in resources is one of the things that drives the players to do quests, as they want the resources they provide. However, the feedback from the testers after the experiment shows that the balance still was far from perfect.

The next chapter will present our evaluation of the development of Radiation Mayhem.

Chapter 26

Development Evaluation

This chapter evaluates the development of the game prototype. First, by discussing how well the functional and quality attribute requirements were implemented. Then it evaluates the game’s chosen technologies and software architecture.

26.1 Evaluation of Functional Requirements

Most of the functional requirements were fully implemented in the game. When developing the game, we started with high-priority tasks, which were crucial for the game to work. Many of the lower-priority tasks also depended on the high-priority tasks as they could not be implemented before the high-priority tasks worked as intended. Table 26.1 shows all functional requirements and to which degree they were implemented.

ID	Description	Priority	Implemented
FR 1	A player should be able to play the game on their mobile device.	H	Yes
FR 1.1	A player should be able to play the game on an Android phone.	H	Yes
FR 1.2	A player should be able to play the game on an iOS phone.	M	Yes ³
FR 2	A player should be able to click on a dirty tile and clean it up.	H	Yes
FR 3	A player should be able to click on a cleared tile to build a community tile there.	H	Yes
FR 4	A player should be able to use resources to speed up the building process of a tile.	H	Yes
FR 5	A player should be able to edit the layout of the community.	M	Yes
FR 5.1	A player should be able to move a community tile to a cleared tile.	L	Yes
FR 5.2	A player should be able to delete a tile.	M	Yes
FR 6	A player should be able to keep track of their resources.	H	Yes
Continues on the next page			

³Radiation Mayhem ran on iOS, but due to not getting access TestFlight in time, the iOS version could not be distributed remotely. Therefore it had to be distributed through manual side-loading.

ID	Description	Priority	Implemented
FR 7	A player should be able to collect their accumulated rewards	H	Yes
FR 7.1	A player should be able to collect energy generated by the player's movement.	H	Yes
FR 7.2	A player should be able to collect money generated by the community tiles	H	Yes
FR 8	A player should be able to collect energy generated by the windmill.	H	Yes
FR 9	A player should be able to track their game score	M	Yes
FR 10	A player should be able to see how their score compares to other players.	M	Partially
FR 10.1	A player should be able to see how many points there are to the next player.	M	Yes
FR 10.2	A player should be able to see how they are ranked in the overall stands.	L	No
FR 11	A player should be able to keep track of the resource goals of their community.	H	Yes
FR 12	A player should be able to access a help guide	M	Yes
FR 13	A player should be able to see the different quests they can complete	H	Yes
FR 14	A player should be able to collect the reward from the quests they have completed.	H	Yes
FR 15	A player should be able to save a corrupted tile by clicking on it	H	Yes
FR 16	A player should be able to see how long their current streak is	H	Yes
FR 17	A player should be able to collect today's streak if the streak goal is completed.	H	Yes
FR 18	The game should save the player's progress when the game is paused and reload it when the game continues	H	Yes
FR 19	The game should keep track of the player's data using a player ID.	H	Yes
FR 20	The game should calculate money rewards based on how the players fulfil the resource goals.	H	Yes
FR 21	The game should store the players score in the database	M	Yes
FR 22	The game should calculate if any tiles have become corrupted, and if they have, display it to the player	H	Yes
FR 23	The game should increase the streak reward as the streak length increases	M	Yes
Continues on the next page			

ID	Description	Priority	Implemented
FR 24	The game should have different types of quests, with varying levels of challenge	M	Yes
FR 25	The game should keep track of the player's progress on the different quests	H	Yes
FR 26	The game should have low-fi music and sound effects	L	Yes
FR 27	The game should calculate reward bonuses for the player depending on the layout of the community	L	Yes
FR 28	The game should show the player changes to their resources and score by adding counting animation.	L	Yes
FR 29	The game should collect the player's movement data even if the game is not running.	H	Yes
FR 30	The game should send notifications to the player, reminding them to return to the game to collect their rewards.	L	Partially

Table 26.1: Functional requirements evaluation

FR 30 was only partially implemented as notifications were only implemented on Android using Unity's Android notification system. Unity has a system for iOS, but there was no time to implement it because of the limited development time. There were also some issues with the implementation on Android, where some phones gave notifications as instructed, some gave notifications at random, and others sent notifications if the player entered the exergame after a long time away. We think the reason is that different phones handle "sleeping" apps differently. A "sleeping" app is when a user exits an app without closing the application manually, which makes the app continue to run in the background. The Unity notification system only works if the app runs in the background. Some phones automatically "close" unused apps after some time, even if the player has not closed them. This automatic "closing" stops the notifications from coming through since, from the phone's perspective, the app is inactive and cannot send notifications.

FR 10 was only partially implemented since *FR 10.2* was not implemented at all. Implementing a live high-score list was not prioritised in favour of other more important tasks. Instead of implementing it into the game, we sent a high-score list to the testers every third day. Sending out the high-score list instead of implementing it in the game saved development time while retaining most of the benefits of having a high-score list. Overall, we believe the experiment results were not affected much by the fact that the game had no implemented high-score list.

When creating the exergame, the team suggested numerous functional requirements, but not all were accepted and added to the list. Some of the discarded suggestions were unsuitable for the overall theme and mechanics of the exergame, while most were discarded due to the limited time frame of the project. Although many of the discarded suggestions would have been enjoyable game features, they were not feasible within the given time frame. These suggestions were kept as potential future implementations if the game were to be further developed or if there was extra time for development. The list below displays the suggestions that were discarded due to time constraints.

- Different types of energy tiles that would generate energy at different rates and could store different amounts of energy. The different tiles would be more or less reliable depending on things like in-game weather (Solar panels would, for example, need the sun to charge)
- Natural obstacles like rivers and mountains that the players would have to work around when building their community.
- Relics from before the nuclear catastrophe that is hidden in the contaminated area, and if the players find them, they unlock its power and a new way of collecting energy (or other things, depending on what they find).
- Themed tile quests where the reward unlocks a specific tile type.
- Time-limited quests, which are similar to tile quests but only available for a limited time, and if the player is unable to complete the quest within the time, they do not get access to the tile
- Integrating weather predictions from Yr based on player locations. When the game registers player activity to generate energy rewards, the reward will be higher if the weather data says that it was less than optimal weather during the player's walk. The player would only get the bonus if the walk were done outside. This suggestion comes from some of the concepts in Chapter 17.

26.2 Evaluation of Quality Attributes Requirements

This section shows the measured performance of the system's quality attribute requirements. The evaluation includes the observed response measure, an overall evaluation of whether the requirement was met, and a comment on the evaluation.

ID	P1
Source	User
Stimulus	User opens the exergame
Artifact	The exergame
Environment	Normal
Response	The exergame load and start as expected
Response Measure	10 seconds
Observed Response Measure	5 second average
Evaluation	<i>Success</i>
Comment	The game loaded within 10 seconds unless the game crashed for unknown reasons. After closing the app completely after a crash and restarting it, the game loaded as normal.

Table 26.2: Evaluation of Quality Attribute Scenario P1

ID	P2
Source	Game client
Stimulus	The exergame saves the required data
Artifact	The exergame
Environment	Normal
Response	The client stores the required data to the database
Response Measure	< 1 seconds
Observed Response Measure	< 1 seconds
Evaluation	<i>Success</i>
Comment	While there was no way of getting an exact measurement of the time it took for the game to update the database, we observed when the database updated in real-time through the Firebase console. The updates happened observably instantaneously after exiting the game, which was the trigger point for the game to send data to the database.

Table 26.3: Evaluation of Quality Attribute Scenario P2

ID	P3
Source	Game client
Stimulus	The exergame needs to load data from the database
Artifact	The exergame
Environment	Normal
Response	The client asks for the necessary data and receives it from the database
Response Measure	< 5 seconds
Observed Response Measure	2 second average
Evaluation	<i>Success</i>
Comment	The only time it did not work as intended was if the game crashed on startup, as then the request was never sent.

Table 26.4: Evaluation of Quality Attribute Scenario P3

ID	M1
Source	Developer
Stimulus	Wishes to add a new type of tile to the exergame
Artifact	Client source code
Environment	Design
Response	The new tile is implemented into the exergame
Response Measure	3 hours
Observed Response Measure	3 hours
Evaluation	<i>Success</i>
Comment	Time varies a lot depending on the functionality of the tile. A basic tile only needs to be added to some lists and designed. More advanced tiles also need working scripts and testing to make sure it works with the other tiles

Table 26.5: Evaluation of Quality Attribute Scenario M1

ID	M2
Source	Developer
Stimulus	Wishes to add a new quest to the exergame
Artifact	Client source code
Environment	Design
Response	The new quest is implemented into the exergame
Response Measure	10 minutes
Observed Response Measure	2 minutes
Evaluation	<i>Success</i>
Comment	All necessary information about quests are stored in lists. To create a new quest, all the developer needs to do is add a new element to the list.

Table 26.6: Evaluation of Quality Attribute Scenario M2

ID	U1
Source	User
Stimulus	User plays the exergame for the first time
Artifact	The exergame
Environment	Normal
Response	The user explores the exergame and understands how to play it
Response Measure	5 minutes
Observed Response Measure	3 minutes
Evaluation	<i>Success</i>
Comment	While there is no way of knowing how quickly all players understood the basics of the game, in some cases, players played the game for the first time while they were with us, and they understood it within a few minutes. We were not contacted by players wondering about the basics of the game. The interviewees also stated that the game was easy to understand.

Table 26.7: Evaluation of Quality Attribute Scenario U1

The quality attribute requirements were successfully achieved and even exceeded in some cases. This result shows that the system functioned effectively and as intended and that the code was written in a manner that allowed for easy modification and the addition of features with minimal complications. As mentioned in some comments, the game sometimes crashes on startup. These crashes mostly happened on iOS and were mostly fixed after an update to the iOS version of the game early in the test period. More on this issue and fix can be found in Section 28.3.

26.3 Evaluation of Chosen Technologies and Architecture

The most influential technology choice was to develop the game as a native *mobile application*. This choice profoundly affected how we approached the game’s development and how the game’s system architecture was designed. Developing for mobile devices, on both Android and iOS, meant that the game would be more accessible to a larger test group.

Unity was chosen as the game’s engine, despite the team members having little experience with it beforehand. While there was a steep learning curve, *Unity* has a lot of learning materials, free assets, and forums that made the development process easier and quicker than if we had developed it without a commercial engine. However, there were some issues with using *Unity*. Specifically, we did not get Google authentication for Google Fit to work on iOS devices and had to switch to using *Apple Healthkit* on iOS.

The *health data* was collected using existing *fitness tracking apps* and their associated APIs. Using existing apps and APIs instead of a self-made system meant that we saved development

time and could take advantage of the considerable development that has gone into making these apps excellent at detecting and tracking physical activity while the user is carrying the phone or a smartwatch.

While the original plan was only to use the Google Fit app and the Google Fit API, the authentication problem on iOS forced us to change to Apple Health for iOS devices, which was not ideal. The problem with using two different fitness tracking apps is that the *software architecture* is different between *Android* and *iOS*. Since Google Fit and Apple Health gather different activity data, the game has to rely on different metrics in the two versions. While Google Fit tracks active minutes, Apple Health does not, meaning that all quests on iOS had to be changed to steps by approximating how many steps there were in one active minute. This calculation was not perfect, which led to situations where iOS players had to do more or less physical activity to reach their goals compared to the Android testers. Another problem with having a split software architecture is that the application is harder to maintain, as changes to the game must be done on both versions.

The last significant technology and architectural decision was the database. Here we chose to use *Firebase* and its database solution *Cloud Firestore*. This choice was because one of the team members had experience with the database solution and due to its tight integration with Google Cloud Services and, by extension Google Fit. *Firebase* has been easy to work with during the project, and it was fast to set up and has given us very few issues.

Overall, we are happy with our choices in implementing these different technologies and architectures. If we were to do this project again, the choices of technology and architecture would remain the same except for the use of both Google Fit and Apple Health. Ideally, we would stick with the original plan of only using one API and avoiding the split software architecture by getting Google Fit to work on iOS as well. However, looking back at this project, knowing that we ended up having to switch to Apple Health, the only thing we would change is to switch to Apple Health earlier, saving time we could have used on other tasks.

26.4 Summary

This chapter evaluated the development of the game prototype. First, it presented the functional requirements of the game, to what degree they were implemented, and mentioned some proposed requirements that were discarded due to time constraints. Second, it shows the system's performance testing results concerning the quality attribute requirements and whether they were fulfilled. Lastly, it evaluates the implementation of the game's different chosen technologies and architecture.

After developing the exergame, it was time to test it. The next part will cover the experiment, starting with the experiment preparation.

Part V

Experiment

Part V concerns the experiment run on the developed prototype. It starts with presenting the pre-work necessary to run the experiment, from ensuring that privacy and ethics guidelines were followed to recruiting testers. Then it details the testing period itself, from the distribution of the exergame to the end of the testing period. Lastly, it breaks down and explains the different methods of data generation and what data the experiment collected.

Chapter 27

Experiment Preparation

This chapter details the preparations needed to run the experiment. First, it details the process of ensuring that the project followed all the necessary ethics and privacy guidelines and stored the testers' data safely. Then, it describes the process of recruiting testers and how that could affect the results.

27.1 Ethics and Privacy

When doing research, it is essential to follow all the rules and guidelines to ensure that the project does not commit any ethical or legal violations. Therefore, it was important to ensure that the project's data collection methods had no issues and that all data was collected and stored correctly.

27.1.1 Declaration of Consent

This project involves collecting, storing, and analysing user data throughout the duration of the project. When collecting data on users, it is crucial to get formal consent and make the user aware of what information is collected about them, why it is collected, and for how long the information is stored. This project had two different test groups, both tested the exergame and answered two questionnaires, but one group would also partake in a short interview. Therefore, two different declarations of consent were necessary. The declarations explained the project's purpose, how the testing and data collection would occur, and how the project would handle the provided data. The participants had to sign the declarations before participating in the experiment, and if they wanted to withdraw, they were free to do so. The declarations can be found in Appendix H and Appendix I.

27.1.2 Player ID

Since the project collects personal data about the testers, the data must be stored correctly. If someone got an insight into the answers from the questionnaires, they should not be able to identify who the tester is. However, to analyse the results properly, it was necessary to compare the participants' answers in the pre- and post-questionnaires. Therefore, there needed to be some way of identifying which answer belonged to which tester. Thus, every tester was provided with a unique player ID to use throughout the testing process. By using the player ID, we would know that the same person answered a pre- and post-questionnaire without knowing who that person was. In some cases, like the interviews, finding the questionnaires

the interviewee had answered was necessary, as the goal of the interview was to go more in-depth on some of the answers and get some reasoning. The player ID and the user's name and contact information were stored in a separate encrypted file and are the only way to figure out who has what player ID. The file will be deleted after the completion of the project.

27.1.3 Norwegian Centre for Research Data (NSD)

This project needed to collect and work with different kinds of user data considered sensitive. In Norway, if researchers want to do a research project with data collection and testing, they must apply to the Norwegian Centre for Research Data (NSD - Norsk senter for forskningsdata). NSD ensures that the research project follows all rules and guidelines regarding data collection and storage of personal and sensitive information. The NSD application and approval for this project are shown in Appendix A.

27.2 Recruitment of Testers

As the project would be relatively accessible and easy to distribute, we wanted to get as many testers as possible. Having many testers will provide more data, and any false or inconsistent data, like cheating, will have less impact on the overall dataset. If one out of ten is cheating, it will skew the overall data much more than if it is only one in fifty. With a larger test group, it is also more likely that the group is more representative of the general population as it could contain a wider variety of participants.

The testers were mainly recruited from the master students' social circles as it was easier to spread the word and find potential testers among people they already knew. Therefore, a big part of the testers naturally fell into a similar demographic to the master students, but there were other demographics in the test group as well. The testers come from different social circles, with different studies and jobs, making the test group more varied regarding interests and social status. Some testers were not from within the master students' social circles but were recruited by other testers through word of mouth.

Also, being able to test on some iOS devices made it possible to reach a larger group of testers. Unfortunately, the exergame could not be deployed remotely, so remote iOS users could test the exergame. If that had been the case, the test group would have been even bigger. The issues with iOS deployment are described in more detail in Section 28.1.

One potential problem with most testers being acquaintances, friends, or family is that they join the testing because they want to help with the research. While personally knowing the testers is not a problem, it can become an issue if they answer more positively on the questionnaires because they want to satisfy and help by giving a positive result. This problem is discussed further in Section 36.2.

27.3 Summary

This chapter discussed the different preparations done before the experiment started. First, it presented the issue of ethics and privacy, as this project collected some personal data on the participants. To follow all rules and regulations, the Norwegian Centre for Research Data (NSD) had to approve the project, and the testers had to sign a declaration of consent agreeing that the project could collect, store, and use the data collected about them. All users also got a unique player ID, making it possible to compare their results without knowing who the person was. Lastly, it detailed the process of recruiting testers, explaining how testers were recruited and how we ensured getting as large a test group as possible.

With the experiment prepared, the next chapter will look at how the experiment was executed.

Chapter 28

Experiment Execution

This chapter will discuss the execution of the experiment. First, it will detail how the game was distributed and deployed on Android and iOS devices. Then, it will explain how communication with the testers was handled during the test period. Lastly, it will give a summary of the two-week-long experiment.

28.1 App Deployment

Radiation Mayhem was made available on Android and iOS but not through the Google Play Store or the App Store. This decision was made to ensure that only testers had access to the exergame and to avoid the time-consuming process of getting the exergame approved for distribution on those platforms.

28.1.1 Android

For Android devices, the exergame was built as an APK file and uploaded to Google Drive. A link to download the file was shared with the testers. Android allows for the side-loading of apps (installing apps without using an official distribution channel) out-of-the-box. This feature means that for most Android users, installing the exergame was as simple as downloading the file and following the on-screen instructions. A few testers could not install the exergame due to having too old an Android version (Android 9.0 and earlier). This issue was due to one of the dependencies of the Unity Firebase plugin requiring later versions of Android. This problem meant that some Android users could not test the game. However, some users, of their own volition, installed the exergame onto tablets and other devices with newer versions of Android than their phone and played the exergame on that device instead.

Before the testing period, the testers were given an installation guide and a game guide. They were instructed to play the exergame only when the testing period had begun. Android testers could install the exergame by following the installation guide.

On the backend, the users' emails had to be added to the exergame's OAuth consent form in Google Cloud Console. This step was necessary for Google to allow the exergame to read data from the users' Google Fit Accounts. This step is not necessary for production-ready apps distributed through the Google Play Store, but since the exergame was in "test mode", additional security steps were required by Google.

28.1.2 iOS

The exergame was distributed to our testers' iOS devices through manual side-loading. The original idea for distributing our exergame to our iOS testers was to use Apple's app testing service, TestFlight. Unfortunately, due to issues with the Apple Developer account, we did not get access to TestFlight and, therefore, could not upload the exergame. Apple has stricter rules for side-loading apps onto iOS devices compared to Android. Each tester had to connect their device to a Mac running Xcode, turn on developer mode on the device, and transfer the app using a cable. Therefore, to get the exergame on iOS devices, the testers had to meet us and manually install the app. Unfortunately, due to scheduling conflicts, some iOS testers could not receive the app until a few days into the testing period.

28.2 User Communication

Our primary communication channel with our testers during the test period was via email.

In the weeks and days leading up to the start of the test period, we sent out a series of emails welcoming the testers and informing them about the consent form and questionnaire they had to fill out before the test period. The weekend before the test period, we sent installation instructions to the Android testers and scheduled meet-ups with the iOS testers.

During the test period, high-score lists were sent every three days. These emails were part of the experiment to see if getting notified about the high score helped motivate players to be more active.

For urgent situations, such as when a bug caused the recall of all iOS testers, we contacted some testers through social media or face-to-face. Naturally, this could only be done with the testers we knew personally.

As some testers are close friends, it happened that they contacted us and asked us questions about the exergame. When asked, we tried to reply as honestly as possible without giving away details about game tactics or game mechanics.

28.3 The Experiment

The two-week test period started on Monday, the 24th of April, and lasted until Sunday, the 7th of May. In the week before the testing, we ensured that all the testers had answered the first questionnaire to prevent the data from being influenced by the testers playing the exergame.

Initially, the test period was set to run from the 17th to the 30th of April, but this was changed to have enough development time to get the iOS version of the exergame working. We got access to the equipment we needed to build for iOS a couple of weeks before the test period. As having iOS testers would add many testers, it was reasonable to postpone the test period by a week.

The experiment was run as a "One group, pre-test and post-test" design [8]. With this type of design, all testers are in the same group and are "tested" before and after a treatment

is applied. The treatment in our case is playing Radiation Mayhem, and the tests are the questionnaires the testers filled out before and after the test period. The test also included an interview after the test period for some testers.

Word-of-mouth added a few extra testers during the testing period. These new testers were required to complete the first questionnaire before installing the exergame. The new testers also got a slightly shorter test period, but they could still play the exergame for a relatively long period.

A bug in the iOS version of the exergame was discovered early in the test period that required us to recall all iOS testers and reinstall their apps. The bug caused the exergame to occasionally freeze or crash on start-up and prevented the testers from collecting money. One week into the test period, all iOS testers had to be recalled again due to an Apple-mandated one-week time limit on side-loaded apps. Fortunately, all iOS testers were very helpful and understanding during this process.

As part of the experiment, an anonymous (using the testers' playerID) high-score list was sent to the testers every three days per email. At the end of the experiment, a final high-score list was sent out where the top three testers were (anonymously) congratulated.

Except for the two iOS callbacks, the experiment ran smoothly, with only a few bugs discovered. Any issues that did crop up can be found in Section 34.1.

28.4 Summary

This chapter presented the technicalities of how the experiment was executed. The experiment ran over a two-week test period lasting from the 24th of April until the 7th of May. During the test period, the testers downloaded and played the game of their own volition. Android testers could install the game themselves, but iOS testers had to meet up with us as the game had to be side-loaded onto their devices. Throughout the experiment, we tried to be as hands-off as possible with the testers. An exception to this was a bug that forced a recall and re-installation for all iOS testers. All iOS testers also needed to have their apps re-installed after one week due to an Apple-mandated one-week limit on side-loaded applications. During the test period, anonymous high-score lists were sent to all testers.

In the upcoming chapter, we will discuss the various methods of generating data employed during this experiment.

Chapter 29

Experiment Data Generation

This chapter details the different data generation methods used during the experiment. First, it describes the two questionnaires the participants had to answer before and after the experiment. It explains the reasons for the different questions and lists all of them, translated from Norwegian to English. Then it goes through the interviews and how they were structured and carried out. Lastly, it describes the different data the game logs to the database.

29.1 The First Questionnaire

The first questionnaire was about the user and their physical activity and video gaming habits prior to the test period. It was sent out to the testers before the testing started, and all testers answered the questionnaire before they started playing the exergame. The goal of the questionnaire was to map the user demographic and their relationship with gaming, physical activity, and exercise. Having data from before the experiment is important as it can be used as a baseline when comparing the results from before and after the experiment. Any changes in the results would be apparent and could be seen in correlation to the testing. The complete questionnaire is in Appendix B.

29.1.1 Demographics

The demographic part of the questionnaire maps out the basic information about the testers. Grouping the results from the questionnaire based on demographics gives a better overview of how representative the test group is to the general population. It also makes it easier to compare the results with data from WHO and Helsedirektoratet and look for other correlations within the results. The questions related to user demographics are shown in Table 29.1.

Q1	Player ID	Text
Q2	What gender do you identify as?	Multiple choice
Q3	How old are you?	Number

Table 29.1: Questions related to user demographics.

29.1.2 Physical Activity

The next part of the questionnaire aims to map the tester's relationship with physical activity and exercise. The results would work as a baseline for the second questionnaire and show

the testers' level of physical activity, exercise, and motivation before they started testing the exergame. The questions related to physical activity, exercise, and motivation are shown in Table 29.2.

Q4	How many walks, jogs, or bike rides do you complete in the course of a week? (This does not include activity or exercise at a fitness centre or through organised sports.)	Number
Q5	How long does a trip usually last?	Number
Q6	On a scale of 1 to 5, how motivated are you to do physical activities like running, jogging or biking? (This does not include activity or exercise at a fitness centre or through organised sports.)	Multiple choice
Q7	Do you partake in organised sports? (In a sports club/team)	Binary
Q8	How often do you exercise? (This includes all types of exercise, including jogging, running and cycling outside and in the centre, as well as organised sports)	Multiple choice
Q9	On a scale of 1 to 5, how motivated are you for other physical activity or exercise? (Like organised sports or training at a fitness centre)	Multiple choice

Table 29.2: Questions related to physical activity, exercise and motivation.

29.1.3 Video Games

The last part of the questionnaire maps the tester's relationship with video games and gaming. Knowing what gaming experience the testers have is important, as different experiences can influence the data and results due to the tester's preconceptions and previous experience with similar games. The questions related to games and gaming are shown in Table 29.3.

Q10	How much time do you spend, on average, playing video games each week (including PC, phone and console games)? (answer in hours)	Number
Q11	Which gaming platform do you use the most?	Multiple choice
Q12	Have you ever paid for progress in a game (microtransactions)? (This includes buying hints, hearts, power-ups, better gear etc., with real money)	Multiple choice
Q13	Have you ever considered/wanted to pay for progress in a game (microtransactions)? (This means that you have not done it but have wanted/considered paying for it)	Multiple choice
Q14	Have you ever wished there were other methods to get faster progress in games other than waiting for a process or paying with real money?	Multiple choice

Table 29.3: Questions related to video games

29.2 The Second Questionnaire

The second questionnaire inquired about the user’s activity and motivation during the testing and questions about the exergame. Comparing the physical activity and motivation questions from the first and second questionnaires shows changes in physical activity, exercise and motivation levels that are due to the exergame. The questions about the exergame focus on three different topics: what the players thought about the exergame, how the exergame and different in-game aspects affected their motivation for physical activity, and some questions about the testing itself. The complete questionnaire is in Appendix D.

The first “question” of the questionnaire was for the players to enter their player ID. Having the player ID made it possible to compare the answers of a person in the first and second questionnaires.

Q1	Player ID	Text
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Table 29.4: The player’s anonymous identifier

29.2.1 Physical Activity

The questions about physical activity and motivation are almost identical to those in the first questionnaire, with one question removed and some new ones added (see Table 29.5). This questionnaire only focused on the two weeks when the players tested the exergame. The goal was to see if there had been any changes in the player’s activity, exercise, and motivation level that might have been due to the exergame.

Q2	During the test period, how many walks, jogs, or bike rides did you complete in the course of a week? (This does not include activity or exercise at a fitness centre or through organised sports.)	Number
Q3	During the test period, how long did a trip usually last? (answer in minutes)	Number
Q4	During the test period, on a scale of 1 to 5, how motivated were you to do physical activities like running, jogging or biking? (This does not include activity or exercise at a fitness centre or through organised sports.)	Multiple choice
Q5	How did playing Radiation Mayhem affect your motivation for being physically active?	Multiple choice
Q6	During the test period, how often did you exercise? (This includes all types of exercise, including jogging, running and cycling outside and in the centre, as well as organised sports)	Multiple choice
Q7	During the test period, on a scale of 1 to 5, how motivated were you for other physical activity or exercise? (Like organised sports or training at a fitness centre)	Multiple choice

Table 29.5: Questions related to physical activity, exercise and motivation during the test period.

29.2.2 The exergame

The questions about the exergame focus on three different aspects. The first is the exergame itself and how it was to play. The second is about if and how the exergame motivated the player to be more physically active and what aspects of the exergame had the most impact. The third is some questions about the testing of the exergame and if the player had any issues or other circumstances which affected the testing. The questions about the exergame were a large part of the questionnaire and are shown in Tables 29.6, 29.7, 29.8, 29.9, 29.10, and 29.11.

Q8	How much time, on average, did you spend playing Radiation Mayhem per day?	Number
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Table 29.6: Question about how much the player played the game

Q9	Rate the following elements based on how much they motivated you to be active and play the game (highest to lowest)
Item 1	Points to the next player
Item 2	Faster progression in the game / faster collection of resources
Item 3	Maintain streak to get bigger bonuses
Item 4	Complete quests to get resources
Item 5	The risk of losing areas if you do not play
Item 6	The desire to build a nice and optimal society
Item 7	Your position in the high-score lists that were sent out
Item 8	Complete the most challenging quests because they are challenging

Table 29.7: Different elements the participants were asked to rate based on how they affected their motivation

Question 10 (see Figure 29.7) and 13 (see Figure 29.9) are a set of statements about the testing period and the exergame that the tester rates on a Likert scale. Question 10 has several statements about how different aspects of the exergame affected the player's activity level. Question 13 was a set of claims about the exergame, some focusing on player motivation and others focusing on different aspects of the exergame.

Q10	During the testing,...	
Q10.1	I was more motivated to be physically active	Likert scale
Q10.2	I was more physically active	Likert scale
Q10.3	I went for walks, jogs, or bike rides I would not have gone on if I was not playing the game	Likert scale
Q10.4	I went for walks, jogs, or bike rides because I wanted to reach a quest goal	Likert scale
Q10.5	I went for walks, jogs, or bike rides because I wanted to collect more resources	Likert scale
Q10.6	I went for walks, jogs, or bike rides because I wanted a higher game score	Likert scale
Q10.7	I went for walks, jogs, or bike rides despite bad weather (rain, snow, wind)	Likert scale
Q10.8	I walked, jogged, or biked places instead of using other means of transportation	Likert scale

Table 29.8: Statements related to how the exergame motivated for physical activity

Q11	Approximately how many walks, jogs, or bike rides did you take each week that you would not have taken if you were not playing the game?	Number
Q12	Have you changed daily habits to become more physically active? (Started walking to school, work, training, and daily walks)	Binary

Table 29.9: Questions related to physical activity, exercise and motivation.

Q13	Claims about the game	
Q13.1	I found the game fun	Likert scale
Q13.2	The daily quests motivated me to do some activities each day	Likert scale
Q13.3	Weekly quests motivated me to be active throughout the week	Likert scale
Q13.4	Challenging quests motivated me to be extra active so that I would reach the quest goals	Likert scale
Q13.5	The game was, for the most part, simple and easy to understand	Likert scale
Q13.6	The high-score lists motivated me to try to do better to get higher on the list	Likert scale
Q13.7	I like the use of active minutes and steps as an alternative to paying for game progression	Likert scale
Q13.8	I think physical activity as an alternative for microtransactions and ads will make people want to be more active	Likert scale

Table 29.10: Statements about different aspects of the exergame.

Question 15 (see Table 29.11) asks if the testers were sick, injured, or otherwise indisposed during large parts of the test period. The question allows the testers to answer if they were impacted to a greater or lesser extent if they were impacted at all. With so many testers

over a relatively long time, some testers will inevitably be indisposed. This question is vital for mapping these testers, as being indisposed could lead to changes or discrepancies in the results that should be looked into further.

Q14	Can you tell us your thoughts about using activity as an alternative for ads and/or microtransactions	Text
Q15	Were you sick, injured or had other circumstances that meant you could not test the game for large parts of the test period?	Multiple choice
Q16	Did you discover any bugs or problems with the game that hindered you from playing?	Binary
Q17	What were they? Can you describe them?	Text
Q18	Did you cheat while playing Radiation Mayhem?	Multiple choice
Q19	How did you cheat?	Text
Q20	Why did you cheat?	Text
Q21	Do you wish to continue playing Radiation Mayhem after the testing period?	Multiple choice
Q22	Is this a game/game concept you would want to play if it was fully developed?	Multiple choice
Q23	Is there something in the game you liked really well?	Text
Q24	Is there something you disliked about the game?	Text
Q25	Was it any part of the game you did not understand?	Text
Q26	Do you have any other comments about the game or the testing?	Text

Table 29.11: More open-ended questions about the tester’s thoughts and actions.

Some questions were conditional based on what the participants answered. Questions 17 and 18 were only visible if the player answered that they had discovered a bug. The same is the case for questions 19 and 20, which were only visible if the player answered that they had cheated.

29.3 Interviews

In addition to the questionnaires, interviews were conducted with a couple of testers. The interviews aimed to get more in-depth answers and allow the interviewees to elaborate on some of their answers. An interview opens up the opportunity for a two-sided conversation and reflection about how the exergame affected the player compared to the original intentions.

The interview guide consisted of nineteen questions; some were more open and broad, and others focused on specific aspects of the exergame. Some questions were on the same topics, which led to some questions being dropped because the interviewee had already answered them. A semi-structured interview structure led to a natural conversation while ensuring that the interview went through all predetermined topics. If any answers prompted further questions, they were added to the conversation naturally. The interview questions, including questions added during the interviews, and noted answers can be found in Appendix G.

The interviews lasted about fifteen minutes each, with one master student asking the questions

while the other was taking notes. All interviewees had signed a consent form agreeing to a recorded interview. However, before the interview, they were asked again, and all consented. By recording the interview, we could go back and double-check what the interviewees answered later.

29.4 Game Data

Game data is another type of quantitative data that the exergame collected throughout the test period by logging different data into the database. This data consisted of player scores, how many times they visited the exergame during the testing period, and the quests they completed. Firebase collected data on how many reads and writes happened to the database daily, indicating how much the players interacted with the exergame each day throughout the testing period.

29.5 Summary

This chapter presented the different data generation methods used in the project. First, it went through the two questionnaires and presented the questions in them. The first questionnaire, given to the testers before the test period started, aimed to get an overview of the demographics of the test group and their relationship with physical activity, exercise and video games. The second questionnaire focused on the two-week test period, and the questions aimed to see what the players thought of the exergame and how playing the exergame had affected their physical activity and motivation. Next, it described the interviews. The interviews were semi-structured and aimed to get more in-depth answers, as interviews allow for a more two-sided conversation. Lastly, it described the different data the exergame stored in the database about how much the participants interacted with the exergame.

In the following part, we will cover the experiment's outcomes, starting with an overview of the test group.

Part VI

Results

Part VI is the experiment results and data collection. First, it presents the results from the data collection by dividing them into three categories: physical activity, motivation and engagement, and game and enjoyment. Then, it presents and discusses external factors that could have affected the results.

Chapter 30

Test Population

The test group consisted of 53 participants, mainly recruited from the master students' social network. Before the two-week testing period began, each tester had to answer a questionnaire with basic information such as age and gender, their motivation for physical activity and exercise, and gaming habits and relationship with video games. For more detail about the questionnaire, see Section 29.1. All the results can be seen in Appendix C.

30.1 User Demographics

Out of the 53 participants, 36 identified as male, 15 as female, while 2 selected "other" or that they did not want to answer (see Figure 30.1). The age of the participants varied a bit, but most participants were between nineteen and thirty. Figure 30.2 shows the full span of the age of the participants.

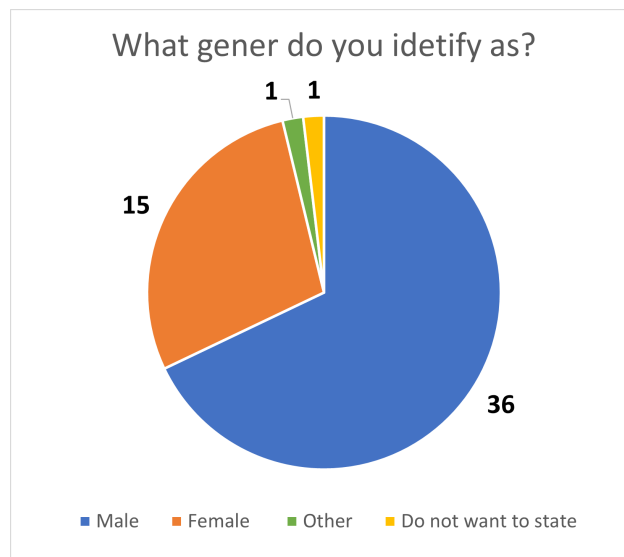


Figure 30.1: Gender distribution

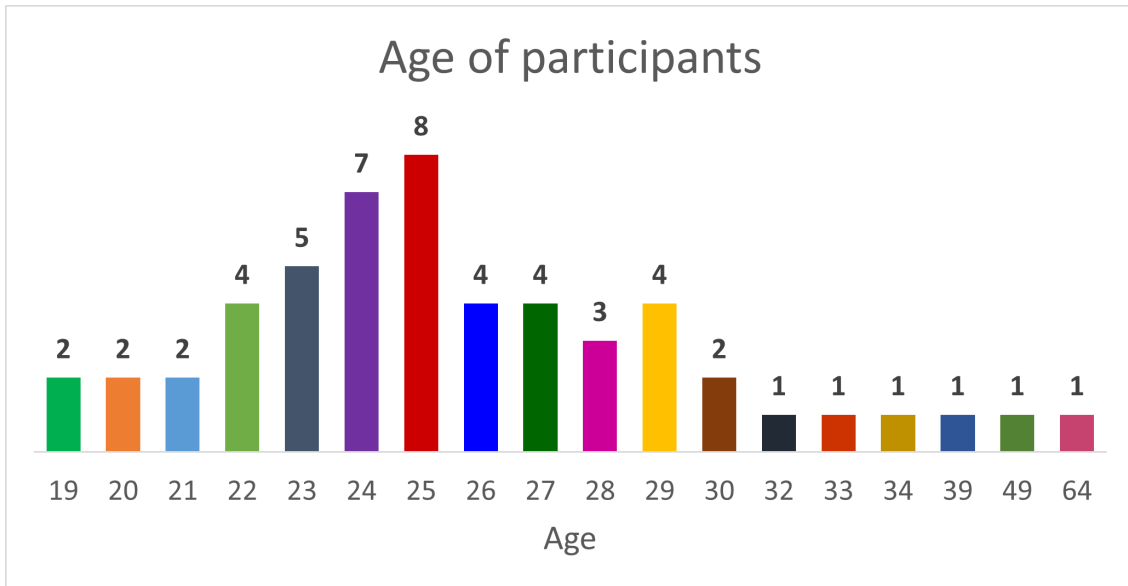


Figure 30.2: Age distribution

30.2 Video Game Preferences

Figure 30.3 shows how much time the participants spend gaming each week. **Most participants spend between 1-10 hours gaming each week**, but almost 17% of the participants do not play any or play only a tiny amount of video games each week.

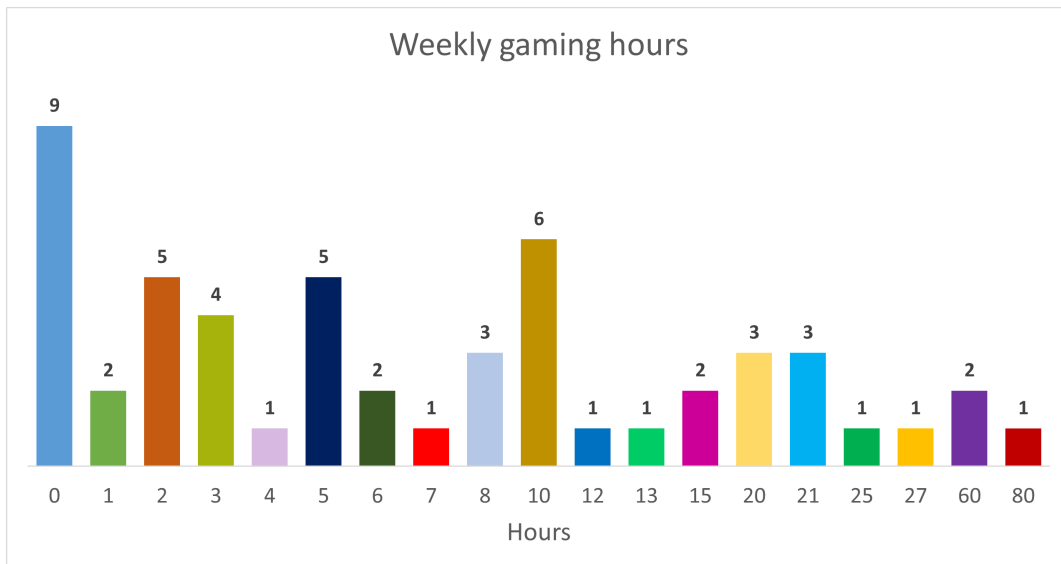


Figure 30.3: Participants' weekly gaming time in hours

Most of the participants prefer to play computer games. Figure 30.4 shows that **60% of the participants use the computer as their primary gaming platform**. 23% of the participants

use their phone as their primary gaming platform, and the remaining 17% use gaming consoles such as PlayStation, Xbox, and Nintendo Switch as their platform of choice.

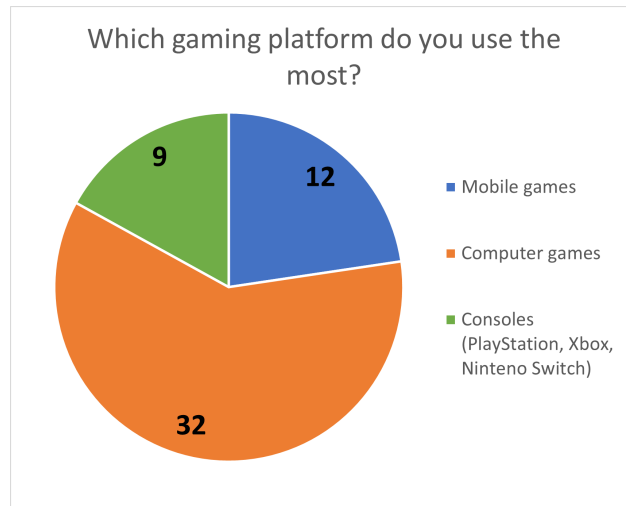


Figure 30.4: Gaming platform distribution

In mobile games, it is normal to have the player watch ads or pay using microtransactions if they want to speed up their game progress. One of the things this project wanted to investigate with Radiation Mayhem was to replace microtransactions with physical activity. Therefore, it was essential to check the participant's experience with microtransactions and their thoughts about them. Figures 30.5, 30.6, and 30.7 show the results of the questions related to microtransactions in games.

