Master's thesis

NTNU
Norwegian University of Science and Technology
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On Fire - A Location Based, Cardiovascular Exergame

Master's thesis in Computer Science
Supervisor: Alf Inge Wang
June 2021

NTNU
Kunnskap for en bedre verden

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Abstract

This master's thesis contributes to NTNU's research on exergames as a part of the Game Technology for Health (GT4H) Network. A lack of physical activity is an increasing concern in today's society, leading to higher probabilities of health issues such as type 2 diabetes and heart attacks. One of the factors that lead to a more sedentary lifestyle is the extensive use of digital media. Therefore, a possible solution to increase physical activity is to develop an exergame that includes physical activity in a portion of the time spent using digital media.

Based on this, the project's overall research goal is to *develop and evaluate a new exergame that contributes to improved physical health amongst people lacking the motivation to stay physically active*. Initially, a literature review was performed to gain insight into exergames, relevant technologies, and game development. The information from this literature review was used to develop the On Fire exergame concept. In this location-based exergame, the player must relocate to extinguish virtual fires in real-world locations, resulting in cardiovascular exercise. The On Fire prototype was implemented for iOS mobile devices using the Unity game engine, with server and database functionality in the Firebase platform.

The prototype was distributed to a group of 20 users for 19 days to gain insight into its impact on player's motivation for and level of physical activity. Qualitative and quantitative data was produced using questionnaires, interviews, observation, and usage data during the test period. Analyzing this data revealed statistically significant evidence that On Fire had a positive impact on the players' motivation and level of physical activity, especially for users that were considered physically inactive before the test period.

Sammendrag

Denne masteroppgaven bidrar til NTNUs forskning på aktive videospill (exergames) som en del av Game Technology for Health (GT4H) nettverket. Et lavt nivå av fysisk aktivitet er et økende problem i dagens samfunn, da dette kan øke sannsynligheten for helseproblemer som type 2 diabetes og hjerteinfarkt. En faktor som bidrar til en mer stillesittende livsstil, er omfattende bruk av digitale medier. Basert på dette kan en mulig løsning på å bidra til økt fysisk aktivitet være å utvikle et exergame som inkluderer fysisk aktivitet i en andel av tiden brukt på digitale medier.

Basert på dette er prosjektets forskningsmål å *utvikle og evaluere et nytt exergame som bidrar til forbedret fysisk helse blant de som mangler motivasjon til å holde seg fysisk aktive*. Prosjektet startet ved å gjennomføre et litteratursøk for å få innsikt i exergames, relevante teknologier og spillutvikling. Informasjonen fra dette litteratursøket ble brukt til å utvikle On Fire exergame konseptet. Dette er et lokasjonsbasert spill, der spilleren må forflytte seg for å slukke virtuelle branner plassert i den virkelige verden, noe som fører til kondisjonstrening. On Fire prototypen ble implementert for mobile enheter med iOS operativsystem ved hjelp av Unity spillmotoren, med server og database funksjonalitet på Firebase plattformen.

Prototypen ble så distribuert til 20 brukere som testet den i 19 dager, dette ble gjort for å få innsikt i hvordan den påvirket spillernes motivasjon for fysisk aktivitet og deres aktivitetsnivå. Kvalitativ og kvantitativ data ble samlet ved hjelp av spørreskjema, intervjuer, observasjoner og brukerdata gjennom testperioden. Ved å analysere denne dataen fremkom det statistisk signifikante bevis som tilsier at On Fire hadde en positiv påvirkning på spillernes motivasjon for fysisk aktivitet og deres aktivitetsnivå, spesielt for de brukerne som ble kategorisert som fysisk inaktive før testperioden.

Acknowledgements

We would like to thank our supervisor Alf Inge Wang at the Department of Computer and Information Science at the Norwegian University of Science and Technology (NTNU), for giving us the opportunity to work on this project. Thank you for your excitement and for sharing your knowledge in this field of study. The weekly progression meetings with you, where we got your input and guidance have been invaluable.

We also want to thank all the experiment participants for testing our game in their spare time. The project would not be possible to complete without them giving us the necessary data to conclude our master's thesis.

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Part I

Introduction and Methodology

The introduction and methodology part will introduce the project by presenting the context of the project and the project's task defined by the supervisor. Further, a short motivational statement will be given consisting of both personal motivation and how this project can be beneficial to society. A defined research goal combined with related research questions is also presented, and a walkthrough of the process of the master's thesis and the methodologies used throughout the project. Additionally, some of the content in this part is taken from the specialization project.

1 Project task and context

The project task that was given for this project is:

"**[ExerGames] Play to get fit**"

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

The project task is given in the context of the course *TDT4900 - Computer Science, Master's Thesis* at NTNU in Trondheim. This course is given in the 5th and final year of a computer science master's degree. It should provide the student knowledge and insight into how research results are generated and reported within the chosen specialty area, understanding advanced theory and practice within the topic of the master's thesis (NTNU, 2021). The master's thesis will continue where the specialization project left off, which mainly covered the first phase of the project and parts of the second phase. The specialization project results will work as a foundation for this master's thesis, covering the second and third phases of the project, involving further development and implementation of the game concept. It will also include the evaluation and testing of the prototype.

This project is carried out as a part of the Game Technology for Health (GT4H) Network to contribute to NTNU's research on exergames. The GT4H Network brings together knowledge and expertise about serious gaming for health benefits from different research groups across Departments and Faculties at NTNU. The network aims to connect researchers and professionals both within and outside NTNU that develop or use game technology for health to deliver high-quality research and advance our knowledge at the best value possible (NTNU, 2020).

2 Motivation

In today's society, physical inactivity is one of the biggest health problems, and professor Steven N. Blair has raised concerns that "the crucial importance of physical activity is undervalued and underappreciated by many individuals in public health and clinical medicine" (Blair, 2009, p.1). With this being a significant health issue, undervalued by people working with health and medicine, it is crucial to focus on solving this problem. Studies show that young people between the age of 8 and 18 spend an average of 7.5 hours per day using media technology, which is a considerable part of their awake hours (Rideout, Foehr, & Roberts, 2010). The fact that technology, including gaming, is embedded in young people's daily routines to such an extent can be utilized to encourage physical activity. If we can alter media technology usage to include some form of physical activity, it could also be part of a solution, not only the problem. Therefore, a game that motivates its users to increase their physical activity could be a gateway to better health for individuals who struggle to motivate themselves to exercise. One of the most prominent motivational aspects of doing this project is creating something that can help other people increase their quality of life by having fun playing the game and increasing their level of physical activity.

In addition to the motivating factor of making an application that contributes to better health, both students working on this project have chosen specialization within software development in their studies. This has given the students a considerable amount of knowledge of different technologies and developing applications, including games. Although they have experience with software development and project work, the projects have usually been performed over a short period of time, restricting the research and planning phase of the projects. The fact that the preliminary specialization project focuses on prestudy and concept development will give the students more time to perform thorough research before the concept is implemented and tested in this master's thesis, which is another motivational factor for doing this master's thesis.

3 Research goal and questions

The *Goal Question Metric* approach will be used as part of the research approach (Caldiera & Rombach, 1994). This approach is divided into three levels. The first level is referred to as the conceptual level, where the group will define an overall research goal for the project. The next level, called the operational level, includes the research goal combined with related research questions highlighting the project's challenges and issues necessary to answer. The quantitative level is about the metrics and methods used to answer the provided research questions and further reach the research goal, which is described in Chapter 4. Our research goal for this project has been defined as:

Research goal: *Develop and evaluate a new exergame that contributes to improved physical health amongst people lacking the motivation to stay physically active.*

It is essential to exercise frequently over a longer period to improve physical health. Therefore, it is vital to understand how to develop an exergame that is both fun and exercise-efficient to motivate the users to keep exercising while playing the game. Further, a set of research questions (RQs) from the research goal and its underlying challenges are formed. These are important to answer for reaching the goal.

RQ1: *How to make an exergame physically demanding while still being enjoyable to play?*
RQ1 explores different design principles and mechanisms for making an enjoyable, motivating, and engaging exergame. This research question also highlights the challenges of developing an exercise game that is both fun and physically demanding.

RQ2: *How to develop a new exergame concept that contributes to improved physical health for its users?*
This research question will, among other things, explore how to use the results of RQ1 to develop a new exergame concept that motivates physical activity.

RQ3: *How to implement the exergame with satisfactory performance and usability, using existing technologies and methodologies?*

RQ3 will explore different technologies and consist of a technical overview of existing technologies, architecture, and methods used to realize and develop the new exergame.

RQ4: *How do the theories of enjoyment contribute to the players' motivation, engagement, and enjoyment of the exergame?*

RQ4 will investigate if the theories of enjoyment implemented into the exergame contribute to the game's enjoyment and engagement. It will also explore what motivates players to keep playing the game.

RQ5: *Does the exergame have a positive effect on the players' motivation for- and level of physical activity?*

RQ5 investigates how the exergame has affected the players' motivation to perform physical activity and if the game has affected their physical activity level.

4 Methodology

To structure the work performed in this master's thesis, the model of the research process presented by Oates (2005) will be used. A visual representation of this model, where the elements used in this thesis are highlighted, can be seen in Figure 4.1. This model suggests that you develop a set of research questions based on your personal experience and motivation as well as a literature review. In this master's thesis, the research goal was defined based on the project task given. To make answering this research goal more manageable, it was divided into several research questions. These questions were based on both students' previous *experience* with software engineering and the literature review performed in Part II.

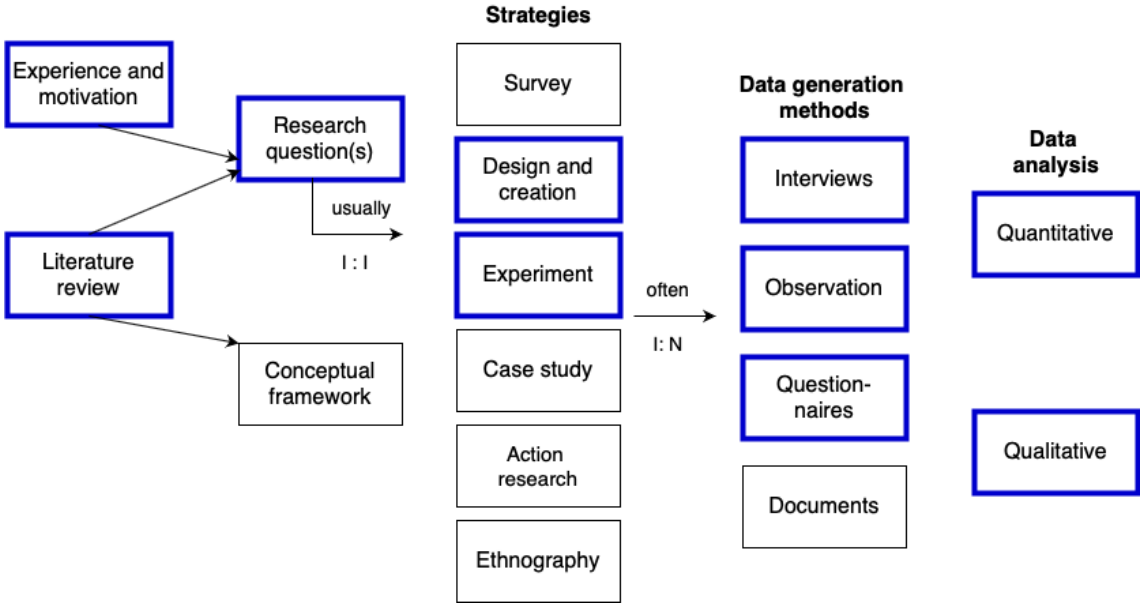

Figure 4.1: Research process model

Literature review

When performing a *literature review*, it is important to be selective in what sources you include as "a literature review distills the existing literature in a subject field; the objective of the literature review is to summarize the state of the art in that subject field." (Rowley & Slack, 2004, p.32). Because of this, the CRAAP test developed by Blakeslee (2004) was used to evaluate the sources used. The CRAAP test includes reviewing the sources on its Currency, Relevance, Authority, Accuracy, and Purpose. Currency looks at

how recent the information is. Relevance looks at how reliable the content is. Authority reviews the author/publisher. Accuracy checks if the information given is backed up by evidence. And purpose looks for the purpose of the literature.

Strategies

Further on, Oates presents several strategies that can be used to answer these research questions. Based on the nature of the task given in this master's thesis and the research questions, this project's preferred strategy is *Design and creation*. Oates describes this strategy as "developing new IT products", which involves the development of the prototype in this master's thesis. The process of developing the prototype started with creating different exergame concepts based on the research conducted in the prestudy. These concepts were produced by looking at previous exergames, game genres, and the technology available. Further on, one of these concepts was chosen for further development. The elements of the selected concept idea were developed by focusing on the theories of enjoyment. A more detailed description of how the concept idea was developed can be found in Chapter 17. In addition to the *Design and creation* strategy, the *Experiment* strategy was also used to test the application produced by the other strategy. The experiment included distributing the prototype to 20 users who tested the prototype for two weeks. More information on how the experiment was conducted can be found in Part V.

Data generation methods

After developing the prototype, three of the data generation methods highlighted by Oates were used before, during, and after the experiment. The first and most central data generation method used is the questionnaires, which collected data about the test users' experience of the prototype. Questionnaires were chosen as the primary data generation method because they are useful when "the research objectives centre on surveying and profiling a situation, to develop overall patterns." (Rowley, 2014, p.310), which is important when evaluation the prototype. Interviews and observations were also used to collect more detailed data about how the users interacted with the prototype.

The data produced from these data generation methods can be either *qualitative* or

quantitative. Oates describes the difference between these types of data as "Quantitative data is numeric data, for example, number of website hits, number of employees, annual turnover, last year's profit. Qualitative data is all other types of data: words, images, sounds and so on" (Oates, 2005, p.36). The qualitative and quantitative data from the data generation methods are:

Qualitative data

The qualitative data produced from the data generation methods include:

- Quotes from the test user collected through the questionnaires
- Quotes from the test user from the interviews.
- Pictures and descriptions of how the users interacted with the prototype produced by the observations.