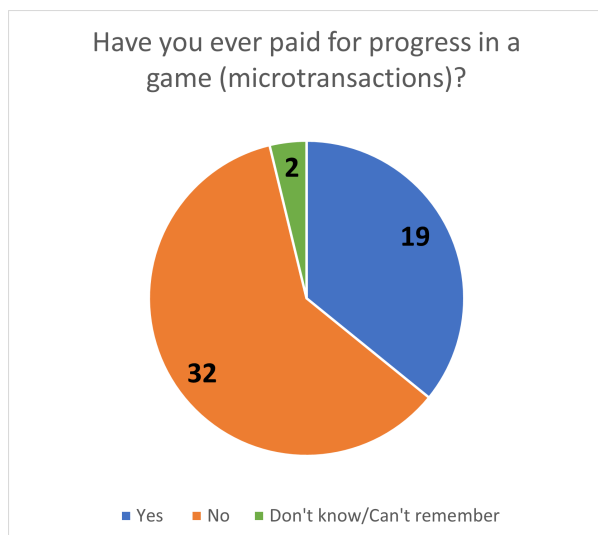


Figure 30.5: Distribution of participants who previously have paid for game progress

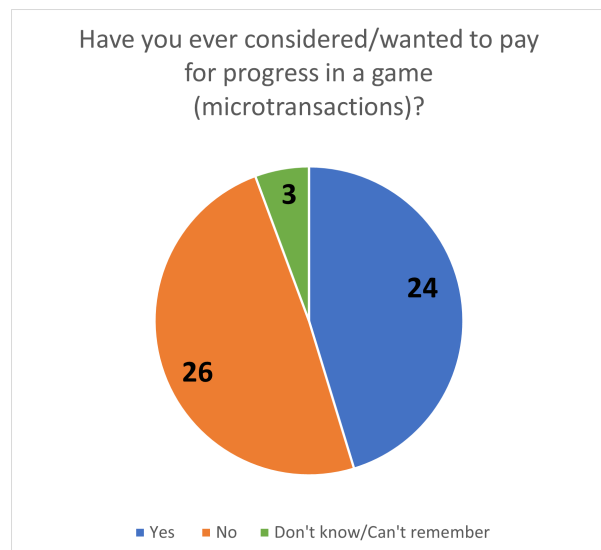


Figure 30.6: Distribution of participants who previously have wanted to buy game progress

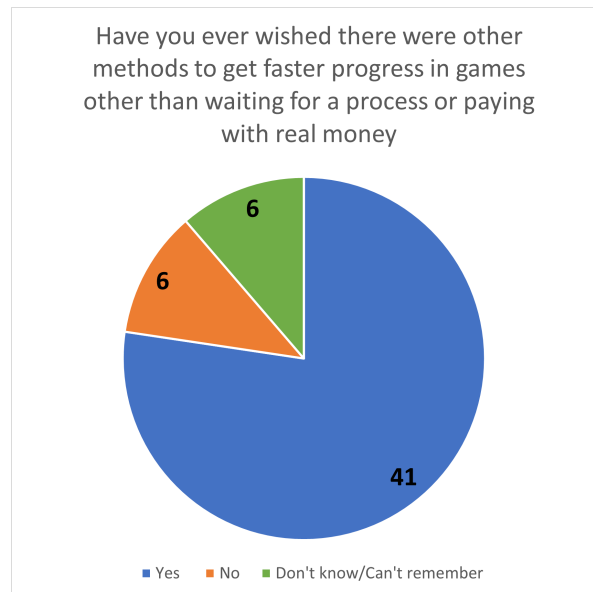


Figure 30.7: Distribution of participants who want other methods for getting game progress

The results show that while only **36% of the participants have ever paid for game progress, more than 45% of the participants at least once considered it but decided not to pay**. While there is likely some overlap between the two categories, the results show that many of the participants want faster game progress but might not be willing to pay for it. **The most significant result was whether the participants wished there were other ways of getting faster game progress, with more than 77% answering “Yes”**.

30.3 Motivation for Physical Activity and Exercise

One of the goals of this study was to see if playing Radiation Mayhem would impact a person’s motivation for physical activity and exercise. Therefore, it was important to register the participant’s existing levels of motivation for physical activity and exercise before the test period. Then, the results from before the test period could be compared to the results after the test period to see if there were any changes. Figure 30.8 shows the player’s existing motivation for physical activities done outside and not at a fitness centre or as part of organised sports. This question aimed to map the participant’s motivation for “casual” jogs and walks that were not part of an exercise regime but more for casual enjoyment or travel. Figure 30.9 shows the player’s existing motivation for more organised activity and exercise, like organised sports and training at a fitness centre.

The results showed that **83% of the participants had medium to high motivation for physical activity, and more than 90% had medium to high motivation for exercise**.

The reason for the division between physical activity and exercise is that, as mentioned in Section 7.2, physical activity and exercise are not the same. While they are often mistakenly used as synonyms, important differences in their definitions make the motivation for them incomparable. For example, someone who loves going for walks but hates high-intensity training has

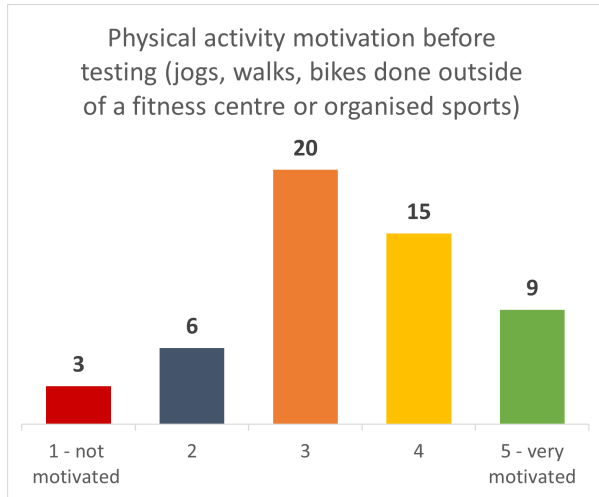


Figure 30.8: Participant motivation for physical activity

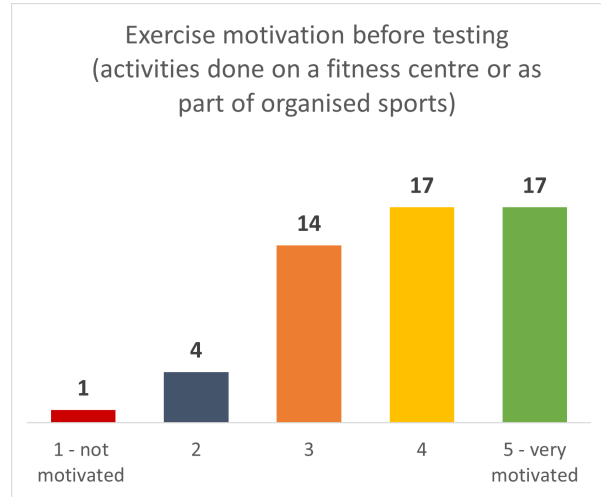


Figure 30.9: Participant motivation for exercise

high motivation for physical activity but low motivation for exercise.

It was also important to get an idea of how active the participants were in their day-to-day life before they started testing. The results, shown in Figure 30.10, showed that more than 75% did at least one training session each week. The results also show that only 21 out of 53 participants partake in organised sports in a club or team (see Figure 30.11).



Figure 30.10: Participant level of exercise

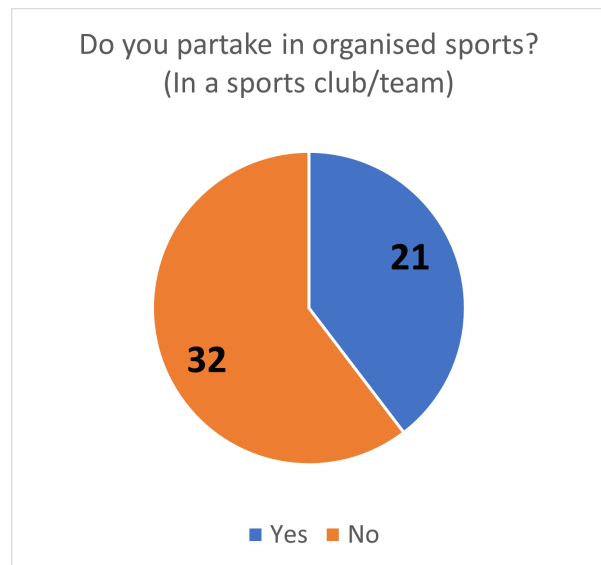


Figure 30.11: Participant motivation for exercise

30.4 Summary

This chapter presented the data collected on the test population regarding user demographics and their relationship with physical activity, exercise, and gaming. First, it presented the data mapping the demographic distribution of the test group. Then it presented the participants' gaming habits and relationship with video games and microtransactions. Lastly, it presented the participant's motivation for physical activity and exercise, as well as their exercise level before the test period.

The next chapter will detail how the experiment influenced the test population's physical activity.

Chapter 31

Physical Activity Results

This chapter presents the results from the experiment relevant to the participant's physical activity level. First, it presents the results from the questionnaires on how playing the game influenced the participant's activity level. Second, it goes through the results from the interviews. Lastly, it presents the database data on how many of the testers completed their WHO weekly goals and how many went the extra mile to complete the challenging non-repeating quests.

The full data from the first questionnaire, second questionnaire, interviews, and database data can be found in appendices C, E, G, and F, respectively.

31.1 Questionnaires

Seventeen testers, which equals **32% of the participants, reported that they changed their daily habits to include more physical activity.** The changes to daily habits were things like daily walks or things like walking, jogging, or biking to work or university instead of taking the bus or car.

Figure 31.1 shows the number of weekly walks and their average duration for each participant. Note that if two participants state the same number of walks with the same duration, the dots in the figure will be on top of each other. Looking at the data, **we can see a general trend towards users taking more and longer walks.** On average, **the number of walks increased by 138%, and the length of the walks increased by 6%.** In the first questionnaire, some testers reported that they did not go on any weekly walks. Most of these went on walks during the test period, but they are not counted in the percentage, as they would cause the percentage change to be infinite. **One tester increased their weekly walks from 0 to 21.** The second questionnaire mapped if any testers had been sick, hurt, or otherwise indisposed to such a degree that it impacted the game. 11 testers stated that their gameplay had been greatly affected. **Out of these 11 testers, seven showed a decrease in their number of weekly walks and walk duration,** which might skew the walks and duration results more negatively than they would have been if they had not been sick or hurt.

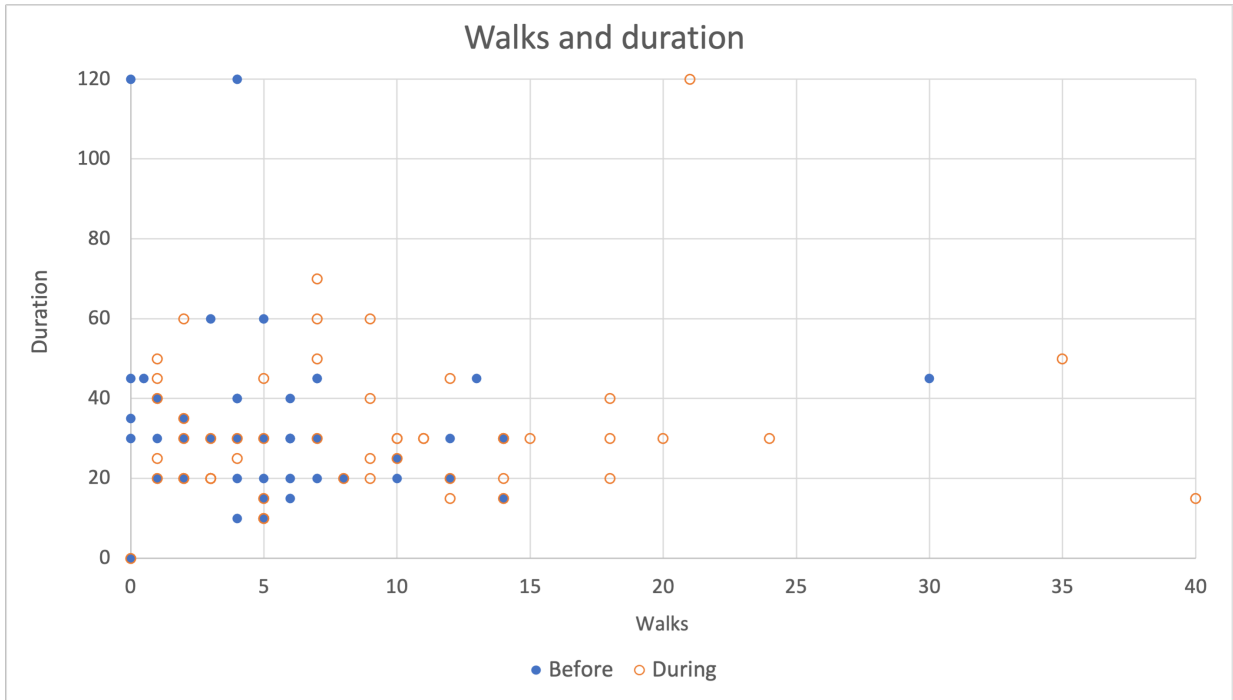
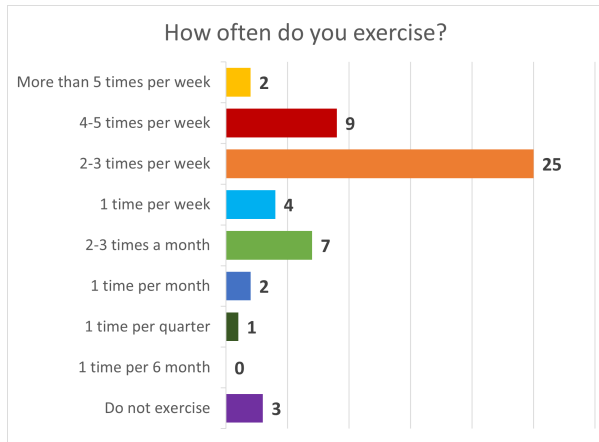


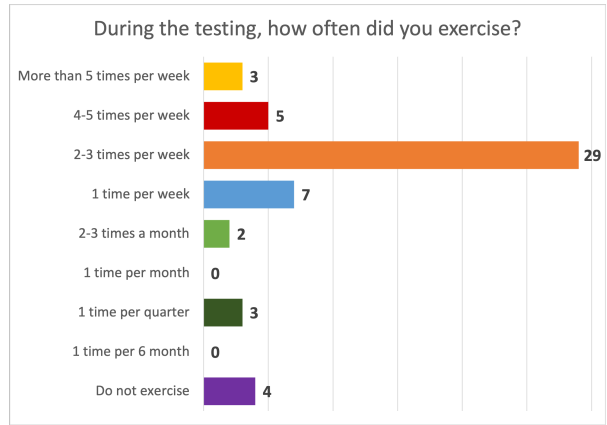
Figure 31.1: Number of walks and duration per week before and during the test

Figure 31.2 compares the exercise frequency among the testers before and during the test period. There is a definite difference between the two samples, and four testers changed from exercising less than once a week to exercising once or more per week. This change is pretty small, but that is not that surprising given that Radiation Mayhem encourages overall physical activity in the form of walks, jogs, runs, and biking but is not that good at motivating for more static forms of exercise. As explained in Section 15.1, fitness tracking apps are great at detecting steps and other activities where the user is moving their entire body while having their phone in their pocket or while wearing a smartwatch. However, they are less efficacious at detecting static exercises like weight-lifting or full-body exercises, where people often leave their phone somewhere else and do not carry it on their person. These kinds of activities can only be detected if the user is wearing a smartwatch. The result is that the players of Radiation Mayhem are not directly incentivised to exercise explicitly.

The reason for asking the testers for information about their exercise frequency is twofold. The first reason is as a data point that can be used for correlation with other findings. The other reason is to check if the game did have any impact on how frequently the testers exercised.



(a) Exercise frequency among participants before the testing (Copy of Figure 30.10)



(b) Exercise frequency among participants during the testing

Figure 31.2: Comparing exercise frequency before and during the testing

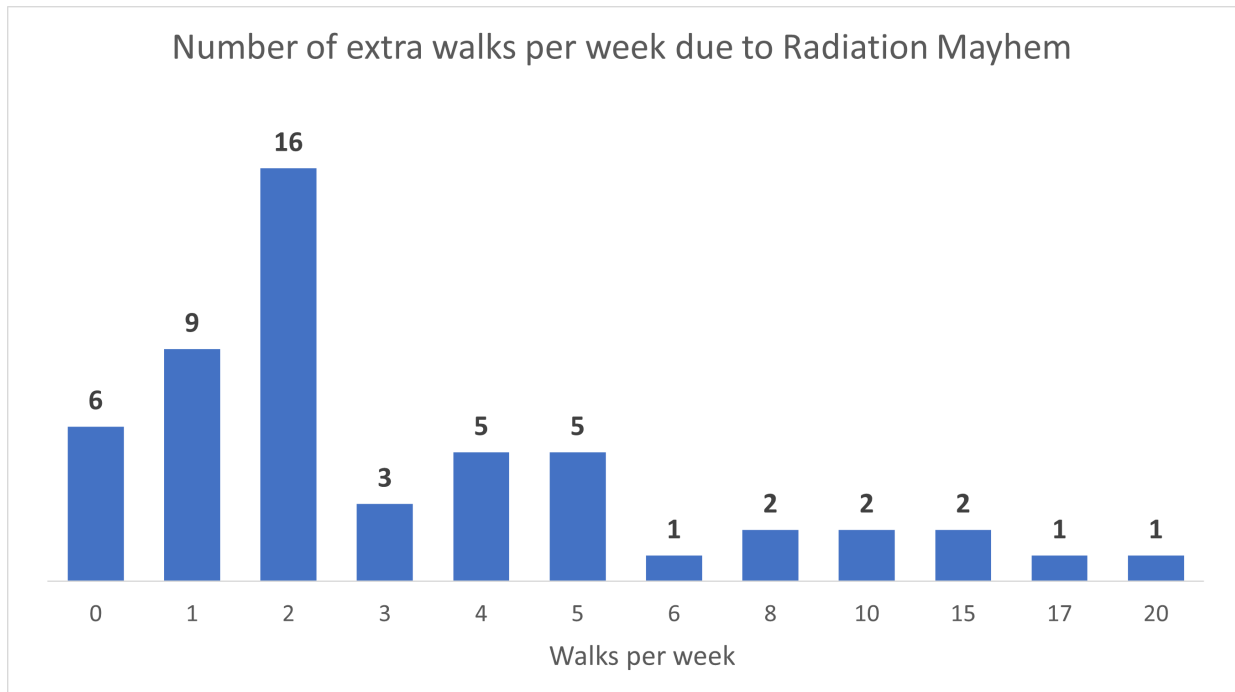


Figure 31.3: Number of extra weekly walks due to playing Radiation Mayhem

ID	Statement	Disagree	Neutral	Agree
Q10.2	I was more physically active	15%	36%	49%
Q10.3	I went for walks, jogs, or bike rides I would not have gone on if I was not playing the game	30%	11%	59%
Q10.8	I walked, jogged, or biked places instead of using other means of transportation	32%	13%	55%

Note: This table combines the slightly and strongly disagree/agree categories. For more details, see Appendix E

Table 31.1: Questions related to physical activity, exercise and motivation.

One type of activity that Radiation Mayhem is much better at encouraging is walks. Figure 31.3 shows the number of extra weekly walks our testers conducted due to playing Radiation Mayhem. **89% (47 testers) of the testers reported that they went on walks specifically because they were playing Radiation Mayhem.** On average, each tester went on 4 more walks per week during the test period compared to before. This result seems weird when compared to question 10.3 (see Table 31.1), where only 59% agreed that they went on walks they would not have gone on if they were not playing the game. However, one can assume that those who answered “neutral” or “slightly disagree” did not go on many extra walks, maybe only one or two extra throughout the week. Only 13% answered “strongly disagree”, which is not far from the six people (11%) saying that they went on zero extra walks. Some of these extra walks may have replaced other means of transportation.

As seen in question 10.8 (see Table 31.1), **55% of respondents answered agreed to the statement “During the test period... I walked, jogged, or biked places instead of using other means of transportation”.** One quote from one of the free-form questions from the questionnaire stated: **“I want to say that the game has a good potential that few other games benefit from, everyday exercise/activity. I hope to see continued development so that the game can contribute to increased everyday activity [...]”.** These results indicate that Radiation Mayhem is a good motivator for players to change their daily habits to be more physically active.

Question 10.2 (see Table 31.1) asks if the respondent agrees with the statement, **“During the test period... I was more physically active”.** **To this, 49% of respondents agreed. 36% responded with neutral.** This result does not initially map cleanly to the number of extra walks reported (89% reported extra walks). This discrepancy might be due to players taking extra walks but overall being at about the same level of activity due to external factors. This is discussed in Chapter 34.

31.2 Interviews

Four of the six interviewees reported a modest increase in their physical activity, usually as extra walks. One of the interviewees described the games as more of a bonus, slotting nicely into the walks and activities they were already doing. The interviewees were

also asked what activities these additional walks replaced. **Out of the interviewees, five reported that they did go on extra walks due to the game, substituting sedentary activities.** All of them mentioned that they enjoyed having the game motivate them to go on recreational walks instead of being idle or watching TV.

31.3 Database Data

Throughout the test period, a total of 765 quests were completed. These consisted of 539 daily quests, 143 weekly quests, and 83 non-repeating quests. As detailed in Section 18.3.3, the weekly quests are modelled after WHO's and FHI's weekly physical activity recommendations, with weekly quest 1 and quest 2 being modelled after recommendations 1 and 2, respectively (seen in Table 7.1). From Figure 7.2 and 7.3, we can see that 76-82% of Norwegians in the age range 20-34 hit their first weekly recommendation, and 41-49% hit their second weekly recommendation. When comparing this Norwegian average to the percentage of completed weekly quests, the result for recommendation 1 was approximately the same. However, **looking at weekly quest 2, there is an increase of 15-23% for the first week of testing and 8-16% for the second week**⁴⁵. Regrettably, we do not have any quest data from the initial test day. The data was lost due to an error during the setup of the database collection for completed quests. The error caused a player's completed daily quests to overwrite themselves each day, resulting in the database only being able to capture a snapshot of quests completed on the same day. Thankfully, this issue was identified on the second day of testing, so only a small number of completed daily quests were not recorded.

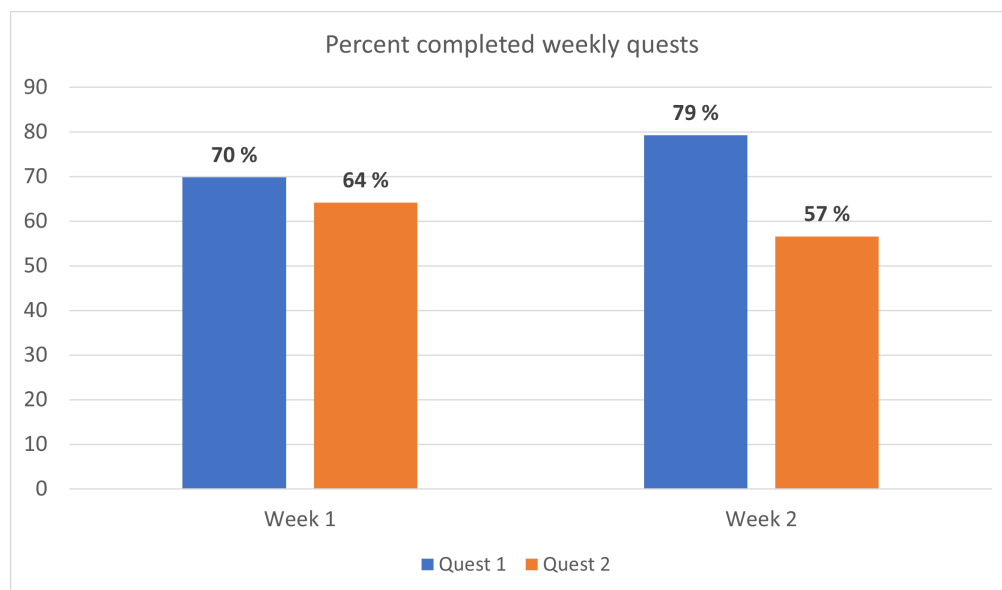


Figure 31.4: Percentage completed weekly quests

⁴Comparisons to the FHI survey are made against the 20-34 age group, which corresponds to the age range of >90% of our test population.

⁵FHI also has a third recommendation. Recommendation 3 states that people with more than 8 hours of daily sedentary activity should follow recommendation 2. This thesis has no data on whether any testers achieved recommendation 3, as we do not know how sedentary our testers were.

Quests 6, 7, 8, and 9 are non-repeating quests that require the player to walk a considerable amount of steps during the two weeks. Quest 8 and 9 are the most challenging, asking the player to walk 140 000 and 175 000 steps during the test period, respectively. **This averages to 10 000 and 12 500 steps per day over the two weeks. In total, eight testers completed both quests 8 and 9.** The full breakdown of completed non-repeating quests can be seen in Figure 31.5.

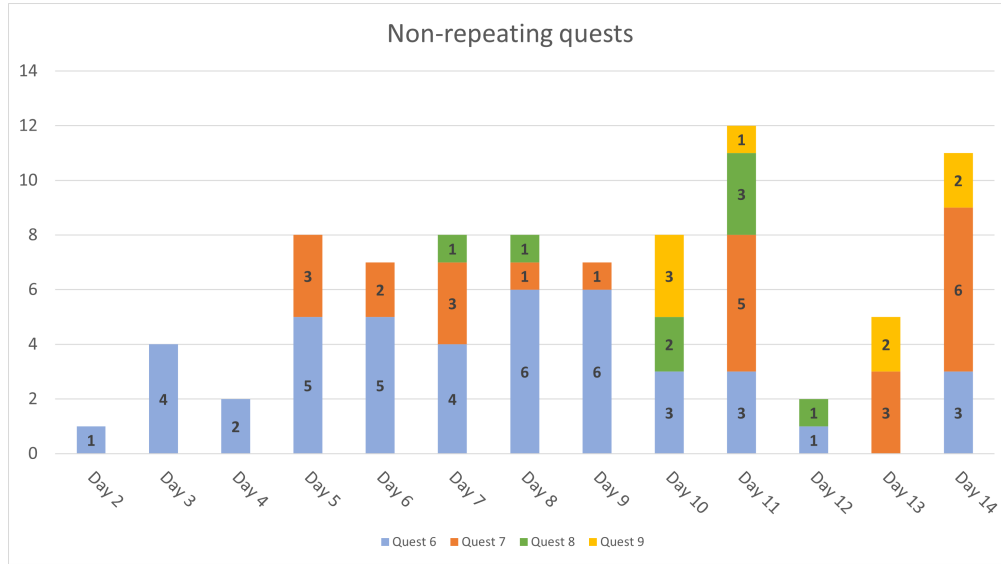


Figure 31.5: Completed non-repeating quests

31.4 Summary

This chapter detailed the results from the questionnaires, interviews, and gathered database data related to physical activity levels. The questionnaire showed that the average number of reported walks and the duration of the walks increased during the test period, with 89% of testers reporting that they went on extra walks due to playing Radiation Mayhem. The results from the interviews showed that four of the six interviewees noticed an increase in their physical activity level. The interviewees also noted that the extra walks they did conduct replaced leisure time. From the database data, we saw an increase in the completion of the second recommendation from WHO and FHI compared to the national average.

The next chapter will present how the tester’s motivation and engagement were affected by the experiment.

Chapter 32

Motivation and Engagement Results

This chapter details the experiment results related to motivation and player engagement. First, it goes through the relevant results from the second questionnaire and, in some cases, compares the results to the first questionnaire. Second, it goes through the results from the interviews. Lastly, the relevant database data is presented, showing how the players engaged with the game throughout the testing period.

The full data from the first questionnaire, second questionnaire, interviews, and database data can be found in appendices C, E, G, and F, respectively.

32.1 Questionnaires

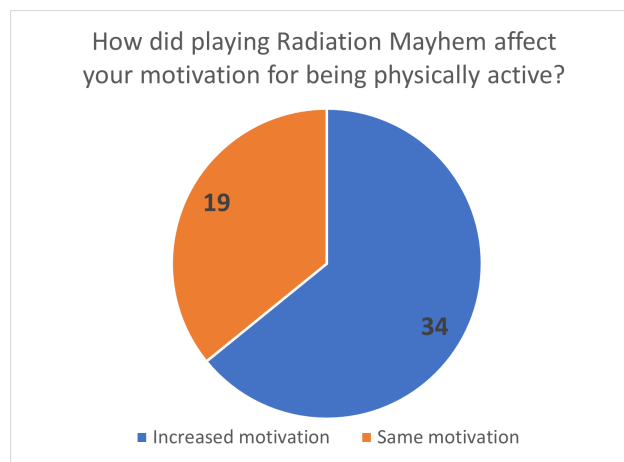


Figure 32.1: The game’s impact on player motivation

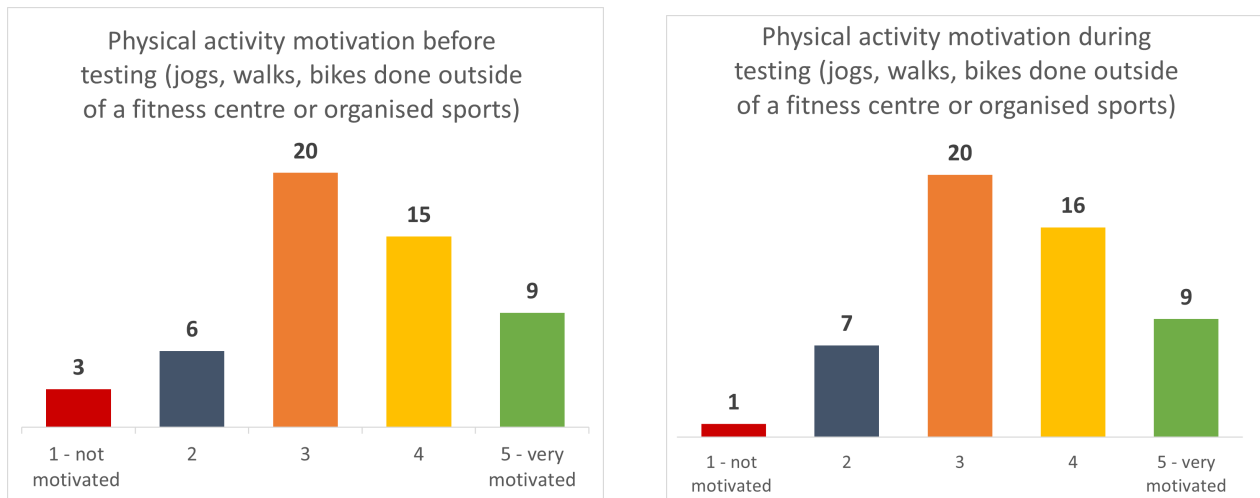
Figure 32.1 shows the reported change in the tester’s motivation due to playing Radiation Mayhem. **More than 64% of the participants felt that playing the game increased their motivation, with the rest answering that they had the same level of motivation.** Zero participants answered that playing the game had decreased their motivation. Question 10.1 asked a similar question regarding the player’s motivation during the testing period, with the users rating a statement on a Likert scale. The results, shown in Table 32.1, are very similar to the result of 64%, with 66% agreeing with the statement that they were more motivated during the testing.

ID	Statement	Disagree	Neutral	Agree
Q10.1	During the testing, I was more motivated to be physically active	6%	28%	66%

Note: This table combines the slightly and strongly disagree/agree categories. For more details, see Appendix E

Table 32.1: Question about the players' motivation during the testing period

When comparing the results from the first and second questionnaires, there is a slight increase in reported intrinsic motivation for physical activity. Figure 32.2 shows that only one participant reported that they had no motivation for being physically active during the test period compared to three before they played the game. Other than that, the reported levels are almost identical. This result might feel weird as 66% of the participants reported increased motivation for being physically active. However, it is possible that playing Radiation Mayhem increased their motivation level, but not so much that participants felt it was enough to move them up a level. There is also a possibility that participants did not remember what they answered in the first questionnaire and answered the same as before, even if their motivation had increased.



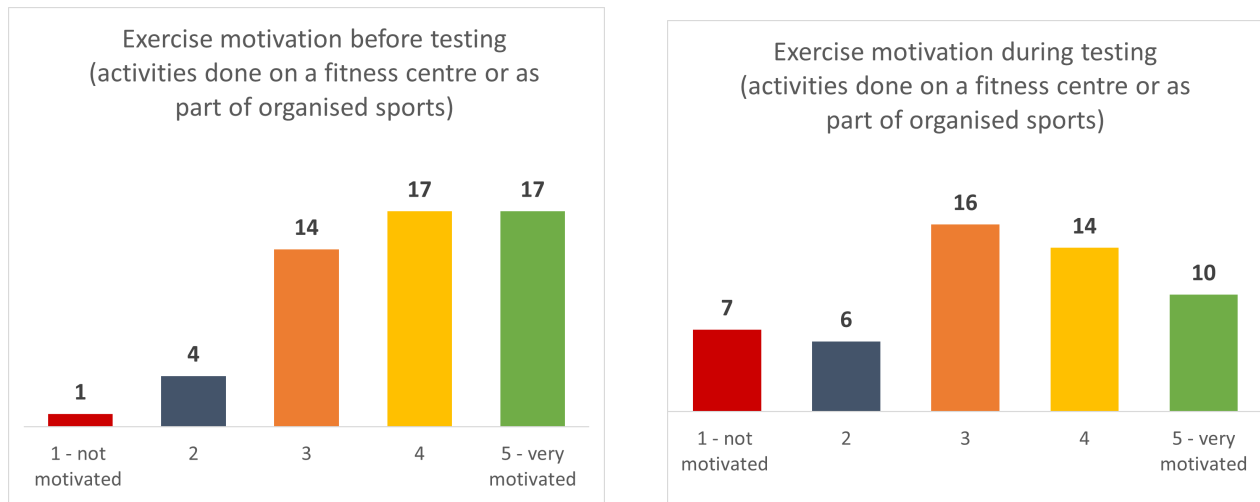
(a) Participant motivation for physical activity before testing (Copy of Figure 30.8)

(b) Participant motivation for physical activity during the testing

Figure 32.2: Comparison of physical activity motivation before and after testing

Figure 32.3 shows the difference in motivation for exercise. There has been a significant decrease in motivation for exercise during the test period. This result is surprising since Radiation Mayhem should, in theory, not directly affect a player's motivation for exercise since it does not track exercise well. However, there could be external factors responsible for the decrease. Of the eleven participants that reported that they were ill, injured, or indisposed during the testing to such a degree that it affected their ability to play the game, seven reported a decrease in motivation for exercise. The decrease is not surprising, as it can be hard to be motivated to exercise while sick. These seven account for a large part of the overall decrease in motivation for exercise. However, the seven people that reported that they were ill, injured, or

otherwise indisposed do not account for all the reported decrease in motivation. It is impossible to know why some other participants also reported a decrease in motivation for exercise, but it could be due to other external factors. Potential external factors are detailed in Chapter 34.



(a) Participant motivation for exercise before testing (Copy of Figure 30.9)

(b) Participant motivation for exercise during the testing

Figure 32.3: Comparison of exercise motivation before and after testing

Question 9 asked the participants to rate which game elements motivated them most to be physically active, from most to least. Figure 32.4 shows the results. **“Complete quests to get resources” got the overall highest rating, with 41 out of 53 participants ranking it in their top 4.** The element that got the most first-place ratings was “points to next player”, with 10 participants rating it highest.

Upon further analysis, there were differences in what elements the participants preferred based on their in-game scores. Looking at the top 7 scoring participants (those who earned more than 100 000 points), 6 out of 7 of them (86%) rated “Complete the most challenging quests because they are challenging” in their top 3. All of the seven top-scoring participants also completed the most challenging quest, walking at least 175 00 steps during the test period. This result indicates that the top-scoring participants were quite competitively minded. The rest of the top 3 selections for the top-scoring participants were fairly similar to the other participants’ results.

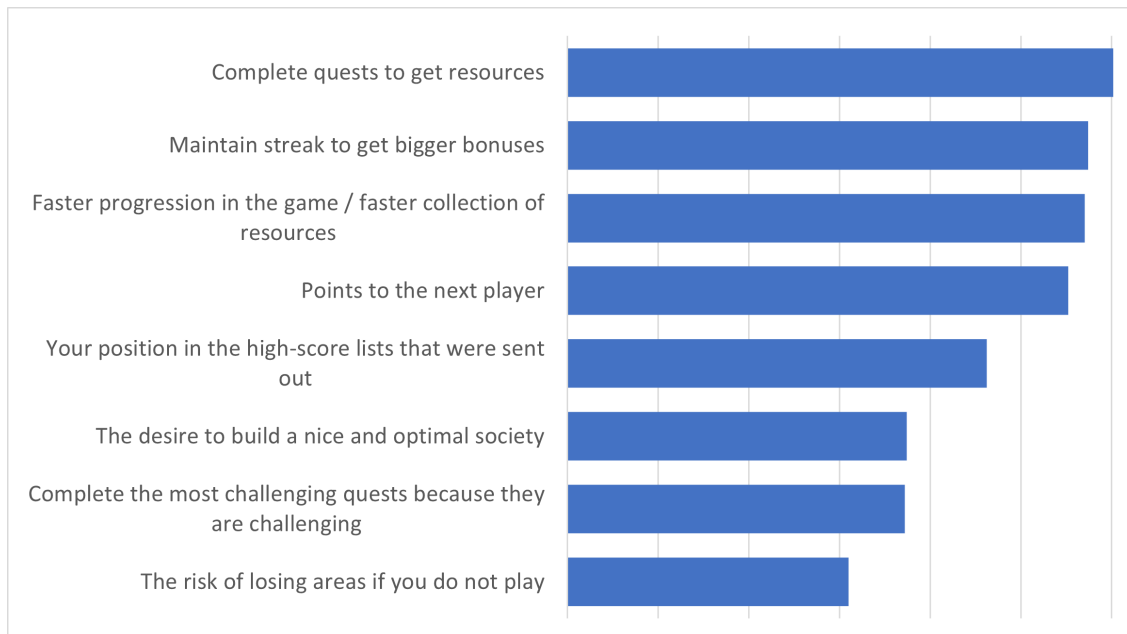


Figure 32.4: The participants' rating of which elements motivated them most to be active

The questionnaire asked more detailed questions about the different quests and high-score lists to see how they affected the player's motivation. The results, shown in Table 32.2, show that the most motivating quest type was daily quests, with **76% of the participants agreeing that daily quests motivated them to do some physical activities each day**. 55% also said that weekly quests motivated them to be active throughout the week, and 53% of the participants also agreed that the high-score list motivated them to try to get higher on the list.

ID	Statement	Disagree	Neutral	Agree
Q13.2	The daily quests motivated me to do some physical activities each day	15%	9%	76%
Q13.3	Weekly quests motivated me to be active throughout the week	32%	13%	55%
Q13.4	Challenging quests motivated me to be extra active so that I would reach the quest goals	32%	26%	42%
Q13.6	The high-score lists motivated me to try to do better to get higher on the list	23%	24%	53%

Note: This table combines the slightly and strongly disagree/agree categories. For more details, see Appendix E

Table 32.2: More detailed statements and results about motivational effects of different game elements

Question 10 gave several claims about the reasons why players went on extra walks. The results, shown in Table 32.3, show that most players wanted to be active because they wanted to get resources, reach quest goals or otherwise engage with the game. The game's score system was also a motivating factor, as more than half of the participants went on walks because they

wanted a higher score. Something interesting is that **the exergame was motivating enough to make 15% of the participants go on walks despite the bad weather.**

ID	Statement	Disagree	Neutral	Agree
Q10.4	I went for walks, jogs, or bike rides because I wanted to reach a quest goal	26%	19%	55%
Q10.5	I went for walks, jogs, or bike rides because I wanted to collect more resources	30%	25%	45%
Q10.6	I went for walks, jogs, or bike rides because I wanted a higher game score	21%	28%	51%
Q10.7	I went for walks, jogs, or bike rides despite bad weather (rain, snow, wind)	53%	32%	15%

Note: This table combines the slightly and strongly disagree/agree categories. For more details, see Appendix E

Table 32.3: More detailed statements and results about the physical activity effects of different game elements, and a question about the weather

Question 8 asked how many minutes, on average, the player engaged with the game each day. The results, shown in Figure 32.5, show that 50% of the participants played an average of ten to fifteen minutes a day. Of the remaining 50%, about half played for less than ten minutes, and half played for more than fifteen, with no one playing more than forty-five minutes daily. This result is as expected as the game is intended to be simple; the player can play for a few minutes when it fits them and then go on with their day without being a huge commitment or distraction.

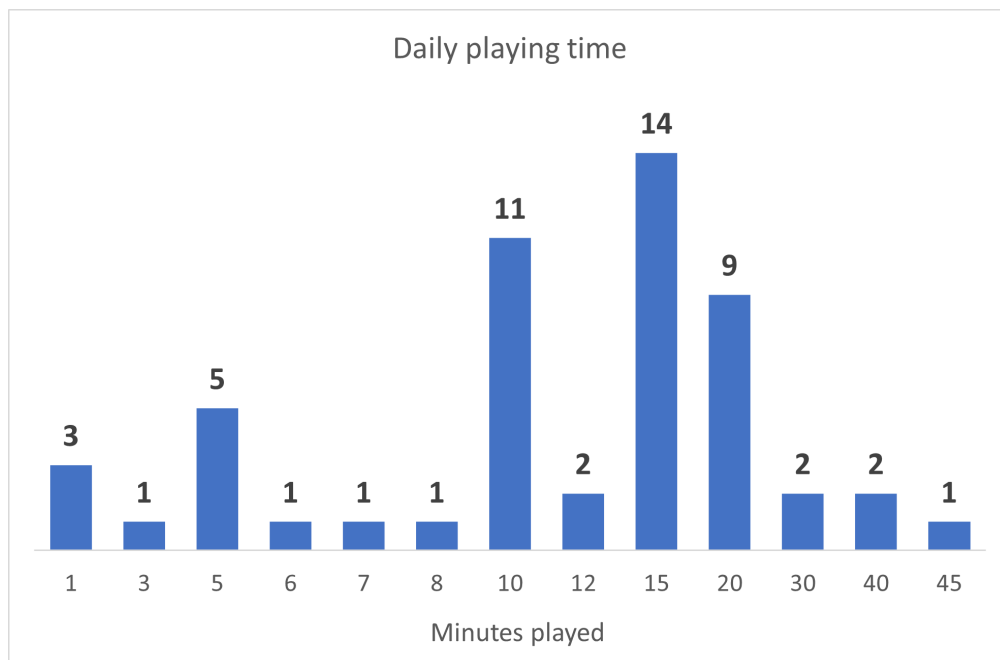


Figure 32.5: How many minutes the participants played the game each day on average

We also ran correlation checks to see what traits of the testers influenced changes in motivation. There were very few strong correlations to be found. It would seem neither total game score ($r = 0.08$), average video game hours played per week ($r = -0.02$), exercise session per week ($r = 0.04$), nor playtime in Radiation Mayhem ($r = 0.16$) has a strong correlation with whether or not the participant's motivation for physical activity increased. This lack of correlation indicates that **the exergame has a good effect on player motivation, regardless of the preconditions.**

32.2 Interviews

Overall, the interviewees thought that the exergame helped with physical activity motivation, with some getting more motivation than others. When asked why they found it motivating and what game aspects motivated them most, most said that daily quests and streaks were a huge motivator for being physically active. In particular, they mentioned that when they were close to reaching a goal, they were motivated to go for a walk to reach it. One interviewee stated, *"If I saw that I was close to reaching a goal, I wanted to go for a walk to reach it"*, and mentioned that they sometimes ended up walking back and forward inside their house. Another interviewee stated that *"I was motivated to go on a walk if I only needed a short walk to reach a goal, say 5-10 minutes"*. One interviewee also stated that the fact that **"Little effort for high in-game reward motivated me as I felt it was worth it"**. When asked what they thought about the exergame as a motivator for physical activity, one person stated, *"It was good, especially since it did not take time away from the activity. With some exergames, like Pokémon Go, you have to go while staring at the screen, which means you collide with things. With this exergame, you can enjoy the walk."*

When asked more directly about what they thought about the quests as a motivating factor, most interviewees said that they found them motivating and wished there were more. One stated, *"Weekly quests were completed rather early in the week, making them less motivating than they could have been."* When talking about the existing quests, one interviewee said, *"The quests were good. They felt well thought out when it came to quality. The goals were reachable and felt just right in size"*.

The high-score lists were highly motivating for the ones doing well in the game, with one interviewee stating that *"It was fun to be at the top"*. The high-score lists were also motivating as players could compare themselves to other players, with interviewees stating *"It was exciting to know your place in the standing and how you were doing"*, and *"It was fun to compare to other people I knew and wanted to beat"*. However, the high-score list was a two-edged sword. One interviewee stated, *"If you were at the top of the list, it was fun, but if you fell behind, it was demotivating as there was no way of catching up"*. **Several interviewees stated that the score up to the next player on the list was more motivating as it felt like a more obtainable goal.**

The interviewees were asked if there were anything the exergame could have done to motivate them to play more. One thing mentioned multiple times was that more things to do in the exergame would have captivated and motivated them more, with one interviewee saying that *"There could have been more things to do when you were in the game, but at the same time,*

the simplicity made it so that you did not spend much time in the game so it did not take up time needed for something else.”. One player said that the exergame would have been more motivating for them if it was extended to include an aspect of risk and reward, stating, “It would have been fun if it was possible to find hidden objects outside of the area by gambling and expanding in one direction, for example, to find a new water source and start a new colony.”.

Most interviewees said they played the exergame when it fit their schedule and if they had some available time. *“I went in after work and then again before I went to bed. As there was not a lot happening in the game, I did not enter that often. I did play right after I had finished exercising.”.*

32.3 Database Data

Throughout the test period, **the database got almost 60 000 reads and 12 500 writes.** Each time a player enters the game, there is at least one read and two writes to the database. In addition, every time a player passes another player’s score, there should be a new read to the database, and every time a player completes a quest, there should be a write. However, there is some uncertainty about the numbers registered in the database due to a rare bug where a couple of players’ stats were not always updated. How much this has affected the overall database stats is unclear, but it is fair to assume that there it had little to no effect on the general database trend. This bug was only discovered to happen for two testers, but it is possible that it happened to other testers as well without them noticing and notifying us. Figure 32.6 and 32.7 show the reads and writes throughout the testing process. The ups and downs of the reads graph indicate that there were many changes in the rankings on the score table.

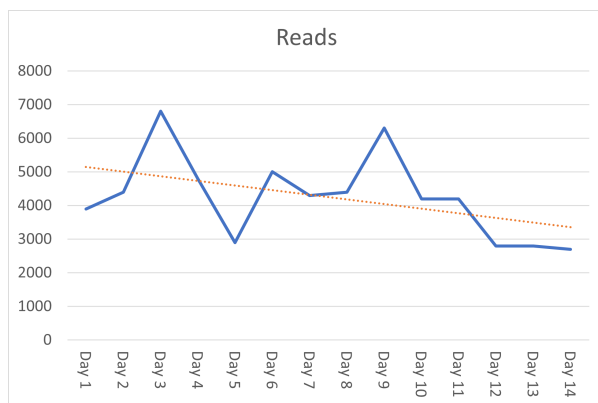


Figure 32.6: Database reads

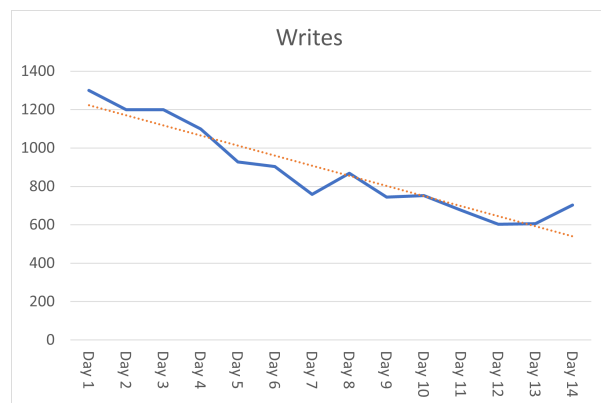


Figure 32.7: Database writes

The player scores can be divided into three levels. The first group consisted of the top two players, with the first-place score being 190 570 points and the second-place score being 162 076 points. Then there was a small jump down to the second group of players who had between 124 604 points and 60 000 points. The last group, which also consisted of the majority of testers, were, for the most part, evenly spread from 60 000 to 2000 points. Figure 32.8 shows the score trend line.

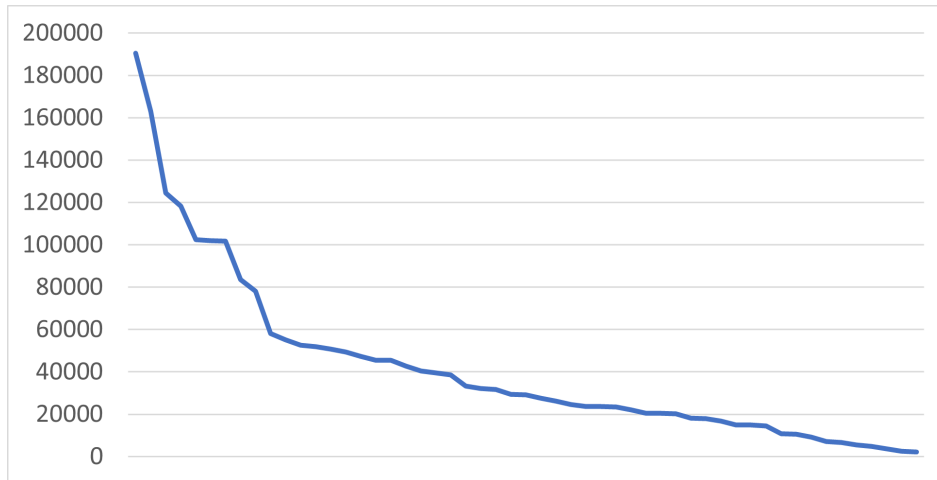


Figure 32.8: Score trend from highest to lowest

On average, a player visited the game 90 times during the testing period, with a standard deviation of 95. With a testing period of two weeks, it averages ~6 visits per day per player. However, some testers visited the game far more than others, with two visiting a total of 435 and 424 times, respectively. The third-highest visit count was 221.

The players engaged a lot with the quests. In total, 765 completed quests were registered; 539 daily quests, 143 weekly quests, and 83 non-repeating quests. Figure 32.9 shows the number of quests completed every day, while Figure 32.10 shows a more detailed distribution divided into the different quest types.

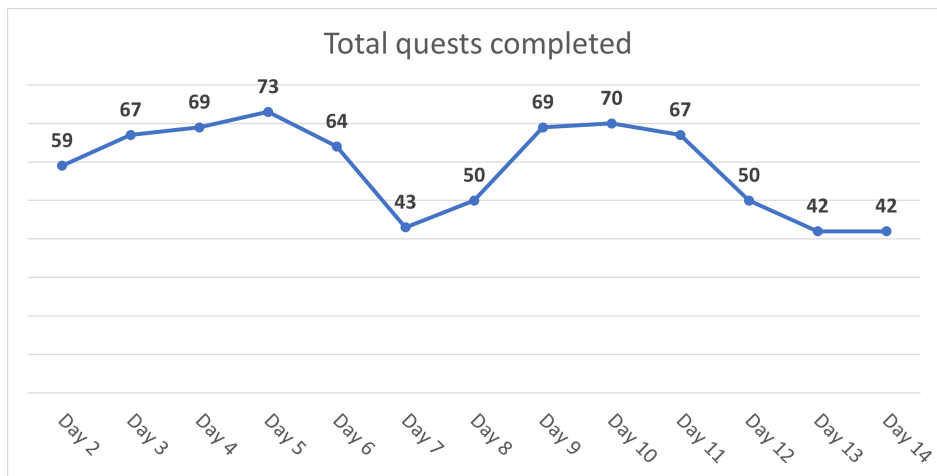


Figure 32.9: Number of quests completed each day

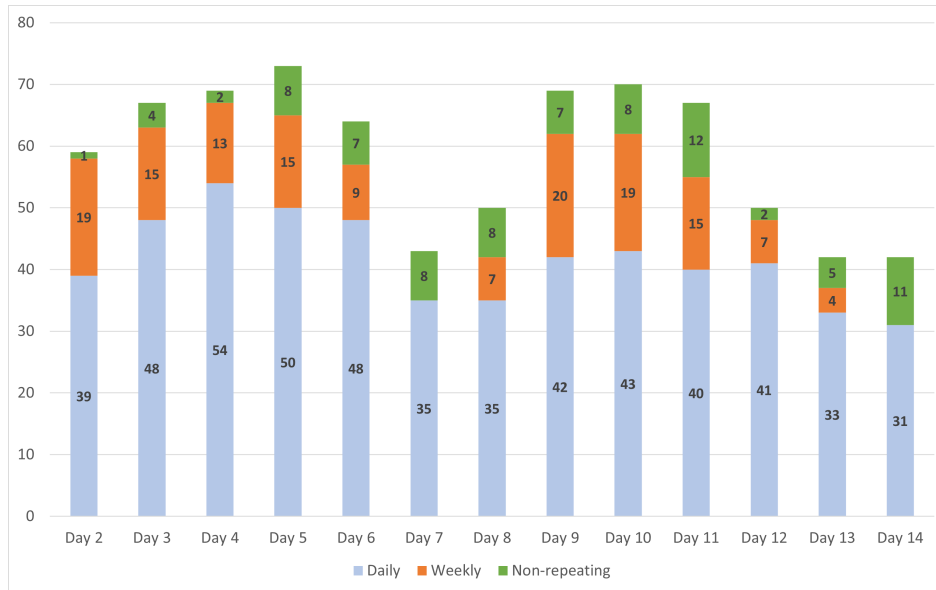


Figure 32.10: Quests completed each day, divided into quest types

32.4 Summary

This chapter detailed the results related to motivation and engagement. The results from the questionnaire showed overall positive results and that most of the testers got increased motivation, which in turn made them more physically active. Of the exergame elements meant to increase player motivation, “Complete quests to get rewards” were rated highest by the participants, and 76% of the participants agreed that the daily quests motivated them to be physically active throughout the day. The interview results showed that players were willing to be more active if they were close to reaching a goal and that the quests were easy enough to be motivating and not daunting.

Regarding player engagement, most participants played the exergame for ten to twenty minutes every day. The database data showed that there had been a lot of engagement with the exergame throughout the testing period, with many visits and quests completed. All in all, 765 quests were completed during the test period, and each tester visited the exergame on average 6 times per day. In the interviews, players stated that they often played the exergame whenever they had some spare time or right after being active. The fact that the exergame took up little time was positive, as they did not end up getting lost in the exergame and “wasting” time.

In the next chapter, we will look at if the testers enjoyed the exergame and what changes they wanted to see done to the exergame.

Chapter 33

Game and Enjoyment Results

This chapter presents the experiment’s results as they relate to the enjoyment of the game and details about the game itself. The results from the second questionnaire will be presented first, followed by the results from the interviews.

The full data from the second questionnaire and interviews can be found in appendices E, and G, respectively.

33.1 Questionnaires

Question 13 in the second questionnaire consisted of several statements about the game that the testers were asked to grade on a Likert scale. Question 13.1 asked if the testers found the game fun. As seen in Figure 33.1, **78% of testers thought the game was fun.**

“I found the game fun” Likert scale answers

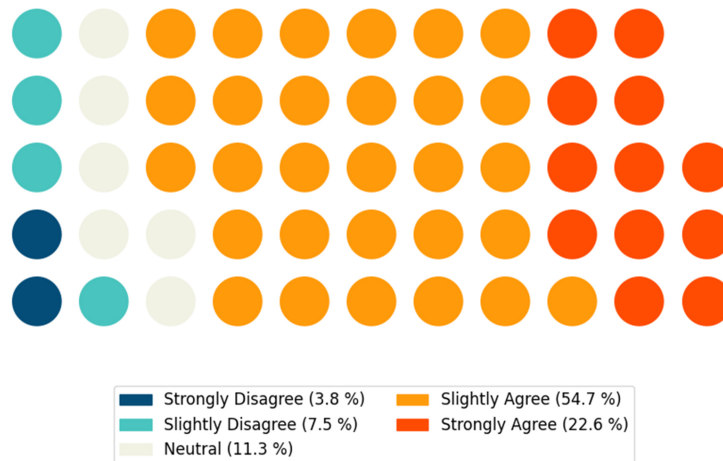


Figure 33.1: Answers to the statement “I found the game fun”

The rest of the statements from question 13 relevant to gameplay and game enjoyment can be found in Table 33.1. One factor important for game enjoyment is that the player understands and feels mastery of the game. The results show that **72% of testers agree that the game was simple and easy to understand.**

ID	Statement	Disagree	Neutral	Agree
Q13.5	The game was, for the most part, simple and easy to understand	11%	17%	72%
Q13.7	I like the use of active minutes and steps as an alternative to paying for game progression	6%	13%	81%
Q13.8	I think physical activity as an alternative for microtransactions and ads will make people want to be more active	4%	7%	89%

Note: This table combines the slightly and strongly disagree/agree categories. For more details, see Appendix E

Table 33.1: Questionnaire statements about the game with result

Question 13 also focused on the user’s thoughts about using physical activity as an alternative to microtransactions and other monetising methods in mobile games. Here the testers responded very positively, with **81% liking the use of active minutes and steps as an alternative to paying for game progression and 89% of thinking that using physical activity as an alternative to microtransactions and in-game advertisements will make people want to be more active.**

When asked if they wanted to continue playing the game after the end of the test period, 43% answered yes, and 30% answered that they did not know. The testers were also asked if they thought Radiation Mayhem was a game they wanted to play if it was fully developed. Here, 79% answered yes, and 13% answered that they did not know.

At the end of the questionnaire, several long-form questions asked if there was anything the tester liked, disliked, or found confusing about the game or if there were anything else they wanted to say.

From the comments, it is clear that the testers generally had a positive view of the game. Different testers found different parts of the game appealing. One nearly universally positive feedback was that the testers liked that the game encouraged them to be more physically active. Several testers pointed to the daily steaks and quests being encouraging. They also liked the mechanic of the player’s physical activity translating to energy in the game. One of the testers wrote:

“I actually wanted to go for a short run when I saw that I was missing ~400 steps to reach a big quest! Well done! In addition, I felt a bit guilty a couple of times when I took the bus home from school. My town needed money!”

33.2 Interviews

The interviewees were asked several questions about the game and how they enjoyed it. **The consensus among the interviewees was that the game was a great start and a base for further development.** The game had enough content to keep them engaged for the two-week test period. However, one of the interviewees expressed that the game would need more content to keep them engaged beyond the two weeks.

The interviewees were also asked if they felt any ownership of the community they built in the game. Here the feedback was mixed. All except one felt some degree of ownership over what they built. The degree varied from one tester “not” being able to delete what they had built to be afraid of losing what they had built to the spreading radiation.

The interviewees all had feedback on what they wanted to see changed in the prototype and what they would like to add to the game if they were in charge. **The main thing the interviewees wanted to see changed was the balance in the game’s economy.** Especially early in the test period, while their communities were small, the players would receive too much energy compared to money. This imbalance resulted in situations where the player would have more than enough energy to clean tiles and expand their area but not enough money to build anything on the newly clean tiles. This situation created a negative feedback loop where players expanded so much that they could not reach their resource goals. Not reaching the resource goals led to the community generating less money, making it even harder to afford the tiles needed to reach the resource goal and generate more money. Luckily, there were other ways of getting gold in the form of the streaks and some of the quests, meaning that the economic imbalance would eventually even out. The other things the interviewees wanted to see changed was an increased amount of quests and more variation in the game board’s landscape and visuals.

The interviewees were also asked if there were any new elements they would like to add to the game. Two of the interviewees suggested adding camera rotation to improve the visibility of the game board’s tiles. This mechanic would help the user see tiles that may be obstructed by tiles with large buildings or hovering elements. It was also suggested to add social functions where users could sign up to compete against friends. One interviewee suggested adding different types and tiers of buildings, for example, different levels of energy-producing buildings. It was also suggested to add a system where placing tiles next to each other would make the tiles merge and evolve into other tiles or layouts. One interviewee suggested adding hidden buildings or other water sources among the dirty tiles that could be discovered as the player expands their area, stating that it would add a “cool sense of risk and exploration”. Since buildings close to a water source are cheaper to build, finding a new one would be worth the risk of spending resources to explore the unknown. The interviewee also wondered if adding trade lanes between the different water sources would be a cool element.

It is interesting to note that many of these suggestions for changes and additions to the game were features we had considered adding but discarded due to time constraints. The list of game features discarded due to time constraints can be found in Chapter 26.

33.3 Summary

This chapter detailed the results as they relate to the game and enjoyment. Overall, the exergame got a positive reception from the players. The results from the questionnaire showed that 78% of testers thought the game was fun, and 72% thought the game was simple and easy to understand. The results related to the use of physical activity instead of microtransactions were also positive, with 81% liking using physical activity as an alternative to paying for game progression and 89% thinking that using physical activity instead of microtransactions would

increase physical activity level in players. Regarding the interviews, all agreed that the game was a good prototype with much potential if it were developed further. The interviewees came up with several recommendations and ideas for features to add to the exergame that would help increase player engagement.

Having presented all the different results from the experiment, we will look at some of the external influences that might have influenced the experiment's data.

Chapter 34

External Influences

This chapter explains some external influences that might have affected the experiment data. First, it explains technical difficulties and bugs that appeared during the testing, some more crucial than others. Second, it discusses the possibility of players cheating in the game and how it could have affected the game. Then it shows the weather data for the test period, as the weather could impact a person's willingness to go for a walk. Lastly, it details other factors that could have affected the results but were not linked directly to aspects of the game, like illness or scheduling conflicts.

34.1 Technical Problems

During the testing, some technical issues arose. As mentioned in Section 28.3, there was an issue where iOS testers did not get the money reward from the community. There was also a bug that could happen on iOS where testers could generate infinite resources and points. This bug was only discovered by two testers. Both these issues were fixed during the test period.

Some testers discovered minor bugs during the testing, which they reported back to us. These bugs were not critical, and there would be more work fixing them than the minor hassle for the tester of restarting the game or waiting for it to fix itself. The most significant bug discovered was "The midnight bug", which occurred if a player entered the game close to midnight, collected a daily quest reward, and exited the game after midnight. The game registered the quest as completed on the wrong day (after midnight) instead of the previous day. When the player wanted to do the quest the next day, they could not do it, as the game already thought they had completed it. The problem would go away the next day, and it was decided that it would be easier to inform the tester about the bug and how to avoid it than to make all testers update the game.

In the second questionnaire, three testers answered that they had found bugs during the test period. In addition to "The midnight bug", other bugs discovered were that the game stopped working on the last day of testing and that Google Fit did not register the person's activity.

Two testers had problems with Google Fit during the test period. If Google Fit does not register any activity data, the game does not get any data from Google Fit and, therefore, has no data to convert into energy. The reasons why Google Fit did not work were different for the two testers. One person just had to clear their Google Fit cache, but another did not get it to work until they got an Android software update. The Google Fit problem was not caused by Radiation Mayhem and was due to external conditions. While the game did not cause the problem, the issues caused some problems for the players, who lost playing time.

Two bugs were not reported during the test period or in the questionnaire. Still, they were

mentioned directly to us after the testing period was over. The first was that the database would only sometimes update the player's score. As the player's correct scores were stored locally on their devices, they did not lose any points over it, but their scores in the high-score lists were wrong. Two players reported this bug. Luckily it did not affect them too much as they knew what their game score should be and could see where they were supposed to be on the list. The researchers manually updated the final high-score list with the correct scores for these two players. The second was that the weekly quests reset themselves on Sunday instead of Monday during the last week of testing.

34.2 Cheating

According to the results from the second questionnaire, most of the testers did not cheat when playing the game. Two testers answered that they had cheated in the game, but only a few times. When asked why they cheated, they both said they wanted to generate extra steps to reach a reward goal and collect the reward. Specifically, they wanted extra money because they had far too much energy and needed more money to buy tiles.

There is a chance that people cheated while playing and lied about it in the questionnaire. While the questionnaire is supposed to be anonymous, the testers know there are ways of figuring out what player ID belongs to what person, which might make them not want to tell for fear of being judged. There is also the fact that the score lists are public, and by admitting to cheating, they fear that it might invalidate their score regardless of if the cheating had any impact on the scoreboard.

As mentioned in Section 34.1, a bug was discovered on iOS that enabled the players to generate infinite resources and score. The extreme cases were easily detectable in the database and were fixed as soon as possible. However, there is a possibility that some players used the bug for small boosts. These would not have been detected, as it would look like natural progress in the database. There is no way to determine if this happened, so the only way is to trust the testers when they answer if they cheated or not.

34.3 The Weather

Radiation Mayhem is a game mostly focusing on getting people out walking, jogging, or being active in different ways. The fact that the game relies on outdoor activity introduces the external factor of the weather. While some testers were testing the game in other locations, most were in Trondheim or the surrounding area. The weather data for Trondheim during the test period is shown in Table 34.1.

As the weather data shows, it was not ideal weather for being outside during parts of the test period. The temperatures were around 5°C on average, and many days had precipitation in the form of snow, rain, or hail. When it was not raining or snowing, it was mostly cloudy. The less-than-ideal weather could impact the result data, as people will be more inclined to take a walk in nice weather, and it is more tempting to drive or take the bus if it is snowing or raining.

Date	Min temp (°C)	Max temp (°C)	Average (°C)	Precipitation (mm)
24.04.23	0.3	7.2	2.7	3.9
25.04.23	0.5	2.8	1.2	0.6
26.04.23	0.4	7.4	2.4	3.6
27.04.23	1.5	3.9	2.7	2.0
28.04.23	1.8	11.3	5.3	5.7
29.04.23	-0.4	7.0	2.0	0.0
30.04.23	0.7	6.4	2.3	5.6
01.05.23	0.9	10.1	3.5	15.5
02.05.23	1.4	9.6	5.2	3.1
03.05.23	1.7	8.1	3.9	3.1
04.05.23	0.1	10.7	4.8	2.3
05.05.23	-0.6	12.7	4.8	0.0
06.05.23	2.4	16.8	8.6	0.0
07.05.23	3.8	17.4	9.5	0.0

Table 34.1: The weather data for Trondheim during the test period

34.4 Illness, Scheduling Conflicts, and Other Influences

The testing period ran from the 24th of April to the 7th of May. Because of the long testing period, there was a high probability that some testers would not be able to play the game throughout the entire period due to external reasons.

Question 15 of the questionnaire asked, “Were you sick, injured or had other circumstances that meant you could not test the game for large parts of the test period?”. As mentioned in Part VI, 20% of testers (11 testers) answered, “Yes - it had a big impact on the game”. Out of these 11 testers, 4 reported that they had decreased motivation for physical activity done outside, and 7 reported decreased motivation for exercise at a fitness centre or through organised sports. 7 out of 11 also reported that they went for fewer or shorter walks during the test period. These results show that it is fair to assume that testers being ill or injured would affect the results on motivation and activity levels negatively. However, this does not mean that all their results are invalid. Firstly, there is no way of knowing how much of the test period they lost because of the circumstances, and secondly, they could still have played the game enough to get a valid opinion on the game. There is no way of knowing if they would have played the game more, even if they had been able to, as the game is not suited for everyone, but the fact that many testers lost testing time is important to keep in mind when analysing the data.

Other external reasons that could affect the data are things like scheduling conflicts or that a tester, for some reason, was more busy than usual during the testing period. Such situations were not part of question 15, as the question focused more on more extreme cases and not just things that happen in day-to-day life. The most prominent factor that could affect the results is that the testing coincides with the end of the school semester and the beginning of the exam period. The exam period is a time when most students are very busy finishing their semester

courses, reports, and assignments, as well as starting to read for their exams. With deadlines and exams rapidly approaching, many testers likely had a dip in activity level because they had to prioritise the assignments and exams. While not all the testers are students, it is a high probability that most participants between the ages of nineteen and twenty-six, which is more than 60% of the participants, are students.

In fact, during one of the interviews, when asked if there were anything they would like to change about the testing, an interviewee said that they would have liked it if the testing was earlier in the semester as the testing came close to the exams and they did not have time to be as active as they wanted. Another interviewee mentioned that they lost some motivation because they lost their streak due to having to work on an assignment. During the days up to the deadline, they had been less active than usual, which impacted their gameplay.

Initially, the plan was to test the last two weeks of April so it would not be so close to the exam period. However, the testing was pushed back a week due to technical difficulties and bug fixing. While this ensured a better user experience for the testers and made it possible for iOS, it made the exam period overlap with the beginning of the exam period, which was not ideal.

There is also a possibility that a tester was more or less active than they usually would without a definite reason like illness or an exam, but just because they were tired or something unpredictable happened either at school, work or in their personal life. One interviewee mentioned that, for unknown reasons, they had just been less active during the test period as they, for unrelated reasons, had had less energy than normal. This lack of energy just happened to coincide with the test period, which made their data less representative of their activity level than if it had been two “normal” weeks. While there is no way of knowing if a tester’s reported increase or decrease in activity and motivation during the test period is due to the game and other external factors. It is important to remember that there are error margins when analysing the data.

34.5 Summary

This chapter discussed different external influences that could have affected the experiment results. First, it described some of the technical issues discovered during the experiment. Most difficulties and bugs were fixed during the test period, but some were so small that they would have been more work to fix than they were worth, or they were due to technical difficulties with external factors like *Google Fit* not registering steps. Second, it discussed the potential of cheating. Two testers reported that they had cheated a little during the game’s testing. Small-scale cheating should not significantly impact the results, but there is a possibility that more participants cheated but did not report it. Then, it presented the weather in Trondheim, where most of the testers resided, as the weather could have affected the person’s motivation for going outside. Lastly, it listed other factors that could have affected the person’s activity level, motivation, and ability to play the game. Factors like illness, injuries, schedule conflicts, and other unforeseen circumstances could negatively affect their results and the experiment data.

In the upcoming part, the team will discuss the results as they relate to the different research questions.

Part VII

Discussion

Part VII is the discussion of the results. First, it will relate the results to the different research questions presented in Chapter 3. Then it discusses different factors that could affect the validity of the project.

Chapter 35

Discussion of Research Questions

This chapter will address the research questions posed in Chapter 3 of this thesis and discuss the findings relevant to each of them. The findings have been collected throughout the entire project, from the literature review, which led to the creation of the game concept, the development of the prototype, and the data collection done during the testing of the prototype.

35.1 Research Question 1

***RQ 1** - How to create a new exergame that combines natural gameplay with physical activity?*

Exergames can be a tool for combatting global overweight and obesity problems by motivating players to be more physically active. Studies have shown that playing exergames give health benefits while being more motivating than traditional physical activity and exercise. When it comes to creating a new exergame concept, it is important to explore what makes some games successful and why some games fail. Researching different game genres and existing exergames gave a good overview of what existing games did to entice players. Looking at existing exergames also gave insight into how they incorporated activity or exercise into the gameplay. By having an overview of what makes a good exergame, it is easier to identify new exergame concepts that can help motivate more people to be active by incorporating activity as a natural part of the game.

Our research for a game concept found that most popular mobile games are simple idle/RPG/puzzle games that do not require much effort [134]. Many of these are free-to-play games that use the player's wish for faster game progress to entice them to pay for it through microtransactions. When players are invested in a game they find enjoyable and engaging, they are more willing to invest in the game, for example, by buying boosts through microtransactions. We found a lack of exergames that tried to take advantage of this successful formula used by mobile games. Therefore we decided on a concept that worked like a normal mobile phone game. However, instead of paying microtransactions to get game progress, the player needs to be physically active.

***RQ 1.1** - What existing technologies can be used to create an exergame?*

Countless technologies can be used to create exergames. As we argued in Chapter 13, exergames can cover all the same genres as regular videogames, meaning that the only difference between exergames and regular games is that exergames integrate some level of the player's physical activity into the game. Using the player's physical activity requires that the

game has some way of registering or gathering the player's movement or physical activity level. The myriad of different sensors and software that can be used for this purpose is detailed in Chapters 14 and 15.

Existing fitness apps and their corresponding APIs can be used by exergames to track players' activity levels and movements. Using a fitness tracking app and API allows an exergame to leverage the far more advanced tracking algorithms these services use, compared to what a small development team could realistically create themselves. It also allows for tracking the player's physical activity even when the exergame is closed. One disadvantage when using fitness-tracking apps and APIs is that some fitness apps, like Apple Health, have a delay between the player doing a movement and the fitness data from that movement being available [128]. This delay means that only some fitness-tracking apps can be used for exergames that require real-time data. Google Fit, for example, allows games to access fitness data in real-time [132]. Another inconvenience is that in order to utilise these APIs requires the players to have the corresponding app installed on their device. However, **if we had to build the tracing system ourselves, we recommend using an accelerometer and a GPS, as it is the easiest and most accessible way to track the movement of a device.**

RQ 1.2 - *How to create an exergame that is fun and engaging for the player?*

Our findings suggest that an exergame can be designed within any of the traditional game genres as long as it incorporates some level of physical activity or exercise as part of its game mechanics. The most important factor is to make the exergame enjoyable to play. Many theories detail how to create an enjoyable game. The two we have identified as the two "main pillars" of game enjoyment theories are *GameFlow* [28] and *Malone's model of Challenge, Fantasy, and Curiosity* [30]. Along with these two, there are other aspects we recommend utilising when creating an exergame, namely *reward systems*.

A game should aim to let the player reach a state of flow. Being in a flow state, the player can let go of everyday worries and concentrate on enjoying the game [28]. The *GameFlow* framework presents eight criteria a game can utilise to reach a state of flow. The player must be able to *concentrate* on the game. To accomplish this, the game must provide something worth concentrating on. **The game must provide the right level of challenge, balanced with the player's skill level.** The player must be able to feel in *control* of the game. The player should feel as if the game's interface "disappears" when they play and that they are controlling what is in the game directly. The *goals* of the game should be *clear*; the player should at any point know what they are doing and what they should be doing next. The game should also provide *feedback* to the player; when the player does something in the game, the game should respond logically. The last two criteria are *immersion* and *social interaction*. These are often antithetical to each other but can create a lot of enjoyment. If the game goes for *immersion*, it should be designed to have as few distractions for the player as possible and allow the player to roam and immerse themselves in the game world. *Social interaction* can often break immersion, but many players find it highly enjoyable to play with friends and be social. This trade-off might lower overall immersion and sometimes Flow, but it is often worth it.

Another prominent game enjoyment theory is *Malone's model*, which highlights three charac-

teristics of engaging video games: *Challenge, Fantasy, and Curiosity* [30]. As with GameFlow, Malone's model recommends that games balance their *challenge* with the player's skill level. In addition, Malone recommends providing *clear goals* to the player, split over *multiple levels* of goals. This way, the player always knows what they need to focus on when playing. Malone also recommends introducing *outcome uncertainty*; this ensures that the game will always have some variance and that the player will not be able to predict the game's outcome every time they play. Immersion is another big key to player engagement and enjoyment. To make the game feel immersive, the player should be presented with challenges rooted in the game's *fantasy*, making the game feel *intrinsic*. Another factor to help the player become immersed is *curiosity*. Games should engage both the players *sensory* and *cognitive curiosity*.

How a game rewards its players is an integral part of how the players will perceive and enjoy the game [40]. Research shows that **using several different reward "affordances" will lead to greater player enjoyment** [38]. There are four classifications of rewards: *Glory, Sustenance, Access, and Facility*. These different reward classifications can be implemented through a variety of *reward systems*. Generally, a game should reward what it wants the players to do. For example, in Radiation Mayhem, the players are rewarded for being physically active, expanding and maintaining their community, and completing quests.

Radiation Mayhem was designed with all of these theories in mind. While Radiation Mayhem has room for improvement, **a large percentage of testers still stated that they found the game enjoyable and engaging**. This feedback indicates that using the mentioned theories when developing a game will result in a fun and engaging game for the player.

35.2 Research Question 2

RQ 2 - *How does our exergame impact the player's motivation for physical activity?*

One of the main goals for Radiation Mayhem, and this thesis, was to research if and to what extent motivation for playing a game could help motivate people to be more physically active by increasing or replacing missing motivation for physical activity or exercise.

The result shows that **playing Radiation Mayhem increased the players' motivation for physical activity. 66% of the participant agreed that playing Radiation Mayhem increased their motivation**. In another question, 64% of the participants answered that Radiation Mayhem increased their motivation. The remaining 36% answered that they had the same level of motivation as before, and zero participants answered that playing Radiation Mayhem decreased their motivation.

The results showed decreased motivation for exercise and organised sports. This result was a bit of a surprise, as Radiation Mayhem should, in theory, not have a huge effect on players' motivation for exercise. While there is a possibility that players lost motivation for exercise in favour of motivation to go on walks, it would mean they lost their existing intrinsic motivation for exercise, which is unlikely. A more likely reason for the loss of motivation for exercise is that it is due to external factors. Out of the 11 participants reporting that they had been injured or ill and that it had greatly affected their ability to play the game, 7 reported decreased motivation for exercise. These participants alone account for a large part of the decrease in

motivation for exercise. Other reasons for the decrease in motivation could be due to external factors mentioned in Chapter 34.

Other results from **the questionnaire also showed positive results regarding the game's ability to motivate participants to be physically active. 89% of the participants reported that they went for walks they would otherwise not have gone on had they not been playing the game**, showing that the game was able to motivate them to increase their activity level. 55% reported that the game motivated them to walk, jog, or bike places instead of driving or using other means of public transport. This result is especially promising considering the poor weather during the test period (see Table 34.1). When asked, 15% of testers agreed that they went for walks despite bad weather. Several interviewees mentioned that the different game aspects, especially streaks and daily goals, motivated them to be more active in order to reach their goals. In fact, 76% of participants reported that they found the daily quests motivating. Some interviewees also answered that if they were bored, they decided to go for a walk instead of doing other leisurely activities.

This thesis wanted to investigate if replacing microtransactions with physical activity requirements could improve motivation for physical activity. Before the test period, 77% of the participants wished there were alternative methods of getting in-game bonuses and faster game progression. After the test period, 81% of the participants thought that physical activity goals were a good alternative for getting in-game bonuses and a good alternative to microtransactions. 89% thought that using physical activity in this way would increase people's activity levels. These findings show that **players are willing and motivated to use physical activity to gain game progress**. This result also means that exergames such as Radiation Mayhem has the potential to significantly increase players' motivation for physical activity by leveraging the techniques that the mobile game industry has developed to entice players into paying for microtransactions.

These results show that the game Radiation Mayhem can achieve the first step of getting a person to develop autonomous self-regulation, which is crucial if they want to start an activity or exercise regime [24]. Suppose someone lacks the motivation for physical activity. In that case, the two ways of increasing their motivation are either by finding other extrinsic motivators or increasing their intrinsic motivation for physical activity. Radiation Mayhem does the first by adding the extrinsic motivation for physical activity using the player's intrinsic motivation for playing the game. When trying to adapt or start a new activity or exercise regime, the most challenging part can be changing one's existing daily routines and habits. The game was motivating enough that 32% of the participants changed their daily habits to be more physically active by walking, running, biking to school or work, or adding daily activities to their schedule.

For a person to achieve autonomous self-regulation, some basic psychological needs must be met. These needs are part of Basic Psychological Needs Theory (BPNT) and are the need for *autonomy*, *competence*, and *relatedness* [26][27]. The player plays the exergame of their own accord. In the same vein, Radiation Mayhem does not force the player to be physically active, meaning that when the player goes for a walk, it feels self-endorsed and authentic, fulfilling the *need for autonomy*. The exergame also covers the *need for competence* by adhering to the challenge and skill principles from *GameFlow* and *Malones's model* [28][30]. The exergame matches its challenge with the player's skill level. As the player expands their community, the

challenge will grow, eventually reaching an equilibrium. The exergame also provides multiple levels of goals in the form of quests, streaks, and a score system. *The need for relatedness* is covered both within and outside of the exergame. Within the exergame, the player creates a unique community they are solely responsible for protecting. Outside of the game, there are other players that the player can relate to with how well they are doing score-wise compared to them.

The results from the questionnaire and interviews show that **the exergame was effective in fulfilling the three basic psychological needs**. 72% of the participants agreed that the game was easy to understand. Regarding relatedness, “Points up to the next player” was one of the most popular in-game elements. Some interviewees also said it was fun to compare their community, score, and overall progress with other people they knew were playing, as it gave an extra sense of competitiveness and motivated them to beat their friends. The interviews also mentioned that while they were competing against each other, the game also motivated them to go on walks together and enjoy each other’s company.

35.3 Research Question 3

RQ 3 - How does our exergame impact the player’s physical activity level?

The results from the experiment show that the participants reported an increase in physical activity levels during the test period due to the game. During the test period, **the number of weekly walks reported increased by 138% compared to before the testing, and the length of the walks increased by 6%**. The percentages are not entirely representative as some participants did not go for walks before the test period but started walking because they were playing the game. In particular, one participant went on zero to one walk per week before, but during the test period, they went on twenty-one walks each week. **89% of the participants reported that they did go for walks that they would not have done if they were not playing the game**. On average, each tester went on four more walks per week during the test period.

When it comes to the activity itself, WHO recommends that the average adult get 150 to 300 minutes of moderate-intensity activity every week, as well as some strength training [9]. In 2023, *Helsedirektoratet* (the Norwegian Directorate of Health) and *Folkehelseinstituttet* (Norwegian Institute of Public Health) updated these recommendations, as well as how they calculated if a person reaches the recommendations. In previous years, when tracking a person’s weekly activity, they had excluded all activities lasting less than ten minutes. However, in the most recent study, they included all activities regardless of length, as they had found that any activity was better than no activity at all and should count [23]. We used the recommendations as a foundation for the activity goals in the game, as the recommendations are based on research and recommendations from health specialists.

The recommendations from *Helsedirektoratet* and *Folkehelseinstituttet* were incorporated into the game through weekly quests and the streak. The quest’s goals were taken directly from the recommendations, with the easiest weekly quest requiring 150 active minutes and the harder weekly quest requiring 300 active minutes. Having the recommendations as concrete quests

made it easier for the players to track their progress against the recommendation, allowing them to see how their physical activity level compared to the recommendations.

During the first experiment week, 70% of the participants completed the first weekly quest of 150 active minutes, and 64% completed the second weekly quest of 300 active minutes. During the second week, 79% completed the first, and 57% completed the second. The results for the first quest are approximately the same as the equivalent age group from the 2020-2022 survey results⁶⁷ (see Figure 7.2 and 7.3). The results from the first week are slightly lower, but this is most likely because some iOS testers could not get the game installed until the end of the week and, therefore, did not have enough time to reach the goal for that week. However, **the results for the second quest are 15-23% higher than the equivalent age group for the first week and 8-16% higher for the second week. This result shows that players of Radiation Mayhem had a higher likelihood of reaching a higher recommendation level for weekly physical activity compared to the national averages for the same age groups.** These results are positive for the health of the players, as a large percentage of the population should strive to reach recommendation 2 due to their sedentary lifestyles.

The streak goal was also based on the recommendations, as having 25 active minutes each day throughout the week would surpass the 150-minute goal by the end of the week. In addition, there were also daily quests meant to motivate the players to do some level of physical activity during the day. The results from the questionnaires and interviews show that the streaks and quests were motivating and made players more active. Several interviewees stated that if they were close to reaching a goal, they would go for a walk instead of doing other leisurely activities.

It is important to consider that our game only tracked movement through the tester's phone (and, in some cases, smartwatch), while the survey tracked all activity [23]. If a tester did any activity without carrying their phone around (like if it was placed on a table), the activity would not be registered. The same is the case for exercise at a fitness centre or outside if they are running without a smartwatch or without their phone in their pocket. Some testers had a smartwatch connected to the fitness app, but most testers did not. One thing to note is that the game tracked any activity regardless of intensity. The recommendations from WHO depend on the intensity of the activity. They recommend a minimum of 150 minutes of moderate-intensity activity or 75 minutes of high-intensity activity [9]. Our exergame calculates all forms of activity the same, regardless of intensity. One minute of sprinting and one minute of walking at a normal pace are counted as the same. This way of registering activity leads to situations where the game tracks activity that should not count against the 150-300 minutes. However, it also tracks activities that should count "more" towards the recommended minutes due to the activity being performed at a higher intensity. These considerations, combined with the fact that some types of activities were not tracked by the game at all, we think the different effects more than cancel each other out. Many participants reached their weekly goal relatively early in the week (see Figure 32.9), so they would likely have reached them, even if the game was overcounting.

⁶Comparisons to the FHI survey are made against the 20-34 age group, which corresponds to the age range of >90% of our test population.

⁷FHI also has a third recommendation. Recommendation 3 states that people with more than 8 hours of daily sedentary activity should follow recommendation 2. This thesis has no data on whether any testers achieved recommendation 3, as we do not know how sedentary our testers were.

While the steak and daily, and weekly quests all used active minutes because they were based on the recommendations from WHO, non-repeating quests used the number of steps. One reason was to get some variety, but another reason was that steps are another way to calculate a person's activity. The results from the non-repeating quests show that eight participants walked more than an average of 12 500 steps daily over the two-week testing period. Twenty-four participants (45% of all participants) reached the goal of quest 7, which was to have more than an average of 6000 steps daily. In the questionnaire, 42% said they were willing to be more active because they wanted to reach challenging goals.

One thing to note is that for the iOS testers, active minutes were converted to steps, as Apple Health does not track active minutes (See Section 21.3). While we tried to convert to steps as accurately as possible, there were likely some approximation errors. In fact, one interviewee mentioned that, in some cases, it felt easier to reach some of the goals on iOS than on Android.

35.4 Research Question 4

RQ 4 - *How do different parts of our exergame motivate players to be physically active?*

When creating Radiation Mayhem, one of the focuses was to implement as many elements as possible that would help foster player motivation. **Different game elements are likely to motivate players differently, and having more elements ensures that most players find at least one element that motivates them.** This approach is in line with the theory showing that using multiple affordances correlates with higher game enjoyment and motivation [38].

In the second questionnaire, the players were asked to rate eight different in-game elements based on how much they motivated them to be physically active. The elements with the highest overall score were *"completing quests to get resources"*, *"maintaining streaks to get bigger bonuses"*, and *"getting faster game progress"*. However, none of these elements got the most first-place ratings. That title went to *"points up to the next player"* with ten first-place ratings. It only placed fourth in the overall ratings, but there were only nine points up to third place. Other elements that got many top rankings were the previously mentioned *"maintaining streaks to get bigger bonuses"* and *"getting faster game progress"*, with nine and eight first-place rankings. *Position in the high-score list* also got eight first-place rankings. Interestingly, *"Completing quests to get resources"* only got seven top rankings. However, it still won the overall rating, as 41 out of 53 participants ranked it among their top four, showing that most participants found that element motivating.

On the other end of the scale was *"The desire to build a nice and optimal society"*, *"Complete the most challenging quests because they are challenging"*, and *"The risk of losing areas if you do not play"*. *"The desire to build a nice and optimal society"* was third to last, with five top rankings and seven last-place rankings. *"Complete the most challenging quests because they are challenging"* was rated second to last with five first-place ratings and eleven last-place ratings, and *"The risk of losing areas if you do not play"* was at the bottom with one first-place rating and twenty-two last-place ratings.

The feedback in the questionnaire and interviews showed that due to the imbalance where the players had much more energy than money at the start of the game, there was never any real risk of losing tiles, so the players never feared this would happen. There was no direct feedback

on why "Complete the most challenging quests because they are challenging" got such a low rating. However, it is likely due to different player types, as it would appeal primarily to *achievers* that wanted to challenge themselves and "complete" the game [37]. This theory is strengthened by the fact that 6 out of 7 of the top-scoring players put this element in their top three. When it came to the desire to build a nice and optimal community, the issue was the lack of opportunities to personalise the community. Since the game contained only a small variety of tiles, it was challenging for the players to be creative when building their communities. When it came to optimising the community, there were specific ways to build the community that would make it more efficient and able to generate more resources. Both resource goals and tile placement would affect how much money the community generated. However, the feedback showed that this was not clearly explained to the players, so most of them did not understand what they needed to do.

When asked about some of the elements in more detail, 76% agreed that the daily quests motivated them to be active every day, and 55% agreed that weekly quests motivated them to be active throughout the week. 42% reported that they were motivated to try to do the challenging quests because they were challenging. This fits well with the feedback from the interviews; **participants were willing to be more physically active if the task did not feel too daunting. They found that if they were only 5-15 minutes away from reaching a goal, they were more motivated to do it, as the additional effort felt worth the reward.** If the goal was too far away, it was perceived as a greater effort and something that had to be planned rather than something to do on a whim when the participants had some spare time. This result is backed up by the *Multiple level goals* recommendation from *Malone's model* [30].