Quantitative data

The quantitative data produced from the data generation methods include:

- Data from the questionnaires.
- Data collected from the database describing the usage of the application.

Triangulation

Using multiple sources of qualitative and quantitative data generation methods supports *triangulation* of data which is described as "the combination of two or more datasources, investigators, methodologic approaches, theoretical perspectives, or analytical methods within the same study" (Thurmond, 2001, p.253). This will provide a better understanding of the findings by looking at them from different perspectives and strengthening the results and findings' validity and reliability. Using both quantitative and qualitative data leads to methodologic triangulation. Thurmond argues that this "has the potential of exposing unique differences or meaningful information that may have remained undiscovered with the use of only one approach or data collection technique in the study" (Thurmond, 2001, p.255). Both the qualitative and quantitative data produced were used to answer this master's thesis's research questions.

5 Readers guide

This chapter provides an overview of the different parts of the report and a reader's guide.

Part I - Introduction

This part introduces the project, motivation, and research questions. This part is suited for readers interested in the purpose of this master's thesis and the student's motivation for completing it.

Part II - Prestudy

The prestudy contains an introduction to physical activity benefits, the concept of exergames, and a review of some previous successful ones. Further, it presented a set of theories on designing enjoyable games and relevant technologies to develop exergames. This part is recommended for readers interested in technology, exergames, the theory behind games, and game development.

Part III - Concept

This part includes a set of new exergames concepts and a review of them to decide which concept to develop further. This concept will be described in detail and tied up with the theories of enjoyment. A description of the prototype based on the chosen concept is further described. The presentation of the prototype is recommended for all readers, as it provides a simple explanation of the application developed in the master's thesis. Additionally, readers interested in details about the process of developing the On Fire exergame concept are recommended to read the other parts of this part.

Part IV - Development

This part contains a review of the technologies used for developing the concept, where each technology is tested and reviewed to ensure that it can be used as intended. More details about the development of the application from a technical point of view are also provided. Therefore the Development part is recommended for readers interested in the technical details about the development and architecture of the application. Thus, it is

recommended to have some technical knowledge when reading this part.

Part V - Experiment

This part presents details surrounding the purpose, content, and process of the experiments to evaluate the prototype. These experiments focus on the theories of enjoyment and the physical aspect of the game. It is recommended for readers who want to gain insight into the test procedure used to produce the results presented in the next part.

Part VI - Results

The Results part presents the data collected from the experiments described in the previous part. It presents graphs and data describing the test-users performance and evaluation of the application. It is recommended for readers with interest in the data collected from the experiments.

Part VII - Discussion and Conclusion

This final part discusses how the prototype performed based on the data collected from the test period. This is done by evaluating how the implementation of the theories of enjoyment and other concepts helped the application affect the users' physical activity. The discussion is recommended for readers interested in a detailed evaluation of the data produced from the experiments.

Finally, the conclusion will answer the research questions presented in the Introduction, based on the discussion. Readers interested in the final results of the master's thesis are recommended to read the conclusion.

Part II

Prestudy

The prestudy is based upon the prestudy performed in the specialization project and provides an overview of the current possibilities in the field of exergaming. Starting with an overview of the society's physical status and a study of what exergames are, and a set of previously successful ones. Furthermore, it will give an overview of commonly used technologies in exergames and a set of frameworks and theories for designing and evaluating player enjoyment in games. This will all together give the group a fundamental understanding of exergames and their possibilities to further design and develop an enjoyable, motivating, and engaging exergame concept of their own.

6 Physical activity

Physical activity is a part of human nature, and Bouchard, Blair, and Haskell (2012) describes at least three reasons that support this: The first one being human's ability to adapt to the physical requirements of work and exercise. Secondly, it would not be possible for early humans to survive and evolve without performing physical labor and have the required motor skills. The third and final reason is that a sedentary lifestyle, including a low level of physical activity, can reduce functional capabilities and increase the risks of common diseases. There are over 30 diseases associated with physical inactivity, including heart attacks, cancer, and type 2 diabetes (Ekelund & Ariansen, 2017). Combining these three factors identifies physical activity as one of the most critical factors for having a healthy lifestyle, primarily because it reduces the risk of contracting certain diseases and maintains your functional capabilities.

To reduce the risks associated with physical inactivity, each individual should adhere to the recommended amount of physical activity. Adults between the ages of 20 to 64 are recommended 150 minutes of moderate activity or 75 minutes of high-intensity activity per week (Ekelund & Ariansen, 2017). Additionally, if you spend over eight hours of your day sitting still, it is recommended to have at least one hour of moderate activity per day (Ekelund & Ariansen, 2017). Thus, the more time you spend sitting still, the more time you need to spend on physical activity to reduce the health risks associated with inactivity.

As mentioned in the introduction, the lack of physical activity is a significant health problem that may be undervalued by people working within health and medicine (Blair, 2009). Considering the possible health issues resulting from inactivity, including the extensive amount of diseases, it is alarming that professionals may undervalue physical activity. In 2015, the Norwegian Directory of Health reported that only 30 percent of Norwegian adults fulfill the recommended amount of physical activity (Ekelund & Ariansen, 2017), which means that a massive 70% of Norwegian adults could be at risk of facing health issues caused by inactivity. Research performed by the Norwegian Directory of Health also implies that the Norwegian population spends an increasing amount of time on activities that involve sitting still, either at work, in the car, or at home (Ekelund & Ariansen, 2017).

The increase in activities lacking a significant physical element is probably related to the fact that digital media platforms have risen in the past decades. This is because individuals often sit still while interacting with digital platforms such as TV, computers, and mobile phones. Studies by Rideout et al. (2010) show that young people spend on average 7.5 hours a day on various digital platforms. This significant amount of time spent on digital media could present an excellent opportunity to motivate people to be more active. A solution to this can be to develop applications on a digital platform that would require its users to perform some sort of physical activity, thus utilizing the rising interest in and usage of digital media to promote physical activity.

7 Exergames

This section introduces the concept of exergames and gives a brief overview of the history of exergames and pervasive games.

7.1 What are exergames?

An exergame is a term used to describe a video game that requires some form of exercise or physical activity to play the game, thus promoting physical activity among its users. Bogost (2005) introduces exergames as "games that combine play and exercise" (p.1). Sinclair, Hingston, and Masek (2009) gives a more detailed definition of exergaming and defines it as, "The merger of exercise and video games, tries to use the engaging experience of playing a video game to help people achieve their exercise requirements" (Sinclair et al., 2009, p. 1). These games can be seen as an essential ally for people working within health because it often promotes a healthy lifestyle, develops motor skills and increases caloric expenditure (Finco & Maass, 2014). Moholdt, Weie, Chorianopoulos, Wang, and Hagen (2017a) defines *exergaming* as the use of video games in an exercise activity and can be a means to produce physical activity (Moholdt et al., 2017a). There are many different types of exergames, from applications that directly instruct their users to perform a physical activity such as squats to games where exercise indirectly affects the gameplay.

When looking at the problems related to physical inactivity combined with the increasing amount of time spent on digital media, exergames could be part of a solution to raise activity levels. This is because these types of games would utilize people's interest in digital media to lower the physical activity threshold, especially for those who already play video games.

7.2 History of exergames

The history of exergames begins with the introduction of the Atari Joyboard in 1980 (Finco & Maass, 2014). This was a platform on which the player would stand and control the game by leaning in different directions. Almost a decade later, in 1988, Nintendo released the Power Pad, a plastic mattress containing twelve sensors (Finco & Maass, 2014).

The 1990s saw the introduction of the Tectrix VR Bike, which was a bicycle game with a screen displaying the gameplay and pedals for controlling the game, illustrated in Figure 7.1. It would also blow air towards the user to simulate the bike's movement, which led to the game being considered the first virtual reality game (Finco & Maass, 2014). Throughout the 1990s, several arcade games that required physical activity were released, including the ski simulator Alpine Racer and the hugely popular dancing simulator Dance Dance Revolution.

Figure 7.1: Tetrix VR Bike

In 2003 Playstation launched the EyeToy, a webcam for the PlayStation 2 that could recognize gestures. This opened up the possibilities of controlling video games on the platform using full-body motion, including games like EyeToy Play and EyeToy Groove. A year later, Nintendo introduced the Wii, which included acceleration detection in its remote. Later on, the Wii Balance Board was released together with the exergame Wii Fit (see Figure 7.2). This game used the balance board to track the player's center of balance while performing different exercises.

Figure 7.2: Wii Balance Board and Wii Fit

The success of the Wii gaming console contributed to increasing the popularity of exergaming. After the Nintendo Wii release, other gaming companies released gaming

accessories and controls that tracked body movement, including the Kinect for Xbox and Playstation Move, both released in 2010. The Kinect could track the entire body of the player using a camera. Playstation Move is a motion controller much like the Wii remote.

The commercialization of virtual reality (VR) headsets has also opened up new possibilities for exergames during the last decade. These headsets can often be combined with motion controllers. An example of this is that many games for the Playstation VR use Playstation Move as the controller, seen in Figure 7.3. Combining VR headsets and motion controllers can also be an excellent tool for ensuring player immersion in exergaming. Beat Saber, which was released in 2018, is an example of such a game.

Figure 7.3: PlayStation VR and Move

In addition to games made for the platforms mentioned above, there has also been a rise in popularity and availability of exergames for mobile phones in the past decade. The most considerable success among these games is Pokémon Go, which uses GPS location services and requires its users to relocate in the real world to play the game. Many other exergames for mobile phones are also location-based, including Zombies, Run!, and Run An Empire. In addition to GPS, many sensors in today's mobile phones can be used to develop exergames, providing multiple possibilities for developers.

7.3 Pervasive games

Computer games have traditionally decreased the users' physical activity and social interaction by constraining them to keyboard and mouse controls in 2D/3D virtual envi-

ronments. Pervasive games are a new genre of gaming, dealing with this problem by integrating the real world's physical and social aspects into the virtual environment of computer games (Magerkurth, Cheok, Mandryk, & Nilsen, 2005). Smart toys, affective gaming, augmented reality games and location-aware games are examples of different types of pervasive games mentioned by Magerkurth et al. (2005).

One can argue that exergames belong in the pervasive game genre as they share a lot of similarities. Both enable a mixed reality of the virtual- and the real world by utilizing context-aware technology to control and interact with and within the game (Magerkurth et al., 2005). Motion detection and controllers, GPS, and various other sensors such as accelerometers, gyroscopes, etc., are commonly used in exergames. An example of this is the immersive running exergame Zombies, Run!, which can be seen as a pervasive game as it is location-aware. The game uses the real world as the game board by utilizing the phone's GPS and accelerometer to record the player's movement and speed.

7.4 Summary

This chapter has introduced the term exergame as a description of video games controlled by physical activity. Exergames can also be seen as pervasive games because most exergames use context-aware technology to create a reality that combines elements from the virtual- and real world. Exergames have been around since the 1980s and have evolved a great deal in the 40 years that have passed. This evolution involves going from the Atari Joyboard balancing board to today's motion controllers, including the Microsoft Kinect and Playstation Move. Some new exergames also combine motion controllers with VR headsets to increase player immersion. Exergames have also become more available, with an increasing amount of games being developed for mobile devices.

8 Existing exergames

This chapter will briefly introduce a selection of existing exergames and research about their exercise effectiveness.

8.1 Dance Dance Revolution

Dance Dance Revolution (DDR) is a music video game series produced by Ross Tanner, first released in 1998. It is played by hitting eight colored arrows on the "dance platform" by stepping on them to the rhythm of the music and visual indicators on the screen as seen in Figure 8.1. The player is then evaluated on their performance and given a score (Liu, 2004).

Figure 8.1: Dance Dance Revolution

A literature review of DDR by Lieberman (2006) refers to multiple studies reporting DDR to be an excellent aerobic exercise (Lieberman, 2006). One of the studies listed

found that DDR increases a player's heart rates to obtain an aerobic workout and gain cardio-physiological benefits, even at the game's most manageable level (Unnithan et al., 2006). Another study looked at the exercise intensity of playing DDR at a medium level of difficulty and found it met official standards for developing and maintaining cardio-respotary fitness (Tan et al., 2002). The home releases of the game have also been used in schools and gyms to aid exercise. The state of West Virginia incorporated the game into its curriculum for all 765 public schools in 2006 and 24 Hour Fitness into their youth-oriented workout programs to deal with the increasing obesity among the youth (MTV, 2006).

8.2 Wii Fit

Wii Fit is an exercise video game released for the Nintendo Wii game console in 2007. The game comes with and is mainly played with the Wii Balance Board as the controller. The balance board detects and tracks the player's center of balance. The game features more than 40 activities, including yoga, strength exercises, aerobic, and balance activities (Figure 8.2). Wii Fit is considered one of the most successful exergames, with more than 22 million copies sold worldwide in 2012 (Wash, 2008).

Research conducted by Graves et al. (2010) about Wii Fit's physiological cost and enjoyment amongst young and older adults, compared against aerobic exercise concluded that Wii Fit appears like an enjoyable exergame for all adults, stimulating light-to-moderate intensity activity. The enjoyment rating was also significantly greater for Wii Fit than treadmill walking and jogging (Graves et al., 2010).

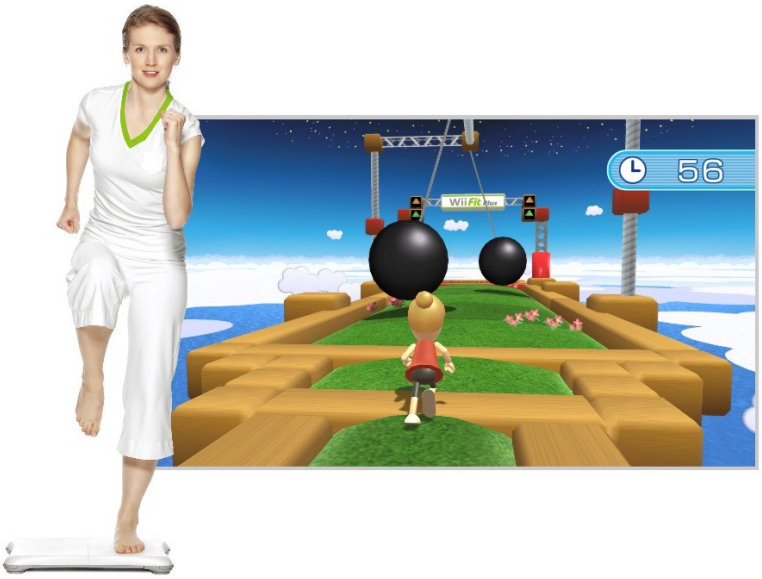

Figure 8.2: Wii Fit

8.3 Run an Empire

Run an Empire is also a mobile exergame, first released in 2014 on iOS and Android. The game is a location-based pervasive game, using the world map as the game world divided into hexagons as seen in Figure 8.3. The game's overall goal is to conquer the world, which is done by running through the hexagons to claim them. Run an Empire uses the phone's GPS to record the player's movement and is compatible with Strava, a social network for exercising (Run An Empire, 2020).