All in all, the results indicate that **the most popular and motivating elements were individual tasks that were relatively easy and did not require a tremendous amount of planning or effort.** While the game had elements that allowed players to compete against each other, the results show that they were less effective on a large scale, as people who fell behind in the rankings felt that they had no way of catching up to the top-ranking players. On the other hand, "Points up to the next player" gave the players more achievable goals, which the results showed were more motivating. These findings align well with the challenge theories from *GameFlow* and *Malone's model* [28][30]. Both *GameFlow* (and its progenitor *Flow*) and *Malone's model* state that one of the most important factors for game enjoyment is to balance the game's challenge with the player's skill. In this case, the "overall" goal of getting a top score is too difficult for most players. However, following *Malone's* recommendation of using *Multiple level goals* and *Variable difficulty*: the "points up to the next player"-element becomes an intermediary goal that is more in line with any given player's skill level. Thus it is more motivating. The popularity of the daily quests and the streaks also show that our design of having *repeat rewards* to motivate players to be physically active worked well (see Section 20.4).

35.5 Research Question 5

RQ 5 - How does our exergame affect the player's enjoyment and engagement?

Radiation Mayhem had high levels of enjoyment and engagement during the test

period, with 78% of the testers reporting that they thought the game was fun. On average, a player visited the game 90 times during the test period, which is an average of 6 visits per day. This result is not entirely representative of the average player, as some players visited the game far more than others. However, over half of the players played the game more than 50 times during the two weeks.

Question 9 in the second questionnaire asked the players to rate different game elements based on how much they motivated them to be physically active and play the game. It is very likely that the elements the players find motivating also reflect what elements they find enjoyable and engaging, as motivation for physical activity is very tied together with the gameplay and game progress in Radiation Mayhem. The results showed that the game elements that got the highest overall ratings are quests, streaks, the wish for faster game progress, and points up to the next player.

Which elements the players found most engaging varied depending on the type of player. **The players at the top of the scoreboard tended to find the aspect of achieving challenging quests just because they were challenging and engaging. 6 of the 7 highest-ranked players placed it in their top three for elements that motivated them.** These top-scoring players fit well with Bartle's *achiever*-player type [37]. These are players who go the literal extra mile to get the highest score possible. In contrast, other players were more focused on reaching quest goals to get resources, maintaining streaks, expanding their community, and getting past the person in front of them on the scoreboard.

The "*Points to the next player*"-element was the element that got the most first-place ratings when it came to motivating players to be active and play the game. The large number of reads to the database indicates that there was lots of competition and that players passed each other's scores a lot during the two weeks. Players reported that they liked the element because it was a more achievable goal than reaching the top of the high-score lists. These results align with both *GameFlow* and *Malone's model*, which both state that the challenge of the game should be adjusted to the player's skill [28][30]. They also state that the game should have multiple levels of goals so the player can focus on the intermediate goals on their way to the bigger ones. In this case, surpassing the next player on the board is a more attainable goal, in line with the player's skill. "*Points to the next player*" also gave Radiation Mayhem a way for players to interact and compare themselves to other players. Comments from the interviews and the long-form answers show that the players who knew others who played the game often met up and compared their community and score with each other. Players enjoying the possibility of interacting with other players matches well with game enjoyment theory. *GameFlow's* Social Interaction elements recommend games to include social elements to increase player enjoyment and engagement [28]. The creation of small "communities" also aligns with how *GameFlow* predicts that players wanting social connections through their games will act.

The quests and the streak system were two other popular systems. Many players reported that they liked trying to uphold their streak throughout the test period and felt upset if they lost out on it. Maintaining the streak and getting bigger bonuses scored second highest on the overall ratings on what motivated the players to be active and engage with the game. This implies that it was one of the most engaging elements in the game. Players being afraid of losing their streaks also indicates that the streak system works as intended by utilising the *Loss & Avoidance driver* from the Octalysis Framework [34]. The quests were also

the source of a lot of game engagement. In total, 765 quests were completed during the test period. These consisted of 539 daily quests, 143 weekly quests, and 83 non-repeating quests. **On average, 43% of players completed a daily quest on any given day. The weekly quests were also popular, with 70% of the players completing at least the first weekly quest the first week and 79% the second.** The players' engagement with streaks and quests fit neatly into *GameFlow's* "Clear goals"-element [28] and *Malone's* recommendation of using *Multiple Level Goals* [30]. The streak and quests give the player something to focus on as short-term, achievable goals. The setup of having multiple levels of quests also fits with *Malone's* recommendation of using multiple levels of goals.

One of the core features of *Radiation Mayhem* is the ability to collect resources to spend on cleaning tiles and developing the community. The three elements that got the overall highest rating from players all focused on resource collection and faster game progress. **The fact that the core element of the game was rated that high is an endorsement of the game's main gameplay loop.** One of the reasons this element resonates so well with so many players is that it is well-rooted in game enjoyment theory. Whenever the player collects resources, a pop-up text showing how many resources the player just collected appears and a short audio clip plays. Their total score (displayed in the UI) also ticks up. These elements are called *Feedback messages* and are from the *Glory* category of rewards [39][40]. Collecting resources also allows the player to do more actions in the game, meaning that this system also can be classified as a *Resource reward system* from the *sustenance* category.

Some players found the game enjoyable enough to continue playing it after the test period ended. While the iOS players lost access to the game, the 34 Android players could continue playing. In the first week following the test period, the game got approximately 531 visits, with an average of 538 reads and 147 writes daily. Over the two following weeks, the game got approximately 437 visits, with the average daily reads and writes being 130 and 53, respectively. **This data shows that the game concept can keep players engaged even though the test period was over and the game was not updated with new quests or features.**

35.6 Summary

This chapter discussed the research questions presented in Chapter 3 by looking at the findings and results generated by this project.

Chapter 36

Reliability and Validity

This chapter will discuss the reliability and validity of this project and how different factors could affect the results of the thesis. In addition to the external factors mentioned in Chapter 34, other factors could have affected the experiment results that were not directly related to the experiment execution. This chapter discusses these factors, how they could have affected the experiment, and how we tried to avoid them. First, it presents the novelty effect. The novelty effect is a phenomenon where testing new or existing technology can lead to inflated and sometimes unrepresentative engagement. Second, it presents the phenomenon of familiarity bias. Familiarity bias is when testers act or answer favourably because they know the people doing the research. Next, it discusses the probability of leading questions that could result in favourable data. It also reflects on how the experiment execution could have affected the results and what could be improved. Lastly, it discusses if the results from this project could be applied to similar games and studies.

36.1 The Novelty Effect

The novelty effect is a phenomenon where the introduction of new or improved technology results in a massive surge in interest and popularity among the population due to it being “cool” or “trendy”. However, as the surge in interest is due to hype rather than actual interest in the new technology, the interest quickly falls after the initial interest burst ends. There is a possibility that the novelty effect had some impact on the testing, as the exergame was new, and the test period was relatively short. However, any potential novelty effect likely disappeared after the first couple of days and did not affect the rest of the results too much. Neither idle city-builder games on mobile nor exergames on mobile are entirely new concepts. As Radiation Mayhem has some similarities to Pokèmon Go, the concept is not new to the players, which most likely reduces the novelty effect.

36.2 The Faimiliarity Bias

The composition of the test group could have had an impact on the results. As mentioned in Section 27.2, most of the testers recruited are friends, family, and acquaintances. This familiarity could affect the results, as some might play the game because they want to help and not because they find it interesting or engaging. It is also possible that they answer the questionnaire more favourably because they want to give results that will support the study. While there is no way of knowing how much the familiarity bias impacted the results, several things were done to reduce the effect. We asked the testers to answer the questions as

truthfully as they could. The use of a player ID also gives the participants a sense of anonymity when answering, which could make them more comfortable with answering truthfully.

36.3 Leading Questions

Leading questions are formulated in a way that proposes or encourages a specific answer. While the questions ensure that the interviewer gets a favourable answer, the only thing achieved is to invalidate some of the data. While we tried to keep the questions in the questionnaire and interview as open and neutral as possible, there is a possibility that some of the questions were more leading than intended. Especially in the interviews, where there were some open conversations, some questions might have been more leading than they should have been. To ensure that the questions were as neutral as possible, we asked our supervisor to review all the questions in the questionnaires. In addition, if one of the interviewers found that a question that was asked was too leading, they would mention it afterwards to try to contain the damage.

36.4 Experiment Execution

The testing period ran over two weeks, from the 24th of April to the 7th of May. A two-week test period was good, as it gave the testers plenty of time to try the game, and if participants got sick or indisposed for a few days, they would still have time to test the game. Ideally, the testing period would be even longer, but because of the time limitation of this project, this was not possible. A longer test period would show clearer user trends over extended periods and could indicate if the game could change a player's activity level over an extended period.

There was no observation of testers during the experiment. The idea behind the exergame Radiation Mayhem is that it mostly lets the players go about their day as normal and that it is only played for a couple of minutes when the players have some spare time. Following people throughout the day to see if they are playing the game would be unnatural and overly complicated, and forcing them to meet up and play in front of us would take the game out of its natural context. This setup would not have been ideal as it would invalidate the data. While observing players might have given us some useful data, like player strategies, other data would likely be forced and unnatural; therefore, there was no observation of testers.

36.5 Generalisability

The findings of this thesis can be applied to similar games and settings because they build upon proven concepts such as the desire for faster game progress and the willingness of players to pay for it through microtransactions. In Radiation Mayhem, physical activity and exercise replace microtransactions, but other than that, the game acts as any other idle city-builder mobile game. One thing to consider is that the main demographic of this test group is people who are young and used to technology, which might not be representative of other test groups. However, smartphones and apps have become a part of most people's daily lives regardless of

age. Therefore, it is reasonable to assume that a game that uses similar methods to generate player motivation would get results similar to ours as long as the demographics of testers have some experience with using smartphones in their daily lives.

36.6 Summary

This chapter went through different factors that could have affected the reliability and validity of the project. First, it discussed the novelty effect and if it could have impacted the results. While there is a possibility that it affected the results initially, the length of the test period, combined with the fact that an exergame on mobile is not a new phenomenon, indicates that the novelty effect did not affect the results much, if at all. Second, it discussed the familiarity bias, which is that participants act or answer questions favourably because they want to help us get a positive result. To try to reduce this effect, we asked the participants to answer truthfully, and the use of player IDs should give the participants a sense of anonymity, which could make them more comfortable answering truthfully. Third, it discussed the possibility of leading questions in the questionnaire and interviews. We took precautions to ensure the questions were as neutral as possible, but there is a possibility that some questions were more leading than they should have been. Then, it discussed how the execution of the experiment itself could have affected the results. It also explained why there were no observations during the experiment. Lastly, it discussed if the results from this study are generalisable and could be applied to similar games and settings.

In the next part, we will draw our final conclusions and discuss potential further work.

Part VIII

Conclusion and Further Work

Part VIII is the conclusion of the thesis. First, it summarises the thesis and concludes the research goals and questions based on the results from the discussion in Chapter 35. Then it concludes the thesis by suggesting further research on the topic of exergames and the potential further development of the game itself.

Chapter 37

Conclusion

This project aimed to develop and evaluate an exergame that focuses on increasing the player's motivation for physical activity. To achieve this, we did a literature review, created an exergame concept, developed a prototype, completed an experiment on the prototype, and analysed the data from the experiment. The goal of the literature review was to see if there were any research gaps and find information to help us create a fun and engaging exergame concept. The concept was created by brainstorming different game concepts and exploring if there were any research gaps in existing exergame research. The game prototype focused on implementing features that motivated the players to play the game and be physically active. Fifty-three volunteers tested the game, and user data was collected through questionnaires, interviews, and database data. The collected data were analysed and used to answer the research questions.

When creating a new exergame that aims to combine natural gameplay with physical activity and exercise, it is important to have a basic understanding of how and why games and exergames work, as well as an overall understanding of health, activity and exercise (RQ1).

When it comes to existing technologies that can be used to create exergames, we think that any game design could be converted into an exergame as long as the exergame integrates the player's movement or physical activity level, either as a direct part of the gameplay or that it impacts the game in other ways. If the goal is to track player fitness or movement data using a smartphone, we recommend leveraging existing fitness-tracking apps and their corresponding APIs. Using existing fitness-tracking APIs enables a game to leverage the sophisticated activity-tracking algorithms the corresponding apps use when calculating a person's activity, saving development time. Most, if not all, fitness-tracking apps collect data even if the app is not running. The API gives the exergame access to all the player's data regardless of whether the exergame is active or not (RQ1.1).

For exergames to work, they must be engaging and work well as games in their own right. We investigated theories behind game enjoyment and have concluded that following the *GameFlow* criteria and *Malone's* model of *challenge, fantasy, and curiosity* creates a good foundation for an engaging and enjoyable game. We also recommend utilising *reward systems*. Reward systems can help guide the players by rewarding them when they do what the game wants. Reward systems also help engage a broader segment of players, as different player types react differently to different kinds of rewards (RQ1.2).

Exergames need to be able to motivate players to play the game and be physically active. *Radiation Mayhem* achieves this by having multiple features that induce player motivation while simultaneously combining game progress with physical activity. These features were designed to leverage the findings of both game enjoyment theory and motivation theory—namely *GameFlow*, *Malone's* model, *reward systems* and *BPNT*. The results showed that playing the exergame increased players' motivation for physical activity in most participants. Participants

reported that they wanted more resources, which motivated them to go for a walk to fulfil their streak and quest goals. Replacing microtransactions with physical activity is a great solution that received much positive feedback from the participants. Players want faster game progress, and instead of using money, they do something beneficial for their health. Based on these results, it is reasonable to conclude that Radiation Mayhem creates player motivation for playing the exergame, subsequently creating motivation for physical activity (RQ2).

It is clear that playing Radiation Mayhem positively affected the player's physical activity level, as the number of reported walks more than doubled during the test period. The percentage of people reaching Folkehelseinstituttet's second recommendation of 300 active minutes each week was also significantly higher than what Folkehelseinstituttet found for the corresponding age group (20-34 years old) in their 2020-2022 study. Note that some of our testers fall outside the corresponding age group, but these are very few. The exergame relies on the player's physical activity level to work as intended to incentivise the player to be physically active; if the player can play the game at a satisfying level without being active, they have no incentive to be active. By encouraging them to be active to get satisfying game progress, the exergame ensures that the player gets some level of physical activity. Having the WHO recommendations as quest goals ensures that the players who complete the quests reach a level of physical activity that is beneficial for their health. Since the players depend on the rewards to get satisfying game progress, many will put in the extra effort to reach the goal, and when they reach it, they will get two rewards; the in-game resource reward and the knowledge that they have done something positive for their health (RQ3).

Radiation Mayhem contains multiple different features meant to foster player motivation. The most popular elements were all individual tasks that focused on resource collection and getting faster game progress. Looking at the results, we can conclude that players are most motivated by tasks that feel obtainable and are relatively easy to achieve. As long as the value of the reward outweighs the effort the player has to put in, they are willing to do the task. If the task feels unachievable, the player will likely ignore it, or it could demotivate them as they would feel like it is no way they could achieve it. These results align with the existing theories of GameFlow and Malone's model (RQ4).

The results show that the players greatly enjoyed playing Radiation Mayhem and that it positively impacted the player's enjoyment and engagement. The exergame's resource reward system, which is a core part of the exergame, made players want to engage with it, indicating that even just the core features of the exergame can provide an engaging and enjoyable experience for the players. We recommend having many different game features to ensure the exergame is engaging and enjoyable for as many as possible. If a game has many different features, a player will likely find some part of the game fun and engaging, which is enough to make them want to continue playing it (RQ5).

This project's goal was to "*Develop and evaluate an exergame that focuses on increasing the player's motivation for physical activity*". The findings in this study show that the game Radiation Mayhem was an enjoyable game that helped increase the player's motivation and level of physical activity. In fact, Multiple testers continued to play the game after the test period ended, even though no new quests or features were added. This result confirms that the game is more than capable of keeping players motivated and engaged with the game. The next chapter will discuss potential future research and development of Radiation Mayhem.

Chapter 38

Further Work

This chapter goes through potential future work on the exergame Radiation Mayhem. First, it presents potential future research that could provide more information on the effect of playing Radiation Mayhem. Then it discusses further development of the exergame and lists some changes and new implementation ideas based on the feedback from the experiment and our ideas that were not implemented due to the time constraint.

38.1 Further Research

Future studies on Radiation Mayhem should try to get user groups of other demographics. While our experiment had testers of different age groups and in different life situations, most were students between the ages of 20 and 30, and these are people who have grown up with gaming, game consoles, and smartphones and use them in their day-to-day life. Further research is necessary on other user groups who are less used to technology and gaming to see if the game has any effect on their motivation and physical activity level.

The long-term effect of Radiation mayhem also needs further research. The results from the questionnaires show that most players found the game fun, and as mentioned in Chapter 35.5, some testers are still playing the game even with its limited features and no updates. Further testing, with an extended test period and a more complex prototype, can explore Radiation Mayhem's ability to retain players and whether a more complex version of the exergame can increase player retention. The prototype needs to be more complex for long-term testing, as the current prototype was designed for a two-week test period.

Running a test over an extended period can also explore how Radiation Mayhem affects the player's long-term intrinsic and extrinsic motivation towards physical activity. *Self-Determination Theory* states that activities that fulfil the three basic psychological needs will foster intrinsic and well-internalised extrinsic motivation [26]. Games have been shown to fulfil these requirements [41]. It has also been shown that intrinsic and extrinsic motivation is vital for starting to be physically active and participating in long-term physical activities [24]. The missing link is to prove that games can increase motivation for long-term physical activity. We believe that a more developed version of Radiation Mayhem can be a suitable artefact for a long-term study on whether using exergames will eventually internalise and foster purely intrinsic motivation for physical activity in participants.

Our results show that people want an alternative to microtransactions and ads and are positive about using physical activity as an alternative. Using physical activity as payment is a double positive, as they do not "waste" money on unnecessary things and, at the same time, improve their health. Future research is required to study other ways of incorporating activity as a

payment method in games. As far as we can tell, there are not many studies on the topic, and more studies are needed to get a better picture of the overall effect using physical activity as payment for game progress can have on the player.

38.2 Further Development

The answers from the questionnaires and interviews show that while the game was fun and interesting for the players, some things could be improved to enhance the player experience. Implementing some new features would make the game more engaging for the players, as they would get more things to do in the game. With the short development time, the prototype could only have a limited number of features, but with a longer development time, it is possible to implement more complex features. Improving player engagement is essential to achieve long-term motivation and making the players want to continue playing the game. Other aspects of the game, like usability, could also be improved. Making it easier for players to move and navigate around on the map would make it easier to play, which also could increase player enjoyment. Some possible additions and changes to the game are listed below. These changes are based on the discarded functional requirements presented in Section 22 and the feedback from the players.

- Adding new, different types of tiles.
 - Adding other types of energy tiles that uses renewable energy methods to generate energy. The different methods store energy at different rates and can be more or less reliable.
 - Adding other community tiles which improve the community and make it more visually pleasing, as well as diversifying what the community produces.
- Adding more quests
 - Adding more weekly quests as most players completed their weekly quest early in the week and had nothing to push themselves to reach at the end of the week.
 - Adding time-limited quests, which are quests that are available for a certain amount of time and must be completed within that time frame to get the reward.
 - Adding quests with different activity types like elevation difference, active minutes with a specific intensity level, distance and more.
 - Adding tile quests, which are quests where the reward is to unlock a specific type of tile.
- Improve the camera zoom to be less sensitive and have more natural scaling when close in and far away.
- Improve the touch sensitivity when a player clicks on a tile to edit or delete it. As it is now, it is too easy to click on the wrong tile accidentally. The edit/delete UI should only trigger if the player holds on to the tile for some time.
- Enable the player to rotate the camera around their community, making it easier for players to navigate and click on the specific elements they want to reach

- Improve the balance of energy and money. The imbalance between the amount of energy and money the players needs and can gather daily must be improved both in relation to each other and to scale with player progress.
- Implement a better notification system.
- Adding natural obstacles to the surrounding area, like mountains and rivers, that the player can add to their community or would have to work around.
- Relics from before the nuclear catastrophe that is hidden around in the contaminated area, and if the players find them, they can unlock its power and a new way of collecting energy (or other things, depending on what they find)
- Integrating weather predictions based on player locations. When the game registers player activity to generate energy rewards, the reward will be higher if the weather data says that it was less than optimal weather during the player's walk.
- Solving the problem with Google authentication on iOS devices so that the game can use Google Fit on both Android and iOS.
- Adding a high-score table that lets the players compare their score to their friends and the player base as a whole.

One issue with further development and a possible publication of the game is monetisation. For small-scale development, this game works as a hobby project. However, if the game wants to reach as many as possible and help them improve their physical activity level, it will probably need funding. The normal way of earning money through a mobile phone game is to have ads, microtransactions or that the game costs something to install. However, this goes against the entire concept of this game, and adding this will likely prevent many people from playing. One solution would be to find an organisation willing to support the development financially because of the exergame's benefit of improving the population's health.

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Part IX

Appendices

Appendix A

NSD Application and Approval

Meldeskjema

Referansenummer

649305

Hvilke personopplysninger skal du behandle?

- Navn (også ved signatur/samtykke)
- E-postadresse, IP-adresse eller annen nettidentifikator
- Lydopptak av personer

Prosjektinformasjon

Prosjekttittel

Play to get fit

Prosjektbeskrivelse

Prosjektet er en masteroppgave ved NTNU i Trondheim, Fakultet for informasjonsteknologi og elektroteknikk, Institutt for datateknologi og informatikk.

Dette prosjektet har som formål å undersøke hvordan spill kan brukes som en del av løsningen på problemet med økende inaktivitet i dagens samfunn. Prosjektet innebærer å utvikle et spill som skal prøve å motivere brukerne til å øke deres fysiske aktivitet.

For å teste om spillet oppnår den påtenkte effekten vil det bli gjennomført et eksperiment hvor flere utvalg vil spille spillet. I løpet av eksperimentet vil utvalgene være med intervju og besvare spørreskjema. Noe informasjon vil også bli lagret fra spillet. Denne informasjonen er anonyme data om spillfremgang (poeng, antall bygninger bygget, antall oppdrag utført osv.), og antall skritt og aktive minutter spilleren har hatt ilt. eksperimenttiden.

Begrunn hvorfor det er nødvendig å behandle personopplysningene

E-post er nødvendig for å kunne distribuere spillet, spørreundersøkelser og annen informasjon til delagerne i løpet av testingen. Dette er viktig for å kunne begynne med datainnsamlingen. Navn trengs for å kunne koble brukerens svar på spørreundersøkelsen til brukeren, og vil være nødvendig for å kunne gjennomføre mer detaljerte intervjuer. Andre brukeropplysninger som alder og kjønn vil kun brukes til å kategorisere resultatene fra undersøkelsene for å gi et bredere oversiktsbilde.

Ekstern finansiering

Ikke utfyllt

Type prosjekt

Studentprosjekt, masterstudium

Kontaktinformasjon, student

Thomas Bakken Moe, thomabmo@stud.ntnu.no, tlf: 94801667

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

Beskriv utvalget

Personer fra egne netverk som er interisserte i å prøve ut et spill som kan øke personlig motivasjon for trening. Dette utvalget skal gjennomføre en testperiode med spillet og svare på spørreundersøkelser.

Beskriv hvordan rekruttering eller trekking av utvalget skjer

Rekruttering skjer i eget nettverk

Alder

18 - 75

Personopplysninger for utvalg 1

- Navn (også ved signatur/samtykke)
- E-postadresse, IP-adresse eller annen nettidifikator

Hvordan samler du inn data fra utvalg 1?

Elektronisk spørreskjema

Vedlegg

[Spørreskjema 1.pdf](#)

Grunnlag for å behandle alminnelige kategorier av personopplysninger

Samtykke (Personvernforordningen art. 6 nr. 1 bokstav a)

Elektronisk spørreskjema

Vedlegg

[Spørreskjema 2.pdf](#)

Grunnlag for å behandle alminnelige kategorier av personopplysninger

Samtykke (Personvernforordningen art. 6 nr. 1 bokstav a)

Informasjon for utvalg 1

Informerer du utvalget om behandlingen av personopplysningene?

Ja

Hvordan?

Skriftlig informasjon (papir eller elektronisk)

Informasjonsskriv

[Informasjonsskriv - Utvalg 1.pdf](#)

Utvalg 2

Beskriv utvalget

Personer fra egne netverk som er interisserte i å prøve ut et spill som kan øke personlig motivasjon for trening. Dette utvalget skal gjennomføre en testperiode med spillet, svare på spørreundersøkelser, og delta i personlig intervju.

Beskriv hvordan rekruttering eller trekking av utvalget skjer

Rekruttering skjer i eget nettverk. Deltagerene til dette utvalget vil velges slik at det har en så god som mulig fordelig av deltagere i forskjellige aldre og av forskjellige kjønn.

Alder

18 - 75

Personopplysninger for utvalg 2

- Navn (også ved signatur/samtykke)
- E-postadresse, IP-adresse eller annen nettidifikator
- Lydopptak av personer

Hvordan samler du inn data fra utvalg 2?

Personlig intervju

Vedlegg

[Intervjuguide for personlig intervju.pdf](#)

Grunnlag for å behandle alminnelige kategorier av personopplysninger

Samtykke (Personvernforordningen art. 6 nr. 1 bokstav a)

Elektronisk spørreskjema

Vedlegg

[Spørreskjema 1.pdf](#)

Grunnlag for å behandle alminnelige kategorier av personopplysninger

Samtykke (Personvernforordningen art. 6 nr. 1 bokstav a)

Elektronisk spørreskjema

Vedlegg

[Spørreskjema 2.pdf](#)

Grunnlag for å behandle alminnelige kategorier av personopplysninger

Samtykke (Personvernforordningen art. 6 nr. 1 bokstav a)

Informasjon for utvalg 2

Informerer du utvalget om behandlingen av personopplysningene?

Ja

Hvordan?

Skriftlig informasjon (papir eller elektronisk)

Informasjonsskriv

[Informasjonsskriv - Utvalg 2.pdf](#)

Tredjepersoner

Skal du behandle personopplysninger om tredjepersoner?

Nei

Dokumentasjon

Hvordan dokumenteres samtykkene?

- Elektronisk (e-post, e-skjema, digital signatur)

Hvordan kan samtykket trekkes tilbake?

I informasjonsskrivet brukerne får utlevert vil det være en epostadresse som brukeren kan kontakte for å få all sin informasjon slettet. Dette vil også medføre at brukeren ikke lenger er en del av prosjektet.

Hvordan kan de registrerte få innsyn, rettet eller slettet personopplysninger om seg selv?

I informasjonsskrivet vil det stå at brukeren kan kontakte en gitt epostadresse og be om å få innsyn, rettet eller slettet personopplysninger om seg selv.

Totalt antall registrerte i prosjektet

1-99

Tillatelser

Skal du innhente følgende godkjenninger eller tillatelser for prosjektet?

Ikke utfyllt

Behandling

Hvor behandles personopplysningene?

- Maskinvare tilhørende behandlingsansvarlig institusjon
- Ekstern tjeneste eller nettverk (databehandler)

Hvem behandler/har tilgang til personopplysningene?

- Databehandler
- Prosjektansvarlig
- Student (studentprosjekt)

Hvilken databehandler har tilgang til personopplysningene?

Microsoft gjennom NTNU's Sharepoint

Tilgjengeliggjøres personopplysningene utenfor EU/EØS til en tredjestat eller internasjonal organisasjon?

Nei

Sikkerhet

Oppbevares personopplysningene atskilt fra øvrige data (koblingsnøkkel)?

Ja

Hvilke tekniske og fysiske tiltak sikrer personopplysningene?

- Personopplysningene anonymiseres fortløpende
- Opplysningene krypteres under forsendelse
- Opplysningene krypteres under lagring
- Endringslogg
- Flerfaktorautentisering
- Adgangsbegrensning

Varighet

Prosjektperiode

01.03.2023 - 01.10.2023

Hva skjer med dataene ved prosjektslutt?

Data anonymiseres (sletter/omskriver personopplysningene)

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

Vurdering av behandling av personopplysninger

Referansenummer

649305

Vurderingstype

Standard

Dato

07.03.2023

Prosjekttittel

Play to get fit

Behandlingsansvarlig institusjon

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

Prosjektansvarlig

Alf Inge Wang

Student

Thomas Bakken Moe

Prosjektperiode

01.03.2023 - 01.10.2023

Kategorier personopplysninger

Alminnelige

Lovlig grunnlag

Samtykke (Personvernforordningen art. 6 nr. 1 bokstav a)

Behandlingen av personopplysningene er lovlig så fremt den gjennomføres som oppgitt i meldeskjemaet. Det lovlige grunnlaget gjelder til 01.10.2023.

[Meldeskjema](#) **Kommentar****OM VURDERINGEN**

Sikt har en avtale med institusjonen du forsker eller studerer ved. Denne avtalen innebærer at vi skal gi deg råd slik at behandlingen av personopplysninger i prosjektet ditt er lovlig etter personvernregelverket.

DATABEHANDLER

Vi legger til grunn at behandlingen oppfyller kravene til bruk av databehandler, jf. personvernforordningen art. 28 og 29.

INFORMASJONSSKRIV

I informasjons- og samtykkeskrivet anbefaler VI at du endrer våre kontaktopplysninger fra NSD til Sikt, personverntjenester@sikt.no. Det er ikke nødvendig å laste opp revidert skriv i meldeskjemaet.

FØLG DIN INSTITUSJONS RETNINGSLINJER

Vi har vurdert at du har lovlig grunnlag til å behandle personopplysningene, men husk at det er institusjonen du er ansatt/student ved som avgjør hvilke databehandlere du kan bruke og hvordan du må lagre og sikre data i ditt prosjekt. Husk å bruke leverandører som din institusjon har avtale med (f.eks. ved skylagring, nettspørreskjema, videosamtale el.)

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

MELD VESENTLIGE ENDRINGER

Dersom det skjer vesentlige endringer i behandlingen av personopplysninger, kan det være nødvendig å melde dette til oss ved å oppdatere meldeskjemaet. Se våre nettsider om hvilke endringer du må melde: <https://sikt.no/melde-endringer-i-meldeskjema>

OPPFØLGING AV PROSJEKTET

Vi vil følge opp ved planlagt avslutning for å avklare om behandlingen av personopplysningene er avsluttet.

Appendix B

First Questionnaire

Undersøkelse del 1

* Obligatorisk

1. **SpillerID** (din spiller ID gitt i bekreftelsesmail) *

2. **Hvilket kjønn identifiserer du deg som?** *

- Mann
- Kvinne
- Annet
- Ønsker ikke å oppgi

3. **Hvor gammel er du?** (Oppgi svar i tall) *

4. **Hvor mange gå-, jogge-, løpe-, eller sykkelturner gjennomfører du i løpet av en uke?** (dette inkluderer IKKE aktiviteter gjort på treningssenter, eller ved organisert idrett) *

5. **Hvor lenge bruker en typisk tur å vare?** (Oppgi svar i minutter) *

6. **På en skala fra 1 til 5, hvor motivert er du for fysisk aktivitet i form av gå, sykle, og joggeturer?** (dette inkluderer IKKE trening på treningssenter eller organisert idrett) *

- 1 - ikke motivert
- 2
- 3
- 4
- 5 - veldig motivert

7. **Driver du med organisert idrett?** (I en idrettsklubb/lag) *

- Ja
- Nei

8. **Hvor ofte trener du?** (Dette inkluderer all type trening, inkludert jogging, løping og sykling ute og på senter, samt organisert trening) *

- Trener ikke
- 1 gang i halvåret
- 1 gang i kvartalet
- 1 gang i måneden
- 2-3 ganger i måneden
- 1 gang i uka
- 2-3 ganger i uka
- 4-5 ganger i uka
- Mer enn 5 ganger i uka

9. **På en skala fra 1 til 5, hvor motivert er du for annen fysisk aktivitet eller trening?** (Som fritidsaktiviteter eller trening på treningssenter) *

- 1 - Ikke motivert
- 2
- 3
- 4
- 5 - Veldig motivert

10. **Hvor mye tid bruker du i gjennomsnitt på videospill hver uke (inkluderer pc-, telefon-, og konsoll spill)?** (angi svar i timer) *

11. **Hvilke spillplattformer bruker du mest?** *

- Mobilspill
- PC-spill
- Konsoller (PlayStation, Xbox, Nintendo Switch etc.,)

12. **Har du noen gang betalt for fremgang i et spill (mikrotransaksjoner)?** (Dette inkluderer kjøp av hint, hjerter, power ups, bedre utstyr etc. med ekte penger) *

- Ja
- Nei
- Vet ikke / husker ikke

13. **Har du noen gang vurdert/ønsket å betale for fremgang i et spill (mikrotransaksjoner)?** (Dette betyr at du ikke har gjort det, men har ønsket / vurdert å betale for det) *

- Ja
- Nei
- Vet ikke

14. **Har du noen gang ønsket at det var andre metoder for å få fremgang i spill enn å vente på en prosess eller betale?** (Betale med ekte penger) *

- Ja
- Nei
- Vet ikke

Dette innholdet er verken opprettet eller godkjent av Microsoft. Dataene du sender, sendes til skjemaieieren.

 Microsoft Forms

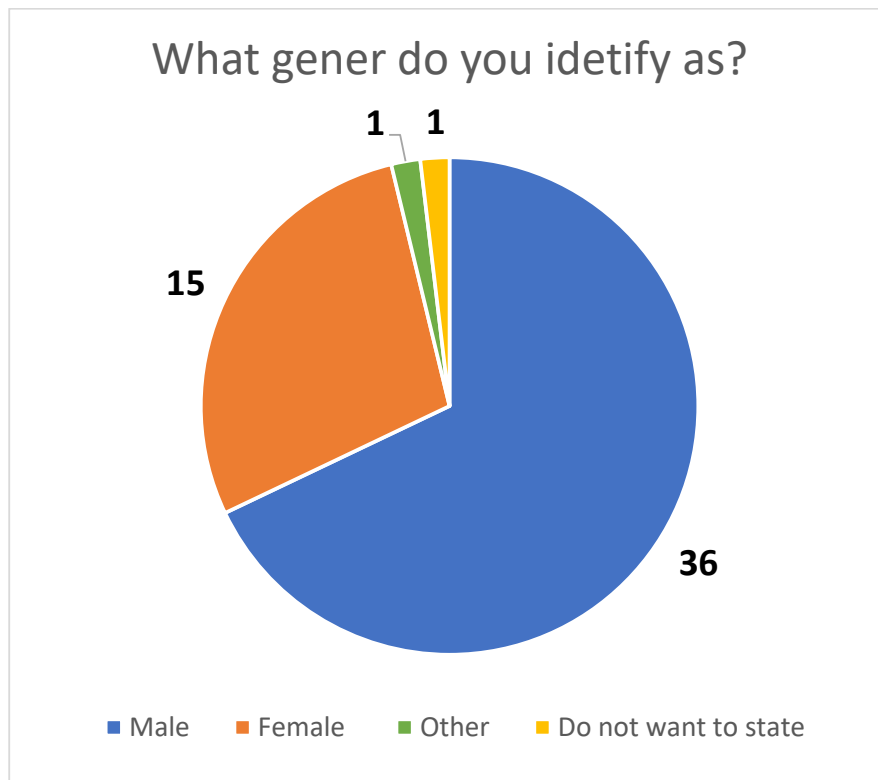
Appendix C

First Questionnaire Results

Results – First questionnaire

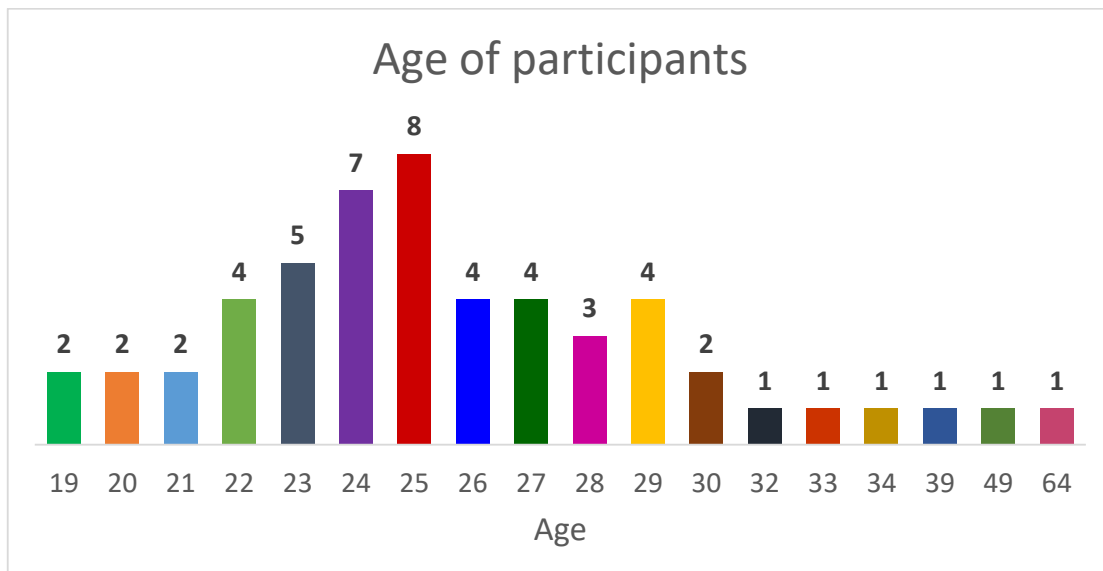
What gender do you identify as?

Categories	Results
Male	36
Female	15
Other	1
Do not want to state	1



How old are you?

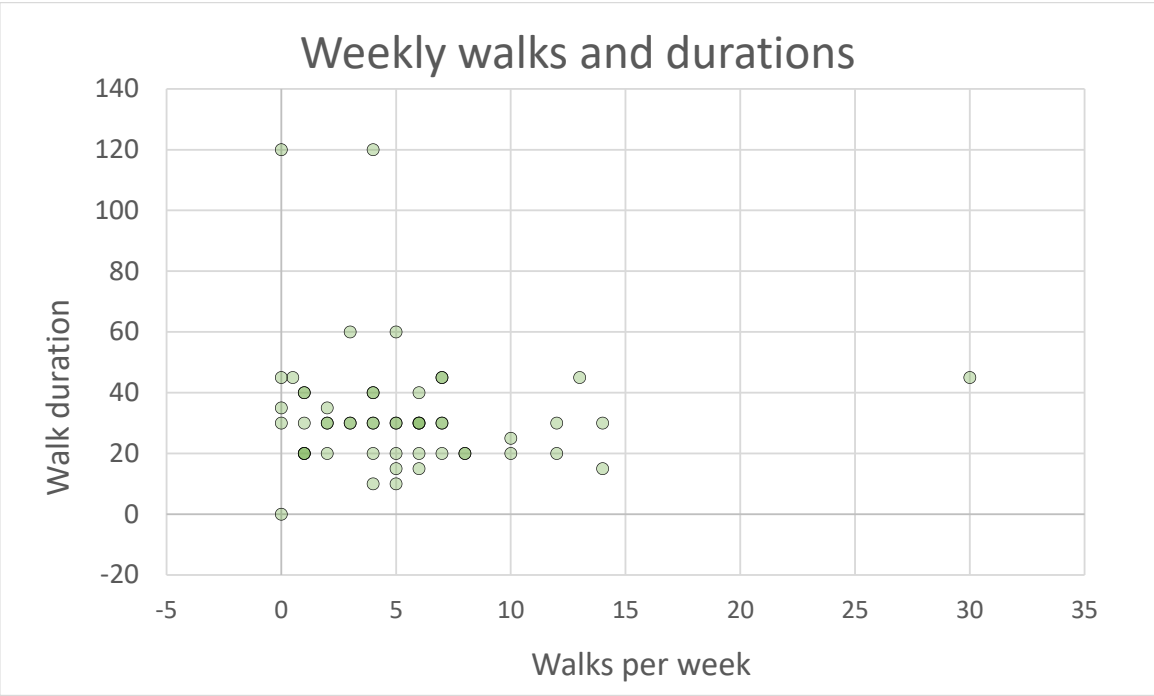
Age	Number
19	2
20	2
21	2
22	4
23	5
24	7
25	8
26	4
27	4
28	3
29	4
30	2
32	1
33	1
34	1
39	1
49	1
64	1



How many walks, jogs, or bike rides do you complete in the course of a week? (This does not include activity or exercise at a fitness centre or through organised sports.) / How long does a trip usually last? (answer in minutes)

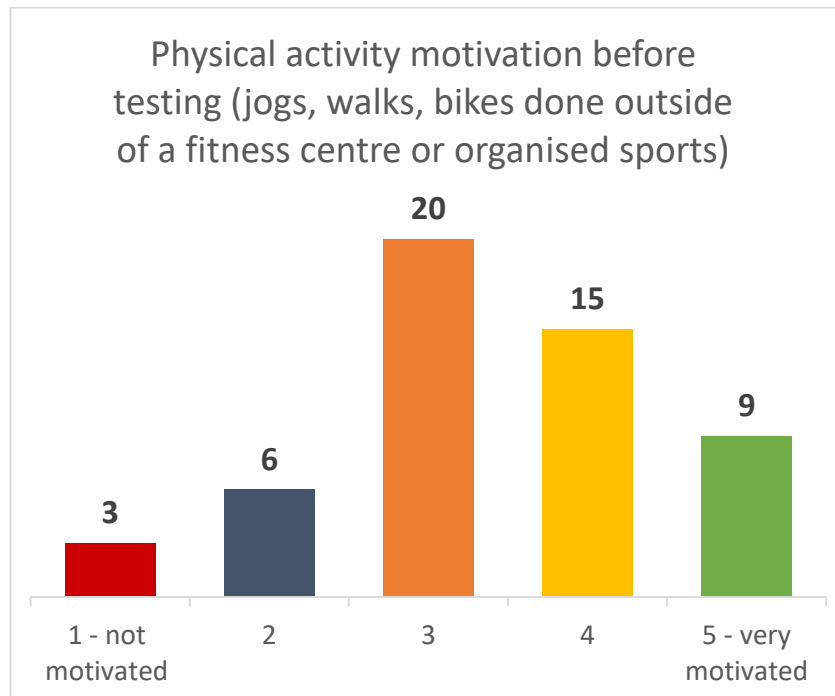
User	Walks per week	Duration of walk
User 1	10	25
User 2	0	35
User 3	6	30
User 4	6	15
User 5	0	120
User 6	6	30
User 7	5	10
User 8	3	60
User 9	12	20
User 10	2	30
User 11	4	40
User 12	1	20
User 13	2	30
User 14	14	30
User 15	14	15
User 16	6	40
user 17	12	30
User 18	4	120
User 19	2	20
user 20	1	40
User 21	5	30
User 22	7	30
User 23	1	30
User 24	8	20
User 25	13	45

User 26	1	20
User 27	30	45
User 28	5	60
User 29	0	30
User 30	1	20
User 31	4	40
User 32	7	20
User 33	6	20
user 34	8	20
User 35	4	30
User 36	5	15
User 37	5	30
User 38	1	40
User 39	6	30
User 40	0.5	45
User 41	4	20
User 42	0	45
User 43	4	10
User 44	10	20
User 45	3	30
User 46	0	0
User 47	2	35
User 48	5	20
User 49	4	30
User 50	7	45
user 51	7	45
User 52	7	30
User 53	3	30



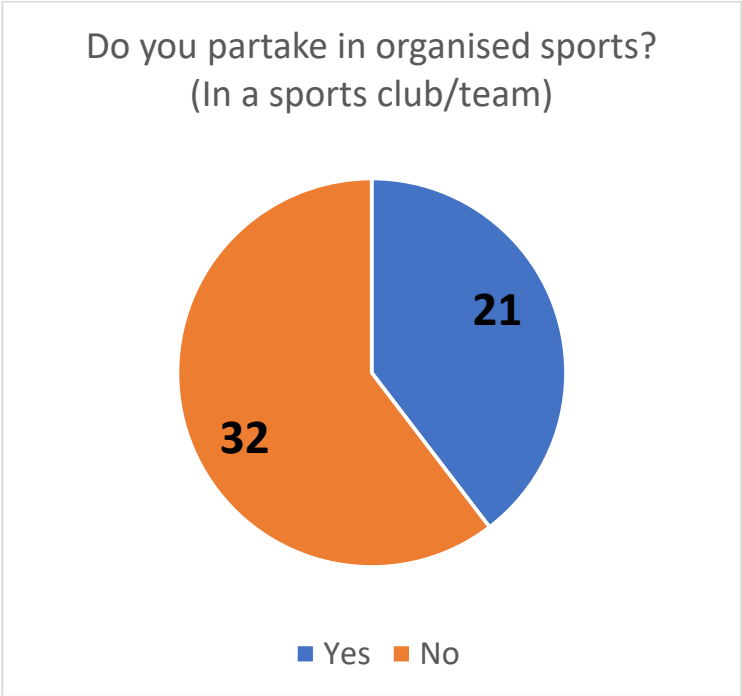
On a scale of 1 to 5, how motivated are you to do physical activities like running, jogging or biking? (This does not include activity or exercise at a fitness centre or through organised sports.)