Figure 8.3: Run An Empire

8.4 Zombies, Run!

Zombies, Run! is a mobile exergame, released on iOS and Android in 2012. It is an immersive running game where the player has to survive a zombie apocalypse by running and collecting supplies in various missions while listening to different audio narratives (Figure 8.4). The interactive audio encourages the players to run faster as they try to get rid of the zombies chasing them, which results in an interval exercise. The game records time, pace and estimates calories burned and distance using the phone's GPS and accelerometer.

After two weeks of its initial release, it became the highest-grossing Health and Fitness app on Apple's App Store and has later received a lot of academic attention (Zombies, Run!, 2020). Higgins (2016) research about smartphone applicants for Patients' Health, and Fitness lists Zombies, Run! as a recommended application for increasing aerobic exercise for "Healthy patient wanting to start basic aerobic exercise" and "Healthy patient already exercising regularly looking to improve fitness or to enter a race" (Higgins, 2016).

Figure 8.4: Zombies, run!

8.5 Pokémon Go

Pokémon Go is a location-based, augmented reality game released in July 2016 on iOS and Android. The game integrates the Pokémon universe into the real world, using the phone's GPS to track the player's location. The game lets the user play as a Pokémon trainer and gives the overall goal to "catch them all". The Pokémons appear randomly in different locations on the map, and the player has to be in the same area as the Pokémon to try to catch them. The player then has to throw Pokéballs at the Pokémon augmented onto the real world seen on the player's phone to catch it, showcased in Figure 8.5. These Pokémons are used in battles against other trainers either in PvP or in particular locations called Gyms (Wang, 2021). Pokemon Go is one of the most successful mobile games of all time, downloaded over a billion times and grossed over $3 billion in revenue (Iqbal, 2020).

Studies have shown that Pokémon Go contributes to increased physical activity, encouraging people to move around outside for hatching eggs, catching Pokémon, collecting items, or battling other players. A literature review done by Wang (2021) showed that

eighty percent of the studies included results related to how Pokémon Go affected the player's physical health, mental health, and motivation. The study concluded that Pokemon Go has a significant positive effect on physical health, increasing the number of steps, distance moved, and time spent on physical activity while playing the game (Wang, 2021).

Figure 8.5: Pokémon GO

8.6 Pedal Tanks

Pedal Tanks was developed as a research prototype of an exergame that can provide continued motivation to exercise, aimed at people already familiar with computer games.

Pedal Tanks is a multiplayer, capture the flag arena exergame based on a stationary bicycle. The game's goal is to capture the other players'/teams' flag and bring it back to your own base. Each player controls a tank with the bike's pedals (see Figure 8.6) and the buttons on the handlebar is used for turning, firing the cannon, and performing other actions. The game uses two optical sensors to map the cycle's movement and controls positioned on the handlebar, connected to a microcontroller running the game. (Hagen, Weie, Chorianopoulos, Wang, & Jaccheri, 2015).

Figure 8.6: Pedal Tanks

The physical effects of Pedal Tanks were evaluated and tested by conducting an eight-person lab study. The lab aimed to examine the viability of using Pedal Tanks to cover the recommended amount of daily physical activity. The game was reviewed as an enjoyable exergame and seen as a viable option to increase physical activity for people lacking the motivation to exercise. The test participants gave the game's exercise intensity a moderate to high rating and were confirmed by the measurements of their heart rate (Moholdt, Weie, Chorianopoulos, Wang, & Hagen, 2017b).

8.7 Exermon

Exermon is a strength-based exergame made for Android mobile phones released in 2018. In this game, each player chooses a personal monster, called an "exermon" as seen in Figure 8.7 (Wang, Hagen, Høivik, & Olsen, 2017). Taking inspiration from Pokémon Go and Tamagotchi, the game revolves around the evolution and maintenance of the player's monster by performing strength exercises. Its stats and appearance show the state of each monster as in Figure 8.7. The game is divided into different parts, including train-

ing, planning, and fighting (Wang et al., 2017). The game's training part is where the player will perform physical activity, completing different strength exercises to evolve the exermon and increase its stats (Wang et al., 2017).

It was also conducted a study investigating whether there were any physical effects from playing Exermon, which concluded that the game gave a positive physical effect, but not on all test subjects. About 40% of the test participants exercised more than they did before playing the game and felt their strength had improved due to the game (Wang et al., 2017).

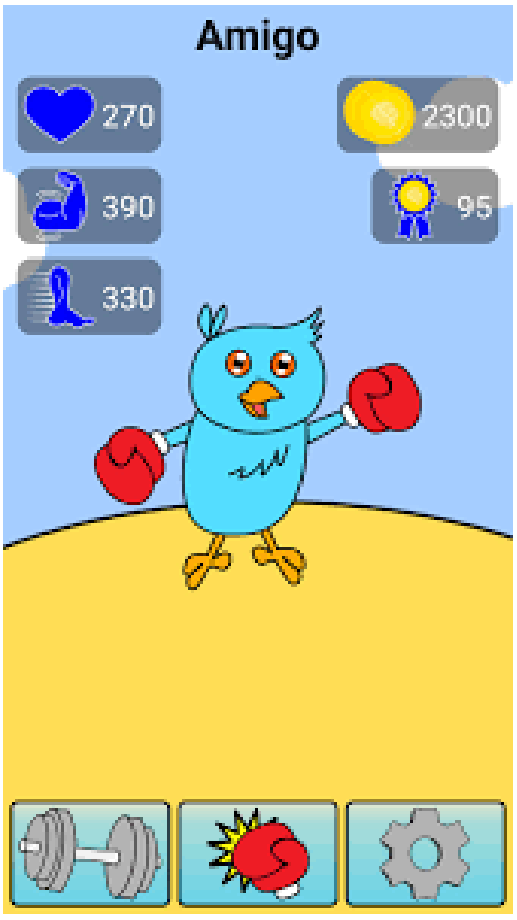

Figure 8.7: Exermon

8.8 Beat Saber

Beat Saber is a virtual reality rhythm game released for Playstation 4 and Microsoft Windows 2019, compatible with the Playstation VR, Oculus Quest, (Beat Saber, 2020). The game's goal is to slash small cubes coming at you with two controllers representing

two virtual swords following the music's beat and rhythm, as can be seen in Figure 8.8. The players also have to dodge obstacles and avoid hitting incoming spikes, which results in a physically demanding game where the player has to use his/her entire body while playing the game.

Research conducted by Tuong Thai about the effect of exercise in Beat Saber concluded that Beat Saber could be considered a substitute form of exercise (Thai, 2019). Another research about the motivational and physical effect of Beat Saber done by Kivelä, Alavesa, Visuri, and Ojala (2019) was carried out by measuring the test participants' heart rate during a game session and interviewing them after the session. The participants found the game enjoyable and effective. Additionally, the participant's heart rate was raised during the whole game session, which led to the conclusion that Beat Saber is good for aerobic exercise (Kivelä et al., 2019).

Figure 8.8: Beat Saber

8.9 Ring Fit Adventure

Ring Fit Adventure is an adventure exergame for the Nintendo Switch game console released in 2019. The game's main mode is a RPG, where the player is teaming up with a sentient ring to defeat an evil dragon. The player earns experience points, new exercises, and abilities when progressing through more than 100 levels in over 20 worlds in the game. The game consists of 60 different exercises grouped by the body's part in the

exercise. The game also includes a fitness routine mode, allowing players to perform the activities without the gamification elements. The game is controlled by the Ring-con and Leg Strap, which holds the switch's Joy-Con controllers (Figure 8.9). These accessories have built-in motion controls to track the player's movement and interactions in the game (Kollat, 2020). Ring Fit Adventure has received a lot of positive feedback since its launch but lacks extensive research about its physical effect.

Figure 8.9: Ring Fit Adventure

8.10 Summary

This chapter has presented different successful exergames, from one of the earlier ones as Dance Dance Revolution, to Ring Fit Adventure being one of the most recent ones. The exergames have been described and supported by research about their physical effects. It is possible to see a wide diversity in the technology used in the different exergames, including exergames for mobile devices such as Pokemon Go, Run an Empire, and Zombies! Run. These games utilize the phone's GPS and sensors to track movement, while the other mentioned exergames use different controllers. For example, a stationary bike in Pedal Tanks, motion controllers in Beat Saber and Ring Fit Adventure, a balance board in Wii Fit, and a dance platform in Dance Dance Revolution. The mobile exergames as Pokemon Go, Run an Empire, and Zombies! Run are the most relevant games for this project and will be a great source of inspiration in developing a new exergame concept.

9 Game genres

There exists a vast amount of game genres, and this chapter will introduce some of the most relevant genres for this project.

9.1 Role-playing games

Role-playing games (RPG) are a huge video game genre originating from pen and paper role-playing games such as Dungeons and Dragons. RPG games typically feature a medieval, fantasy, or science fiction setting where players enact fictitious characters' roles. Role-playing games are characterized by character creation and development, navigating, and interacting within a well-defined world. Fallout (see Figure 9.1) is an example of a role-playing game. Additionally, the earlier mentioned Zombies, Run! and Ring Fit Adventure in Chapter 8 are examples of exergames characterized as role-playing games.

Figure 9.1: Fallout 4

9.2 Sports games

Sports games simulate real-world sports, including team sports such as football and basketball, racing, fighting, and extreme sports being some of the most popular ones. Sports games are often competition-driven, just like real-world sports, and emphasizes playing or managing the sport. Some popular examples of sports games are FIFA (see Figure 9.2), Madden NFL, Forza, and NHL (Vince, 2018).

Figure 9.2: FIFA 21

Sports games are also a popular game genre for exergames, as sports itself is a good source of exercise. Wii sports is one of the most successful sport exergames. It is a game collection of sports, including tennis, baseball, bowling, golf, and boxing. The games are being played by mimicking the real-world sport's actions with the motion controller Wii Remote (Hurkmans, Ribbers, Streur-Kranenburg, Stam, & Van Den Berg-Emons, 2011).

9.3 Strategy games

Strategy video games require players to have high situational awareness and decision-making skills to achieve victory. Strategy games emphasize planning and the use of strategy and tactics to be able to overcome challenges. The strategy game genre is typically divided into turn-based strategy (TBS) and real-time strategy (RTS) and come in many variations and have multiple subgenres (Apperley, 2006). 4X, Artillery, wargames, multiplayer online battle arena (MOBA), and Tower defense are some of the most popular subgenres (Vince, 2018). An example of a strategy wargame is the popular series of games Age of Empires (see Figure 9.3). Turn-based strategy games could be suitable for strength-based exergames as it allows the user to perform strength exercise when it is their turn and rest while the other players take their turn.

Figure 9.3: Age of Empires III

9.4 Simulation games

The simulation genre includes video games that emulate the real world or fictional reality to simulate real-world activities, such as driving, flying, and sports (Apperley, 2006). Another characteristic of simulation games is that they usually provide a lot of freedom to the players as there is often no specific goal for them to reach. An example of this is Microsoft's flight simulator and Euro Truck Simulator, both being transport simulation games. The fact that the real-world activities simulated by simulation games often require physical activity could be utilized to develop exergames within this genre.

Figure 9.4: Sim City

Real-life simulation games are another popular subgenre. These kinds of games allow players to manipulate the game characters' properties, life, and ecosystem. These kinds of games are often referred to as "God games," and The Sims is an example of a life simulation game. Games like Rising Cities and Sim City (see Figure 9.4) are simulation

games, simulating the construction and management of infrastructure, giving the player the ability to plan out cities, their infrastructure, and culture (Vince, 2018).

9.5 Idle games

Idle games is a relatively new game genre used to describe games where the game is left running without much player interaction (Alharthi, Alsaedi, Toups, Tanenbaum, & Hammer, 2018). This main characteristic of idle games is often associated with the collection of in-game resources. The game usually requires the users to start by clicking on the game to collect resources. Items that generate resources can then be bought once the user has collected enough resources by clicking. These items will generate resources automatically when the player is not interacting with the game. When the users come back to the game, these resources can be used to acquire better in-game items that further speed up resource collection. An idle exergame could be made by using fitness trackers to record data about the player's physical activity and use this data to provide the player with in-game resources.

Figure 9.5: Realm Grinder

An example of such a game is "Realm Grinder", which focuses on building your town using coins (GameDesigning, 2020). The buildings in this town represent the in-game items that generate coins, which can be used to buy buildings that generate more coins (see Figure 9.5). Some buildings also collect coins generated by other buildings automatically for the player. This makes the game more "idle" as it collects coins without player interaction.

9.6 Adventure games

Adventure games include a wide range of video games, which can be defined as games that "focus on puzzle-solving within a narrative framework, generally, with few or no action elements" (Bronstring, 2012, p.1). The lack of action elements and combat gameplay separates adventure games from action games. When playing these kinds of games, the player will control a character, often sticking to the same character throughout the game. Bronstring (2012) identifies three main characteristics of adventure games. The first one is the narrative, which is often essential and can range from very predetermined stories to more open-ended ones. Secondly, an adventure game will contain various forms of puzzles. One puzzle type is inventory puzzles, which include collecting items in your inventory and using a combination of these items to progress in the game. The third and final characteristic is exploration. The degree of exploration and how the exploration is presented varies from game to game. Ring Fit Adventure is also an example of an exergame in this genre. Portal is another example of an adventure game. In this game, the player must solve various puzzles to progress throughout the story presented (see Figure 9.6).