Categories	Results
1 - not motivated	3
2	6
3	20
4	15
5 - very motivated	9



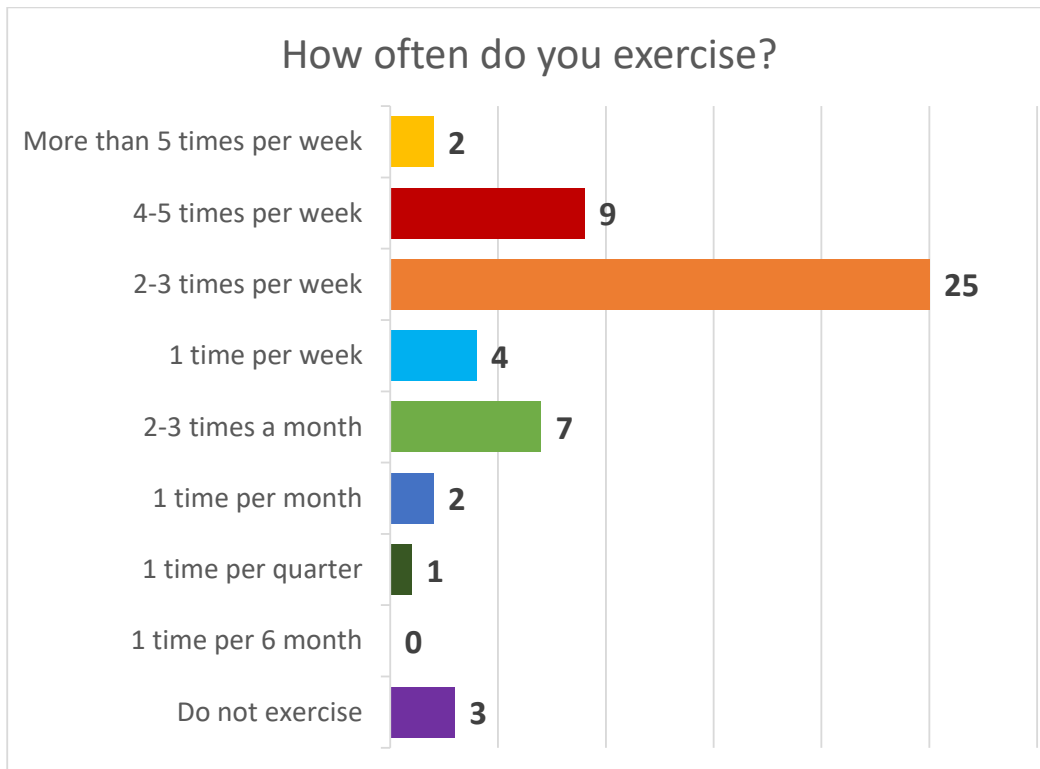
Do you partake in organised sports? (In a sports club/team)

Categories	Results
Yes	21
No	32



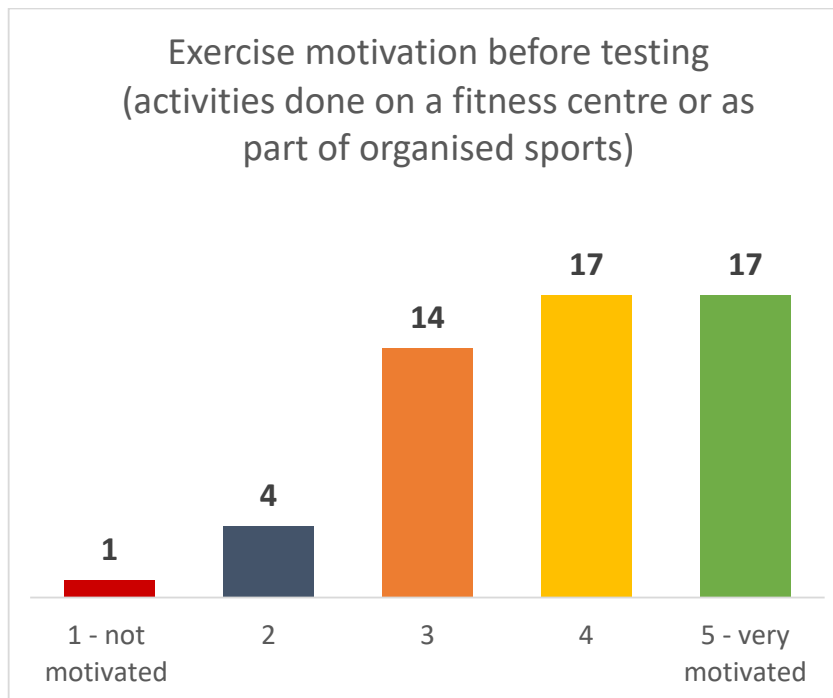
How often do you exercise? (This includes all types of exercise, including jogging, running, and cycling outside and in the centre, as well as organised sports)

Categories	Results
More than 5 times per week	2
4-5 times per week	9
2-3 times per week	25
1 time per week	4
2-3 times a month	7
1 time per month	2
1 time per month	1
1 time per month	0
Do not exercise	3



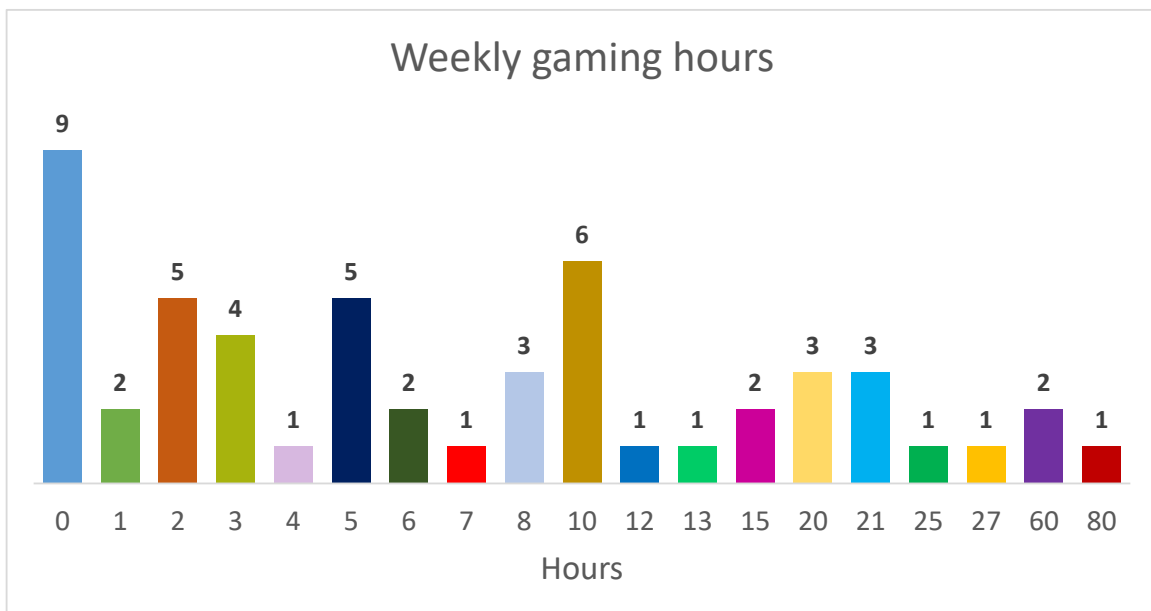
On a scale of 1 to 5, how motivated are you for other physical activity or exercise? (Like organised sports or training at a fitness centre)

Categories	Results
1 - not motivated	1
2	4
3	14
4	17
5 - very motivated	17



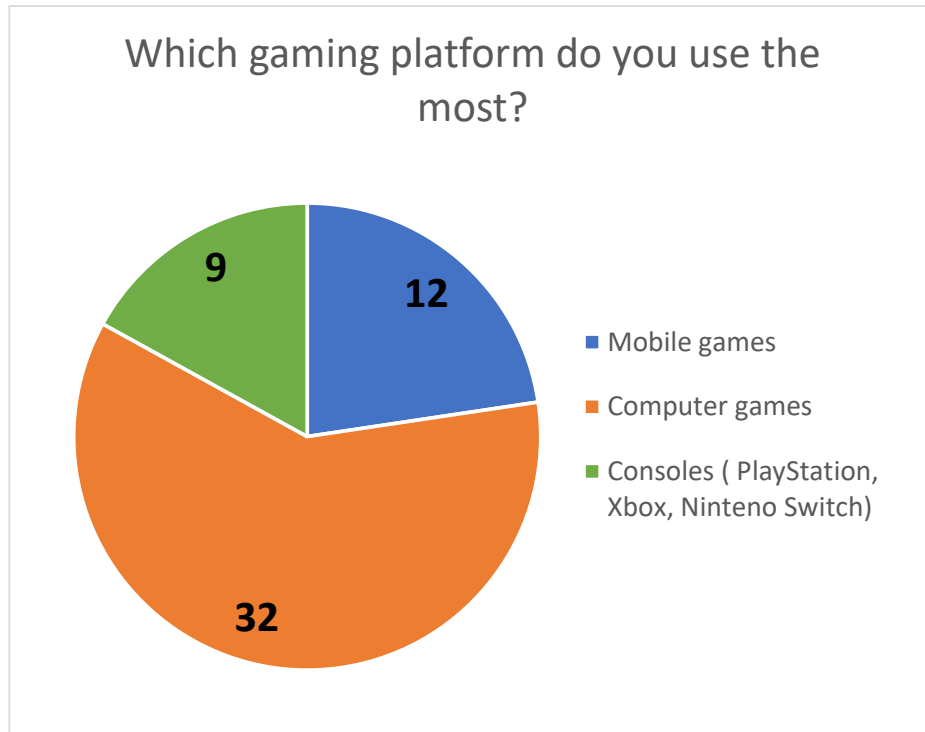
How much time do you spend, on average, playing video games each week (including PC, phone and console games)?

Hours	People
0	9
1	2
2	5
3	4
4	1
5	5
6	2
7	1
8	3
10	6
12	1
13	1
15	2
20	3
21	3
25	1
27	1
60	2
80	1



Which gaming platform do you use the most?

Platforms	Results
Mobile games	12
Computer games	32
Consoles (PlayStation, Xbox, Nintendo Switch)	9



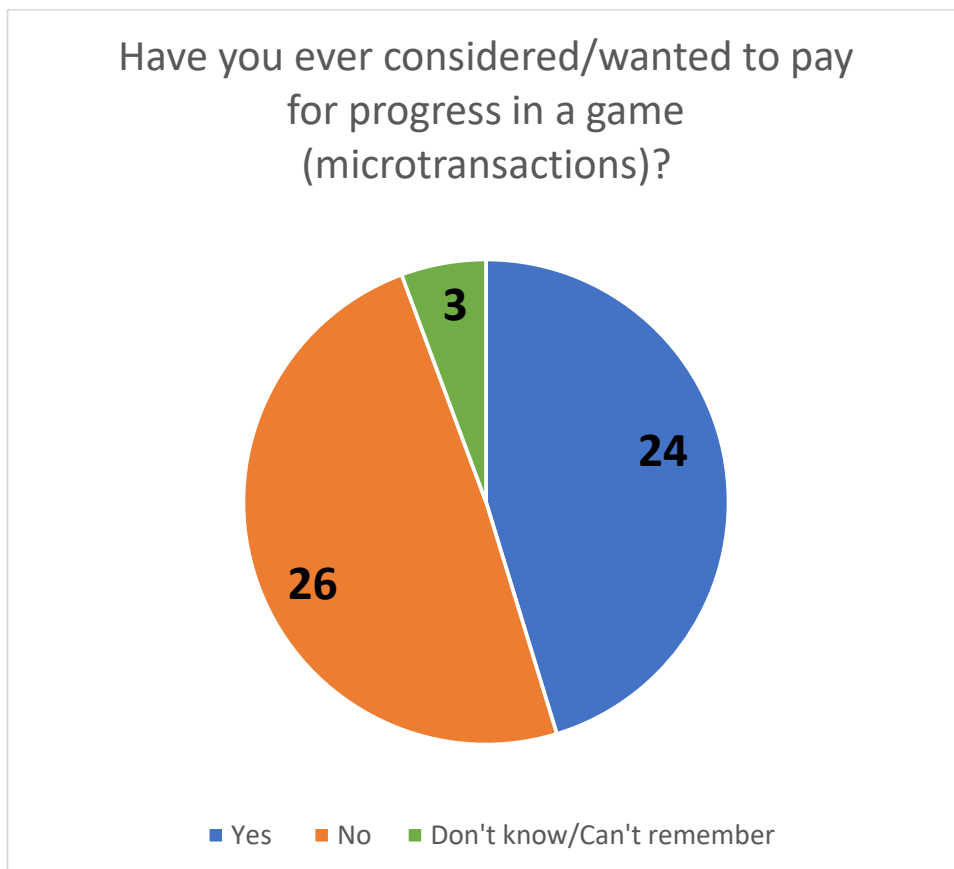
Have you ever paid for progress in a game (microtransactions)? (This includes buying hints, hearts, power-ups, better gear etc., with real money)

Categories	Results
Yes	19
No	32
Don't know/Can't remember	2



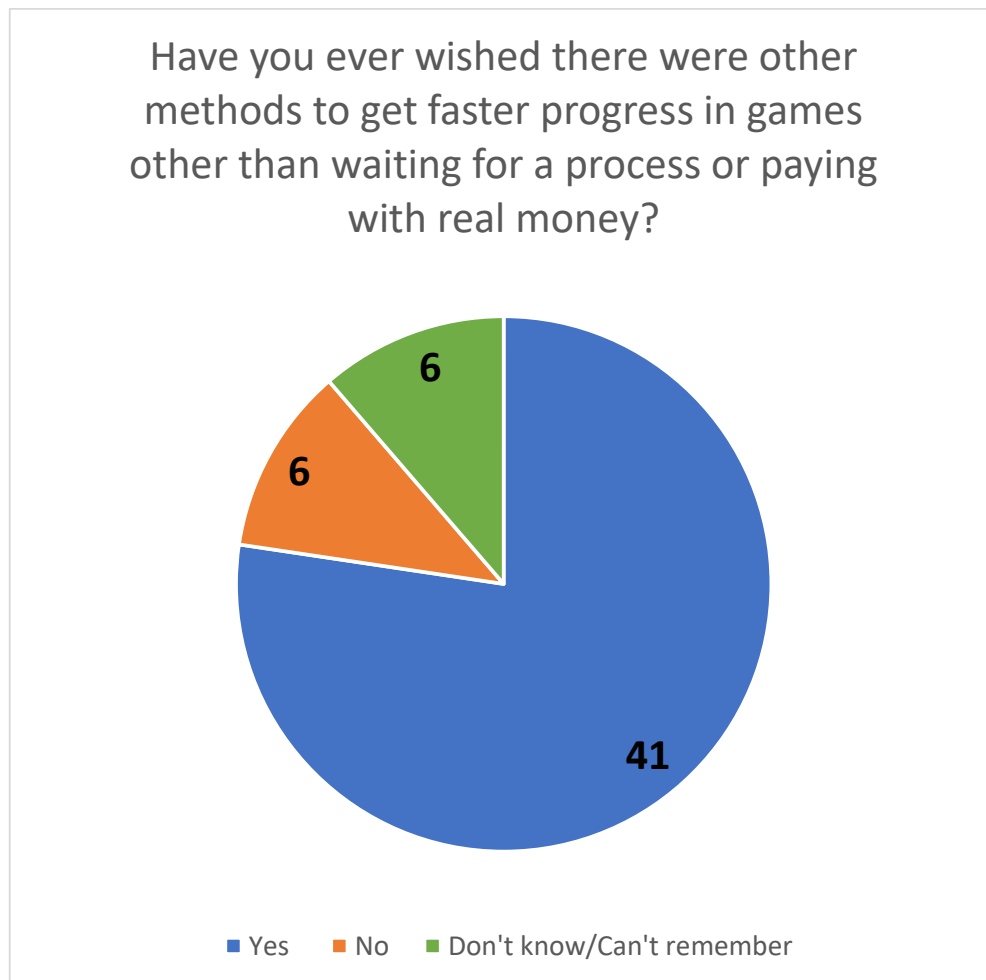
Have you ever considered/wanted to pay for progress in a game (microtransactions)? (This means that you have not done it but have wanted/considered paying for it)

Categories	Results
Yes	24
No	26
Don't know/Can't remember	3



Have you ever wished there were other methods to get faster progress in games other than waiting for a process or paying with real money?

Categories	Results
Yes	41
No	6
Don't know/Can't remember	6



Appendix D

Second Questionnaire

Undersøkelse del 2

Denne undersøkelsen fokuserer KUN på testperioden. Vi spør om at du er så ærlig som mulig med svarene du gir.

* Required

1. **SpillerID** (din spiller ID gitt i bekreftelsesmail) *

2. **Under testperioden, hvor mange gå-, jogge-, løpe-, eller sykkelturner gjennomførte du i løpet av en uke?** (dette inkluderer IKKE aktiviteter gjort på treningssenter, eller ved organisert idrett) *

The value must be a number

3. **Under testperioden, hvor lenge brukte en typisk tur å vare?** (Oppgi svar i minutter) *

The value must be a number

4. **Under testperioden, på en skala fra 1 til 5, hvor motivert var du for fysisk aktivitet i form av gå, sykle, og joggeturer?** (dette inkluderer IKKE trening på treningscenter eller organisert indrett) *

- 1 - Ikke motivert
- 2
- 3
- 4
- 5 - veldig motivert

5. **Hvordan påvirket Radiation Mayhem din motivasjon for fysisk aktivitet?** *

- Økte motivasjon
- Lik motivasjon
- Reduserte motivasjon

6. **Under testperioden, hvor ofte trente du?** (Dette inkluderer all type trening, inkludert jogging, løping og sykling ute og på senter, samt organisert trening) *

- Trener ikke
- 1 gang i halvåret
- 1 gang i kvartalet
- 1 gang i måneden
- 2-3 ganger i måneden
- 1 gang i uka
- 2-3 ganger i uka
- 4-5 ganger i uka
- Mer enn 5 ganger i uka

7. **Under test perioden, på en skala fra 1 til 5, hvor motivert var du for annen fysisk aktivitet eller trening?** (Som fritidsaktiviteter eller trening på treningscenter) *

- 1 - Ikke motivert
- 2
- 3
- 4
- 5 - Veldig motivert

8. **Hvor mye tid brukte du i gjennomsnitt på å spille Radiation Mayhem per dag?** (Oppgi svar i minutter) *

The value must be a number

9. **Ranger elementene basert på hvor mye de motiverte deg til være aktiv og spille spillet** (Høyest til Lavest) *

Poeng opp til neste deltager
Raskere progresjon i spillet / raskere innsamling av resurser
Opprettholde streak for å få større bonuser
Fullføre quests for å få tak i resurser
Risikoen for å miste områder om man ikke spiller
Ønsket om å bygge et fint og optimalt samfunn
Din plassering i high score listene som ble sendt ut
Fullføre de mest utfordrende quest-ene fordi de er utfordrende

10. Under testingen *

	Helt uenig	Litt uenig	Nøytral	Litt enig	Helt enig
var jeg mer motivert for å være fysisk aktiv	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
var jeg mer fysisk aktiv	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
gikk jeg på gå, sykle, eller joggeturer jeg ikke ville gått på om jeg ikke hadde spilt spillet	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
gikk jeg på gå, sykle, eller joggeturer fordi jeg ville nå et quest mål	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
gikk jeg på gå, sykle, eller joggeturer fordi jeg ville samle inn flere ressurser	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
gikk jeg på gå, sykle, eller joggeturer fordi jeg ville ha en høyere score i spillet	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
gikk jeg på gå, sykle, eller joggeturer på tross av været (regn, snø, vind)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
gikk, syklet, eller jogget jeg steder istedenfor å bruke andre transportmidler	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

11. **Omtrent hvor mange gå, jogge, eller sykkelturner gikk du, i uka, under testingen som du ikke ville ha gått på om du ikke hadde spilt spillet?** (Oppgi svar i tall) *

The value must be a number

12. **Har du endret daglige vaner til å bli mer fysisk aktiv pga. spillet?** (Begynt å gå til skole, jobb, trening, daglig tur) *

Ja

Nei

13. Påstander om spillet *

	Veldig usant	Litt usant	Nøytral	Litt sant	Veldig sant
Jeg synes spillet var morsomt	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Daglige quest motiverte meg til å gjøre litt aktivitet hver dag	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Ukentlige quest motiverte meg til å være aktiv utover i uka	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Utfordrende quest motiverte meg til å være ekstra aktiv for å kunne nå målene	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Spillet var for det meste forståelig og enkelt å spille	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
High score listene som ble sendt ut motiverte meg til å prøve å gjøre det bedre for å komme høyere på listene	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Jeg liker å bruke aktive minutter og skritt som et alternativ til å betale for spillprogresjon	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Jeg tror fysisk aktivitet som alternativ til reklame eller betaling kan bidra at folk blir mer aktive i hverdagen	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

14. **Kan du begrunne dine tanker om aktivitet som alternativ til reklame og/eller betaling?**

15. **Var du syk, skadet eller hadde andre omstendigheter som gjorde at du ikke kunne teste spillet gjennom store deler av testperioden? ***

- Nei
- Ja - men det hadde ikke så mye innvirkning på spillet
- Ja - det hadde stor innvirkning på spillet

16. **Oppdaget du noen feil eller problemer med spillet som gjorde det umulig å spille? (Her regner vi ikke med bugs som vi fikset under testingen) ***

- Ja
- Nei

17. **Hva var de? Kan du beskrive dem? ***

18. **Jukset du under testingen av spillet Radiation Mayhem? (Her regner vi ikke med dere som oppdaget bugs som vi rettet under testingen, eller dere som fikk uforventede fordeler pga bugs) ***

- Nei
- Ja - et par ganger
- Ja - ca 50% av tiden
- Ja - nesten hele tiden

19. **Hvordan jukset du? ***

20. **Hvorfor jukset du? ***

21. **Ønsker du å fortsette å spille spillet nå som testperioden er over? ***

- Ja
- Nei
- Vet ikke

22. **Er dette et spill / spillkonsept du kunne se for deg å spille når det er ferdigutviklet?** (Ta hensyn til at spillet er en prototype, og at en eventuell release vil ha flere ting å gjøre i appen inkludert flere tiles, quests, minispill, etc.) *

- Ja
- Nei
- Vet ikke

23. **Er det noen ting du likte spesielt godt med spillet?**

24. **Er det noen ting du kunne ønske IKKE var i spillet?**

25. **Var det deler eller aspekter av spillet du ikke forstod?**

26. **Har du noen andre kommentarer om spillet eller testingen?**

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 Microsoft Forms

Appendix E

Second Questionnaire Results

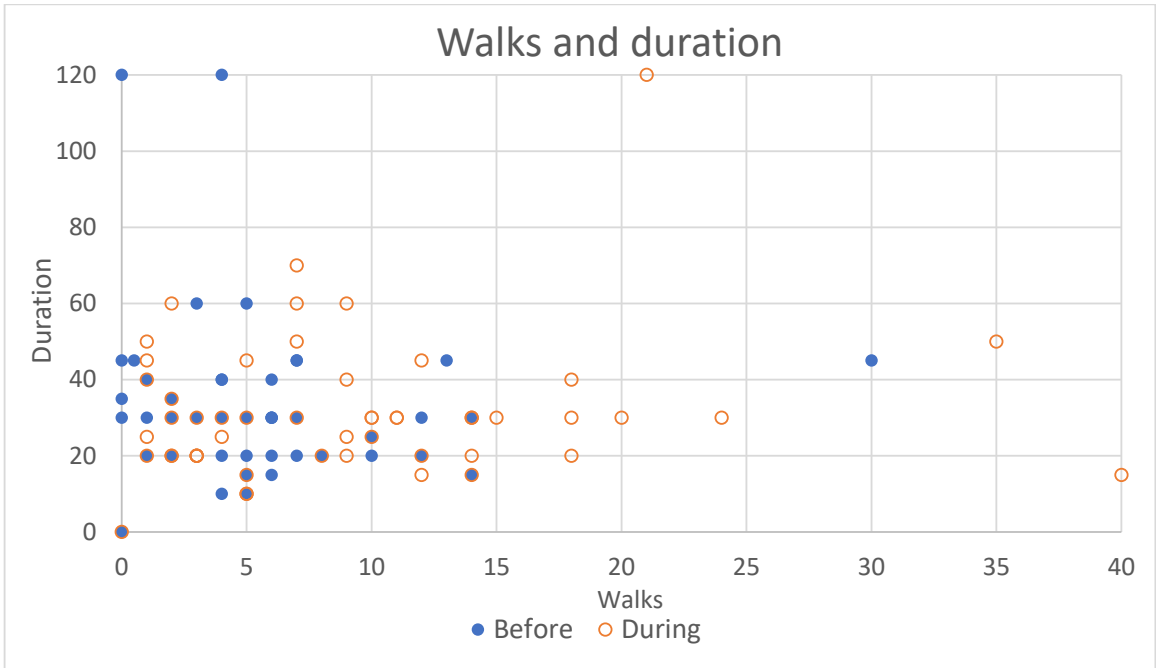
Results – Second questionnaire

During the test period, how many walks, jogs, or bike rides did you complete in the course of a week? (This does not include activity or exercise at a fitness centre or through organised sports.) / During the test period, how long did a trip usually last? (answer in minutes)

	1st questionnaire		2nd questionnaire	
	walks	duration	walks	duration
User 1	10	25	7	30
User 2*	0	35	0	0
User 3*	6	30	3	20
User 4	6	15	14	20
User 5	0	120	21	120
User 6	6	30	18	20
User 7	5	10	9	20
User 8	3	60	7	70
User 9	12	20	40	15
User 10	2	30	2	60
User 11*	4	40	3	20
User 12	1	20	1	50
User 13*	2	30	2	30
User 14	14	30	14	30
User 15	14	15	14	15
User 16	6	40	9	40
User 17*	12	30	8	20
User 18	4	120	7	60
User 19	2	20	2	20
User 20	1	40	10	30
User 21	5	30	5	45
User 22	7	30	15	30
User 23	1	30	4	25
User 24	8	20	18	30
User 25*	13	45	18	40

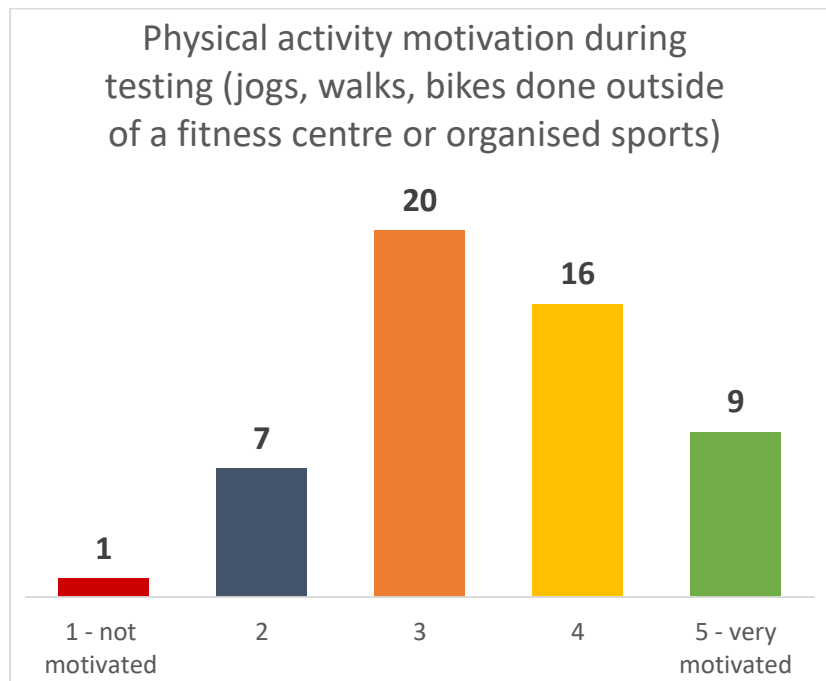
User 26	1	20	4	30
User 27	30	45	35	50
User 28	5	60	12	45
User 29	0	30	5	30
User 30	1	20	10	25
User 31	4	40	9	60
User 32*	7	20	1	20
User 33	6	20	14	30
User 34	8	20	12	20
User 35	4	30	9	25
User 36	5	15	5	10
User 37	5	30	7	50
User 38	1	40	24	30
User 39	6	30	11	30
User 40	0.5	45	1	40
User 41	4	20	3	30
User 42*	0	45	1	45
User 43*	4	10	2	20
User 44	10	20	12	15
User 45*	3	30	5	10
User 46*	0	0	1	25
User 47	2	35	2	35
User 48	5	20	5	15
User 49	4	30	3	20
User 50	7	45	10	30
User 51	7	45	11	30
User 52	7	30	20	30
User 53	3	30	3	20

A * means that this tester reported that they were sick, injured or otherwise indisposed and that it had a big effect on the game. Out of these 11, 7 reported a reduction in either number of walks or duration of walks.



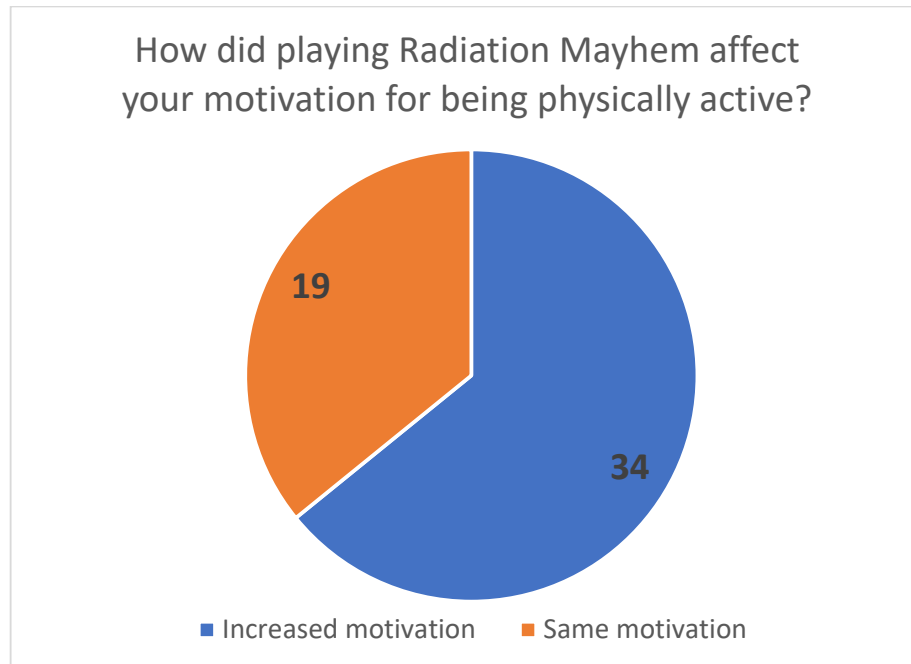
During the test period, on a scale of 1 to 5, how motivated were you to do physical activities like running, jogging or biking? (This does not include activity or exercise at a fitness centre or through organised sports)

Categories	Results
1 – not motivated	1
2	7
3	20
4	16
5 - very motivated	9



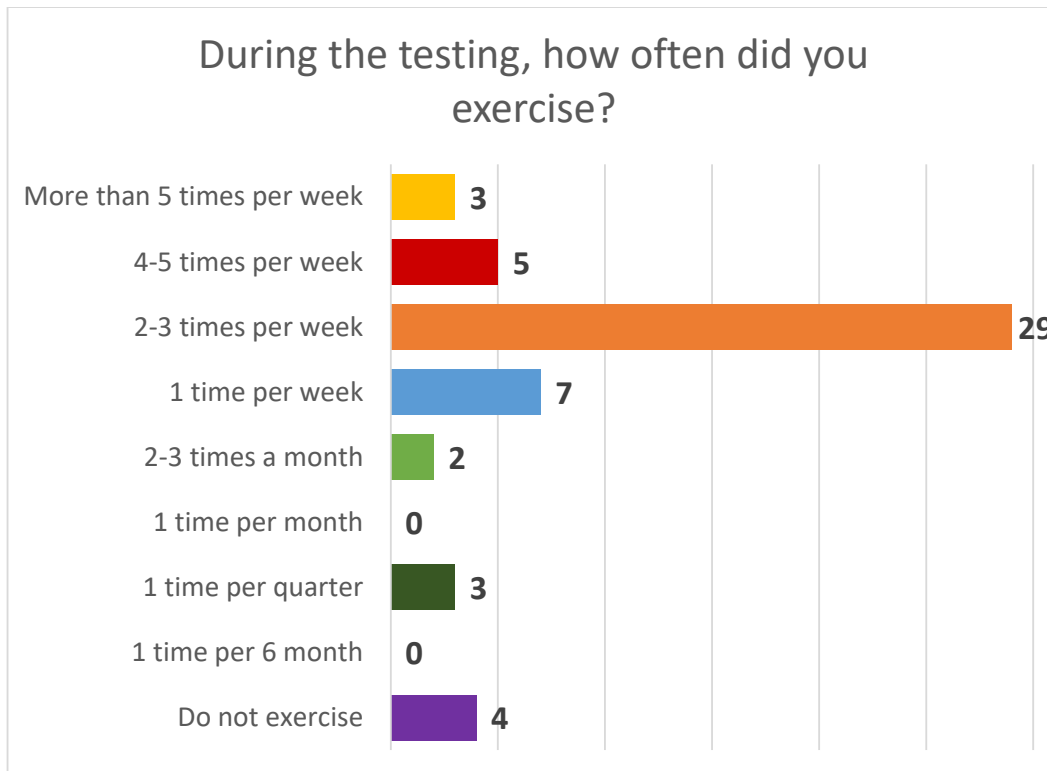
How did playing Radiation Mayhem affect your motivation for being physically active?

Categories	Results
Increased motivation	34
Same motivation	19
Reduced motivation	0



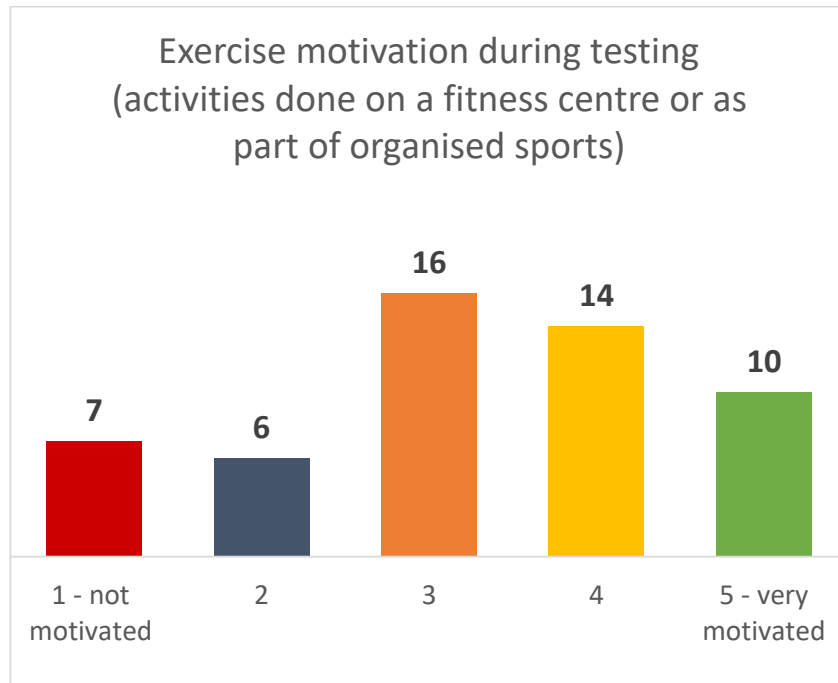
During the test period, how often did you exercise? (This includes all types of exercise, including jogging, running and cycling outside and in the centre, as well as organised sports)

Categories	Results
More than 5 times per week	3
4-5 times per week	5
2-3 times per week	29
1 time per week	7
2-3 times a month	2
1 time per month	0
1 time per month	3
1 time per month	0
Do not exercise	4



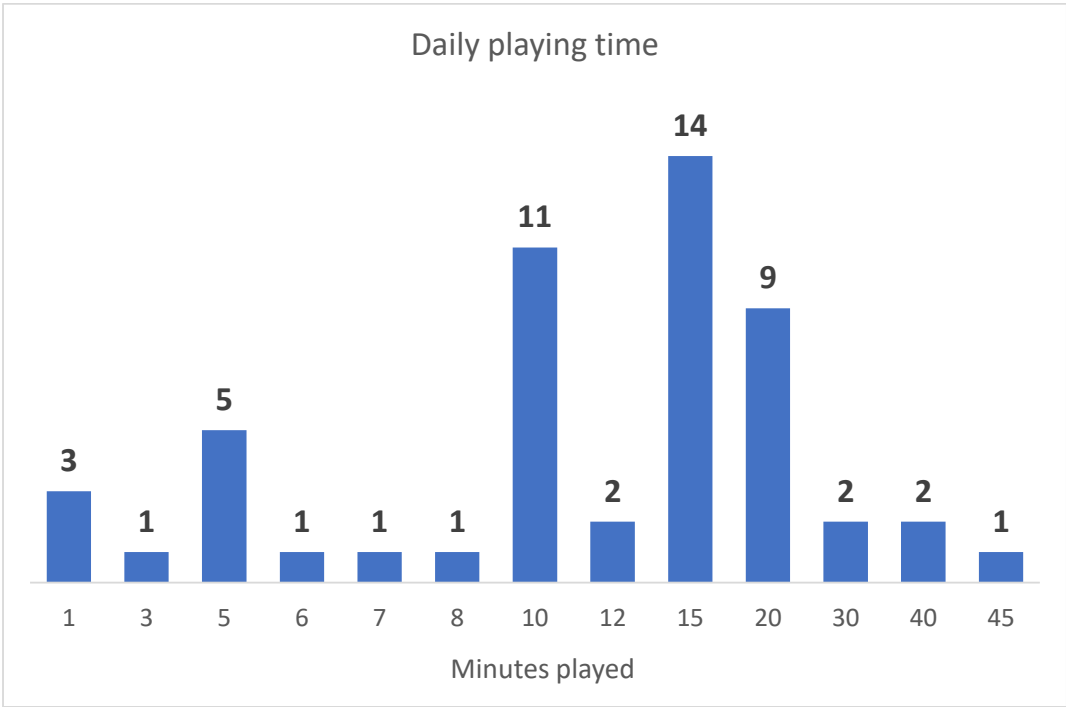
During the test period, on a scale of 1 to 5, how motivated were you for other physical activity or exercise? (Like organised sports or training at a fitness centre)

Categories	Results
1 - not motivated	7
2	6
3	16
4	14
5 - very motivated	10



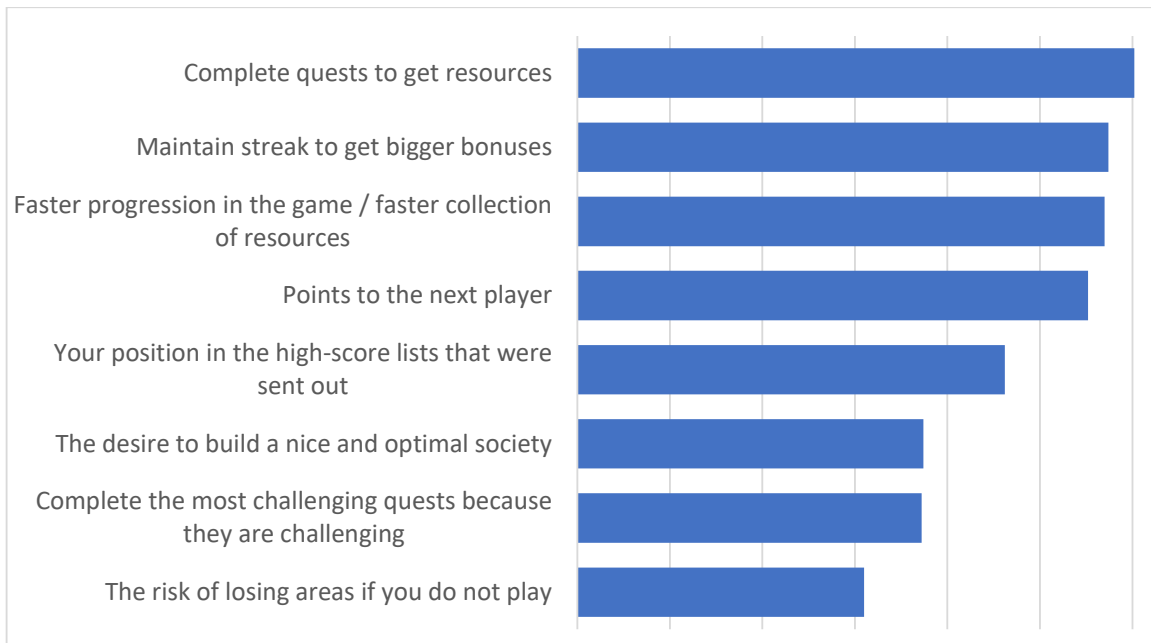
How much time, on average, did you spend playing Radiation Mayhem per day?