Figure 9.6: Portal

9.7 Party games

Party games are multiplayer games that often see the players compete against each other. Many of the games in this genre are made for local multiplayer or split-screen, which allows all players to play on the same gaming device at social gatherings. Party games are often composed of several smaller mini-games, where the results of these mini-games

can contribute to an overall score for each player. The combination of multiple mini-games makes the party game genre suitable for exergames because it allows players to perform various exercise activities. The Mario Party series is a very popular series of party games, with over 51 million copies sold in total (VGSales, 2020). The Mario Party games' gameplay revolves around competing with other players by collecting points from different mini-games (see Figure 9.7).

Figure 9.7: Mario Party 8

9.8 Platform games

Platform games, or platformers, can be defined as "games that mainly revolve around a character controlled by the player, which runs and jumps to avoid obstacles and/or to defeat enemies" (Minkkinen, 2016, p.2). Additionally, many platformers consist of several levels, where one level has to be completed to play the next level. This is the case for Ring Fit Adventure, which can classify as a platformer. Minkkinen (2016) further divides platformers into single-screen platforms and scrolling platformers. Single screen platformers display the entire level on the screen at all times, which is common for arcade games like Pac-Man. In scrolling platformers, the player only sees a part of the level at a time, depending on the character's location. Super Mario Bros is an example of this kind of platformer.

9.9 Summary

Although all of the genres mentioned above are relevant, some apply to exergames more than others. Sports games are one of these genres because sports require physical activity in the first place. Party games and platform games are also very relevant as they often include repetitive levels, reflecting the often repetitive nature of working out. The less relevant of the game genres mentioned above is idle games, as it is described as games that run without a considerable amount of player interaction. This characteristic could be undesirable for an exergame where there is a strong link between gameplay and exercise because the nature of idle gaming would lead to a lower amount of physical activity.

10 Mobile phone technology

The technologies associated with mobile phones provide many possibilities for the development of exergames. This chapter will explore the most relevant of these technologies.

10.1 Augmented reality

Augmented Reality (AR) is used to place virtual objects in the real world, making users "see their view augmented with 3D objects registered such that they appear to exist in real space" (Magerkurth et al., 2005, p.11). An example of a mobile application that utilizes Augmented Reality is IKEA Place, illustrated in Figure 10.1. The application is available for iOS and allows users to render IKEA products virtually in the real world. AR technology is also used in existing exergames. For example, Pokemon Go uses this technology to place virtual Pokemon in the real world.

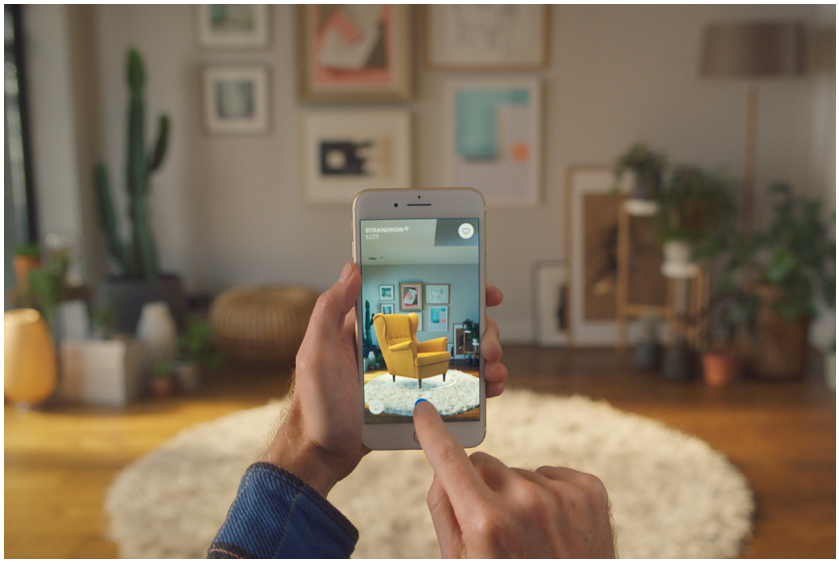

Figure 10.1: IKEA Place

There are three approaches to augmented reality that are appropriate for gaming: Head-mounted displays, image projection on real-world surfaces, and hand-held devices (Magerkurth et al., 2005), which is the most relevant for this project. There exist two main frameworks for developing native AR applications for mobile devices, ARKit for iOS and ARCore for Android (Halabuda, 2019). Both frameworks utilize the device's hardware components to map the surroundings and understand the placement of the device (Halabuda, 2019).

10.2 Location awareness

There are several ways of using a mobile device's location in applications, mainly depending on its mobile platform. Android, iOS, and Web applications can use the Google Maps Platform, enabling the application to find the device's location and display this on a map. Google Maps also offers services such as Map Customization and their Gaming Solution, which could be an excellent tool for building location-based exergames for mobile devices. The Gaming Solution provides access to data about the surroundings like 3D buildings, roads, etc. Additionally, it is possible to customize these elements by using the Unity game engine (Google, 2020b), as be seen in Figure 10.2. Further on, iOS can also use the Core Location framework, but this is only for detecting the device's location and not for displaying a map like Google Maps. There are also several third-party SDKs for map and location services, like Mapbox, which can also be used for Android, iOS, and Web. Location-aware games include a significant amount of existing exergames, including Pokemon Go, Zoombies Run, and Run An Empire.

Figure 10.2: Google Gaming: Customized Big Ben

10.3 Health and fitness data

Most mobile phones record data about their users using the different phone sensors, and this data could be used in an exergame to track users' activity levels. There exist multiple solutions that record this kind of data. Apple has developed the HealthKit framework for iOS, which provides access to health and activity data from the iPhone and other devices

such as Apple Watches. When you integrate HealthKit with an app, it is possible to both read and writes data to the user's Health app on iOS. For Android and web application development, the Google Fit platform can be used. The platform has an API for Android as well as a REST API that web applications can use.

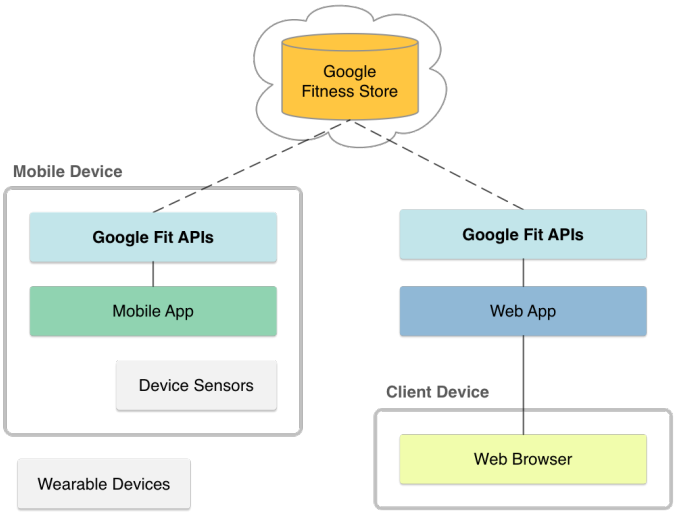

Figure 10.3: Google Fit Platform Overview
(Google, 2020a)

Both APIs have different functionality for storing and reading data from the Fitness Store, a cloud service that provides a central repository for storing data (Google, 2020a). The platform's components and how they are connected are illustrated in Figure 10.3. The difference between the two APIs is that the Android API for native applications can access sensor data and create new data for the Fitness Store. In contrast, a web application will not have access to the phone's health data.

10.4 Sensors

Today's mobile phones contain a large number of sensors that could be utilized when developing an exergame. This section will introduce the most relevant sensors. The information about the sensors in this section is based on Priyadarshini (2018).

GPS

GPS sensors are essential for location-based applications and communicate with satellites to determine the location of the device.

Accelerometer

An accelerometer is a sensor used to determine a phone's orientation, movement, and speed along three axes using tilt, acceleration, and vibration.

Pedometer

This sensor is used to count steps and utilizes values from the accelerometer to track different movements, like walking or running.

Proximity Sensor

The sensor uses infrared LED and IR light to measure the distance from the device to objects. This sensor is commonly placed on the front of the phone.

Magnetometer

The magnetometer detects magnetic fields to provide a compass for the mobile device. It can be used in location-based applications to rotate maps.

Gyroscope

The gyroscope of a mobile device can measure the device's orientation just like the accelerometer, but it also measures rotation.

10.5 Accessories

There are numerous accessories available for mobile phones, but the one that stands out when developing exergames is smartwatches. Smartwatches' main benefits are collecting fitness data like pulse while being easy to use during intense workouts. One of the downsides of smartwatches is that they often have minimal displays, especially in size. Therefore, when creating an exergame, it could be helpful to use a smartwatch's sensors to collect data. However, the game itself should be played on a different device that provides a better user interface. An example of this is that the Google Fit platform mentioned earlier can collect data from an Android smartwatch running Wear OS (Google, 2020) and store it in the Fitness Store. This data could be used in an application by accessing this data using the available APIs.

10.6 Summary

This smartphone technology review provides insight and understanding of smartphones' capabilities and limitations in developing exergames. Smartphones have emerged as a platform fit for games because of their mobility, powerful hardware, operating systems, big screens, and built-in sensors, which gives many opportunities suitable for exergaming. One example is location-based exergame as Pokemon GO, Zombies, Run! and Run an Empire by utilizing the smartphone's GPS to track the players' location and movement. Smartphones also include various other sensors to track players' motion, which can be used in mobile exergames. Accelerometer, pedometer, proximity sensor, magnetometer, and gyroscope are some of the most used and relevant for exergames. Smartphones can also be combined with smartwatches, collecting fitness data that can be used and utilized in an exergame through the provided APIs. Google Fit and HealthKit for iOS are the most popular.

11 Other relevant technologies

This chapter will introduce a variety of technologies that can be used for developing exercise games besides mobile phone technology, which is described in Chapter 10.

11.1 Virtual reality

Virtual reality (VR) can be defined as "a synthetic or virtual environment which gives a person a sense of reality" (Jayaram, Connacher, & Lyons, 1997, p.1). When talking about virtual reality in this prestudy, we refer to these kinds of computer-generated environments. Virtual reality is commonly displayed to the user through a headset that completely covers the user's eyes. By doing this, the player will only see the virtual reality displayed by the headset. There are multiple VR-headsets on the market, including the Oculus Rift for PC (see Figure 11.1) and the Playstation VR-headset.

Figure 11.1: Oculus Rift

When developing exergames, VR technology will not directly contribute to tracking the users' physical activity, besides head movement. However, it can be a good way of increasing player immersion, motivating the users to exercise. This implies that the VR headset must be combined with technology that allows the users to control the game using gestures or other physical movements. An example of this is PaperDude, which combines the Oculus Rift with a Trex FX bicycle attached to a Kickr power trainer and a Kinect camera (Bolton, Lambert, Lirette, & Unsworth, 2014). This is an excellent example of how VR can be used in exergames by combining it with two controllers,

which require physical activity, pedaling the bicycle, and making gestures for the Kinect. Another exergame that uses VR technology is Beat Saber. Beat Saber, is controlled by the PlayStation Move motion controllers, detecting the player's movement and gestures. The developers of Paperdude have stated that their game "can provide an immersive exergaming experience with a natural form of input that encourages exercise" (Bolton et al., 2014, p.477), underlining the effectiveness of combining VR and motion controllers.

11.2 Motion controllers

Motion controllers are a technology that allows the player to control the game using physical movement. There are many different technologies for using motion control in video games, including the Wii Remote, PlayStation Move, and Kinect. The Wii Remote and Playstation Move are handheld controllers that utilize an accelerometer to detect the users' gestures across three axes to control the game. These controllers are therefore limited to detecting a single gesture at a time and not full-body motion.

Figure 11.2: Kinect Sports: Season Two

The Kinect is different from the Wii Remote and PlayStation Move as it uses a camera to detect the player's full-body movement to control the game. When developing Windows applications that utilize the Kinect for voice and gesture recognition, the *Kinect for Windows SDK* can be a good tool (Microsoft, 2020b). There are many sport's related games for the Kinect, including the Kinect Sports series (see Figure 11.2). However, the Kinect manufacturing has been discontinued (Microsoft, 2020b), and the successor

of the Kinect, Azure Kinect, which was released in March 2020, is not built for gaming (Microsoft, 2020a).

11.3 Alternative controllers

When making exergames, it is essential to ensure a sufficient level of player exertion. The design of the controller used in the game is important for achieving physically demanding games. This section will look at alternative controllers that differ from the existing, widespread controllers for exergames that have already been introduced.

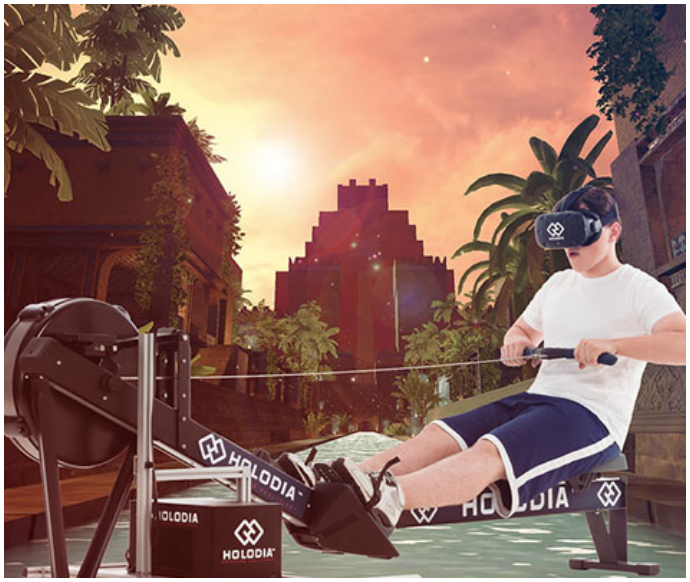

Figure 11.3: HOLOFIT VR Rowing

In addition to controllers such as Kinect and Move, there exist multiple other ways of controlling games using motion. One example is the use of a spinning bicycle like the ones used in Pedal Tanks and PaperDude. Using a spinning bicycle illustrates how conventional exercise equipment can be altered to function as controllers in exercise games. Making motion controllers for games can be very effective in player exertion because the equipment is initially designed for workouts. There already exist many different solutions involving conventional exercise equipment to control games, including martial arts pads, treadmills, rowing machines, and spinning bicycles (Fitness & Solutions, 2020a). An example of such a game is HOLOFIT VR Rowing, a virtual reality game controlled using a rowing machine that offers things like virtual coaching and online multiplayer gameplay (Fitness & Solutions, 2020c), this is illustrated in Figure 11.3.

11.4 Physical monitoring

When talking about physical monitoring in this section, the focus will be on technology that can collect data about physical activity, such as the number of steps, distance traveled, heart rate, etc. The most widespread technology used for physical monitoring is smartwatches and fitness trackers. Additionally, mobile phones can also track some aspects of a user's physical activity but are typically less accurate and unable to record data about heart rate. Fitness trackers are often watches, but with more focus on physical activity than smartwatches, which also have applications unrelated to health and fitness. When discussing the possibilities of using both health and fitness data and accessories for mobile development, it was introduced that both Apple and Google had platforms for managing data about physical activity. It is possible to use the data stored on these platforms, which is typically generated by smartwatches and smartphones, in the development of exergames.

Figure 11.4: Polar fitness trackers

Several fitness trackers can also be used to collect data for Google Fit and Apple's HealthKit. This section will look at the example of the Polar platform. Different Polar fitness trackers can be seen in Figure 11.4. Polar's watches integrate with both Google Fit and Apple HealthKit, meaning that the data collected could be stored on the platforms in addition to the Polar platform (Polar, 2020a). Polar also offers the Polar API, which enables reading data collected from Polar devices and using it in developing appli-

cations. This could be a good way of including data about users' physical activity in a game. The Polar fitness trackers also produce valuable data from the device sensors' raw data, including the amount of time spent in different heart rate zones during a workout. Heart rate zones monitor how hard the exercise is for the users and is calculated as the percentage of the user's maximum heart rate (Polar, 2020b). This kind of information could be beneficial to utilize in an exergame because it is relative to the user's fitness level and reflects the exercise's intensity for the specific user.

11.5 Summary

A wide variety of technologies has been used in the history of exergames. One example is motion controllers, which allow the players to control the game using physical movement and gestures. There are multiple motion controller technologies, with Kinect being an example that uses a camera to detect full-body movement. However, the handheld controllers Wii Remote and PlayStation Move primarily utilize other sensors like an accelerometer to detect gestures and movement. Motion controllers have been combined with virtual reality headsets, contributing to player immersion and exercise motivation. In addition to the motion controllers, multiple other alternative controllers is used in exergames, for example, exercise equipment like spinning cycle, rowing machine, and treadmill.

Another technology that can potentially be used to develop exergames is devices that perform physical monitoring, for example, step counting and heart rate monitoring. This technology exists in modern smartphones, but smartwatches and fitness trackers provide the most accurate measures.

12 Theories of enjoyment

With the goal of making an exergame that improves the player's health, it is essential to make the game both enjoyable and physically demanding. This comes with the big challenge of ensuring player retainment by engaging the users while playing and motivating them to keep playing the game.

This chapter will present three theories on enjoyment: The first one is the GameFlow model, which evaluates the degree of enjoyment in games. The second theory is Challenge, fantasy, and curiosity, highlighting the importance of those three elements for the player's enjoyment. And lastly, the Dual flow model featuring the attractiveness and effectiveness factors for designing a successful exergame. These models will later be used when designing and developing the game concept.

12.1 GameFlow

The GameFlow model is primarily used to evaluate the enjoyment of a game and can also be used during development to ensure that a game will become enjoyable and engaging. To understand the GameFlow model, it is essential to first look at the Flow model, which it is based upon. The Flow model results from research conducted by Csikszentmihalyi and Csikzentmihaly (1990) about what makes experiences enjoyable. The Flow model consists of eight elements, which all combined causes a sense of deep enjoyment where the person is completely engaged in the activity. This mental state is also referred to as "being in the zone" (Csikszentmihalyi & Csikzentmihaly, 1990).

Flow's eight elements:

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

6. A deep but effortless involvement that removes awareness of the frustrations of everyday life.

7. Concern for self disappears, but a sense of self emerges stronger afterwards

8. The sense of the duration of time is altered.

The Flow model was later applied to assess enjoyment in games by Sweetser and Wyeth (2005) which resulted in the GameFlow model. The GameFlow model describes eight elements, each derived and somewhat related to Cziksentmilalyi's flow elements, these elements are described below.

12.1.1 Concentration

The first element described in the GameFlow model is concentration. Games should grab the player's attention quickly and be able to maintain this attention throughout the game. This is done by providing a high but still manageable workload, appropriate stimuli, and reducing irrelevant distractions from the given task requiring their attention. One example mentioned by Sweetser and Wyeth is to dedicate the screen to the action and content of the game by reducing the game interface and nongame-related interactions.

12.1.2 Challenge

Challenge is one of the most important aspects of a game and is highlighted as a crucial element to reach Flow. For games to be enjoyable, it is essential to match the difficulty of the challenges with the players' perceived skill level. The game should also provide new challenges throughout the game and follow the player's learning curve by increasing the difficulty according to the players' skill development. "If the challenges are greater than the skills, the result is anxiety; if the challenges are less than the skills, the result is apathy" (Sweetser & Wyeth, 2005, p.6). Dividing the game into gradually increased difficulty levels is a popular way of balancing the challenges to maintain the players' interest in the game. These levels should be matched according to the different skill levels of the players.

12.1.3 Player skills

For games to maintain the players' interest and be enjoyable, it is important to support player skill development at an appropriate pace, giving them opportunities to develop their skills. The game should also initially provide an in-game tutorial or another way of teaching the player how to play the game, allowing them to be quickly interested and absorbed. It is also essential to reward the players throughout the game, giving them a sense of success.

The game should also provide other necessary information at the appropriate time, following game design trends, making the game interface consistent, and following industry standards for controlling the game. This will all together shorten the player's learning curve.

12.1.4 Control

The players must be allowed to feel a sense of control over their actions to experience a deep sense of enjoyment. This applies to their in-game control over the game interface and input devices by translating their actions, giving the players a feeling of control of their movement in the game world and interactions with the game objects. The players should then feel like their decision of action has made an actual impact on the game world.

12.1.5 Clear goals

Games must have a clear overall goal for the player to experience *Flow*, giving them a reason to spend their time and make an effort. The player should receive this goal early in the game, often combined with a background story and an overview of possible challenges and obstacles for reaching this goal.

12.1.6 Feedback

The players should be able to know their progress and performance in the game. This is provided through feedback. The feedback players receive needs to be relevant and come immediately after acting. The game also needs to provide frequent feedback about the

player's progress to guide them in the right direction toward their goals. The feedback is an excellent source of stimuli, enhancing the player's concentration.

12.1.7 Immersion

Immersion is an essential concept in the field of game design and research. It is described as "Deep but effortless involvement that removes awareness of the frustrations of everyday life" in the flow model (Csikszentmihalyi & Csikzentmihaly, 1990, p.3). Players become less self-aware and aware of their surroundings when having a sense of deep in-game involvement. Immersive games make the players feel like they are a part of the game, often providing a narrative that gives the players background and a storyline to follow. Audio, such as sound effects and soundtracks, is also essential means of creating an atmosphere around the player, absorbing them into the game.

12.1.8 Social interaction

Social interaction is not directly a part of the Flow model but is still a big part of games' enjoyment as people play games for socializing. Therefore, games should provide a platform for player-to-player interaction in the form of competition, cooperation, or connection. This will strengthen the enjoyment inside and outside the game, creating a social community.

12.2 Challenge, Fantasy, and Curiosity

Challenge, Fantasy and Curiosity are initially research conducted by Thomas W. Malone in 1980 on educational games but is still relevant in the field of exercise games since it has a sufficient general taxonomy and a focus on what makes games fun rather than educational. Malone argues that the most important aspects of enjoyable computer games can be organized into the categories challenge, fantasy, and curiosity (Malone, 1980).

12.2.1 Challenge

Malone's model highlights the importance of challenge in games as in the Gameflow model and further ties it to the concept of goal. The game should present challenging goals clearly and engagingly. It should also provide feedback about the player's perfor-

mance as he/she progresses in the game, encouraging him/her to reach the goal.

Malone also argues that a boring game is often caused by the game having a certain outcome of winning or losing. Therefore, the game should provide sufficiently difficult challenges, not guaranteeing to achieve the goal, which will encourage and boost the player's self-esteem at success. Still, it is also important not to damage the player's desire to play the game at failure. Malone then presents four ways of making the game experience more uncertain for the players (Malone, 1980):

1. Dividing the game into various difficulty levels chosen by the player or determined automatically according to the player's skill or the opponent's skill.
2. Structure the game with multiple levels of goals by dividing a general goal into multiple sub-goals or measuring the player's performance reaching the goal.
3. Hiding information will give the players room for creativity and provoke curiosity by slowly revealing it.
4. Introducing randomness to the game.

12.2.2 Fantasy

Provoking players' fantasies in games is an excellent way to make them more engaging and a great opportunity for capturing a broader range of players by triggering different kinds of fantasies.

Malone divides fantasy into two different types, intrinsic and extrinsic fantasies, with the difference in how they depend on skill use (see Figure 12.1). For *intrinsic fantasies*, the skill and fantasy depend on each other. The problem is often presented in context with the fantasy and often indicates how the skill could be used to reach a specific goal. The fantasy world events usually depend on how the skill is used and emphasizes how its use is different from the correct usage. One advantage of *intrinsic fantasies* is that players can exploit analogies between their existing knowledge about their fantasy world and the unfamiliar aspects of the world. *Extrinsic fantasies*, on the other hand, depending on whether the skill is used correctly. Other factors can also affect *extrinsic fantasies*, such

as how quickly the answer is given or how close the solution is to be correct.

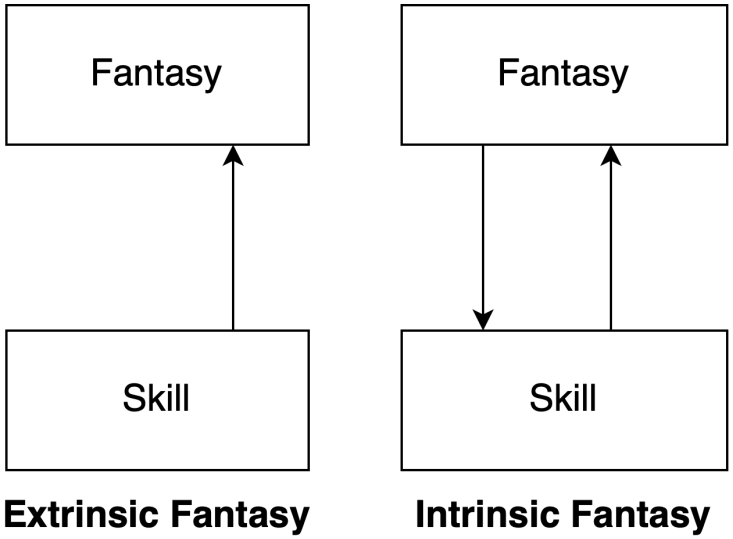

Figure 12.1: Fantasy dependencies (Malone, 1980)

12.2.3 Curiosity

Curiosity is an eager wish to know or learn something. In evoking the player's curiosity, computer games need to provide an environment neither too complicated nor too simple. The optimal level of the environment complexity is when the players can have expectations, which will not necessarily be met.

Malone further distinguishes between sensory and cognitive curiosity. *Sensory curiosity* involves different sensory stimuli of an environment. Computer games usually provoke sensory curiosity through the means of audio and visual effects. These effects can be used as decoration, to enhance fantasy, as a reward, and as a representation system.

Cognitive curiosity is the motivation to structure and complete their knowledge. One way games can trigger the players' cognitive curiosity, is as mentioned earlier, by hiding information. Making the players seem to have incomplete and inconsistent knowledge, which will motivate them to learn in order to complete and structure their knowledge. Providing surprising feedback is another way to engage a player's cognitive curiosity. This can either be done by introducing randomness to the game or revealing underlying inconsistencies in the game world that previously seemed surprising or random at first.

12.3 DualFlow

DualFlow is a framework for optimizing and evaluating exergames. It consists of two interrelated dimensions of an exergame; its *attractiveness* for engaging and motivating the player to keep playing and its *effectiveness* of the exercise for increasing the players' physical health. Sinclair et al. (2007) argues that the most important requirement in the DualFlow model is the balance between skill and challenge and between fitness and intensity to make the exergame both fun to play and physiological effective (Sinclair et al., 2007).