Minutes	Number of people
1	3
3	1
5	5
6	1
7	1
8	1
10	11
12	2
15	14
20	9
30	2
40	2
45	1



Rate the following elements based on how much they motivated you to be active and play the game (highest to lowest)

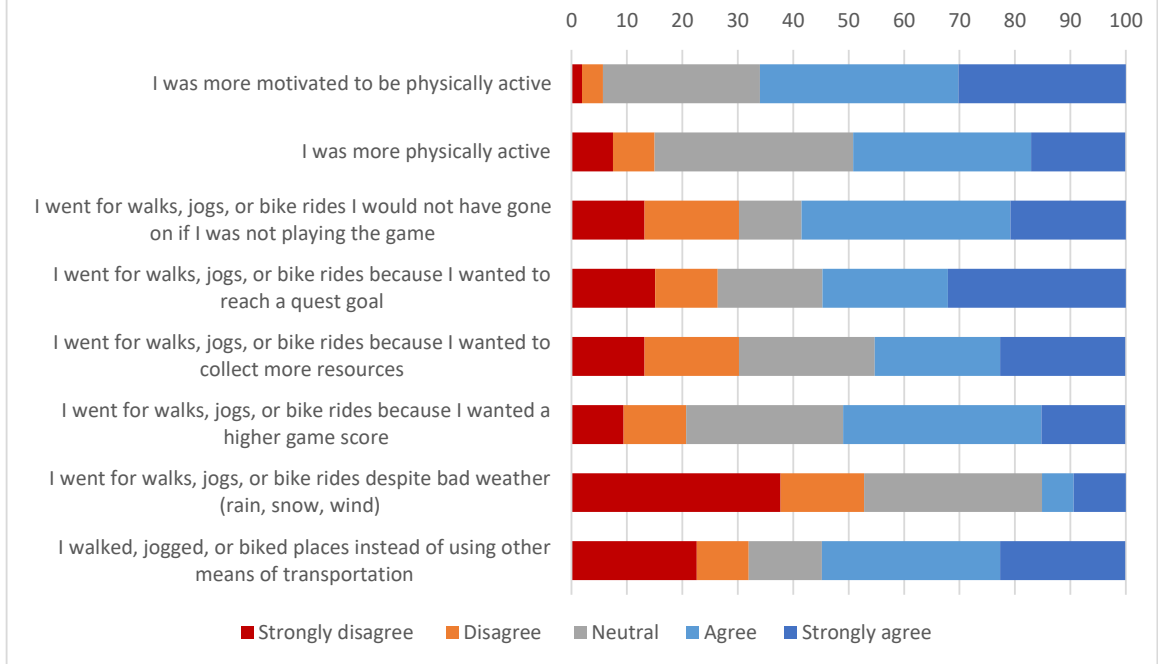
	1st	2nd	3rd	4th	5th	6th	7th	8th
Points to the next player	10	7	10	7	6	4	7	2
Faster progression in the game / faster collection of resources	8	12	8	9	6	3	4	3
Maintain streak to get bigger bonuses	9	11	7	8	9	3	5	1
Complete quests to get resources	7	11	12	11	7	3	2	0
The risk of losing areas if you do not play	1	3	3	6	7	6	5	22
The desire to build a nice and optimal society	5	2	1	7	4	15	12	7
Your position in the high-score lists that were sent out	8	4	7	4	7	10	6	7
Complete the most challenging quests because they are challenging	5	3	5	1	7	9	12	11



During the testing,...

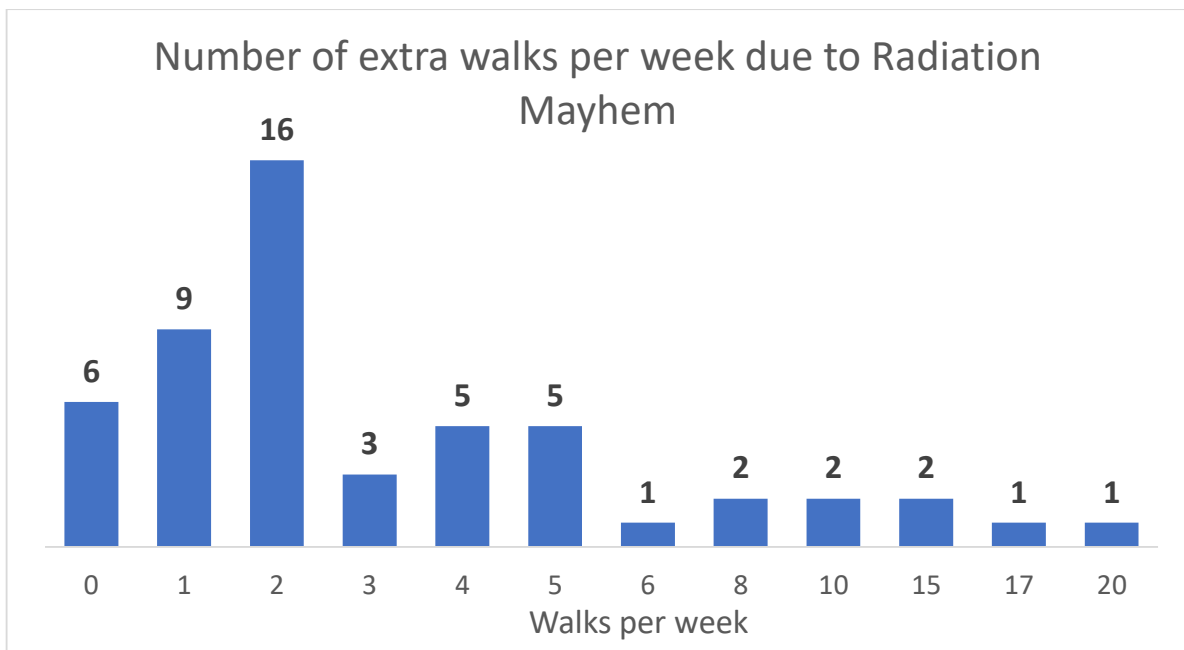
	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
I was more motivated to be physically active	1.9	3.8	28.3	35.8	30.2
I was more physically active	7.5	7.5	35.8	32.1	17
I went for walks, jogs, or bike rides I would not have gone on if I was not playing the game	13.2	17	11.3	37.7	20.8
I went for walks, jogs, or bike rides because I wanted to reach a quest goal	15.1	11.3	18.9	22.6	32.1
I went for walks, jogs, or bike rides because I wanted to collect more resources	13.2	17	24.5	22.6	22.6
I went for walks, jogs, or bike rides because I wanted a higher game score	9.4	11.3	28.3	35.8	15.1
I went for walks, jogs, or bike rides despite bad weather (rain, snow, wind)	37.7	15.1	32.1	5.7	9.4
I walked, jogged, or biked places instead of using other means of transportation	22.6	9.4	13.2	32.1	22.6

During the testing



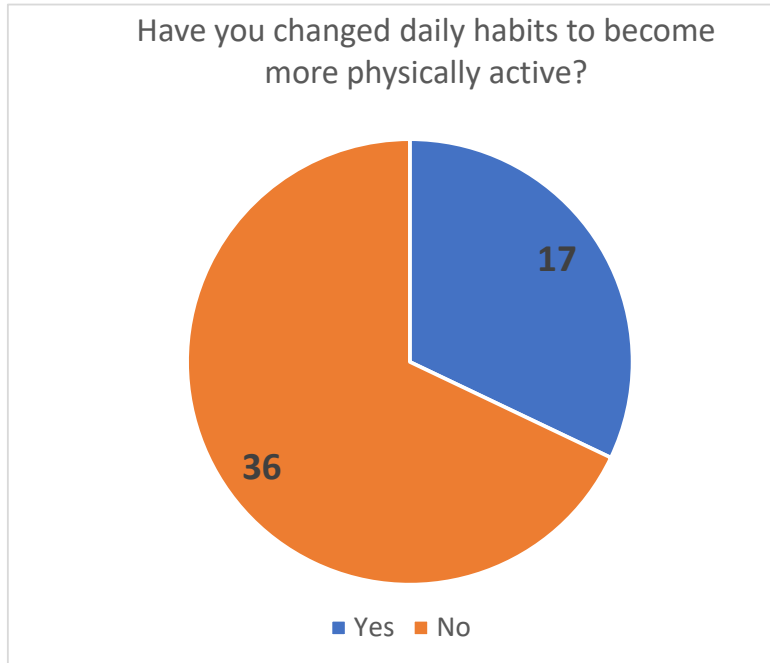
Approximately how many walks, jogs, or bike rides did you take each week that you would not have taken if you were not playing the game?

Walks per week	Number of people
0	6
1	9
2	16
3	3
4	5
5	5
6	1
8	2
10	2
15	2
17	1
20	1



Have you changed daily habits to become more physically active? (Started walking to school, work, training, and daily walks)

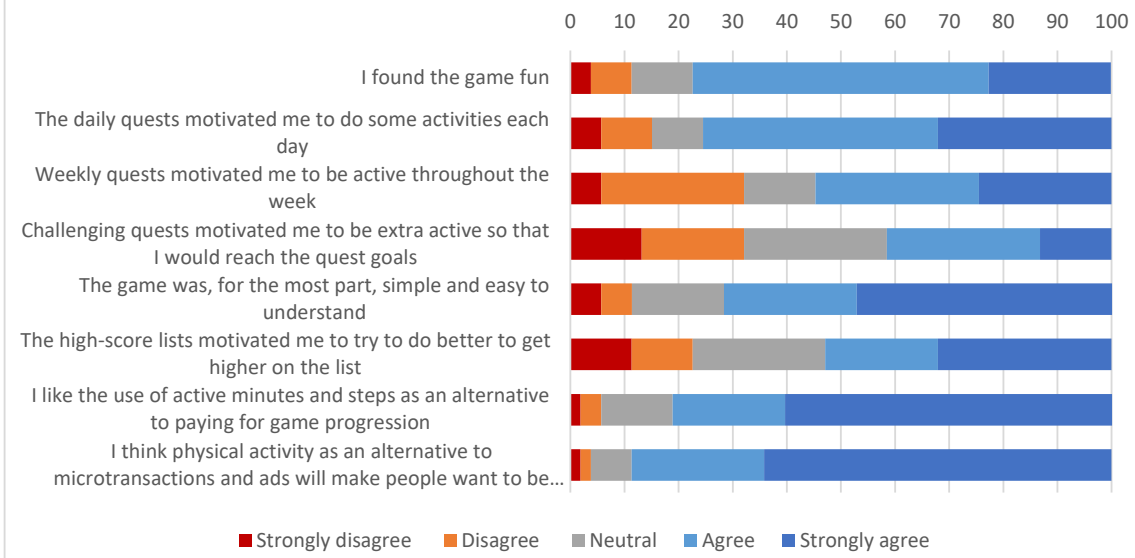
Categories	Results
Yes	17
No	36



Claims about the game

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
I found the game fun	3.8	7.5	11.3	54.7	22.6
The daily quests motivated me to do some activities each day	5.7	9.4	9.4	43.4	32.1
Weekly quests motivated me to be physically active throughout the week	5.7	26.4	13.2	30.2	24.5
Challenging quests motivated me to be extra active so that I would reach the quest goals	13.2	18.9	26.4	28.3	13.2
The game was, for the most part, simple and easy to understand	5.7	5.7	17	24.5	47.2
The high-score lists motivated me to try to do better to get higher on the list	11.3	11.3	24.5	20.8	32.1
I like the use of active minutes and steps as an alternative to paying for game progression	1.9	3.8	13.2	20.8	60.4
I think physical activity as an alternative to microtransactions and ads will make people want to be more active	1.9	1.9	7.5	24.5	64.2

Claims about the game



Can you tell us your thoughts about using activity as an alternative for ads and/or microtransactions

"I tillegg til å gi insentiv til mer fysisk aktivitet, gir det også større mestringsfølelse når du selv gjør noe for å oppnå resultatet istedenfor å kjøpe progresjon. Det er mer givende å jobber for den"

"Tror det blir vanskelig få til, fordi hvordan skal de som lage appen tjene penger da?"

"Avhengig av hvordan aktiviteten blir målt og hvilke verktøy man må ha for å bruke aktivitet som et alternativ, så vil det funke. Etter min mening så vil det være mest effektivt om man bare trenger en mobil og/eller en enkel pulsbelte som kan måle pulsen til spillerne."

"Fremmer helse"

"Så lenge spilleren er villig til å betale for progresjon, så er det absolutt mulig at de vil betale med fysisk aktivitet istedet. Jeg tror kanskje penger kan foretrekkes av noen spillere fordi man får umiddelbart utbytte, i motsetning til fysisk aktivitet. Men jeg tror noen spillere også vil foretrekk fysisk aktivitet fordi man slipper å bruke penger og man får bedre selvfølelse av å trene fremfor å bruke penger. Jeg vet ikke om det funker som alternativ til reklamer, siden reklamer er kortere en en gåtur."

"Kostnaden" er egentlig en gevinst."

"Deilig å slippe reklame"

"Lettere å fortsette å spille når en ikke blir avbrutt av reklame"

"Reklame/mikrotransaksjoner i spill er generelt noe dritt - bedre med belønning for fysisk aktivitet"

"Fordi mennesker liker belønning for arbeid/trening."

"Jeg synes det er et fint tiltak for folkehelsen"

"Det er gratis og det kommer av seg selv av å bare gjøre det man pleier, så man trenger ikke mye ekstra for å oppnå det aktivitetsnivået som trengs for å fullføre oppdrag."

"Jeg tror ikke at fysisk aktivitet er en spesiell motivator for progresjon i slike spill som dette. Konkurransen delen er det jeg tror er den største motivatoren i slike spill, spesielt konkurranse med bekjente."

"I en hverdag fylt med reklame kan et alternativ skape variasjon. Man får samtidig et mål eller en grunn til å være fysisk aktiv dersom man ikke har det i utgangspunktet. Dette tror jeg er en sperre som mange har mot det å være aktiv. Å ha en morsom app med aktivitet for progresjon kan raskt bli en del av hverdagen, og videre skape sunnere vaner med syn på aktivitet."

"Jeg har sett i andre spill (Pokemon Go) at barn blir motivert til å gå pga spill. Jeg aner ikke hvordan aktivitet kan gi inntekter til produsentene, dvs jeg forstår ikke hvordan det skal være et alternativ?"

"Aktivitet er gratis."

“Det er et fint alternativ til mikrotransaksjoner, spesielt for yngre spillere som kanskje bruker penger på kosmetiske elementer. Jeg betaler stort sett aldri i spill, og aktivitet som valuta passet meg ypperlig. Det passer bra for utviklere/eiere av spill, dersom man ikke bare tenker på å maksimere profitt.”

“Reklame og betaling gjør at jeg legger bort spillet og til slutt slutter å spille.”

“Det er alltid en fin alternativ som motiverer folk til å være mer i bevegelse, men det skaper også mindre inntekter til utviklerne. Så man må kanskje legge til en annen betalingsmåte i tillegg (som forhåpentligvis ikke krasjer med gevinstene fra trening).”

“God ide, så lenge det faktisk virker. Men spillet i seg selv må være motiverende.”

“For det første er det betydelig mindre irriterende enn reklame, for det andre gir det gode incentiver til å være i fysisk aktivitet utover det en pleier.”

“Virker bare positivt for meg å slippe reklame, vet ikke om det gir mening kommersielt men ville gjerne tatt den dealen.”

“Det jeg vanligvis ville tenkt på som en "predatory buisniess model" er noe jeg føler jeg kan la meg påvirke mer av enn vanlig hvis jeg vet at jeg får noe positivt ut av det (bedre helse). Derfor tenker jeg det er veldig bra!”

“Støtter dette, men spillet burde gitt push-notifikasjon om å gå mer/ være mer aktiv støttespiller til brukerne. Det ble litt passivt i dette spillet, så mail-listene hjalp”

“Jeg tror dette kan være et positivt tiltak for at folk skal komme seg i lett fysisk aktivitet. Det å være fysisk aktiv i stedet for å se reklame eller betale for framskritt i spill, tror også vil bli sett på som positivt for mange.”

“Gitt at man er nærme å nå et mål i spillet og at man da kan bare ta en gåtur/joggetur eller lignende for å få progresjon, så så jeg meg selv mer villig til å bevege meg mer enn ellers. Hadde et par ganger på kvelden hvor jeg gikk et par runder i stuen for å nå siste stegene som krevdes.”

“Ser ingen ulemper med det”

“Jeg har egentlig aldri brukt penger på spill for progresjon, men hater reklame så det er en bedre måte å gjøre det på. I utgangspunktet så følte jeg ikke helt behovet for å bli "lokket" mer ut da jeg vanligvis går tur hvis jeg synes været er fint eller får aktivitet på trening. Ble mest motivert av å slå andre egentlig, litt som stolpejakten der det er gøy å slå venner. Så motivasjonen kommer litt av det, og ikke nødvendigvis selve progresjonen i spillet for min del. Kanskje det hadde endret seg hvis spillet var mer fangende i form av mer avanserte ting som samspill, raid ol. litt som Clash Of Clans. (Selvfølgelig ute av scopet til en master oppgave)”

“microtransactions som påvirker spill, AKA paytoplay er en grusom måte å få folk til å betale for progresjon, men å betale med aktivitet er gratis og sunt for spilleren. Jeg tror at et spill med interessante nok mekanikker kan bidra veldig positivt for en person som er mottagelig for å bruke trening som valuta i et spill.”

“Ekstrem motivasjon!”

“Reklamer er irriterende og gir ingenting. Trene istedet ville vært supert”

“Jeg liker konseptet veldig godt! Kanskje ikke så bra som businessmodell, men det er morsomt at dere tar noe som i utgangspunktet er ganske kjipt og delvis "predatory" med gratisspill-modellen og gjør det til noe bra!”

“Jeg skadet foten, så fikk ikke vært så mye i aktivitet som jeg skulle ønsket, og det gjorde at jeg mistet streaken som igjen gjorde at jeg mistet litt motivasjon siden den var veldig viktig”

“Det var digg å ikke trenge å bruke penger på det”

“I think its a great idea. Advertising sucks so anything that can replace it is great. Its even better that it has the added benefit of improving one's health”

“Aktivitet høres mye mer fristende ut enn å betale for framgang i spill og slippe reklame, jeg vil heller gå meg en tur ut for å slippe å betale for å spille et spill samt at jeg ser på det som en vinn vinn situasjon hvor jeg får litt trim samtidig som jeg får tilgang til et reklamefritt og betalingsfritt spill.”

“Det er genialt om systemet tillater det! Deg er kanskje den beste grunnen til gamification av fysisk aktivitet jeg har hørt om 😊 ”

“Jeg har aldri brukt ekte penger på spill fordi det er ikke verdt det for meg. Reklamer gjør at jeg lukker appen fordi de kan være irriterende (spesielt de som er 30sek - 1min lange og man ikke kan lukke dem) og jeg sletter appen fordi jeg ikke er interessert i den lenger. Jeg liker aktivitet som alternativ fordi da er jeg fortsatt interessert i spillet og jeg må gjøre noe fysisk i den virkelige verden for å ha progresjon i spillet.”

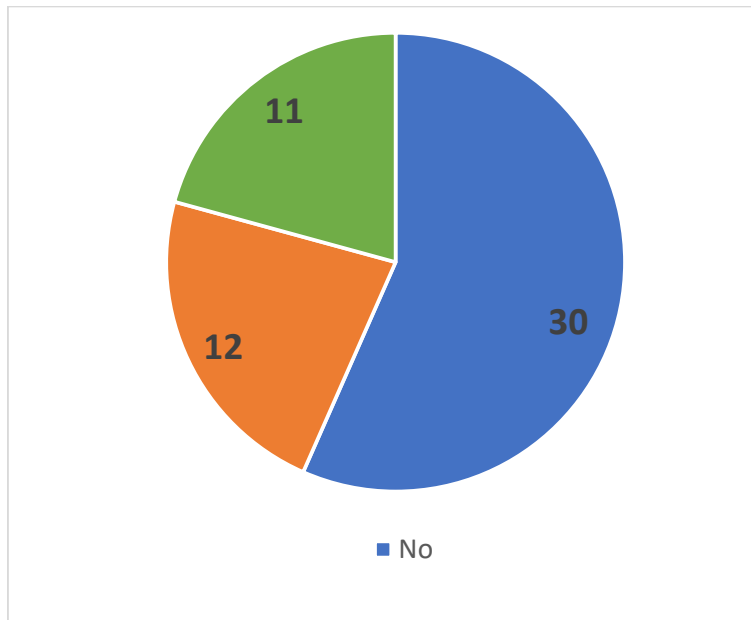
“Jeg har ADHD, noe som gjør at det er vanskelig å motivere seg selv til å gjøre ting som har langsiktige gevinster. Slik som trening. Så å få umiddelbare gevinster for det i et spill hjelper mye på motivasjonen. Tror det vil gjøre at veldig mange som kanskje i utgangspunktet ikke er interessert i trening eller fysisk helse vil komme seg ut å gå. Fordi ved å skulle gå tur for spillet (og ikke for å trene) så forstyrrer det ikke bilde de har av egen identitet. Veldig mange unngår jo trening spesifikt fordi de har bestemt at «de ikke er en sånn person». Dessuten vil det jo også da bli en ting man kan gjøre sammen med noen. Litt artigere å spørre om man skal ut å spille enn «gå tur».”

“Kan være en fin måte å øke motivasjonen til trening. I tillegg slipper man å bruke egne "ekte" penger i et spill man spiller,”

“Du føler du har mer kontroll selv og at du aktivt gjør det i stedet for å betale”

Were you sick, injured or had other circumstances that meant you could not test the game for large parts of the test period?

Categories	Results
No	30
Yes - it did not have a big impact on the game	12
Yes - it had a big impact on the game	11

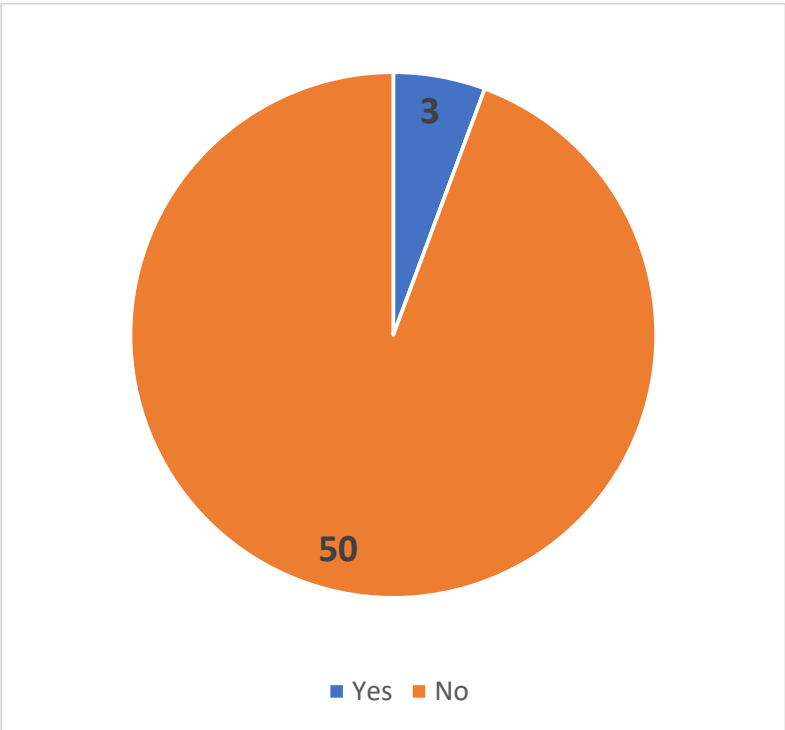


The table below shows what the 11 testers reported regarding motivation for physical activity and exercise. The sum numbers indicate how many reported a decrease in motivation.

	Before testing		After testing		Delta	
	Motivation physical activity	Motivation exercise	Motivation physical activity	Motivation exercise	Motivation physical activity	Motivation exercise
User 46	4	3	2	3	2	0
User 17	4	4	5	5	-1	-1
User 11	1	1	3	3	-2	-2
User 25	4	3	5	4	-1	-1
User 42	3	4	2	4	1	0
User 43	3	2	1	4	2	-2
User 2	2	3	3	5	-1	-2
User 45	3	3	3	3	0	0
User 13	4	3	3	3	1	0
User 32	2	2	2	3	0	-1
User 3	3	3	3	4	0	-1
Sum					4	7

Did you discover any bugs or problems with the game that hindered you from playing?

Categories	Results
Yes	3
No	50



If the players said yes to discovered bugs: What were they? Can you describe them?

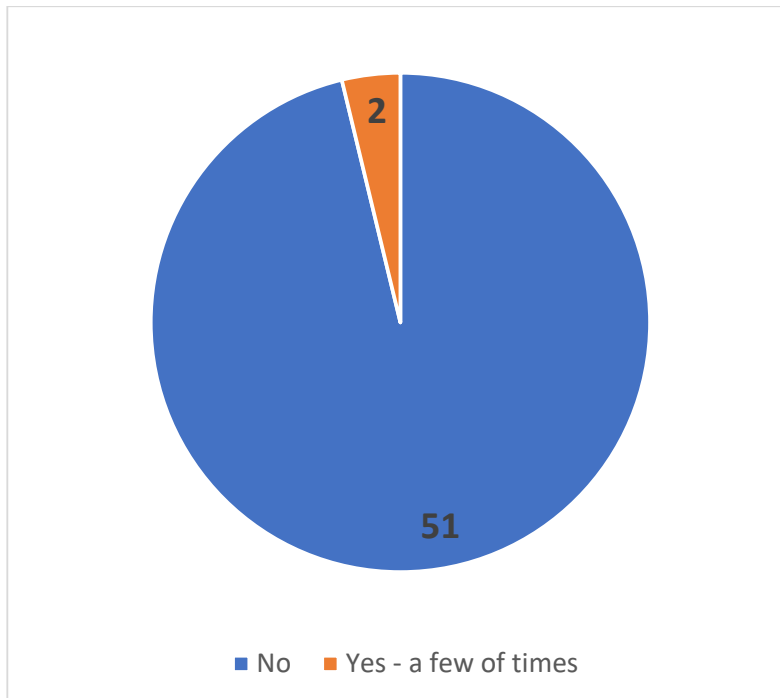
“Siste dagen fungerte egt ikke spillet for meg i det hele tatt, og loadingen tok ofte lang tid”

“Google Fit registrerte ikke mine bevegelser, som gjorde at Radiation Mayhem ikke logget det jeg gjorde. Etter oppdatering av Android OS virket det som Fit funket igjen, så jeg fikk prøvd litt ut siste dagene av testperioden.”

“Da jeg hadde appen oppe over midnatt kunne jeg ikke samle daily rewards for dagen etter.”

Did you cheat while playing Radiation Mayhem?

Categories	Results
No	51
Yes - a few of times	2
Yes – about 50% of the time	0
Yes – all the time	0



Cheating: How did you cheat?

“Latet som jeg gikk ved å imitere håndbevegelser med mobilen i hånda”

“Thomas vet”

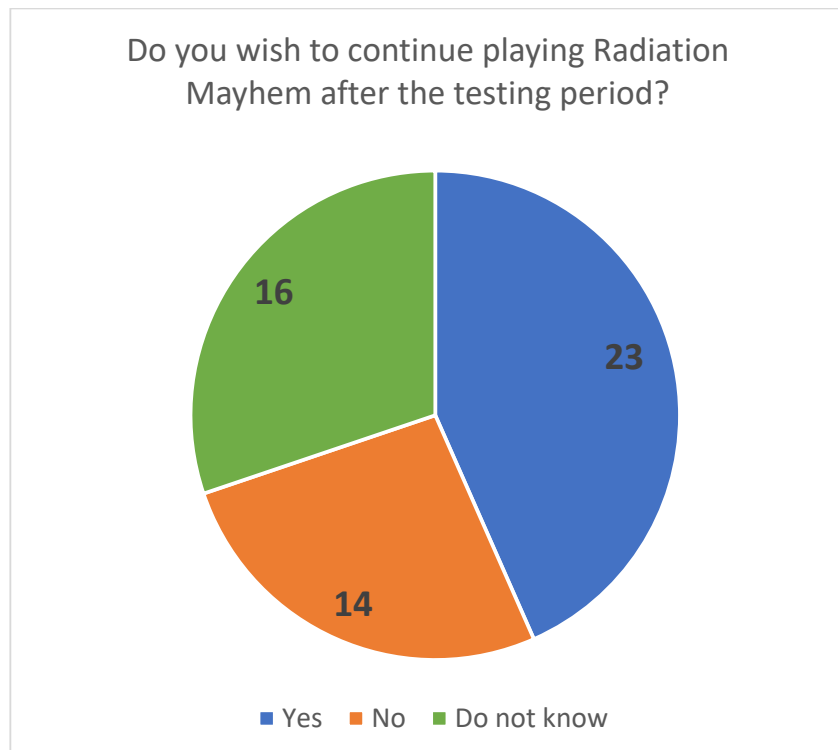
Cheating: Why did you cheat?

“Trenge mer ressurser i spillet”

“Thomas sa «spill som du vil» ˘(ツ)˘”

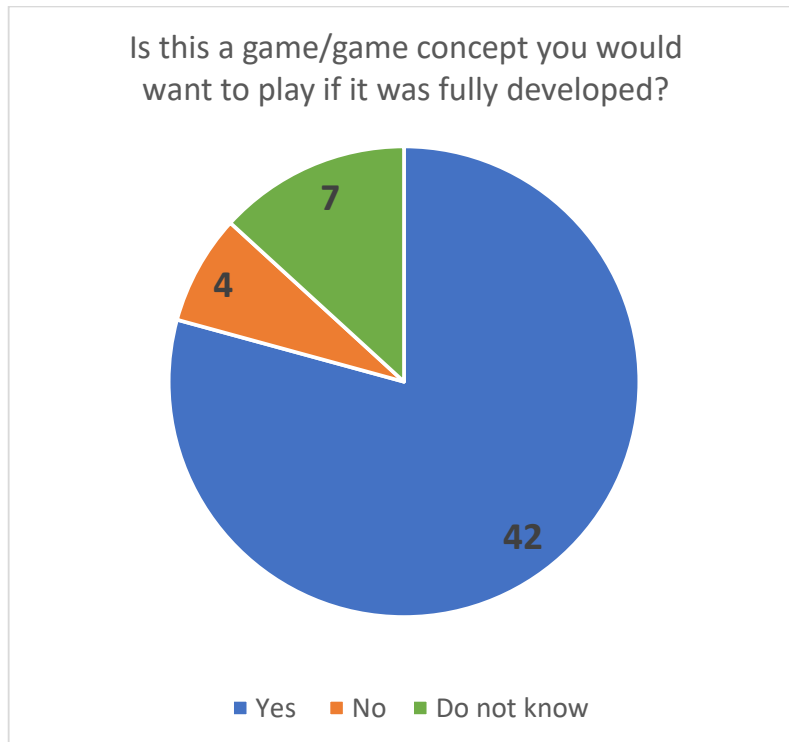
Do you wish to continue playing Radiation Mayhem after the testing period?

Categories	Results
Yes	23
No	14
Do not know	16



Is this a game/game concept you would want to play if it was fully developed?

Categories	Results
Yes	42
No	4
Do not know	7



Is there something in the game you liked really well?

“Var lett og forstå, og fungerte for det meste godt”

“Det var kult at man kunne bruke skritt som progresjon, men var mest det at jeg visste at det varte kun to uker (limited time) som gjorde det ekstra unikt”

“Like spesielt de non-repeating questene.”

“Liker at jeg ikke trengte se på det mens jeg gikk eller trente. Mistet ikke en sans som med pokemon go eller zombierun(hvor man må høre på dem)”

“Grunnkonseptet med at man får progresjon med fysisk aktivitet likte jeg. Jeg ble mer motivert til å ta ekstra gåturer, men jeg likte også at turer jeg også uansett ville tatt gir meg progresjon.”

“Oppnåelige daglige og ukentlige quests.”

“Simplisiteten”

“God blanding av enkle og vanskelige oppdrag”

“Likte animeringen av vindmøllene, de var pene å se på”

“Poenglistene og de oppdragene som var”

“For det meste et simpelt og greit design for spill. Er interessant konsept med spill som aktivitetsmotivator. Hex grid er alltid best ofc. Og likte godt design på tilesa.”

“Likte veldig godt quests for å få bonuser med aktivitet, og at man samlet energi når man gikk.”

“At jeg kjente andre som var med i spillet. Spille fortsatte selv om jeg ikke var i spillet. Det krevde ikke mye tid å være med.”

“Ukomplisert.”

“Musikken, responsiviteten, konseptet med aktivitet som valuta, konkurranse-elementet i spillet”

“Konkurranse mot andre du kjenner”

“Enkelt spill som ikke tok for mye av tiden sin per dag. Det gjorde det lett å bare hoppe inn.”

“Belønning av fysisk aktivitet. Animasjonene når du renser en tile. De pene modellene for hus og skog Ellers var det egentlig ganske kjedelig og uferdig.”

“Build town feel good”

“Følelsen av å gjenopprette et samfunn”

“Jeg likte veldig godt at spillet bare skulle spilles før og etter mosjonsøkter. Da kan jeg fokusere på økta, og spillet er mer et "push" til å gå ut og ta en økt.”

“Avstand til neste spiller.”

“Jeg liker det at fysisk aktivitet gir poeng som man kan spille med.”

“Strategi (samle ressurser/balansering) og progresjon”

“art stilen”

“Ukesquests, lange quests”

“Det var tilfredsstillende å interagere med spillet, og jeg likte måten energi og penger fungerte. Ekstra kult å se poeng til neste deltaker”

“Jeg er en stor fan av visuelle aspekter i slike spill. Jeg blir tidvis slukt opp av incremental games eller idle games, og jeg tror mye av radiation mayhem appellerer til meg på samme måte. Å se tall gå opp er i seg selv ofte en belønning, men desto mer liker jeg å se noe visuelt utvikle seg. Jeg likte å se "landsbyen" min vokse, men gitt at det bare er testfasen av spillet føler jeg utseendet og variasjonen i landsbyen fort stagnerte. Fler "brikker" med forskjellige bruksområder ville ikke bare gjort at det ser mye finere ut, men også gitt meg mer kreativitet til å spille spillet på min egen måte.”

“Streaken”

“Jeg fikk faktisk lyst til å løpe ut en kort tur da jeg så at jeg manglet ~400 skritt før en stor quest! Bra jobba! I tillegg fikk jeg litt dårlig samvittighet et par ganger da jeg tok bussen hjem fra skolen. Byen min trengte jo penger!”

“Hele konseptet”

“Bakhistorien”

“Det at spillet er basert på aktiviteten din og framgangen er basert på hvor mye aktivitet man er i iløpet av en dag.”

“Koselig verden, ett litt søtt "escape".”

“Lydeffekter var gøy”

“Jeg fikk ærlig talt ikke testet det noe særlig. Så syntes det er vanskelig å uttale meg om.”

“Steaken”

“At det var mer gøy å gå

“Jeg likte spesielt godt at det va postapokalyptisk”

Is there something you disliked about the game?

“Følt litt unyttig med strålingsgreiene”

“Advarsel om å miste tiles, da den ikke "utvidet" seg til flere tiles enn to stk til tross for ekspansjonen etter å bygge flere hus, etc”

“Vanskelig å bygge nok skog/jorder/hus til å henge med på utvidelsen av tiles”

“Konkurransen mot andre ble litt demotiverende når man ikke har alt for mye tid og energi til overs selv. Dette pga. Livssituasjon.”

“Skulle ønske det var vanskeligere å slette ting/bebyggelser. Slettet ved flere anledninger ting fordi jeg flere ganger skulle samle inn vindmølleenergi (litt kjapt) og kom borti delete-knappen”

“Nei bare diverse små endringer til spillet”

“Jeg fant ikke noe som absolutt ikke skulle vært i spillet. Tror hovedproblemene mine ligger rundt selve konseptet om en bybygger som motivator for aktivitet. Tror andre typer spill som er mer direkte konkurrasedrevne er mer relevante.”

“Kjøping av hexer burde ikke gitt score.”

“Jeg setter høy pris på personvern og ønsker derfor ikke å bruke google fit eller andre sky-baserte fitness-trackere.”

“Det var litt høye krav til antall skoger/byer/åker man måtte ha. Det var vanskelig å gjøre innbyggerne fornøyde”

“At behovet for nye gårder, hus og skog økte så drastisk når man rengjorde nye områder. Skulle ønske man kunne åpne mer før man trengte å bygge nye hus, skog og gårder”

“Jeg skulle ønske minst en daily streak ikke startet på nytt om man går glipp av en dag, men heller "pauses", da slik at man ikke blir demotivert til å fortsette om man går glipp av en pga. uforutsette ting skjer.”

“Jeg kunne ønske at spillet hadde en annen tittel. Jeg forsto meg ikke på dette, og det virket litt sært for meg. Noe nærmere "Farmvill" hadde kanskje passet bedre?”

“Burde være en cap på daily check in, vannkilden i midten hadde så å si ingen innvirkning på spillet”

“Nei. Jeg skulle bare ønske det var mer utfyllt, men jeg vet det er en early access.”

“At dei ikke gikk ann å endre farger og at der ikke var en figur”

“Føler meg litt usikker på det rundt at man blir "straffet" når man har en inaktiv periode, for min del hvor jeg jobber 1 uke på og 1 uke av så kan det fort bli hektisk å skal huske på å stikke innom spillet jevnlig.”

“Synes det burde være mulig å spille med mobilen på høykant, men det er pirk.”

Was it any part of the game you did not understand?

“Jeg skjønnte ikke hva forskjellen på hus, skog og åker var. Endte derfor bare opp med å bygge jevnt.”

“Hvorfor var alle "fjesene" jeg kunne samle alltid lei seg/sinna? Merket ikke forskjell på inntjening mellom fields/houses/forests.”

“Forstod ikke først sammenhengen mellom område og kravet om å fylle opp de forskjellige bygningene. Gull generasjonen virket også tilfeldig.”

“Balanse av ressurser.”

“Skjønnte ikke helt hvordan man samlet poeng,”

“Hvorfor var antall innbyggere i community direkte knyttet til rensede ruter?”

“I starten var det litt vanskelig å forstå hvordan man gjør innbyggerne fornøyd, og får mer ressurser (smilefjes)”

“Hva gir meg egentlig poeng? Vet ikke hvordan det fungerer, instruksjonene var for lange”

“Uten å lese manualen var det ikke åpenbart at tallene nederst til venstre var det antall tiles du måtte ha for å få full dose med ressurser. Jeg tolket det som at det var kapasiteten for de forskjellige tilene. Dette bør kanskje gjøres om til å være i rødt/oransje/med varseltrekant når de er under/over ideelt antall, og jeg vil foreslå at det heller knyttes til antall *hus* enn antall rensede tiles.”

“Tok litt stund før jeg forsto at man måtte klikke på vindmølle energien. Trodde først at det bare var en progressionbar.”

“Hvordan skåren ble regnet ut”

“Skjønnte ikke optimal taktikk i starten, og hvordan utdeling av coins foregikk. Det virket tilfeldig når byene ga coins og mengden. Leste dog ikke så mye av informasjonen som var linket til.”

“Jeg forsto ikke spillet i starten, men det kom seg etter hvert som jeg begynte å spille det.”

“Skjønnte ikke hvorfor jeg fikk surt smilefjes en del ganger da det så ut som at jeg hadde balansert samfunnet greit.”

“Hvordan jeg skulle gjøre innbyggerene fornøyde (balansert kart størrelse og innhold på kartet)”

“Jeg skulle ønske en bedre forklaring av smile/trist fjesene Var usikker på om surfjes betydde mangel på ressurser, ting var for tett på, at jeg ikke hadde vært nok aktiv, eller noe annet.”

“Skjønnte ikke helt det med antall av forskjellige tingene man kunne kjøpe, først stod det f.eks 2/4 så kunne man få 5/4 osv.”

“The instructions were in Norwegian so it was a little hard to understand all the parts of the game”

“slet til å begynne med å forstå hensikten bak de forskjellige tingene man kunne bygge, ellers enkelt å greit spill.”

“Jeg forstod ikke helt hvordan noen fikk mer enn 100 000 poeng, men det hadde sikkert med streak og å begynne spillet tidlig i fasen, å gjøre.”

“Ja, syntes det kunne vært en tutorial av noe slag. Forsto det jo etter å ha knotet med det. Men hadde vært greit å vite hva de forskjellige byggene gjorde før man kjøpte de. Eller altså hadde beskrivelse under de.”

Do you have any other comments about the game or the testing?

“Spillet var en bra prototype. Mangler en del ting som gjør det til noe jeg ville spilt videre, men det forventer jeg heller ikke skulle vært på plass nå.”

“Skulle ønske det var mer balansert, siden de som til vanlig jogger mye hadde en ekstrem fordel”

“Skulle ha vart lenger”

“Tror det har store potensialet med utvikling av konsept historie og spissing/tilpasning av quests og ressursinnsamling.”

“Min app (iOS) plukket bare opp skritt fra Apple Health. Som aktiv syklist ble det da litt lite givende å være aktiv, da de fleste av mine treningsøkter ikke ga noen verdi. Da handlet det mest om hvor mye jeg gikk på jobb (kontorjobb) og om jeg la inn en ekstra gåtur til butikken på ettermiddagen, i stedet for å gi meg verdi for treningen jeg gjorde.”

“Gøy konsept! Skulle gjerne hatt mer klarhet om hvordan penger ble generert. Jeg føler kravet til hvor mange bygninger man måtte ha av hver type begrenset valgmuligheter for hvordan man kunne bygge byen sin.”

“Veldig bra jobbet med spillet generelt sett. Ble positivt overrasket over kvaliteten på prototypen.”

“Skulle ønske det var mulig å rotere rundt på spillet, og ikke kun zoom inn eller ut på spillet.”

“Pga sykdom fikk jeg ikke prøvd spillet skikkelig. Liker veldig godt hele konseptet. Kjør på!”

“Kanskje oppdateringer i form av forskjellige hus eller energi som solceller. Ellers veldig gøy”

“Jeg følte at det lett kunne bli skeivfordeling mellom energi og coins, siden fysisk aktivitet i stor grad ble belønnet med energi. Til fremtiden fikk jeg litt idéer: - tanken er litt i retning av irl mmo/open world. - kombinere med noe lignende som stolpejakten/geo catching for innhenting av ressurser. (Kanskje verktøy for å bygge og reparere). - kunne loggføre "lynaktiviteter" for å fylle på med ressurser. F.eks. ta 10 reps. av en styrkeøvelse (squats, pushups, sit ups etc.) - besøke kategoriserte områder for å samle vann, stein, tømmer etc. Ved et vann, på et fjell eller på tur i skog? - quiz for å øke kunnskapen til beboere, og spilleren selv. - events.”

“Kjørte en ganske kynisk taktikk som egentlig ikke burde ha lønt seg ihht tanken bak/bakgrunnshistorien til spillet”

“Gull generasjon virket tilfredlig. Litt mer forklaring på de forskjellige tingene, slik som hvor lang tid det tar å bygge og hvor mye poeng du får, før du bygger det. Få poeng etter bygget er bygget ferdig? Lite gull på de daglige oppdragene. Tok litt tid i starten å komme i gang. Vanskelig å ta igjen andre hvis de har gått mye fra starten av.”

“Testingen gikk bra på Android, virket som stakkars IOSere hadde større problem, eller hva Thomas? (: Ellers er det vel som jeg har nevnt bare dette med at selve konseptet virker litt uoptimalt. Jeg tror nok det kan være enkelte som liker det med bybygger der man øker progresjon med aktivitet, men tror det kan være et veldig nisje marked.”

“Bra dere bygger videre på konseptet av et spill hvor aktivitet er hovedressurs for progresjon. Likte spillet 😊”

“Litt dumt at man måtte gå med telefonen i lomma selv med klokke for og registrere aktivitet, veldig dumt pga jobb”

“Av og til trykket man på en rute og det kom opp en 'Edit' knapp. Det hørte nok ikke til spillet.”

“Det hadde vært en fordel om non-repeating hadde vært penger og så energi istedet for motsatt. Ellers gøy.”

“Godt jobbet, det var gøy!”

“Hadde gått enda mer hadde det ikkje vært for eksamen den siste uken”

“Jeg er veldig glemsk så flere innstillinger for varsler om f.eks. når vindmøller er fulladet (noe man kan skru av og på kanskje). En annen ting er å legge til flere typer brikker, som fabrikk eller noe, men også noen som endrer landskapet som fjell eller elv. Dette er hvis dere har tenkt å videreutvikle spillet. Jeg er allerede veldig imponert med resultatet så langt.”

“Spillet var ikke motiverende nok i seg selv. Viktig at jeg ønsker å spille spillet”

“Gjør om ikonene øverst til venstre til hvitt med sort ramme for bedre kontrast mot den veldig grå og utrolig kjedelige bakgrunnen. Erstatt den grå bakgrunnen. Kanskje grå skyer som letner når en tile renses? Få appen til å fungere i portrett-layout og regn dette som standard. Vil være mye mer praktisk når en er inne og kikker på appen en kjapp stund.”

“Kunne vært kult om man kunne finne flere vannkilder, slik at det blir litt risk og reward å "strekke" seg ut i en retning på jakt etter nye områder som det er billigere å bygge på lengre ut”

“Spillet var kjekt, og jeg ser mye potensial i det. Hadde det vært enda mer delmål og byggemulighet som gjorde at jeg kunne spilt litt mer før jeg måtte vente / gå ut å være aktiv så hadde det nok vært enda kjekkere.”

“- Ville vært fint å gjøre det inkluderende for folk med bevegelseshemming. Om spillet blir veldig populært bør det være tilgjengelig for alle. - Dere nevner sykkel mange ganger, men jeg opplevde ingen fordeler med sykling. Dere kan kanskje inkludere flere aktiviteter.”

“Åpen high-score-liste hadde vært gøy, mer storytelling, kanskje milepæler i samfunnet”

“Kunne vært mer informasjon eller hint i spillet om hva man kan gjøre for å få en bedre sivilisasjon, fornøydhet osv. En poengtabell i spillet hadde også vært motiverende!”

“Jeg syns det var, for hvordan jeg spilte, lite balanse mellom ressurser. Jeg fant alltid at jeg hadde en overflod med energi, men lite penger. Vil også nevne at jeg syns det var litt rart med daily og weekly quests. Jeg fulgte generelt lite med på når timeren på disse resettet, men hvis man ikke claimet ressurserne så (tror jeg) de bare forsvant? Dette endte opp med å bli litt black hat for meg, siden jeg merket at jeg åpnet appen midt på dagen og ikke hadde fullført quests, men jeg ville ikke spille rett før jeg la meg da det kanskje var mer effektivt så man kunne claime alt man hadde gjort. Jeg tror for en spiller som spilte så lite som jeg gjorde at det hadde vært interessant å utforske limited quests som

spilleren aksepterer. Hvis en villager fikk et utropstegn, jeg trykket på han og han sa at han ønsket at jeg gikk 20km på en uke fra da jeg aksepterte questet, så hadde jeg tenkt mye mer over det. Det hadde gitt meg mer motivasjon til å fullføre dette questet, og ikke de daily er weekly quests som bare lå i en tab. Jeg må også nevne at mitt spillløp var utrolig påvirket av sykdom. Jeg lå sengeliggende nesten de siste 10 dagene av testingen, og fikk derfor ikke gjort så mye under den perioden.”

“Det var kanskje litt høye mål innimellom. 120 aktive minutter som en medium lang tur er ganske mye, hvertfall hvis Google Fit ikke er helt nøyaktig. Skritt som måleenhet synes jeg fungerte bedre!”

“Bra jobba”

“Vil si at spillet har et fint potensiale som få andre spill baserer seg på som er trening/aktivitet i hverdagen. Håper å se en videre utvikling av spillet da dette kan bistå flere til en mer aktiv hverdag hvor man kan kombinere teknologi for å holde seg i aktiv form samtidig som man får konkurrert med andre spillere og får faktisk noe nytte ut av et spill. Dessverre for min del fikk jeg ikke brukt spillet like mye som jeg ville ha gjort i en annen livssituasjon enn i dag, men håper at tilgangen til spillet fortsetter da jeg tror at jeg selv kommer til å fortsette å bruke dette for en aktiv hverdag, tusen takk til dere som har utviklet spillet og at jeg fikk være med å teste spillet, fortsett med den gode jobben dere gjør. Bra jobbet!”

“Om spillet blir en hit håper jeg det videreutvikles så det kommer fler verdener å bygge i utover gressplenen med vindmøllene. Feks en undervannsverden med vannmåler eller ørken-bane hadde vært kult, oh kanskje tilogmed på Mars! Mye gøy å designe”

“Jeg fikk skrittellingen min satt ned til 50% på grunn av at jeg har Apple Watch. Men så stakk noen av med laderen min, så fikk ikke brukt klokka. Så da mista jeg motivasjonen fordi det ble vanskelig når bare halvparten av skrittene mine telles. Skulle også ønske man kunne ha rotert brettet siden det var vanskelig å se hva som var bak enkelte av flisene. Og jeg fikk helle ikke åpne appen etter en uke. Så jeg har nok vært en veldig dårlig test deltager for dere. Og det beklager jeg! Men er veldig spent på å se hva dere får til i framtiden. Og har stor tro på prosjektet! Bra initiativ og bra jobba folkens! 🙌”

“Skulle ønske det var litt flere farger i spillet. Så at man ble mer dratt inn i det visuelle”

“Spiller kunne vært scalea bedre. Vindmøller var for broken i så kort periode, men by for alle penga er bedre for 3 uker”

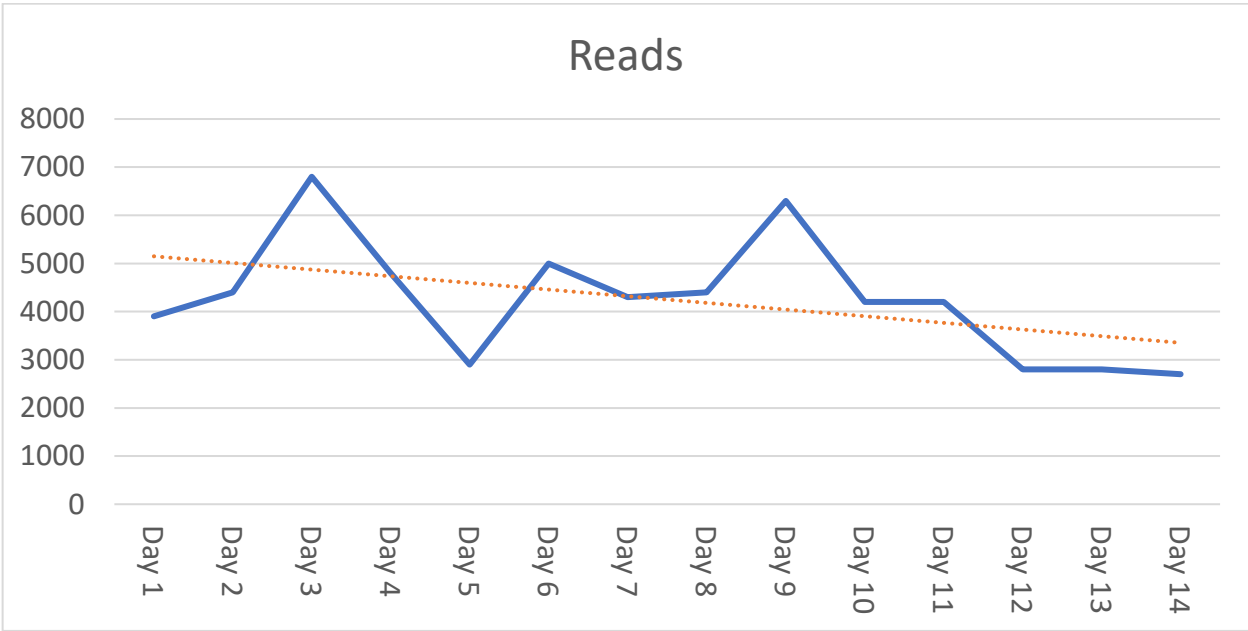
Appendix F

Database Data

Database data

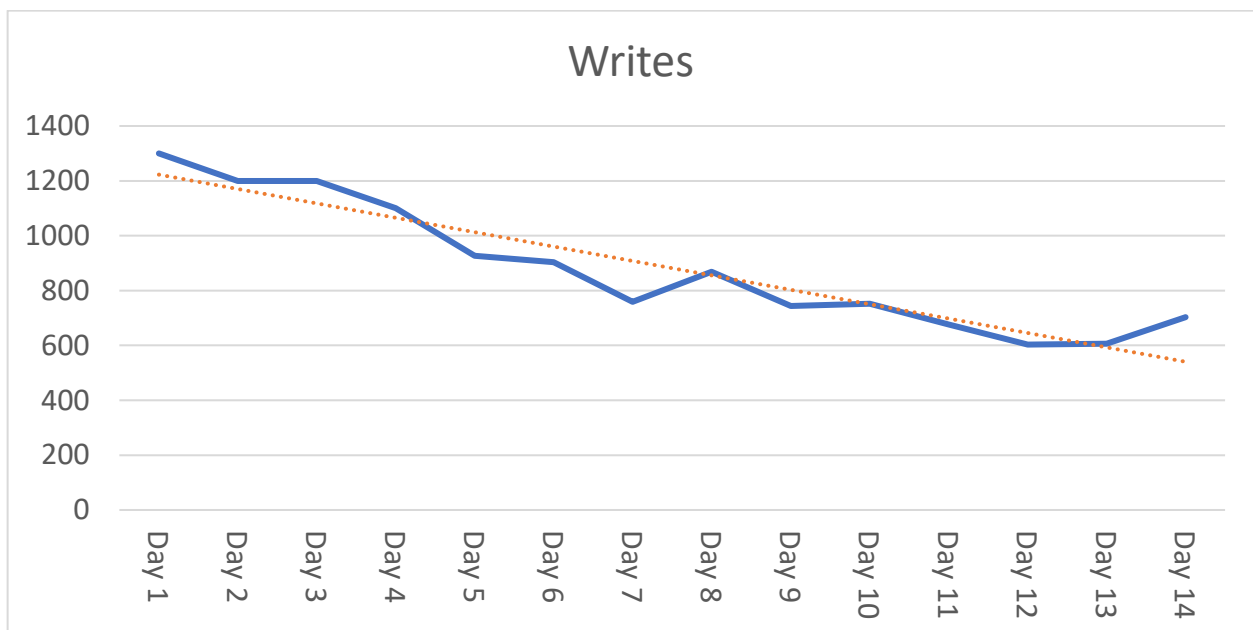
Database reads

Day	Reads
Day 1	3900
Day 2	4400
Day 3	6800
Day 4	4800
Day 5	2900
Day 6	5000
Day 7	4300
Day 8	4400
Day 9	6300
Day 10	4200
Day 11	4200
Day 12	2800
Day 13	2800
Day 14	2700



Database writes

Day	Writes
Day 1	1300
Day 2	1200
Day 3	1200
Day 4	1100
Day 5	927
Day 6	904
Day 7	759
Day 8	868
Day 9	744
Day 10	752
Day 11	676
Day 12	603
Day 13	606
Day 14	703

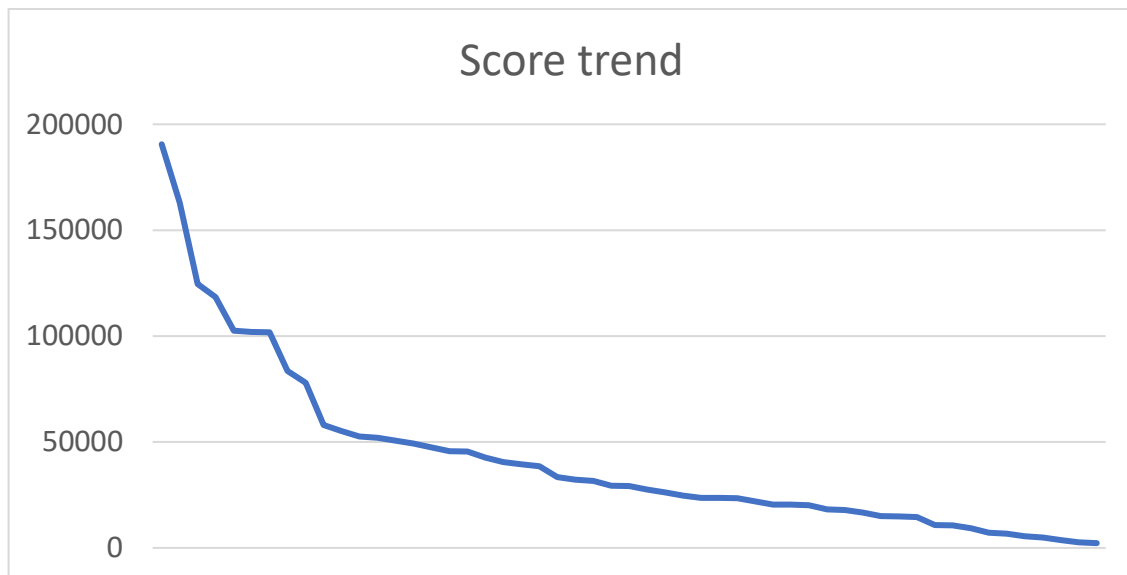


Player scores

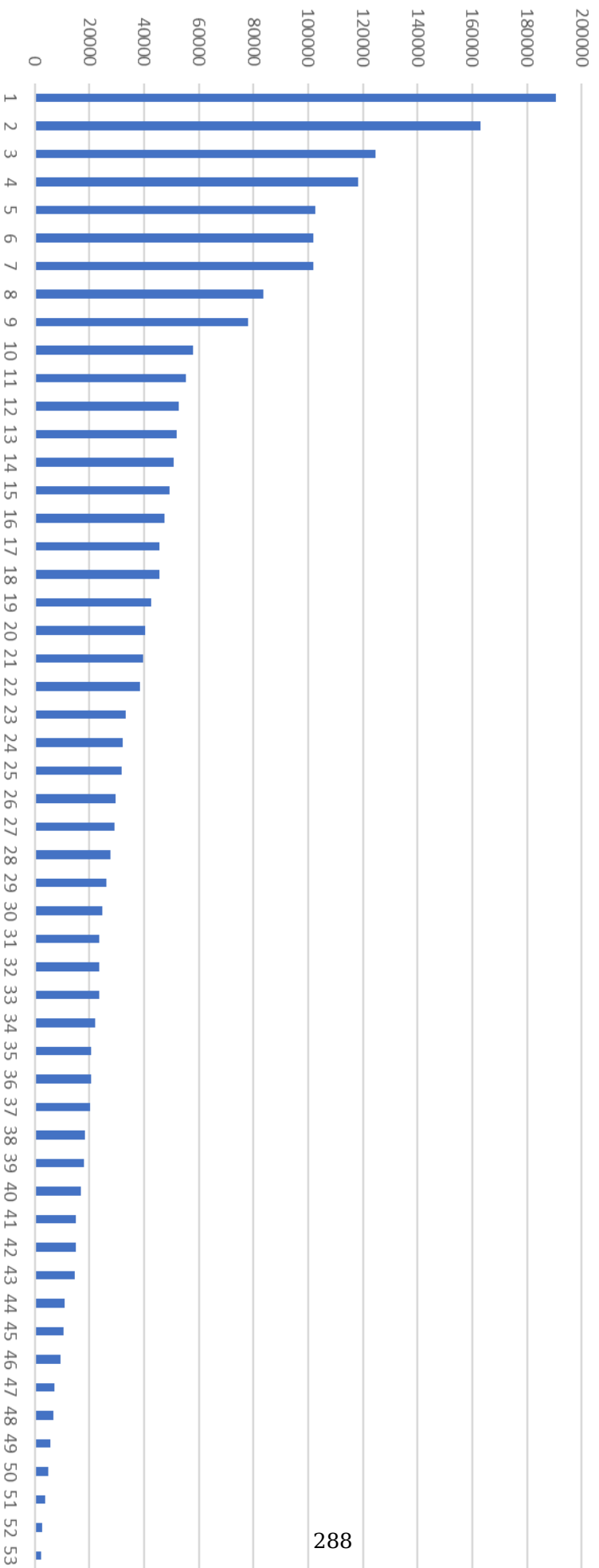
1	190570
2	162976
3	124604
4	118342
5	102540
6	101952
7	101822
8	83562
9	78027
10	58046
11	55220
12	52612
13	52014
14	50684
15	49312
16	47440
17	45586
18	45542

19	42690
20	40546
21	39512
22	38590
23	33412
24	32184
25	31664
26	29416
27	29204
28	27596
29	26148
30	24648
31	23678
32	23592
33	23528
34	21968
35	20476
36	20436

37	20194
38	18220
39	17846
40	16712
41	15058
42	14864
43	14614
44	10774
45	10650
46	9310
47	7176
48	6706
49	5582
50	4860
51	3706
52	2648
53	2254



User scores



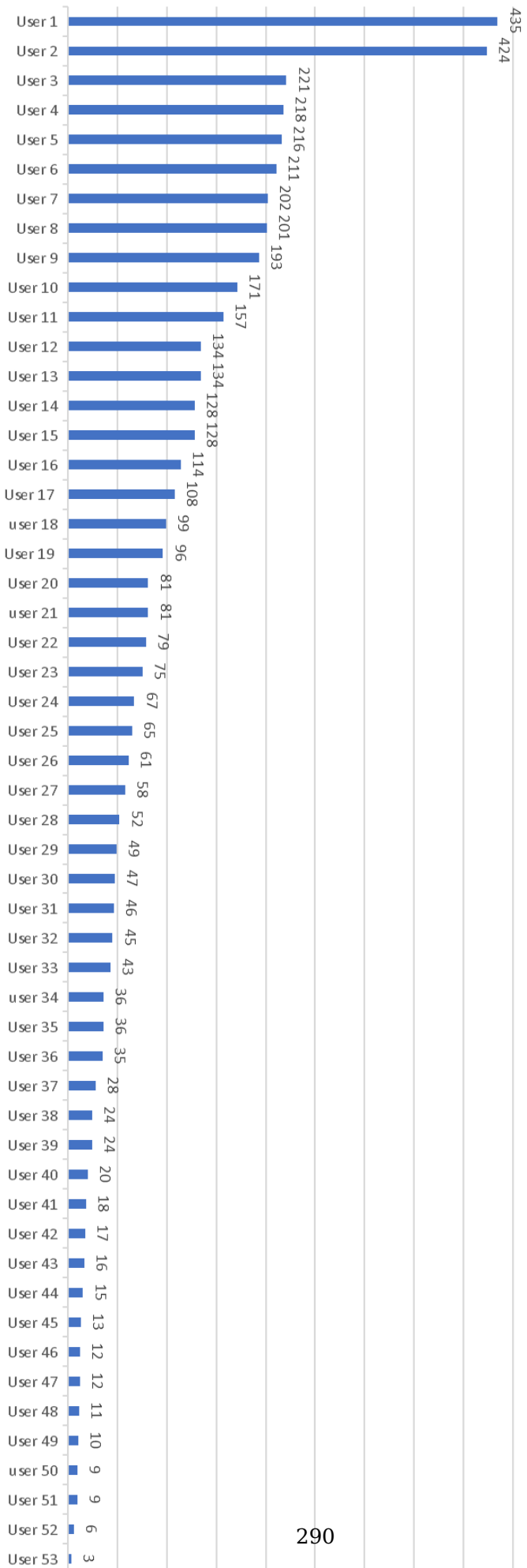
Game visits

User 1	435
User 2	424
User 3	221
User 4	218
User 5	216
User 6	211
User 7	202
User 8	201
User 9	193
User 10	171
User 11	157
User 12	134
User 13	134
User 14	128
User 15	128
User 16	114
User 17	108
user 18	99

User 19	96
User 20	81
user 21	81
User 22	79
User 23	75
User 24	67
User 25	65
User 26	61
User 27	58
User 28	52
User 29	49
User 30	47
User 31	46
User 32	45
User 33	43
user 34	36
User 35	36
User 36	35

User 37	28
User 38	24
User 39	24
User 40	20
User 41	18
User 42	17
User 43	16
User 44	15
User 45	13
User 46	12
User 47	12
User 48	11
User 49	10
user 50	9
User 51	9
User 52	6
User 53	3

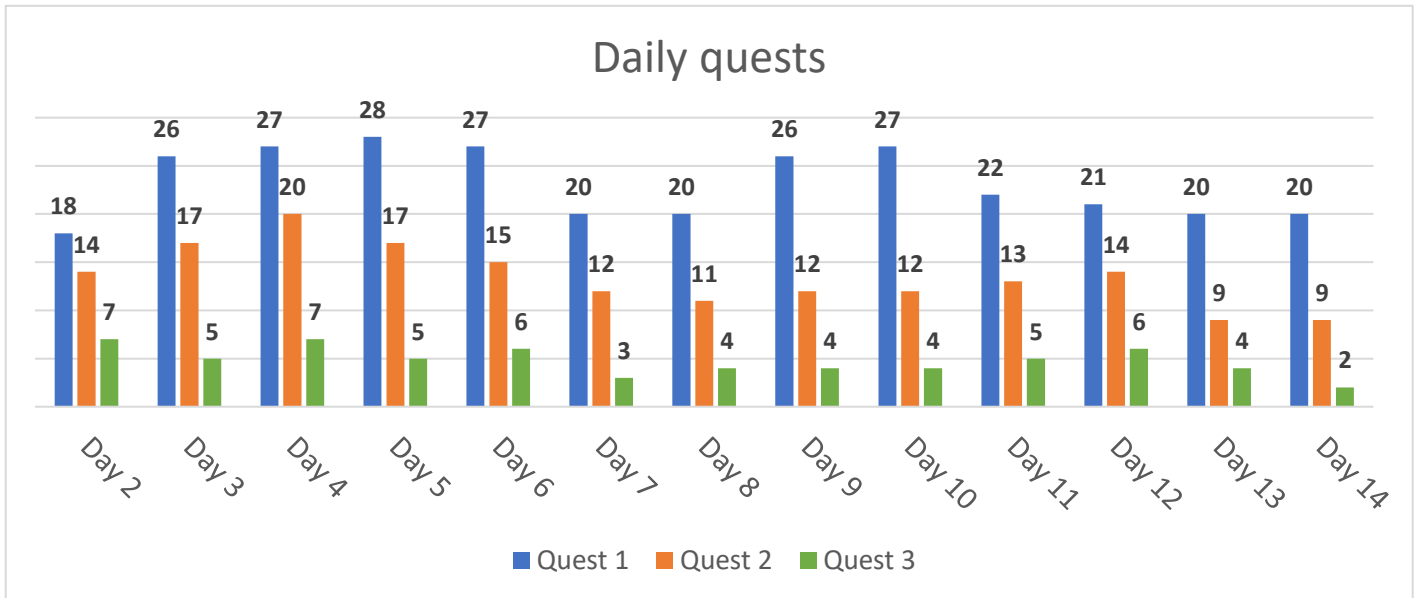
Game visits



Quest data

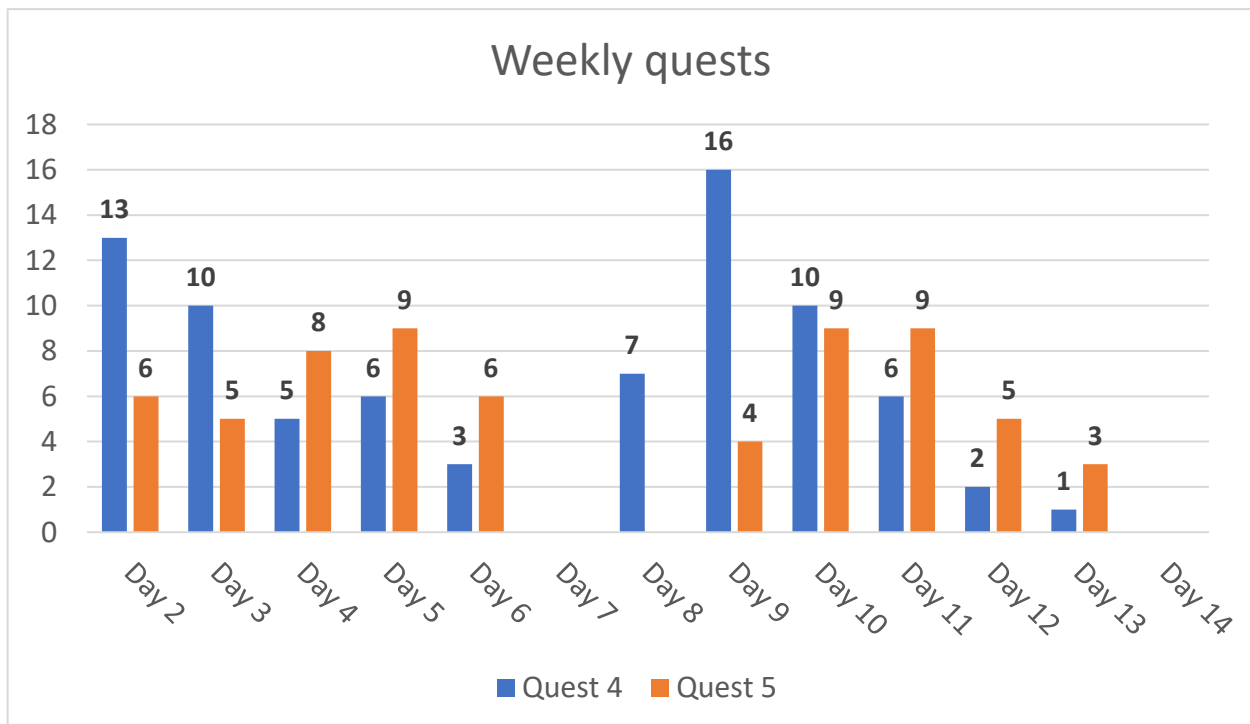
Daily quests

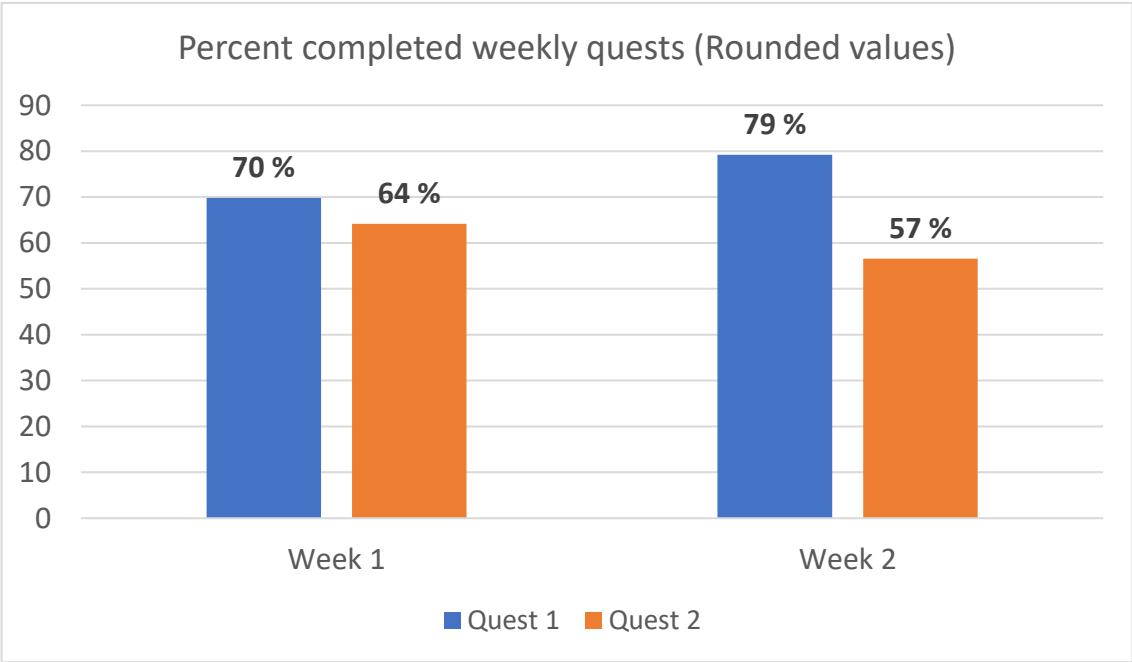
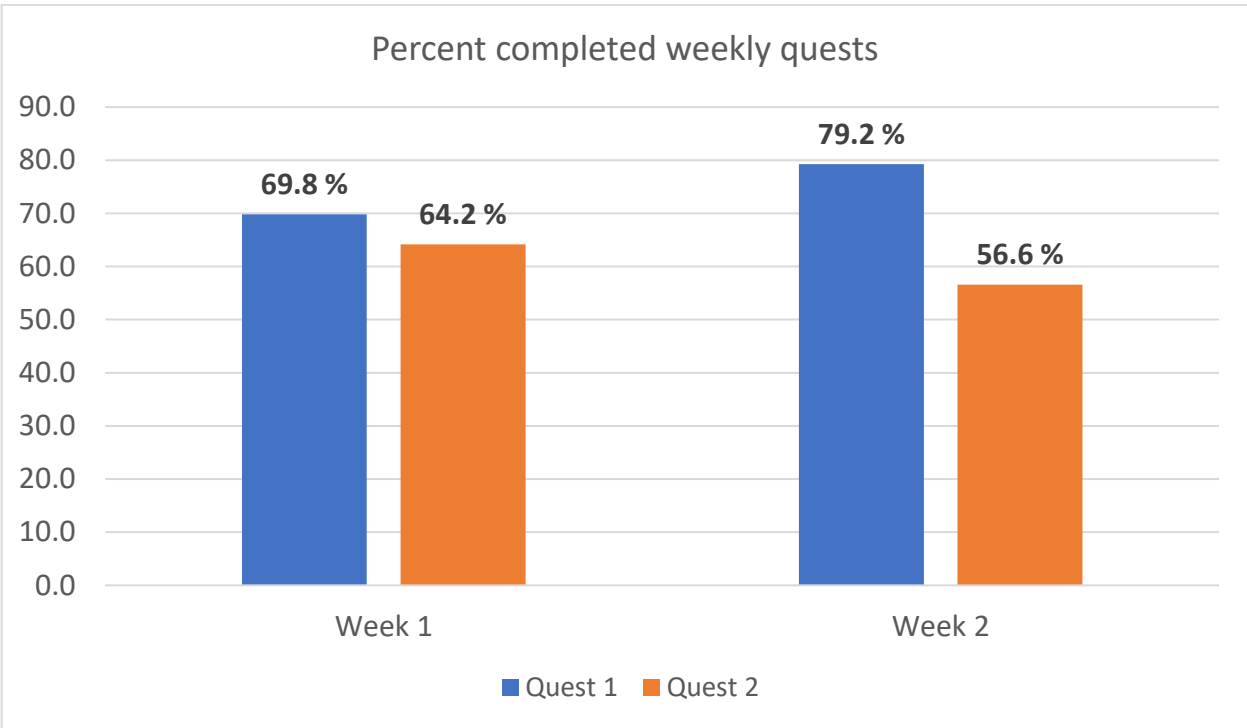
	Quest 1	Quest 2	Quest 3	Sum daily
Day 2	18	14	7	39
Day 3	26	17	5	48
Day 4	27	20	7	54
Day 5	28	17	5	50
Day 6	27	15	6	48
Day 7	20	12	3	35
Day 8	20	11	4	35
Day 9	26	12	4	42
Day 10	27	12	4	43
Day 11	22	13	5	40
Day 12	21	14	6	41
Day 13	20	9	4	33
Day 14	20	9	2	31
Sum	302	175	62	539



Weekly quests

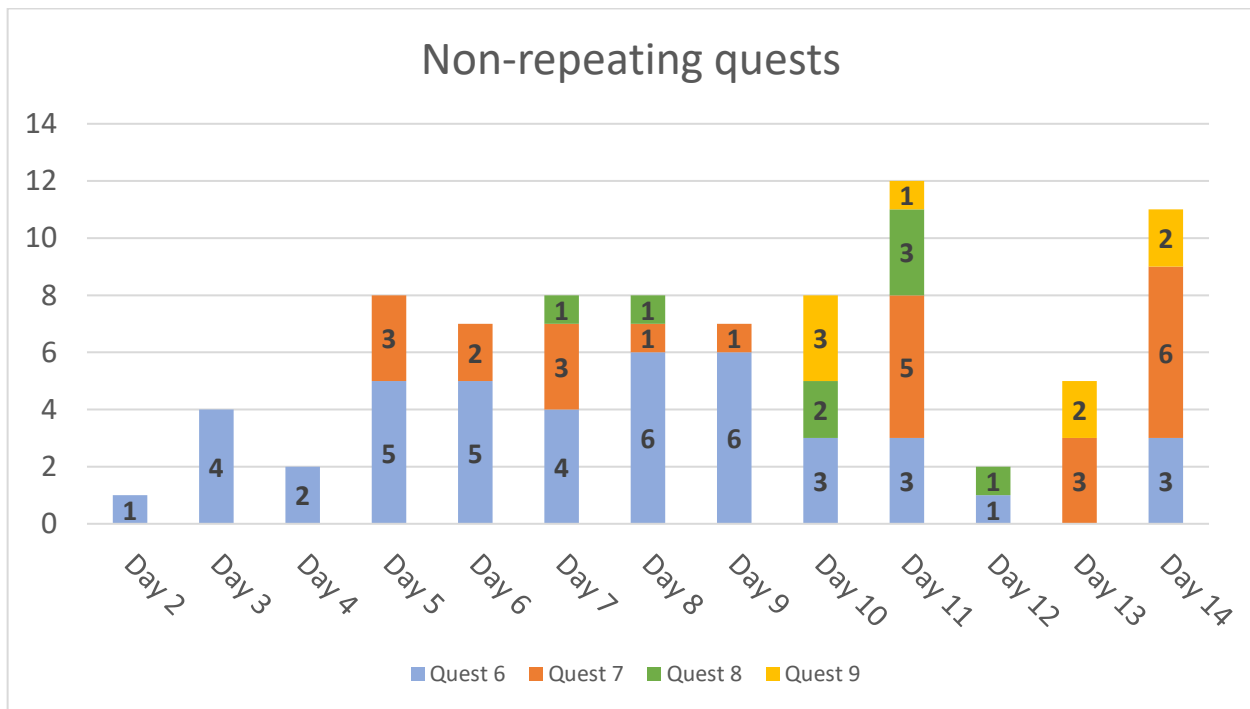
	Quest 4	Quest 5	Sum daily
Day 2	13	6	19
Day 3	10	5	15
Day 4	5	8	13
Day 5	6	9	15
Day 6	3	6	9
Day 7	0	0	0
Day 8	7	0	7
Day 9	16	4	20
Day 10	10	9	19
Day 11	6	9	15
Day 12	2	5	7
Day 13	1	3	4
Day 14	0	0	0
Sum	79	64	143





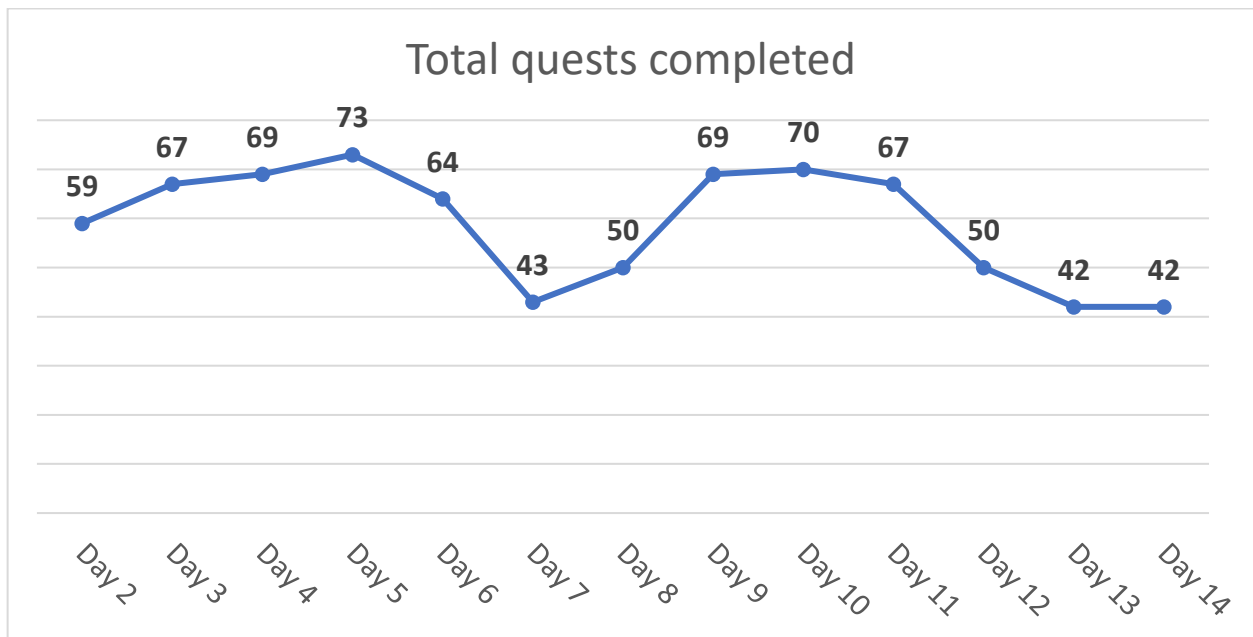
Non-repeating quests

	Quest 6	Quest 7	Quest 8	Quest 9	Sum daily
Day 2	1	0	0	0	1
Day 3	4	0	0	0	4
Day 4	2	0	0	0	2
Day 5	5	3	0	0	8
Day 6	5	2	0	0	7
Day 7	4	3	1	0	8
Day 8	6	1	1	0	8
Day 9	6	1	0	0	7
Day 10	3	0	2	3	8
Day 11	3	5	3	1	12
Day 12	1	0	1	0	2
Day 13	0	3	0	2	5
Day 14	3	6	0	2	11
Sum	43	24	8	8	83

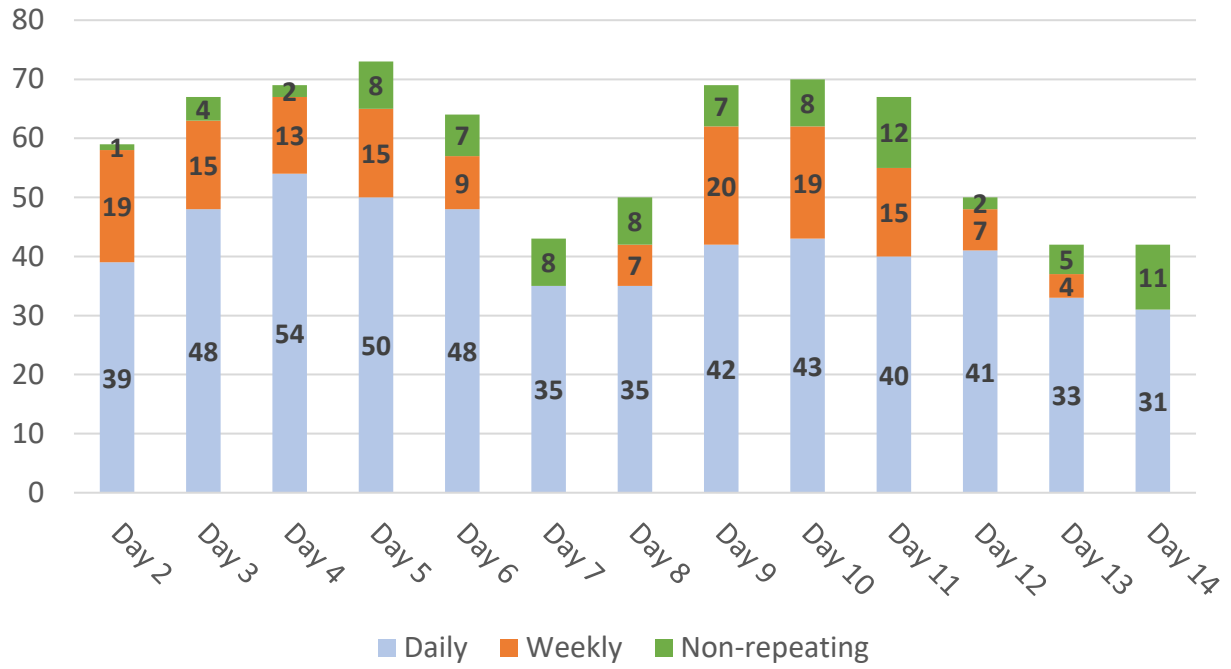


Total quests

	Sum all quests
Day 2	59
Day 3	67
Day 4	69
Day 5	73
Day 6	64
Day 7	43
Day 8	50
Day 9	69
Day 10	70
Day 11	67
Day 12	50
Day 13	42
Day 14	42
Sum	765



Total quests completed - detailed



Reads and writes after the test period

Dato	Read	Write
08.05.2023	1700	212
09.05.2023	999	218
10.05.2023	725	125
11.05.2023	135	96
12.05.2023	69	130
13.05.2023	84	142
14.05.2023	54	103
15.05.2023	577	88
16.05.2023	156	70
17.05.2023	27	58
18.05.2023	42	89
19.05.2023	415	74
20.05.2023	43	95
21.05.2023	45	65
22.05.2023	819	64
23.05.2023	22	53
24.05.2023	28	59
25.05.2023	26	38
26.05.2023	34	40
27.05.2023	54	41
28.05.2023	169	40

Appendix G

Interview Notes

Notater fra intervjuer

(Dette er notater av de viktigste punktene og ikke nødvendigvis direkte siteringer)

Intervju 1

- Hva synes du om opplegget rundt testingen?
 - Helt greit
- Føler du at testperioden var lang nokk til å få testet spillet?
 - Ja, syntes test perioden var lang nok til få prøve spillet
 - Var greit at test perioden stoppet før eksamensperioden begynte.
- Var det greit med informasjon rundt testingen?
 - Var en bra ordning for informasjon.
- Har du noe med selve testingen du skulle ønske var annerledes?
 - Måtte laste inn appen på nytt på iOS etter en uke, som var litt dumt
- Har dine vaner rundt fysisk aktivitet endret seg ilt. testperioden? Hvis ja, hvordan? Hvis nei, hva føler du manglet?
 - Gikk litt ekstra under testingen, men går ganske mye fra før, så det endret seg ikke så mye
- Hva var det som motiverte for tur?
 - Det var sosialt og hyggelig å gå turer sammen siden det var flere som spilte spillet.
 - Det som motiverte for turene, var målet om å få inn ekstra skritt
- Hvis du gikk tur på grunn av spillet. hva slags aktivitet var de turen erstattet? trening eller stillesitting?
 - Turer erstattet sittestilling og TV-titting, som var ganske greit
- Hva synes du om spillet som en motivator for fysisk aktivitet?
 - Det var gøy å spille spillet. Spesielt det å sammenlikne og å konkurrere mot andre
- Hvilke elementer i spillet motiverte deg mest?
 - Det var gøy å ligge på toppen av high-score listen.
- Følte du noen tilhørighet eller eierskap til landsbyen du bygde?
 - Ja, klarte ikke å slette landsbyen da testperioden var over
- Hva er dine tanker om high-score listene som ble sendt ut?
 - Synes det var bra med listene. Det var gøy å ligge på toppen.
 - Så ikke så mye på poengene opp til neste deltaker, mye fordi de lå øverst.
- Hva er dine tanker om questsene i spillet?
 - Burde vært flere quests av alle typene
 - Ble for fort ferdig med daglige og ukentlige quests, og da var det ingen ting å pushe mot.
- Er det noe mer du tenker spillet kunne ha gjort for å øke motivasjonen din?
 - Det kunne vært flere ting å gjøre i spillet, men samtidig gjorde det at det var lite å gjøre at man ikke var inne så mye
- Ble spillet ensformig? Hva tenker du kan gjøres for å gjøre det mindre ensformig?
 - Nei, det var ganske greit, for det krevde ikke så mye tid ut av dagen
 - Er lettere å spille sånne spill over en leger periode siden de ikke tar opp for mye tid

- I hvilke situasjoner brukte du/gikk du inn på spillet?
 - Var raskt innom i situasjoner når det passet, eller når det var andre som spilte som kunne sammenliknes med.
- Hvis du kunne endret på en ting i spillet, hva ville det vært?
 - Hadde vært greit om man kunne rotere landsbyen. Ting var ofte i veien for hverandre og det var vanskelig å se alt. Var lett å trykke feil.
- Hva ville du ha lagt til i spillet om du kunne ha bestemt?
 - Lage egne grupper som man kunne konkurrere mot
- Til slutt: er det noe mer du vil si? Hva som helst 😊
 - Tror det kommer til å bli et bra spill.