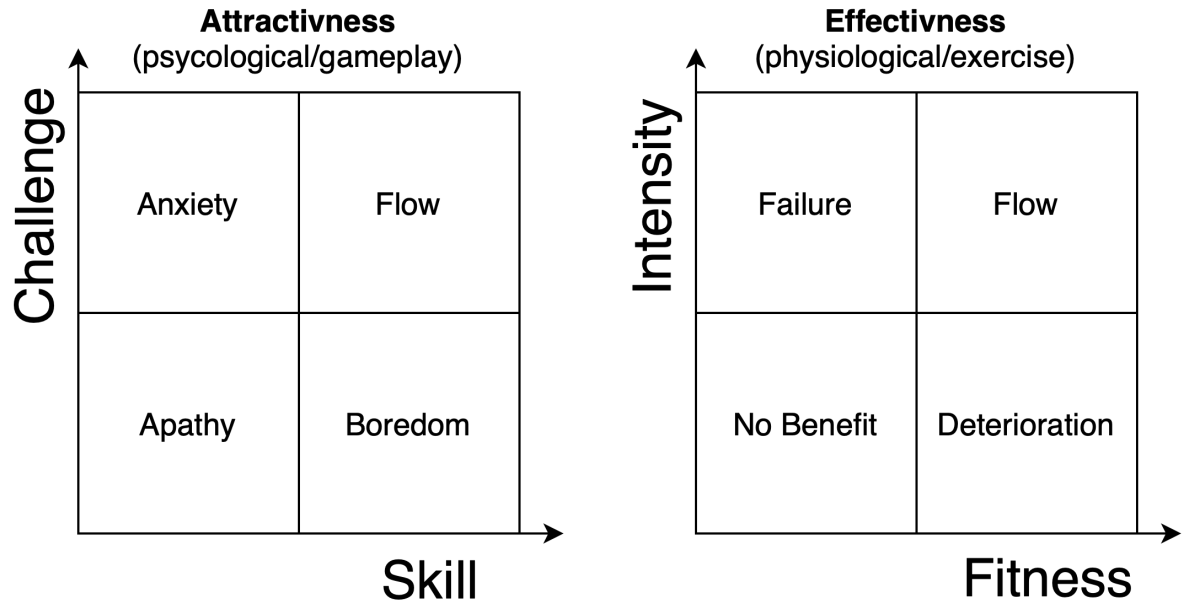

Figure 12.2: The DualFlow model (Sinclair et al., 2007)

12.3.1 Attractiveness

The attractiveness dimension is described as a psychological model based upon and modeled by the Flow or GameFlow model presented in Section 12.1. The attractiveness dimension primarily deals with the gameplay and the balance of the player's perceived skill with the perceived challenge to maintain the players' interest. This is also described as the *Golden rule of Flow*. Figure 12.2 illustrates four attractiveness quadrants representing different balances of challenge and skill. If the skill is too high compared to the challenge, it will result in boredom. The opposite of this is anxiety, which occurs if the challenge is higher than the skill. Apathy is achieved when there is a lack of both skill

and challenge, and Flow is achieved when making the game neither too easy nor too difficult by balancing the perceived skill and perceived challenge appropriately.

12.3.2 Effectiveness

Effectiveness is the physiological dimension of exergaming. This is shown in the effectiveness quadrants in Figure 12.2, illustrating the importance of balancing the intensity of the exercise with the fitness of the player to allow the player to reach a physiological flow. Reaching this flow will result in improved fitness and health over the time with continued exercise. If the intensity of the exercise is greater than the player's fitness level, it will result in a feeling of failure, and the player may not continue playing. On the other hand, if the game's intensity is lower than the player's fitness, the player enters a state of deterioration, and their fitness level may drop. And lastly, not provide any benefit to the player if the game lacks intensity and the player's fitness level is too low.

12.4 Summary

All three models mentioned above address enjoyment in games, which can be used when designing an exergame. The different theories present different requirements to be considered when designing an enjoyable game, which is especially important to motivate players to exercise.

One of the most important requirements mentioned by all three theories is the provided *challenges* and it being sufficiently challenging, balanced with the players' skill level and development. This applies to both the physical challenges and the gameplay challenges, highlighted in the DualFlow model by (Sinclair et al., 2007).

The players should also feel in *control* over their actions, work toward a *clear goal* and receive immediate *feedback* as they progress. The feedback is a great source of stimuli, enhancing the player's *concentration*. Furthermore, it is also beneficial to trigger the players' *fantasy* and *curiosity*, which will result in an immersive experience.

Part III

Concept

This concept part will introduce and describe the different new exergame concepts developed by the group in the specialization project. These concepts are developed by performing several brainstorming sessions and taking inspiration from previous successful exergames, such as Pokémon Go, Zombies! Run and others. The proposed exergame concepts will be reviewed by looking at their pros and cons, resulting in one chosen concept to be implemented and tested in this master's thesis. It further provides a detailed description of the selected concept and how it utilizes different theories of enjoyment. The actual prototype developed and used to test the exergame concept will also be presented, showcasing screenshots and a walkthrough of the game's design.

13 Concept ideas

This chapter will present the exergame concepts developed in the specialization project, as well as determining which concept to develop further.

13.1 Asteroid Attack

Asteroid Attack is a concept that combines strength exercise and video games. The gameplay is inspired by the platform game genre, more specifically scrolling platformers. The scenario depicted in the game is that an asteroid is on a collision course with earth, and the only way of preventing a collision is to destroy the asteroid using a rocket. This rocket will be controlled by the player and must be guided to the asteroid through a series of levels, avoiding obstacles along the way, as illustrated in Figure 13.1. The rocket will automatically move in the x-direction, and the player must move the rocket in the y-direction to avoid obstacles so that the rocket goes either over or under the obstacle. If the rocket hits an obstacle, it will explode and the player will have to restart the current level.

Figure 13.1: Asteroid Attack

The game is intended to be developed for mobile devices and controlled using the device's accelerometer and proximity sensor, taking inspiration from the Exermon game. The device will be placed on the floor with the screen and the proximity sensor facing upwards. The user then stands in a push-up position with the body located directly over the device. The proximity sensor will measure the distance from the player to the device, while the accelerometer will ensure that the device is not moving to try to pre-

vent cheating. Moving closer to the device will make the rocket move downwards, and pushing up from the ground will move it upwards. Thus the controls will require the user to perform push-ups. The number of pushups required will be controlled by the level design, providing a variable level of static exercise.

The game's progression will be based on completing levels, with each level taking the rocket closer to the asteroid. Completing a level is done by avoiding all obstacles, thus surviving the level to unlock the next one. The final level will be a boss-fight which can be won by colliding with the asteroid headed for earth, thus destroying it. Other game modes could also be included to extend the gameplay after the final level. An example of this is a multiplayer game mode where the last player to hit an obstacle wins. In this game mode, the frequency and distance between obstacles will increase until a single player is left.

Pros

- Easy to play - Played on mobile phone.
- Strong link between exercise and gameplay.

Cons

- Easy to cheat.
- Hard to see the screen when using the sensors to control the game.

13.2 Exer City

The concept of Exer City is inspired by games in the idle games genre, more specifically idle games that revolve around gathering resources that can be used to build a city. In Exer City, each player is given its own piece of land to develop, primarily by building new buildings and infrastructure. The game's goal is to build and expand a virtual city on this piece of land as much as possible. Based on the nature of these kinds of games and the game's goal, it would most likely not have a final ending, but rather encourage the player to keep expanding its city indefinitely. This concept is inspired by both idle

games and simulation games, especially Realm Grinder and Sim City. To make the game accessible for as many users as possible, it would be developed for mobile devices.

In contrast to idle games where resources are produced by actively clicking and passively by in-game items over time, Exer City will require its users to work out to produce these resources. The players' physical activity could be recorded using fitness trackers or health and fitness data collected by the mobile device. Each time the user returns to the game, it will check if the player has recorded physical activity since the last time the player was logged in. If this is the case, the player will be awarded resources accordingly.

To utilize the different data produced from fitness trackers and mobile devices, the game could include various resources, where each resource can only be obtained from specific physical activity. The resources associated with physical activity could be: Number of steps produce stone, cardio exercise produces wood, and strength exercise produce steel. Different buildings could require different combinations of materials to build. Based on this, the buildings that make up a player's city will reflect the nature of their physical activity. A player performing mainly strength exercise will have a city made of steel, while a player more focused on cardio will have a city made out of wood. To promote varied physical activity, the most valuable buildings will require a combination of resources.

Pros

- Users can perform their preferred exercise.
- Easy to play - Played on mobile phone.

Cons

- Indirect link between gameplay and exercise.
- No clear goal - infinite building.
- Requires fitness trackers.

13.3 Exer-Tribe

This exergame concept is inspired by the location-based exergame Run an Empire mentioned in Chapter 8, which uses the real world as the game world divided into hexagons (see Figure 13.2). Run an Empire's goal is to conquer the world by running through the different hexagons to claim them as yours. The Exer-Tribe concept will also use the real world as the game board and have the overall goal to conquer the world, but in this concept as a tribe.

Figure 13.2: Run An Empire

Each player will be randomly assigned to one of three tribes, all competing to conquer the world. This is done by claiming the other tribes' regions by attacking them and maintaining your own regions by defending them, inspired by the Gym feature in Pokémon Go. If no tribe has claimed a specific region, it is only necessary to run through it to claim it for the player's tribe, but if the region is already claimed by another tribe, the player needs to attack it before claiming it. This attack could be done by performing some sort of strength exercise to break down the other tribe's region's defense. The player may also need the help of one or more tribe members if the region's defense is too strong for the

player to break alone. The player can also strengthen the defense of their tribe's regions by running through them. By doing this, the game combines both strength and cardio exercise.

The game is a social strategy game with an emphasis on cooperation and competition. It gives the player a choice of aerobic and strength exercises based on if the player wants to defend or attack. The player's performance could also be recorded and presented to the player for skill development by dividing them into levels. The game is intended to be developed for mobile phones, using the device's GPS and accelerometer to record the player's speed and location when moving around in the world. The games also need to utilize different sensors to measure the player's motion in the strength exercises.

Pros

- Easy to play - Played on mobile phone.
- Strong link between exercise and gameplay.
- Strong social aspect.

Cons

- Easy to cheat.

13.4 Slither.io exergame

This exergame concept is inspired by both the platform game Slither.io and the exergame Pedal Tanks. The object of Slither.io is to control and grow a worm on a large platform to become the largest in the game (see Figure 13.3). This is done by eating small orbs found on the platform or by consuming other players. Other players have to collide with your worm to defeat them, the defeated worm then turns into orbs that can be consumed. The game also features boosting, which increases the worm's speed in a short period of time used to tackle or escape other worms (Gil, 2016).

Figure 13.3: Slither.io

The exergame version of the game will utilize the same stationary bike as Pedal Tanks to control the game. This bike is customized with different sensors for measuring the pedaling speed and buttons located on the handlebar. Each player will use the bike's pedals to maintain the worm's momentum and the handlebar's buttons for turning and boosting the worm. The players also have to increase their pedaling pace to use the boost feature.

To keep players continuously pedaling the bike, their worm's size will slowly shrink when they are inactive. As Slither.io is a never-ending game, it can become tiresome to play in the long run, especially when exercising at the same time. A solution to this could be to divide the matches into 20 or 30 minutes segments and let the player's worm respawn on the platform when dying. The player has to then retake the aim to become the longest worm before the time runs out.

Pros

- Equipment intended for exercise.
- Strong link between exercise and gameplay.

Cons

- Requires special equipment to play.

- Difficulty finding enough players riding a similar bike at the same time.

13.5 On Fire

The concept of On Fire is based on firefighting as the players control a virtual firefighter. In this game, the player will receive missions that require moving to specific locations in the real world and performing tasks. These tasks will mainly be the extinguishment of virtual fires, but could also be other activities usually associated with firefighting. Both relocation and the task must be completed before a countdown has ended. If not, the game will be over. When a task is completed, the player will be given a new task and location, and a new countdown will begin. If the mission involves the extinguishment of a fire, it will start by giving the player a location where there is a virtual fire out of control. As soon as the player arrives at this location, the task is unlocked, and the gameplay for extinguishing the fire can be started. The concept is inspired by games like Pokemon Go that include traveling to different in-game elements, which are located at specific locations in the real world, to play parts of the game.

By having the player posing as a firefighter, the game could be categorized as an RPG. To further immerse the player in this role, the game will have some elements that provide a story during missions as well as in-between these. The players' character will also develop as the game progresses. This would mainly be reflected in the increasing level of the character based on experience points gained from playing the game. The level of the character could, in turn, be used to unlock different things in the game, including new game modes, firefighting equipment, skins, etc.

With the concept requiring the player to physically move from location to location in the real world, it leads to cardiovascular exercise. In contrast to other similar exergames like Zombies, Run!, or Run An Empire, where the player is mostly moving during gameplay, On Fire will lead to the player standing still while performing a task after arriving at the location. This characteristic of the physical activity will make the game more focused on interval training.

Pros

- Easy to play - Played on mobile phone.
- Strong link between exercise and gameplay.
- Easy to adjust the physical difficulty level.

Cons

- Easy to cheat.

13.6 Review of concepts

This review will go through the most important limitations and benefits of the different concepts and conclude with choosing one of the concepts for further development.

All of the concepts, except the Slither.io exergame, are intended to be played on mobile phones. Developing for mobile devices presents a significant advantage as most people have access to this technology. It is also beneficial to develop exergames for mobile devices as it increases the number of locations and situations where the users can exercise. This also highlights drawbacks for the Slither.io and Exer City concepts, as they require the user to have access to special equipment such as stationary bikes and fitness trackers. Another benefit of developing for mobile devices is that both students have experience with mobile application development. Both students have worked with the Android and web-based frameworks in previous projects.

Another critical aspect to consider is how the exergames adjust the gameplay's difficulty according to the players' physical health. The On Fire concept handles this by providing different intensity levels that the players can choose from, enabling every player to play and progress independently of their initial physical health. This concept will reward the players according to their performance based on their intensity level to motivate them to further push themself and progress in the game. Asteroid Attack, on the other hand, is structured in a way where every in-game level and intensity progress will be the same for all players, making the game more challenging as you progress. The other concepts do

not have any specific skill-based adjustments to the difficulty.

The link between gameplay and physical activity is also crucial to justify an exergame's physical activity and motivate the players. Exer City is a special kind of exergame concept idea since it separates the game's exercise and gameplay, requiring the player to perform regular exercise to gather resources in the game. This will affect the relationship between the exercise and gameplay and may also hurt the player's motivation. On the other hand, the other concept ideas will provide continuous feedback and integrate exercise as a central aspect of the gameplay.

One of the biggest challenges when developing exergames is the prevention of cheating. This is especially challenging for the concepts of Asteroid Attack, Exer-Tribe, and On Fire concepts. In Asteroid Attack and Exer-Tribe, the players can mimic the strength exercise motions to trick sensors. This challenge was also highlighted by Wang et al. (2017) for a similar exergame, Exermon, which uses the smartphone's sensors to detect the player's motion. The location-based nature of Exer-Tribe and On Fire is also an issue as the players can use various means of transport such as motorized bicycles and scooters.

Based on the aspects discussed above, the On Fire exergame concept has been chosen for further design and implementation. One of the most significant advantages of this concept is that the players can start a game wherever they are located using a mobile phone, lowering the threshold for physical activity. Additionally, there is a strong connection between physical activity and gameplay. The concept can also be adjusted to fit the players' current fitness level, providing an appropriate degree of challenge for each individual. Mobile phone technology is also familiar to the students, and there exists good support for location-based games provided through various services such as Google Maps.