Intervju 2

- Hva synes du om opplegget rundt testingen?
 - Fungerte bra. Møtte på en bug, men ellers ingen ting.
- Føler du at testperioden var lang nokk til å få testet spillet?
 - Ja
- Var det greit med informasjon rundt testingen?
 - Ja, det var veldig rett frem, og informasjonen som ble gitt dekkende og enkelt.
- Har du noe med selve testingen du skulle ønske var annerledes?
 - Nei, eneste var at det ble litt dårlig tid opp mot eksamen
- Har dine vaner rundt fysisk aktivitet endret seg ilt. testperioden? Hvis ja, hvordan? Hvis nei, hva føler du manglet?
 - Nei, brukte spillet mest som “når jeg først var ute og gikk uansett” og var mer en bonus.
- Hvis du gikk tur på grunn av spillet. hva slags aktivitet var de turen erstattet? trening eller stillesitting?
 - Var et par ganger de gikk ekstra turer.
 - Turene erstattet sittestilling
- Hva motiverte deg til å gå disse turene?
 - Det at det var kort igjen for å nå et mål, slik at det bare manglet en kort tur. Typ 15 min gåing igjen for å nå målet.
- Hva synes du om spillet som en motivator for fysisk aktivitet?
 - Streaks var det mest motiverende aspektet i spillet
 - Spillet kunne kanskje ha hjulpet å motivere, men på grunn av andre omstendigheter var det ganske travelt, så spillet hjalp ikke så mye.
- Hvilke elementer i spillet motiverte deg mest?
 - Det å nå målene til streaks og quests slik at man kunne få mer penger.
- Følte du noen tilhørighet eller eierskap til landsbyen du bygde?
 - Nei
- Hva er dine tanker om High score listene som ble sendt ut?
 - Brydde seg ikke så mye, så hadde ingen påvirkning.
- Hva er dine tanker om questsene i spillet?
 - Weekly quests var så lett at de sluttet å være motiverende.
 - Non-repeating burde startet med å gi penger siden det var det som manglet.
- Er det noe mer du tenker spillet kunne ha gjort for å øke motivasjonen din?
 - Hadde vært fint med litt mer varians på questene. For eksempel å ha distanse som mål. Aktive minutter er ikke like motiverende som distanse gått.
- Ble spillet ensformig? Hva tenker du kan gjøres for å gjøre det mindre ensformig?
 - Ja, litt. Hadde vært bedre om man kunne gjøre mer underveis i spillet som å endre farger på hus og ha større varians av ting. Det vil gi mer kompleksitet til byggingen av samfunnet.
- I hvilke situasjoner brukte du/gikk du inn på spillet?
 - Gikk inn etter at de kom tilbake fra ting for å samle inn nye ting og se om man har nådd mål
- Hvis du kunne endret på en ting i spillet, hva ville det vært?

- Det burde vært lettere å få penger tidligere i spillet. Kanskje en mulighet er å få noe penger av å gå?
- Hva ville du ha lagt til i spillet om du kunne ha bestemt?
 - Evnen til å kunne rotere kamerat rundt landsbyen.
- Til slutt: er det noe mer du vil si? Hva som helst 😊
 - Var bra
 - Eneste var at weekly quest resatte seg på søndagen og ikke mandagen den andre uka i testperioden.

Intervju 3

- Hva synes du om opplegget rundt testingen?
 - Ganske greit. Tenker selv de var litt dårlig på å sjekke e-poster, men kom i gang med testingen greit.
 - Det at de var på Android gjøre at det var lett å starte.
 - "Tok 5 klikk og så var jeg der"
- Føler du at testperioden var lang nokk til å få testet spillet?
 - Ja
- Var det greit med informasjon rundt testingen?
 - Ja, det var ikke noe de satt igjen og lurte på
- Har du noe med selve testingen du skulle ønske var annerledes?
 - Alt virket helt i orden
- Har dine vaner rundt fysisk aktivitet endret seg ila. testperioden? Hvis ja, hvordan? Hvis nei, hva føler du manglet?
 - Litt. Spiller vanligvis mye Pokémon Go, så er vant til å gå mye.
 - Radiation Mayhem hjalp til å planlegge turer mer og var en konstant påminnelse og en «dytt» bak hele tiden for å gå tur. Det førte til litt mer uplanlagte turer.
- Hvis du gikk tur på grunn av spillet. hva slags aktivitet var de turen erstattet? trening eller stillesitting? Hva motiverte deg til å gå disse turene?
 - Gikk ekstra turer og de turene erstattet sittestilling.
- Hva motiverte deg til å gå disse turene?
 - Det å være x antall minutter fra å nå et mål. Da måtte man ut og gå for å få det til.
- Hva synes du om spillet som en motivator for fysisk aktivitet?
 - Veldig greit. Spesielt med tanke på at det ikke var noe som tok tid fra aktiviteten. Selve spillet spilles rett før og etter aktiviteten, men ikke under. Når man må gå og stirre på telefonen (som for eksempel under Pokémon Go) så stirrer man hele tiden ned i telefonen som gjør at man snubler inn i ting og tar oppmerksomhet og tid vekk fra aktiviteten.
- Hvilke elementer i spillet motiverte deg mest?
 - Det å være litt unna å fullføre et quest motiverte mest siden de ønsker å fullføre det.
 - Ønsket av å ekspandere og å vokse for å kunne bygge nye sett hus, Åkre, og skoger. De fant ut at den beste måten å gjøre det på var å kjøpe alle tre samtidig, og da var det motiverende å gå en tur for å kunne få til dette.
- Følte du noen tilhørighet eller eierskap til landsbyen du bygde?
 - Litt, men det var ikke en del av motivasjonen at landsbyen skulle bli gigantisk.
 - Tilhørighet og eierskap er ikke en ting som ikke motiverer dem i spill uansett
 - Hvis tiles hadde utviklet seg og "vokst" etter som de ble kombinert hadde det kanskje vært bedre siden man kunne utforske hva neste «evolusjon» ville være. Imagery kunne vært motivasjon nok
 - De var aldri i fare for at ting skulle mistet så de opplevde aldri å få en følelse av eierskap og at de måtte beskytte samfunnet sitt.
 - Var mer skummelt før de forsto hvordan spillet var balansert, men etter hvert be de trygge på at de aldri kom til å miste tiles.

- Hva er dine tanker om High score listene som ble sendt ut?
 - Første gang skaffet det litt motivasjon, men ettersom folk begynte å “ta av” i spillet så ble det ikke like motiverende.
 - Ble motiverende å sammenlikne seg selv mot andre folk som de kjente og ønsket å slå. Den interne konkurransen var velig motiverende.
 - Det å se poeng opp til neste spiller var mer motiverende siden den var mer oppnåelig.
- Hva er dine tanker om questsene i spillet?
 - Questene var veldig motiverende når de holdt på med dem, men det ble mindre motiverende når de mistet streaken de hadde.
 - De enkleste questene var veldig motiverende, men de litt mer vanskeligere virket ofte litt uoverkommelige som gjorde dem mindre motivverdener. Flere lav-nivå quests hadde nok vært enklere.
 - Testere som hadde quests som bare var skritt (iOS testere) sine quests følte mye lettere å nå enn på Android hvor det var minutter.
- Er det noe mer du tenker spillet kunne ha gjort for å øke motivasjonen din?
 - Hadde vært mer motiverende om spillet hadde et element av risk and reward. Hadde vært gøy å kunne se om du kunne risikert å utvide samfunnet i ulike rettinger, utforske og se om man kan finne nye vannkilder eller liknende for å prøve å etablere nye kolonier.
 - Ukjente ting ute i mørket hadde skapt spenning i det å utvide området.
- Ble spillet ensformig? Hva tenker du kan gjøres for å gjøre det mindre ensformig?
 - Rakk ikke å bli lei av spillet, men kunne ønske det var noe mer «mystisk» ved det som man kunne utforske.
 - Det å miste streaken gjorde at de ble ganske demotivert, men for det meste var spillet spennende fordi det var vekst i det hele tiden.
- I hvilke situasjoner brukte du/gikk du inn på spillet?
 - Som regler rett før eller rett etter mosjonsøkter. Når de sto opp og gjorde seg klar for dagen og etter at de hadde gått ulike steder.
 - Gikk inn når de ble minnet på det etter at spillet ga dem en påminnelse via notifikasjon.
- Hvis du kunne endret på en ting i spillet, hva ville det vært?
 - I starten fikk man alt for mye strøm, men seinere ble strøm mye vanskeligere å få tak i. En bedre balanse i dette hadde vært bra,
- Hva ville du ha lagt til i spillet om du kunne ha bestemt?
 - Det å legge til elementer av risk and reward kunne vært en fin motivator for å få tak i og å bruke strøm.
- Til slutt: er det noe mer du vil si? Hva som helst 😊
 - De fant ut at for å få optimalt med penger var den beste taktikken og alltid kjøpe i sett slik at de hadde likt antall hus, åker og skog. Det at man måtte kjøpe alle samtidig var en greie de ble pushet til, og de vet ikke helt om det er en god eller dårlig ting, men er en observasjon.

Intervju 4

- Hva synes du om opplegget rundt testingen?
 - Var bra og kom raskt i gang med testingen.
 - Poenglistene som kom etter noen dager, var også bra.
- Føler du at testperioden var lang nokk til å få testet spillet?
 - ja
- Var det greit med informasjon rundt testingen?
 - Alt var veldig klart. En feilmelding kom de de prøvde å starte, men de tok raskt kontakt og etter et par minutter var det fikset.
- Har du noe med selve testingen du skulle ønske var annerledes?
 - Nei
- Har dine vaner rundt fysisk aktivitet endret seg ila. testperioden? Hvis ja, hvordan? Hvis nei, hva føler du manglet?
 - På en måte ja. Var bittelitt mer aktiv enn vanlig, men det har også fortsatt egentlig litt etter perioden
 - Noe korrelasjon med at de har spilt spillet, men også noe utenforstående som været og ny sportsklokke de ønsket å teste ut. Samtidig så har spillet gjort at de var mer gira på å være aktiv og den motivasjonen har holdt videre etter at testingen sluttet.
- Hvis du gikk tur på grunn av spillet. hva slags aktivitet var de turen erstattet? trening eller stillesitting? Hva motiverte deg til å gå disse turene?
 - Ekstra turer tok tid fra stillesitting.
 - Noen ganger endte de opp med å gå rundt i stua for å få de siste skrittene de trengte
- Hva motiverte deg til å gå disse turene?
 - Det at de var så nærme å nå målet gjorde at det virket “overkommelig”. Hadde det virket uoverkommelig ville de ikke gjort det.
 - Var lite «effort» for mye «reward» i spillet
- Hva synes du om spillet som en motivator for fysisk aktivitet?
 - Det er åpenbart en prototype og de er begrenset hvor mye man kan gjøre. Hvis man kunne gjøre mer ting, så hadde nok vært mer spennende, men de var gira på å prøve ut spillet.
 - Flere ting som kunne gjøres i spillet ville nok hjulpet for å gi spillerne ordentlig motivasjon. Det var noe motivasjon i quest, men er potensiale for mye mer.
 - Trengte litt mer ting å gjøre for å få ordentlig motivasjon.
- Hvilke elementer i spillet motiverte deg mest?
 - Quests, og spesielt det å fullføre daglige og ukentlige quest.
 - Fra gang til gang var det de daglige questene som motiverte mest.
 - Quests ga penger så dermed ga mere resurser.
- Følte du noen tilhørighet eller eierskap til landsbyen du bygde?
 - Ikke mye. Noe glede og stolthet for at “dette har jeg fått til”, men tror det kanskje hadde vært noe som kom seinere.
 - Hadde det vært mulig å bygge flere ting hadde det kanskje gitt mer tilhørighet. muligheten til å bygge mer hadde det kanskje vært mer tilhørighet

- Det å kunne navngi byen og å bestemme fargetema hadde nok hjulpet
- Hva er dine tanker om High score listene som ble sendt ut?
 - Synes det var spennende. Så etter seg selv på lista og var gøy å vite plasseringen man lå på.
 - Det å se hvor nært man var nestemann og de over ga en motivasjon for å ta dem igjen.
 - Hadde vært morsommere om det var kjente folk man spilte mot så man kunne sette ansikt på de ulike konkurrentene.
- Hva er dine tanker om questsene i spillet?
 - Fine de som var der, men skulle gjerne hatt flere. Da ville det blitt mer granulært slik at man alltid var like ved å nå et mål, som ville motivere mer.
 - Burde være en veldig god premie om det er langfarende quests
 - Non-repeating var bra, men var dessverre litt unna å få dem til.
- Er det noe mer du tenker spillet kunne ha gjort for å øke motivasjonen din?
 - Mer kompleksitet i spillet. Det å kunne bygge flere typer bygninger og kanskje en mulighet til å sende folk for å angripe andre samfunn.
 - Hadde vært fint om det var mer man kunne gjøre før man ble stoppet av ressursmangel.
- Ble spillet ensformig? Hva tenker du kan gjøres for å gjøre det mindre ensformig?
 - Ble litt ensformig etter hvert. Tenkte litt "hva gjør jeg nå som jeg er ferdig med alt".
 - Det å kunne se hvem man spilte mot, mer utfordringer fra spillet og at spillet kunne gi en følelse av oppnåelse etter som spillere nådde milepæler kunne hjulpet.
- I hvilke situasjoner brukte du/gikk du inn på spillet?
 - Etter arbeidsdag og så seinere på kvelden. Det skjedde ikke så mye i spillet så ventet at par timer mellom hver gang de var inne.
 - Gikk inn etter å ha fullført treningsøkter.
- Hvis du kunne endret på en ting i spillet, hva ville det vært?
 - Hatt flere quests
- Hva ville du ha lagt til i spillet om du kunne ha bestemt?
 - Mer innhold i spillet og mer kompleksitet. Det å kunne bygge flere bygninger.
- Til slutt: er det noe mer du vil si? Hva som helst 😊
 - Var gøy å være med. Godt gjennomført og det var kult å være med.

Intervju 5

- Hva synes du om opplegget rundt testingen?
 - Var ganske greit. Installasjonen var enkel. De har mye erfaring med å installere ting på telefon på den måten
 - De var ikke så flinke til å sjekke e-post, men det var mer et personlig problem
- Føler du at testperioden var lang nokk til å få testet spillet?
 - Den kunne vært lengere, men gikk fint. Fikk ikke brukt det så mye som de hadde lyst til
 - Har vært mindre aktiv i det siste enn de vanligvis pleier å være på grunn av lite tid og energi
- Var det greit med informasjon rundt testingen?
 - Syntes det var bra
- Har du noe med selve testingen du skulle ønske var annerledes?
 - Nei, kommer ikke på noe spesifikt
- Har dine vaner rundt fysisk aktivitet endret seg ila. testperioden? Hvis ja, hvordan? Hvis nei, hva føler du manglet?
 - Spillet hadde ikke noe å si, men de har vært mindre aktiv i det siste av eksterne grunner som gjorde at de ikke fikk testet spillet så mye som de ønsket og også påvirket resultatene.
- Hvis du gikk tur på grunn av spillet. hva slags aktivitet var de turen erstattet? trening eller stillesitting? Hva motiverte deg til å gå disse turene?
 - Nei, det var ganger hvor de var klar over at de hadde spillet og tenkte at de kanskje burde ta en tur. Var mer en ekstra dytt for å ta en tur de skulle ta seg uansett.
 - Målet var å komme seg ut og få inn skritt.
- Hva motiverte deg til å gå disse turene?
 - Det var en stund siden sist tur og high score listene minnet dem på det og at de burde komme seg ut en tur
- Hva synes du om spillet som en motivator for fysisk aktivitet?
 - Det fungerte på et vis, men på grunn av personlige årsaker hadde det nok ikke så stor effekt som det kunne ha hatt. Det kunne kanskje ha pushet enda litt mer, men samtidig hadde det noe effekt.
 - Kunne ønske spillet pushet litt mer enn det alt gjør. De fikk ikke push notifikasjoner, og de tror at å få det ville ha hjulpet.
- Hvilke elementer i spillet motiverte deg mest?
 - Det at tiles forsvinner dersom man ikke rengjør dem og high score listene var mest motiverende.
- Følte du noen tilhørighet eller eierskap til landsbyen du bygde?
 - Fikk ikke så mye eierskap av å bygge på det, men det var «ille» å miste ting og at ting ble tatt fra «dem».
- Hva er dine tanker om High score listene som ble sendt ut?
 - Det var noe som motiverte. Det at man kunne se i appen hvor langt bak man lå den foran hadde litt samme effekt.
- Hva er dine tanker om questsene i spillet?

- Gjorde ikke så mye med questene i løpet av testingen. Så på dem, men brukte ikke noe tid på prøve å nå dem.
- Er det noe mer du tenker spillet kunne ha gjort for å øke motivasjonen din?
 - Kunne sendt flere notifikasjoner for å minne spilleren om at spillet eksisterer og at det er tings som trengs å bli gjort. (Litt som Duolingo, men ikke fullt så aggressivt)
- Ble spillet ensformig? Hva tenker du kan gjøres for å gjøre det mindre ensformig?
 - Konstruksjonen av ting var jo at det ikke var så mye å gjøre der. Kunne vært litt mer variasjon med å bygge ting, men det gikk fint. Kunne vært fint med flere bygg og mere muligheter til customising.
- I hvilke situasjoner brukte du/gikk du inn på spillet?
 - Gikk inn da de kom på spillet, som da de var på jobb.
 - Gikk inn etter at de hadde vært på tur.
 - Det å være inne i spillet besto av å gå inn, se seg om, og bygge litt.
 - Gikk inn da de kom på det, som var da de var på jobb
- Hvis du kunne endret på en ting i spillet, hva ville det vært?
 - Usikker. Det som er i spillet, er et ganske bra konsept så det er ikke noe de tenker burde endres på.
- Hva ville du ha lagt til i spillet om du kunne ha bestemt?
 - Forskjellige kombinasjoner og blokker vil lage nye ting og på den måten kan man utforske og finne ut av de ulike kombinasjonene
- Til slutt: er det noe mer du vil si? Hva som helst 😊
 - Synes det var et godt startpunkt på å legge til flere ting i spillet.

Intervju 6

- Hva synes du om opplegget rundt testingen?
 - Det var forståelig og greit. Det var ingen antagelser som var for store, eller for små.
 - Det var greit å forstå at det kunne være vanskelig for vanlige folk å laste inn spillet, men instruksjonene presenterte det på en måte som gjorde det forståelig.
- Føler du at testperioden var lang nokk?
 - Fikk ikke spilt så mye på grunn av at google Fit ikke registrerte data under deler av testperioden, men de fikk spilt noe og kan se for seg hvordan det ville ha vært
 - Opplevde ingen feilmeldinger eller krasjer.
 - Spillet fikk tankeprosessen i gang som at de hadde lyst til å være aktiv for å nå målene sine og det trigget riktige impulser om å være aktiv.
 - Synes spillet mangler midgame og endgame, men det er forståelig siden det var mye å gjøre og synes det spillet som var der var bra gjort på tiden som
 - Mengden med notifikasjoner som kom var en perfekt mengde og fikk dem til å komme på å gå inn på spillet
- Var det greit med informasjon rundt testingen?
 - Nei. Var bra med instruksjoner og hjelpemidler.
- Har dine vaner rundt fysisk aktivitet endret seg ilt. testperioden? Hvis ja, hvordan? Hvis nei, hva føler du manglet?
 - Ja, gikk tur for å nå streak-målet. Siden Google Fit ikke registrerte data så la de det inn manuelt selv og det fikk spillet til å funke.
 - De klarte å legge ting manuelt og det fikk spillet til å funke.
- Hvis du gikk tur på grunn av spillet. hva slags aktivitet var de turen erstattet? trening eller stillesitting? Hva motiverte deg til å gå disse turene?
 - Daily quest og miste streak var det som var mest motiverende. Siden måneden var så lave så var det lett å klare det hver dag, som var givende
- Hva synes du om spillet som en motivator for fysisk aktivitet?
 - Det var det at penger for å få quests var det som motiverte mest. Ble litt overasket av spillet siden de så for seg et mer AR spill, men det var greit at spillet ikke var så inngripende.
 - Spillet var gøy, men bygningene ga dem ikke så mye. (Bortsett fra vindmøllene)
- Følte du noen tilhørighet eller eierskap til landsbyen du bygde?
 - Var noe personlig om hvor man passerte ulike bygninger, men for det meste var det bare å bygge ting og å se triste fjes.
- Hva er dine tanker om High score listene som ble sendt ut?
 - Både motiverende og demotiverende. Ligger man høyt oppe så er det gøy, men faller man langt ned så er det ikke mulig å ta igjen og da blir det demotiverende .
 - Noe som var bra med listene var at det viste at for å få god fremgang i spillet måtte man være aktiv. I starten, da aktivitet ikke ble registret ble det vist at det ikke funker å spille spillet dersom man er inaktiv, og det er en bra ting.
- Hva er dine tanker om questsene i spillet?
 - Bra. Virket godt gjennomtenkt kvalitetsmessig. Ting var oppnåelig og de virket som det var riktig størrelse på dem.

- Er det noe mer du tenker spillet kunne ha gjort for å øke motivasjonen din?
 - Ikke noe de kommer på, men tenker at etter at man har spilt litt vil spillet kanskje bli litt generisk
 - Det å sette lave mål som er basert på virkelige krav er bra og det gjorde at spillet var bra nok for en slik kort test periode.
- Ble spillet ensformig? Hva tenker du kan gjøres for å gjøre det mindre ensformig?
 - Ja, selve spilldelen var jo fort ensformig med tile-bygging og redding, men de ikke testet så mye av «aktivitet» delen som kanskje ville bringe litt mer motivasjon
 - Ved eventuell videreutvikling burde verden vært mer variert, og skaleringen av kostnaden til tiles kunne vært mer utforskende som gjør verden mer spennende med at ting kan bli oppdatert eller at man kan få spesielle ting ut av spesielle quests.
- I hvilke situasjoner brukte du/gikk du inn på spillet?
 - Når påminnelsene kom og hadde tid til å gå inn. Når man hadde ledig tid, gikk de inn og sjekket energi-nivået
- Hvis du kunne endret på en ting i spillet, hva ville det vært?
 - Verdenen burde vært mer dynamisk og ikke like flat
- Hva ville du ha lagt til i spillet om du kunne ha bestemt?
 - Research tree
- Til slutt: er det noe mer du vil si? Hva som helst 😊
 - Veldig bra jobba. Var mye bedre enn de trodde det skulle være. Fant ingen store bugs
 - Alt funket. 3D, trykking og tracking.
 - Tenker det er en kul ide å trene via spilling og at dette kan være veien å gå for folk som ikke liker å trene.
 - Spillet var riktig nivå abstraksjon og motiverte for å trene.

Appendix H

Declaration of Consent - Group 1

Du er invitert til å delta i forskningsprosjektet

Play to get fit

Vil du være med på å kanskje finne det neste store innen treningsmotivasjon?

Dette er et spørsmål til deg om å delta i et forskningsprosjekt hvor formålet er å undersøke om spillkonseptet *Radiation Mayhem* kan øke deltagerens motivasjon for fysisk aktivitet. I dette skrivet gir vi deg informasjon om målene for prosjektet og hva deltakelse vil innebære for deg.

Formål

Prosjektet er en masteroppgave ved NTNU Trondheim, Fakultetet for Informasjonsteknologi og Elektroteknikk, Institutt for Datateknologi og Informatikk. Bakgrunnen for prosjektet er at store deler av befolkningen får lite fysisk aktivitet i hverdagen. Dette prosjektet undersøker hvordan videospill kan være med på å øke mengden fysisk aktivitet i folks hverdag.

Dette prosjektet er en del av en masteroppgave ved NTNU. Opplysningene som samles inn i løpet av dette prosjektet vil ikke brukes til noen andre formål enn masteroppgaven.

Hvem er ansvarlig for forskningsprosjektet?

Professor Alf Inge Wang ved Instituttet for datateknologi og informatikk er prosjektansvarlig.

Hvorfor får du spørsmål om å delta?

Du får spørsmål om å delta fordi du befinner deg i nettverket til en av prosjektets deltakere og fordi du passer i målgruppen for eksperimentet.

Hva innebærer det for deg å delta?

Ved å delta i prosjektet er du med på et eksperiment som går over **2 uker**. I starten ønsker vi at du svarer på en elektronisk spørreundersøkelse som kartlegger dine treningsvaner og forhold til spill og fysisk aktivitet. Videre vil vi at du spiller *Radiation Mayhem* så mye du vil over **2 uker**. Under spillingen vil spillet lagre anonyme data om din fysiske aktivitet og spillfremgang. På slutten av eksperimentet ønsker vi at du svarer på et annet elektronisk spørreskjema som oppsummerer erfaringene dine.

Det er frivillig å delta

Det er frivillig å delta i prosjektet. Du kan når som helst trekke samtykket ditt tilbake uten å måtte oppgi noen grunn. Dersom du trekker deg fra prosjektet, vil alle dine lagrede personopplysninger slettes. Det vil ikke ha noen negative konsekvenser for deg hvis du ikke vil delta eller velger senere å trekke deg fra prosjektet.

Ditt personvern - hvordan vi oppbevarer og bruker dine opplysninger

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

Det er veileder Alf Inge Wang og studentene Thomas Bakken Moe og Helene Yuee Jonson som vil ha tilgang til dataene. Ditt navn og din epostadresse vil erstattes med en ID og blir lagret adskilt fra øvrige data. Deltakerlisten og resultater fra de elektroniske spørreskjemaene vil lagres i NTNUs SharePoint som er sikret med kryptering og adgangsbegrensning. Du kan lese mer om SharePoint sin behandling av dine data her:

<https://learn.microsoft.com/en-us/sharepoint/safeguarding-your-data>

Deltagere vil ikke kunne gjenkjennes i publikasjonen. Alle opplysninger som brukes i publikasjonen vil være anonymiserte.

Hva skjer med opplysningene dine når vi avslutter forskningsprosjektet?

Opplysningene dine vil permanent anonymiseres når prosjektet avsluttes/oppgaven er godkjent. Dette vil gjøres ved at listen som kobler relasjonen mellom personopplysninger og ID vil slettes. Prosjektet vil etter planen være avsluttet senest 25. juni 2023.

Hva gir oss rett til å behandle personopplysninger om deg?

Vi behandler personopplysninger om deg basert på ditt samtykke.

På oppdrag fra Institutt for datateknologi og informatikk ved NTNU, har Norsk senter for forskningsdata (NSD) vurdert at behandlingen av personopplysninger i dette prosjektet er i samsvar med personvernregelverket.

Dine rettigheter

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

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

Kontaktinformasjon

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

- Forfattere av masteroppgaven:
 - Thomas Bakken Moe - thomabmo@stud.ntnu.no
 - Helene Yuae Jonson - heleneyj@stud.ntnu.no
 - Veileder/forsker:
 - Alf Inge Wang - alf.inge.wang@ntnu.no
 - Vårt personvernombud:
 - Thomas Helgesen - thomas.helgesen@ntnu.no
- For mer info se: <https://i.ntnu.no/wiki/-/wiki/Norsk/Personvernombud+NTNU>

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

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

Vi håper du finner prosjektet vært interessant og har lyst til å være med!
Med vennlig hilsen

Alf Inge Wang
(Forsker/veileder, NTNU)

Thomas Bakken Moe
(Student, NTNU)

Helene Yuae Jonson
(Student, NTNU)

Samtykkeerklæring: <https://forms.office.com/e/LbTLuKK3M2>

Samtykkeerklæring-gruppe 1

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

* Obligatorisk

1. Jeg har mottatt og forstått informasjon om prosjektet Play to get fit, og har fått anledning til å stille spørsmål. Jeg samtykker til: *

Å delta i eksperiment ved bruk av mobilapplikasjonen Radiation Mayhem

Å delta i to runder med elektroniske spørreundersøkelser

2. Fullt navn *

3. Signeringsdato *

Dette innholdet er verken opprettet eller godkjent av Microsoft. Dataene du sender, sendes til skjemaieren.

 Microsoft Forms

Appendix I

Declaration of Consent - Group 2

Du er invitert til å delta i forskningsprosjektet

Play to get fit

Vil du være med på å kanskje finne det neste store innen treningsmotivasjon?

Dette er et spørsmål til deg om å delta i et forskningsprosjekt hvor formålet er å undersøke om spillkonseptet *Radiation Mayhem* kan øke deltagerens motivasjon for fysisk aktivitet. I dette skrivet gir vi deg informasjon om målene for prosjektet og hva deltakelse vil innebære for deg.

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Dette prosjektet er en del av en masteroppgave ved NTNU. Opplysningene som samles inn i løpet av dette prosjektet vil ikke brukes til noen andre formål enn masteroppgaven.

Hvem er ansvarlig for forskningsprosjektet?

Professor Alf Inge Wang ved Instituttet for datateknologi og informatikk er prosjektansvarlig.

Hvorfor får du spørsmål om å delta?

Du får spørsmål om å delta fordi du befinner deg i nettverket til en av prosjektets deltakere og fordi du passer i målgruppen for eksperimentet. Du har også blitt spesielt valgt for å passe til et personlig intervju som en del av prosjektet.

Hva innebærer det for deg å delta?

Ved å delta i prosjektet er du med på et eksperiment som går over **2 uker**. I starten ønsker vi at du svarer på en elektronisk spørreundersøkelse som kartlegger dine treningsvaner og forhold til spill og fysisk aktivitet. Videre vil vi at du spiller *Radiation Mayhem* så mye du vil over **2 uker**. Under spillingen vil spillet lagre anonyme data om din fysiske aktivitet og spillfremgang. På slutten av eksperimentet ønsker vi å invitere deg til et personlig intervju hvor vi går igjennom dine opplevelser og inntrykk av spillet og prosjektet som helet. Vi vil også at du svarer på et annet elektronisk spørreskjema som oppsummerer erfaringene dine.

Det er frivillig å delta

Det er frivillig å delta i prosjektet. Du kan når som helst trekke samtykket ditt tilbake uten å måtte oppgi noen grunn. Dersom du trekker deg fra prosjektet, vil alle dine lagrede personopplysninger slettes. Det vil ikke ha noen negative konsekvenser for deg hvis du ikke vil delta eller velger senere å trekke deg fra prosjektet.

Ditt personvern - hvordan vi oppbevarer og bruker dine opplysninger

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

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 - Alf Inge Wang - alf.inge.wang@ntnu.no
- Vårt personvernombud: <https://i.ntnu.no/wiki/-/wiki/Norsk/Personvernombud+NTNU>

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

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

Vi håper du finner prosjektet vært interessant og har lyst til å være med!
Med vennlig hilsen

Alf Inge Wang
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Thomas Bakken Moe
(Student, NTNU)

Helene Yuee Jonson
(Student, NTNU)

Samtykkeerklæring: <https://forms.office.com/e/tWC49ayyYW>

Samtykkeerklæring-gruppe 2

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

* Obligatorisk



1. Jeg har mottatt og forstått informasjon om prosjektet Play to get fit, og har fått anledning til å stille spørsmål. Jeg samtykker til: *

- Å delta i eksperiment ved bruk av mobilapplikasjonen Radiation Mayhem
- Å delta i to runder med elektroniske spørreundersøkelser
- Å delta i et intervju om dine opplevelser med mobilapplikasjonen

2. Fullt navn *

3. Signeringsdato *



Dette innholdet er verken opprettet eller godkjent av Microsoft. Dataene du sender, sendes til skjemaieren.

Appendix J

External Unity Assets

External Unity assets used in Radiation Mayhem

- *BEHealthKit*
A framework that allows Unity Games to communicate with Apple HealthKit
<https://assetstore.unity.com/packages/tools/integration/behealthkit-39962>
- *Low Poly Country House*
Assets used to create most of the House Tile
<https://assetstore.unity.com/packages/3d/low-poly-country-house-66203>
- *Low Poly Megapack - Lite*
An asset pack that includes many different types of assets, all in a low-polygon style. The forest assets were used as details in many of the different tiles
<https://assetstore.unity.com/packages/3d/environments/low-poly-megapack-lite-136629>
- *Low Poly Farm Pack Lite*
A small asset pack that includes farm-related low-polygon assets. We used these assets to create most of the Farm Tile.
<https://assetstore.unity.com/packages/3d/environments/low-poly-megapack-lite-136629>
- *Low-Poly Simple Nature Pack*
A small asset pack containing nature-themed low-polygon assets. These were used to create the Forest Tile and detailing many different tiles. The grass assets were especially useful.
<https://assetstore.unity.com/packages/3d/environments/landscapes/low-poly-simple-nature-pack-162153>
- *KayKit - Medieval Builder Pack*
An asset pack containing hexagonal building blocks for creating medieval-style landscapes. The only asset used from this pack was the base mesh for the hexagonal tiles.
<https://kaylousberg.itch.io/kaykit-medieval-builder-pack>

Appendix K

Gameplay Demonstration

Link to a demonstration of Radiation Mayhem's gameplay: <https://youtu.be/UsvgCqm7AxI>

NOTE: This was recorded while using a developer account not registered in the Firestore database. This is why the "Loading next player..." message displays, as it is unable to fetch other players from the database.

Appendix L

Radiation Mayhem Help Guide

Radiation Mayhem

Velkommen til introduksjon / hjelpeguiden til spillet vårt, Radiation Mayhem. Dette dokumentet vil forklare hva spillet handler om og hvordan det fungerer.

Spillhistorie (Story)

Etter at den store strålingsulykken har gjort jorden nesten ulevelig og utryddet store deler av menneskeligheten, prøver en gruppe gjenlevende å finne seg et nytt hjem. Du, en gruppe overlevende og din RCM (Radiation Cleanup Machine) har heldigvis kommet over en av de siste strålingsfrie områdene som er igjen. Dere prøver å etablere et blomstrende samfunn som lever av de ressursene de har.

Spillinstruksjoner

Spillet er et rutenett- og brikke-basert spill som går ut på å ta vare på, og utvikle et samfunn. Ved bruk av RCM-en kan du rengjøre områder for stråling og gjøre dem beboelige. Strålingen vil alltid prøve å spre seg, så det er viktig å passe på samfunnet ved å holde strålingen tilbake.

For å utvide samfunnet må spillerne rengjøre skitne brikker, som vil koste energi. Energi skapes når spilleren beveger seg, fullfører enkelte oppdrag, eller samler energi fra vindmøller. Når en brikke har blitt rengjort, kan den bygges på. Å bygge på en brikke vil koste penger, hvor ulike brikker koster ulike mengder penger, basert på hvor bra de er. Ulike brikker tar også forskjellige mengder tid å bygge.

Brikker

Spillet bruker et rutenett og et brikkesystem. Det finnes ulike typer brikker og hver brikketype har ulike egenskaper som vil påvirke samfunnet på forskjellige måter.

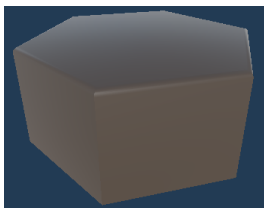
Sentrumsbrikke:

Sentrumsbrikken er en unik brikke som bare står i sentrum av samfunnet. Den er samfunnets vannkilde og dersom den blir korrumpert er spillet tapt. En sentrumsbrikke kan hverken flyttes eller slettes.



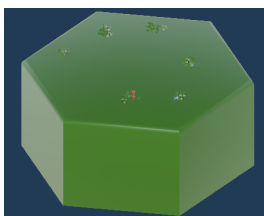
Forurenset brikke:

Brikker som er forurenset av radioaktiv stråling kan ikke bygges på eller bli bebodd. For å kunne ta området i bruk må de rengjøres ved hjelp av energi og RCM. Du kan trykke på forurensete brikker for å rengjøre de.



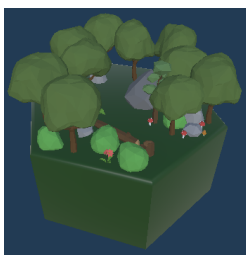
Ren brikke:

Brikker som har blitt rengjort for energi kan brukes av samfunnet. En ren brikke kan bli gjort om til andre type brikker, enten ved å bygge nye ting på den, eller ved å flytte andre brikker dit.



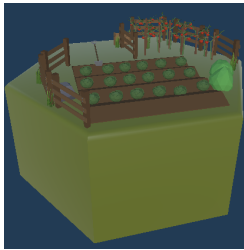
Skog:

Skog er en type samfunnsbrikke. Skogen bringer natur og frisk luft til samfunnet, og skogholt og tømmerarbeid er der samfunnet kan samle og tjene ressurser.



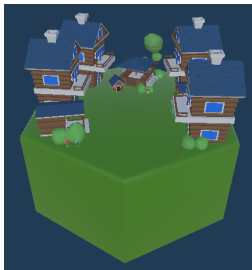
Åker:

Åkre er en samfunnsbrikke der samfunnet gror mat for å overleve. Dersom samfunnet ikke har nok mat til å støtte befolkningen vil de være sultne og ikke klare å ta vare på seg selv på en god måte.



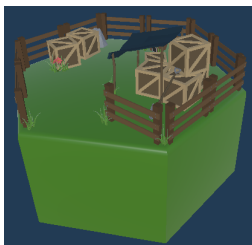
Hus:

Hus er en samfunnsbrikke der befolkningen i samfunnet bor. Gode levestandarder gjør at befolkningen er fornøyd og har et mer effektivt samfunn. Dersom det ikke er nokk hus til alle vil samfunnet bli mindre effektivt.



Konstruksjonsbrikker:

Det tar tid å bygge nye områder og bygninger. Ulike bygg er under konstruksjon i ulik tid, avhengig av hvor komplekse de er. Tidtakeren over brikken forteller hvor lang tid det er igjen før brikken er ferdigbygd. Dersom man ønsker at byggeprosessen skal gå raskere, kan man trykke på selve tidtakeren. Her kan man velge å bruke ressurser på å få prosessen til å gå fortere.



Vindmølle:

Vindmølle er en energibrikke som samler opp energi til samfunnet ved å lade opp et batteri. Energien brukes til å opprettholde og utvide samfunnet, og er vesentlig for at samfunnet skal kunne fortsette å eksistere.



Valuta

Spillet bruker to ulike valutaer: *energi* og *penger*.



- Energi: For å kunne fjerne stråling fra brikker trenger RCM-en energi. Energi kan skaffes via energibrikker (se vindmøllebrikke), opptjente bonuser av å være fysisk aktiv, eller å fullføre enkelte oppdrag.



- Penger: For å utvikle nye områder, og bygge bygninger, trengs det penger. Penger skaffes ved å fullføre oppdrag. Samfunnet er også selvdrevet og jobber for å tjene penger i løpet av dagen. Hvor effektivt det gjøres avhenger av hvor bra samfunnet har det (se ressursmål). Hvordan samfunnet utformes kan også ha konsekvenser for hvor mange penger samfunnet genererer.

Poengscore:

Handlinger i spillet vil enten gi eller trekke fra poeng, avhengig av hvordan det innvirker på samfunnet. Poengene vil lagres og sammenlignes opp mot andre spillere. Den øverste summen viser din score, mens den nedre summen viser hvor mange poeng du har opp til neste person på lista.

3019
74 to next player

Ressursmål:

For at samfunnet skal kunne fungere best mulig trenger det et visst antall samfunnsbrikker. Ettersom området og samfunnet vokser, er det viktig at bebyggelsen i samfunnet også vokser, da et ubalansert samfunn ikke vil kunne fungere optimalt. Ressursmålene viser hvor mange av de ulike ressursene samfunnet trenger for å fungere best mulig. Målene vil variere med størrelsen på brettet, og et samfunn som ikke når målene sine vil ikke kunne arbeide like effektivt.



Quests:

Quests er små og store oppgaver spilleren kan fullføre for å få ekstra penger, energi og poeng. Quest-menyen blir synlig ved å trykke på Quest/papirrull-knappen oppe i venstre hjørnet.

Quests er delt i tre kategorier; Daglig, Ukentlig og Ikke-repeterende.

- **Daglige Quests:**
Daglige Quests er små, relativt lette oppgaver som kan gjøres daglig. Belønningen for å fullføre disse er ikke så store, men de repeteres daglig og spillerne kan sette seg som mål å fullføre et par om dagen.
- **Ukentlige Quests:**
Ukentlige Quests er Quests som gjentas hver uke. Målene som må nås for å fullføre disse er en del høyere enn daglige, etter som at de skal kunne fullføres over et spenn av 7 dager. Siden det vil ta lengre tid å nå målet vil det også gi større belønning.
- **Ikke-repeterende Quests:**
Ikke repeterende Quests er Quests som bare kan fullføres én gang. De er ganske store og vanskelige å fullføre, men vil i gjengjeld gi store belønninger.

Streak:

Målet for å få til "Streak"-oppgaven er veldig lav og derfor ikke vanskelig å oppnå i løpet av dagen. Men, dersom man mister en dag blir Streaken resatt og startet på nytt. Jo lenger Streaken varer, jo større blir bonusen man får.



Spillhandlinger

Korrupsjon av brikker:

Den radioaktive strålingen som er i området vil alltid ønske å spre seg. Dersom en brikke blir korrumpert betyr det at stråling har begynt å sige inn i området igjen. En korrumpert brikke blir vist med hjelp av en advarsel over brikken. En korrumpert brikke rengjøres på samme måte som en forurenset brikke. Dersom en korrumpert brikke ikke blir rengjort tidsnok vil den bli mistet og gå tilbake til å være forurenset.



Rengjøring av brikker:

Forurensete brikker kan rengjøres ved å trykke på dem og betale en sum energi. Summen varierer basert på hvor brikken er og hvor korrumpert den har blitt.

Sletting/flytting av brikker:

Skog-, Åker-, Hus-, og Vindmøllebrikker kan slettes og flyttes. Ved å trykke på den bestemte brikken kan spilleren velge mellom å slette eller å flytte brikken.

Ved sletting av en brikke vil området bli gjort om til et rent område og spilleren vil få tilbakebetalt noe av summen det kostet å bygge brikken.

Ved flytting må spillerne velge hvor de ønsker å flytte brikken. En brikke kan bare flyttes til rene brikker som ikke har noe annet på seg.

Innsamling av ressurser:

Befolkningen samler inn ressurser i løpet av dagen. Disse kan samles inn ved å trykke på de ulike elementene som dukker opp i spillet. Ressursene befolkningen samler inn kommer i form av penger.



Energi blir dannet basert på hvor fysisk aktiv spilleren er. Dersom spilleren går, sykler, eller jogger en tur, vil det bli generert energi som kan samles inn i spillet. Denne energien kan bli hentet ved sentrumsbrikken.



Innhenting av energi fra vindmølle:

Vindmøller lader opp batteriet sitt over tid, men kan ikke lade over kapasiteten sin. For å samle inn energien hos vindmøllen må man trykke på batteriet over vindmøllen som viser hvor mye energi vindmøllen har generert.

Kjøping av brikker:

Når en brikke er rengjort kan spillerne bygge på dem. Ved å trykke på rene brikker vil det komme opp en meny hvor spillerne kan velge hvilken type brikke de ønsker å kjøpe og plassere på den bestemte brikken.

Konstruksjon av brikke:

Etter at en brikke er kjøpt må den bli bygd. Bygging av brikker tar tid, men ved å betale energi, kan tiden reduseres eller bli gjort ferdig med en gang. Dette gjøres ved å trykke på nedtellingen som vises over konstruksjonsbrikken.





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