13.7 Summary

This chapter presented five concept ideas for new exergames. The first one is Asteroid Attack, a strength-based platform game that sees the player controlling a rocket through a series of levels to save the earth from an incoming asteroid. The second concept is Exer City, an idle game that produces resources based on data recorded by a fitness tracker, allowing the player to choose their preferred exercise. The player can use these resources to build their virtual city. The third exergame concept is Exer-Tribe, a location-based exergame where the goal is to control virtual zones in the real world together with other players. This concept bases itself on both strength- and cardio exercise. The fourth concept is based on the Slither.io game. The game will be played using a stationary bike with controls on the handlebar in the exergame concept. The fifth concept is the location-based exergame On Fire, where the player controls a firefighter that must complete different virtual tasks in real-world locations. Due to its location-based nature, this concept will produce cardiovascular exercise for the player. After reviewing the concepts, On Fire was chosen for further development. This is based on the fact that it is easy to play, has a strong link between gameplay and exercise, and can be easily adjusted to fit the players' physical shape.

14 On Fire

This chapter gives a detailed description of the chosen concept for this project, the exergame On Fire.

14.1 Gameplay

Like previously mentioned, the game will be based on moving to specific locations in the real world to perform tasks, thus dividing the gameplay into two parts, relocating and completing tasks. The game can include many different tasks to simulate a firefighter's work, but the game's main tasks will be the extinguishing of virtual fires (see Figure 14.1). One of the gameplay's significant advantages is that the game starts from wherever the player is located when starting the game. Hence it does not require the player to move to a specific location to start a new game.

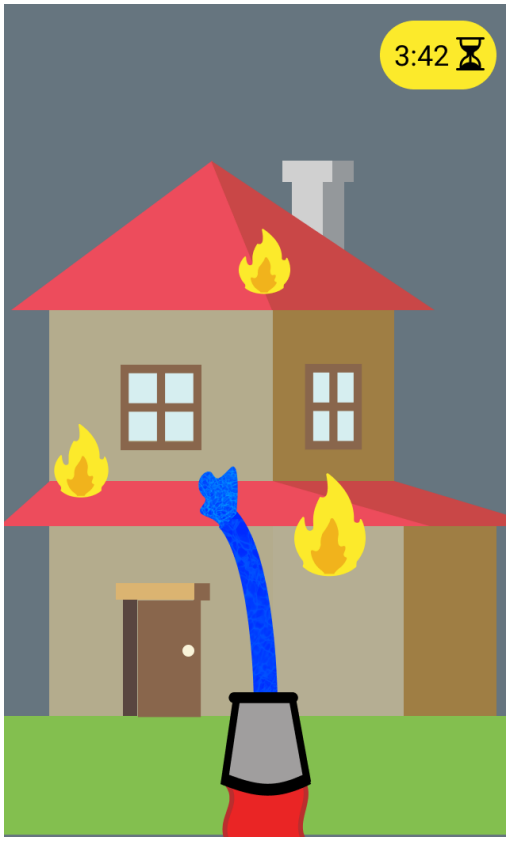

Figure 14.1: Fire extinguishing task

The standard form of gameplay will be the *Fire Run* game mode, which includes going to a predetermined number of locations and finishing the task at each location. When a Fire Run is started, the player will receive the first location, and a countdown will begin. The player will then have to travel to this location before the task can be started, illustrated in Figure 14.2. The intensity of the fires within the task will depend on the time spent moving to the location. For every unit of time, the fires will increase in intensity as they would in the real world. If the player manages to complete the task before the countdown is finished, the player will receive points based on the time used, and a new assignment with a location and a task will be given. Each new assignment will be more challenging to complete than the previous one, with either a longer distance to travel or a shorter countdown time. If the player fails to complete the task in time, the game will be over, and the Fire Run game ends. If the player manages to complete all tasks on time, the Fire Run will be successfully completed, and the player will receive additional bonus points. The total score of a Fire Run will be based on the points gathered from each task and the possible bonus for completing all assignments.

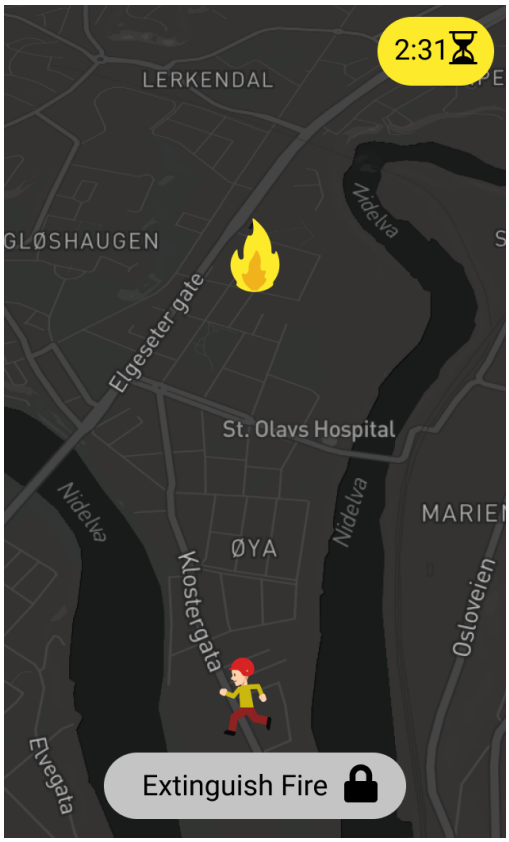

Figure 14.2: Fire Run gamemode, task locked

The second game mode, *Marathon* is similar to Fire Run, but there is no maximum number of tasks. Thus this game mode will continue giving the player tougher and tougher assignments until one is failed and the Marathon ends. The third and final game mode is *City Rescue*, which differs from Marathon and Fire Run that only gives the player one location to travel to at a time. When started, City Rescue will display all locations simultaneously to the player and provide a total countdown for completing all tasks. The City Rescue game mode encourages the player to create a strategy for moving between the locations. Some assignments will have more intense fires than others and must be prioritized, which will add to the game mode's strategy aspect. Meaning the intense fires must be prioritized because the locations may burn down before the countdown has finished, resulting in a failed City Rescue. The intensity of a fire is illustrated by its color, as shown in Figure 14.3. The player will receive a bonus score based on the amount of time left if all assignments are completed before the countdown has ended. If the player cannot complete all tasks in time, the total score will only be based on the completed assignments.

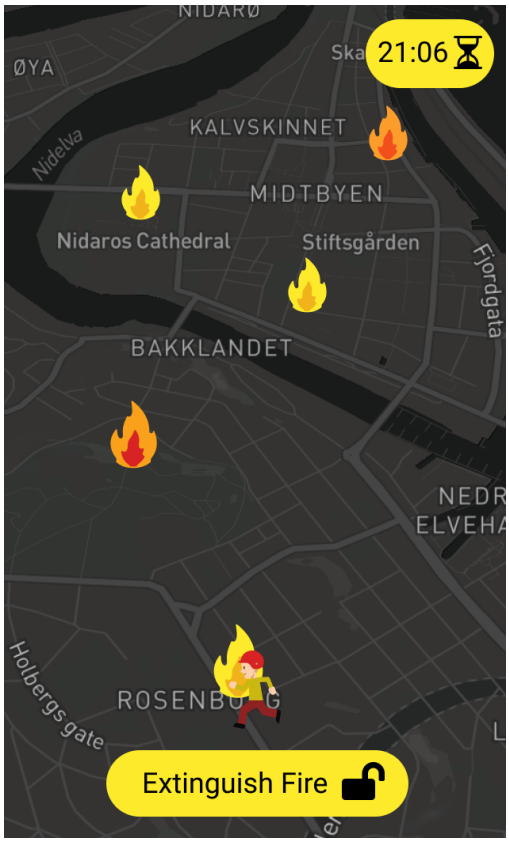

Figure 14.3: City Rescue gamemode, task unlocked

14.2 Progression

The progression of the game will be represented in a level-based system, which is often seen in RPG games. The level of the character represents the players' experience and progression through the game. The player will earn experience points from playing the game, and the player's character will level up at different thresholds. The different levels will be reflected as different firefighter ranks, ranging from recruit to fire chief. By leveling up their character, the player could access new game features such as game modes, cosmetics, and tools to be used to extinguish fires. A simple illustration of how this level system could look like is depicted in Figure 14.4.

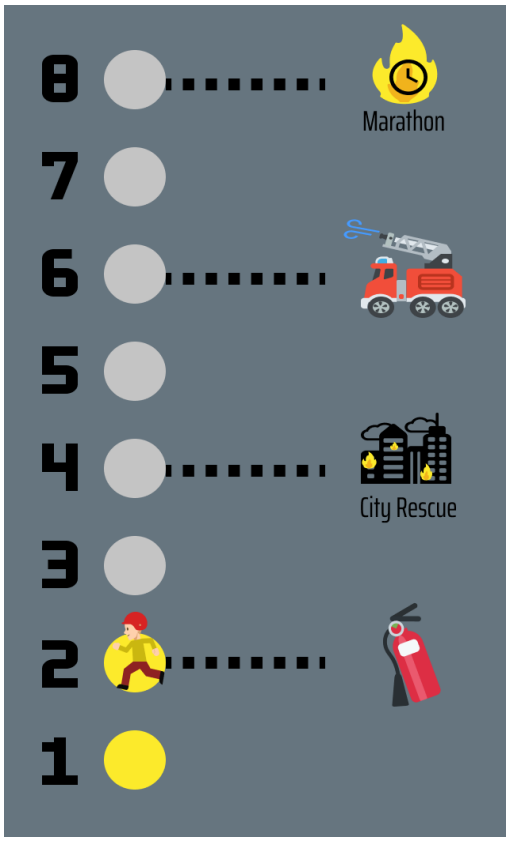

Figure 14.4: Level progress

The game will also provide the player with information about their performance and progression. This can be done by either having an achievement system, giving the player different achievements for their actions, or simply displaying their performance statistics. This information can include things like the number of runs completed or total kilometers traveled.

14.3 Physical activity

The game is a location-aware exergame, which requires the player to move between different real-world locations to perform various tasks in a given time-space. This will encourage the players to run between the points and therefore perform a cardiovascular exercise. The game can also be characterized as an interval running exercise since the pace and distance to move will be slowly increased, and the minigame tasks will function as recovery between the running sessions. The physical aspects of this game also share many similarities with the orienteering sport, requiring the athlete to navigate from point to point using a map, and the biathlon sport requiring the athlete to perform tasks, being rifle shooting between cross-country skiing sessions.

The gameplay's physical intensity will be reflected by the distance to the next location, time to complete the task or a combination of both. Ideally, these values will be automatically balanced and matched with the player's physical health and changed dynamically appropriate to the player's performance. This will allow every player to be physically challenged by the game, independent of their initial physical health. The only game mode that is not adjusted to the player's physical fitness is the Marathon game mode, which will provide the same difficulty for every player. This game mode has the highest intensity level because it includes an endless number of tasks with increasing intensity, which encourages the players to physically push themselves to complete as many tasks as they can to improve their high score.

14.4 Social aspects

The game could also provide different social aspects, the main one being that the players can add other players as their friends. The player will then share their statistics, level, and appearance with their friends. The game could also include a leaderboard for the points obtained in the Marathon game mode, either a global one or among the players' friends. The reason behind having a leaderboard for this specific game mode is that the game mode will have the same intensity for every player, making the results of different players comparable.

The game could also provide another competitive aspect, where the player will have the ability to challenge their friends to perform the same Fire Run game as the player after he/she has completed it. The two players will then see each other's performance and the best one will win the competition.

14.5 Summary

On Fire is a location-based exergame where the player controls a firefighter who needs to run around their local area to complete different tasks. The primary task is extinguishing fires. The tasks will be shown on a map relative to the players' current location. The player must use this map to navigate to the task. Once the player is close enough to the task, the player can start the gameplay to complete it. Relocating and completing the task must be finished before the given countdown has ended. Thus this countdown determines the pace the player must run in to be able to complete the task. The nature of the gameplay provides the user with an interval exercise that can be compared to biathlon, as the user needs to stop and extinguish a fire before relocating to the next fire. The intensity of the exercise can be determined by regulating the countdown time given to relocate and complete the task or regulating the distance between locations.

The game will be playable from anywhere by providing the player with locations in its local area and includes three game modes; City Rescue, Fire Run, and Marathon. City Rescue displays all tasks from the start, allowing the player to choose which task to complete first. Fire Run is the primary game mode and gives the player a finite number of tasks but only displays one task on the map at any given time. To get the position of the following location, the player must finish the current task. The Marathon game mode is identical to Fire Run but with an infinite number of tasks. The game will also have a level system to reward the player for exercising and set partial goals. Several social aspects are also proposed, such as adding friends, challenging friends, and leaderboards.

15 Prototype

This chapter will describe the finished prototype developed in this project based on the concept of On Fire, including how to play the game. To see a more detailed description of the technologies used, see Part IV.

15.1 Log-in page

The application's log-in page (see Figure 15.1) allows users to sign in using their email and password, utilizing the Google Authentication service. A create user page was also developed, but not used in the prototype as the users will receive pre-made log-in details for testing.

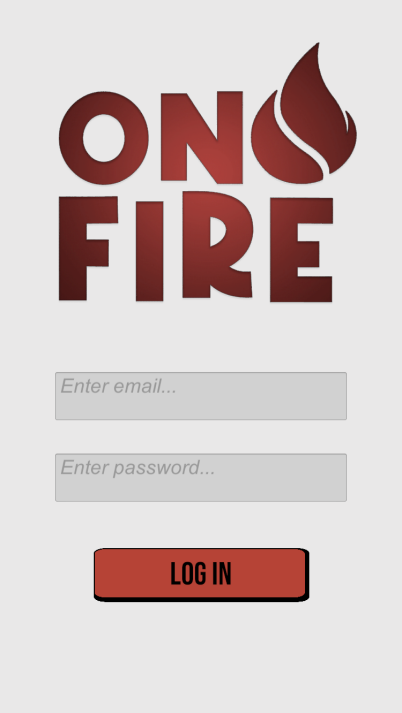

Figure 15.1: Login page

15.2 Menu system

The Main Menu screen displayed in Figure 15.2 is the first screen that the player will see after logging into the application. This screen consists of the top menu bar and three buttons, which allow the player to navigate to every part of the application.

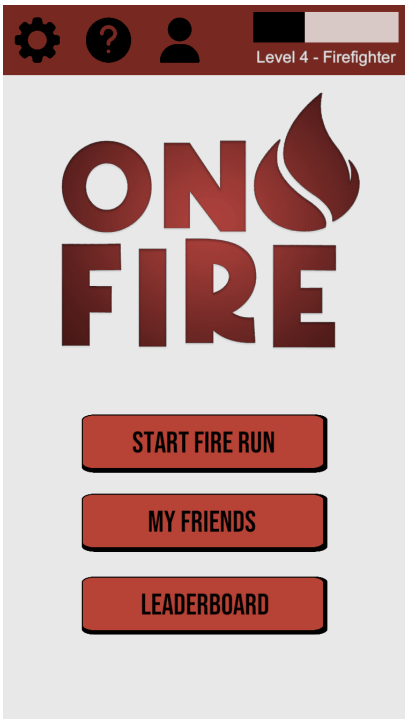

Figure 15.2: Menu page

The top menu bar is used to navigate to the parts of the application that should be accessible from multiple screens. This menu is divided into two parts. Where the first part is located in the left part of the top menu, containing three buttons. This include (from left to right):

- The Settings button: Redirecting the player to the Settings Page of the application.
- The About button: Redirecting the player to the About Page.
- The My Profile button: Redirecting the player to the My Profile Page.

The second part of the top menu bar is located to the right and contains an indicator, showcasing the players' level and progress towards the next level. The player can access the Progress Page by pressing this indicator.

The three buttons on the main menu are used to navigate to other parts of the application, including playing a Fire Run, the Social Page, and Leaderboard Page. These pages are described in detail later on.

15.3 Playing a game of Fire Run

Fire Run is the name of the gameplay available in the prototype. The objective of a Fire Run is to rescue the local area from an increasing number of fires. These virtual fires will be located in real-world locations, which requires the player to move around to extinguish them.

15.3.1 Start a new Fire Run

A new Fire Run is started by pressing the "Start Fire Run" button in the On Fires Main Menu. This will launch the game and simulate virtual fires relative to the players' location when starting the game. The only requirement to start a game is that the player is located in a rural area to find enough locations using Google's Playable Locations API. If the player's current location does not meet this criterion, a notification with suggested actions will be displayed.

15.3.2 The Fire Run map

When the application has successfully found enough locations relative to the starting point, the screen shown in Figure 15.3 will be displayed. The game now displays a map of the players' surroundings with two main elements on it. The first one is the current fire, which is illustrated by an animated flame. Although every game consists of several fires, the player will only be able to see one at a time. The second element on the map is the player character, which illustrates the device's position in the real world. This is made using the Google Maps Platforms Gaming Solution. The map can be rotated by swiping left to right, as well as zoom in and out by pinching your fingers.

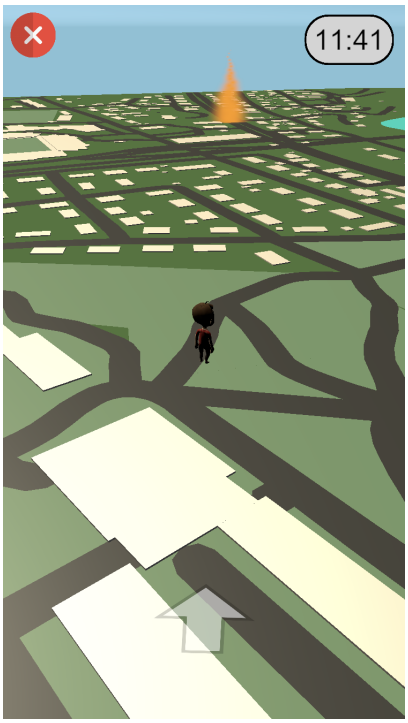

Figure 15.3: Map page

There are also three other elements on the screen, the forfeit button, the guiding arrow, and the countdown timer. The forfeit button in the top left corner allows the player to forfeit a game. This will end the game but save the rewards and progression obtained in the active game. If the player has not extinguished any fires yet, the game will end without saving any data. Forfeiting a game will redirect the player back to the main menu. The guiding arrow at the bottom of the screen points to the location of the fire. This ensures that the player can easily find the fire on the map, although the map is rotated towards the fire by default on start.

The countdown timer in the top right corner displays the time left to complete the current task. This involves relocating to the real-world location of the virtual fire displayed on the map, as well as extinguishing it. This countdown value is calculated using the optimal route to the fire's location and the difficulty selected by the user. More information about how the game difficulty affects the countdown can be found in the Settings Page description (see Section 15.4). The player can use the map to help find roads and pathways that lead to the fire.

15.3.3 Extingushing a fire

When the player is within 10 meters of a fire, it will be able to click on its animation on the map to start extinguishing it. When the player has successfully clicked on the fire animation on the map, the extinguishment of the fire will start, and the screen, as shown in Figure 15.4 will be displayed. Each time this screen is loaded, it will provide a random rotation of the house object and two fire animations with random locations on the house. The location of the fires will be checked to ensure that they are visible to the player.

Figure 15.4: Task page

To extinguish the fire, the player will need to guide the water jet to collide with the fires on the house. The water jet is controlled by swiping in the horizontal direction to adjust its direction and swiping in the vertical direction to adjust the distance the jet travels. The player must extinguish all fires on the house before the countdown timer in the upper right corner reaches zero to complete the task. This countdown is a continuation of the countdown on the map screen.

The fire icons in the top left corner illustrate how many fires are left. As the water jet hits a fire, it will emit smoke and gradually decrease in size until it is extinguished. Once a fire is extinguished, it will be removed from the house, as well as removing one of the fire icons. Fires that are not in contact with the water jet will gradually increase in size over time. If the player does not manage to extinguish all fires before the countdown ends, the game will be over. This will redirect the player to a screen showing a summary of the game.

15.3.4 Task completed feedback

If the manage to extinguish all of the fires before the countdown has ended, it will receive experience points (XP) based on the following factors:

- Completion XP: Base XP for completing the task. This is always 200.
- Time Bonus: Bonus XP based on time left of the countdown. This has a maximum value of 60 to balance the game. If a higher value can be given, it will exceed the difficulty multiplier bonus, making it beneficial for players with a better physical condition to run at easier difficulties.

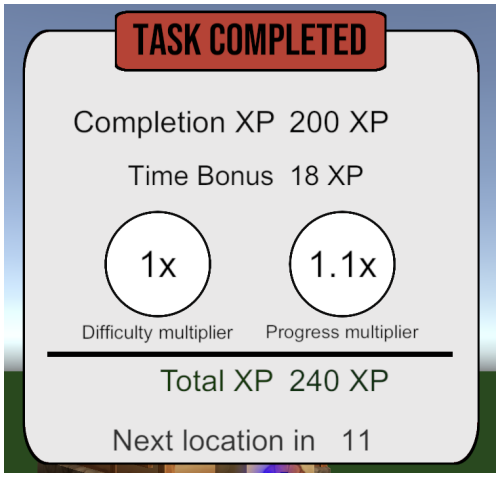

Figure 15.5: Task completed

- Difficulty Multiplier: Multiplies the sum of the completion XP and time bonus based on the players' selected difficulty.

  - Easy: 1.0
  - Medium: 1.2
  - Hard: 1.5

- Progress Multiplier: Multiplies the sum of the completion XP and time bonus based on how many locations the player has completed in the current game. 0.1 is added for each new location.

The XP calculations will be displayed to the player as seen in Figure 15.5. When the countdown at the bottom of the screen ends, the player will either be given a new virtual fire at a new location or complete the game if all virtual fires and tasks are completed.

15.3.5 Game ended feedback

When the On Fire game has ended, the player will receive feedback on their performance. This includes XP gained from this game as well as statistics describing the game, including:

- Number of locations (fire icon): Displaying the number of virtual fire locations completed in this game.
- Distance traveled (map): Described the total distance traveled between locations in the game.
- Time spent (clock): Displays the time spent playing.

If the player has completed the fire extinguishment task for all locations in this game, the Game Completed window will be shown (see Figure 15.6).

This window will display the completion bonus for completing all locations, determined by the chosen difficulty setting. The completion bonus for the different difficulties are:

- Easy: 300 XP
- Medium: 400 XP
- Hard: 500 XP

Figure 15.6: Game completed

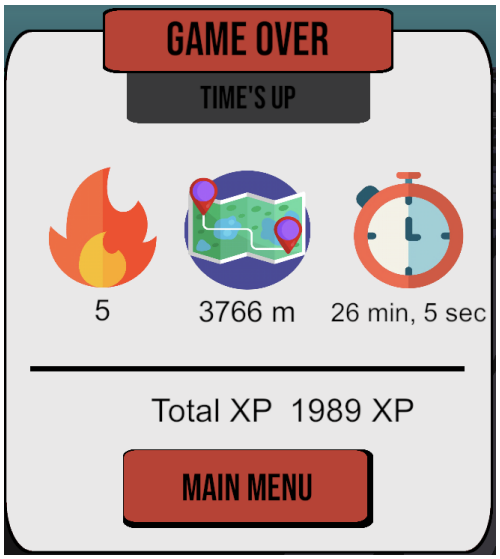

Figure 15.7: Game over

The Game Over window seen in Figure 15.7 will be displayed if the player runs out of time. This window displays statistics and XP gained in the same way as the Game Completed window. If no tasks were completed before the time ran out, no statistics or XP would be displayed, only a message saying that no locations were completed.

15.4 Settings page

The settings page is divided into three sections: gameplay, sound, and map theme, as seen in Figure 15.8.

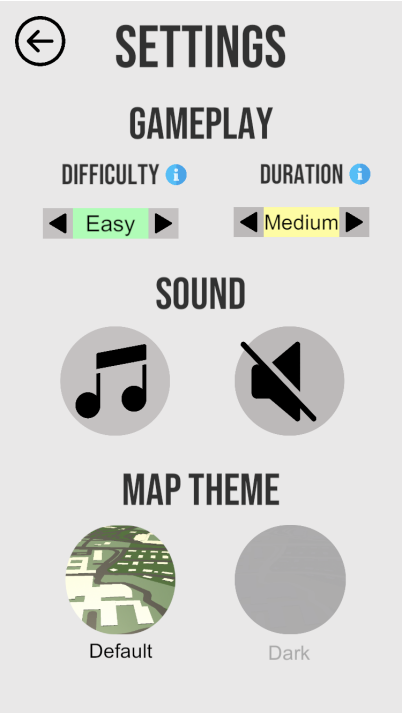

Figure 15.8: Settings page

15.4.1 Gameplay

The gameplay section lets the player change their difficulty and duration of the Fire Run game.

Difficulty: The player can choose between easy, medium, and hard difficulty using the arrow buttons. Greater difficulty gives the player less time to locate and complete each task, but a higher XP multiplier. The time and distance to each location are calculated using Google's Distance Matrix API. This time estimate is then multiplied by the player's chosen difficulty, wheres each difficulty level represent the following average running speed:

- Easy: 5 km/h
- Medium: 7.5 km/h
- Hard: 10 km/h

Duration: Determines the number of locations given each game, and the player can choose between the short, medium, and long duration using the arrow buttons. The different durations the players can choose are:

- Short: 5 locations
- Medium: 7 locations
- Long: 10 locations

The locations are retrieved from Google's Playable Locations API in a 500m radius around the player's start position. Suppose it is impossible to find enough locations around the start position based on the player's chosen duration, the locations found will be used

several times to build the game duration to the player's preference. The player will not be able to start the game if it is not possible to find any locations around him/her.

15.4.2 Sound

The sound section gives the player the option to toggle on and off the music by pressing the "music" icon and sound effects by pressing the "sound" icon.

15.4.3 Map theme

The map theme section gives the player the option to choose between the default map theme and a dark map theme. The dark map theme can not be selected and has a lock icon on it until it is unlocked at level 3.

15.5 Social page

The social page, shown in Figure 15.9, is accessed by clicking the Social button in the main menu. The Social page allows the player to connect with other On Fire players. This page is divided into three sections: My Friends, Friend Invites, and Sent Invites. The buttons at the top of the page are used to navigate between the different sections. The currently displayed section is highlighted in a darker color than the others.

Figure 15.9: Social page

Figure 15.10: Friend comparison

15.5.1 My friends

The My Friends section will list the players' On Fire friends and their level. The player will be able to compare their stats to their friends by pressing their friend's name to open the comparison window seen in Figure 15.10. This window will display both their own and the player's friend statistics, including:

- Number of locations completed (fire)
- Distance traveled (map)
- Time spent playing Fire Run (clock)

The player can also remove their friend by clicking the button at the bottom of this window.

The player can add new friends by pressing the plus button at the bottom of this section. This will show a window requesting the nickname of the friend and a Send Request button.

15.5.2 Friend invites

This section will list the friend invites the player has received from other players. If there are any new requests, a number on the Friend Invites button will indicate this, illustrated in Figure 15.11. Each friend invite can either be accepted or rejected. Accepting the invite will add the player to the My Friends section, and if the request is rejected, it will be removed from the list.

Figure 15.11: Friend invites

15.5.3 Sent invites

The Sent Invites section displays the friend requests that the player has sent to other players, as seen in Figure 15.12. They will remain in this list until the player has accepted or rejected the invite.

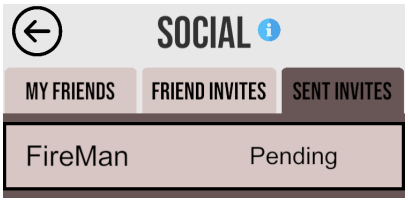

Figure 15.12: Sent invites

15.6 My profile page

The profile page seen in Figure 15.13 is accessed by pressing the "Person" icon in the top menu bar. This page displays the player's nickname as the header with their level and firefighter rank beneath it. The player can edit their nickname by pressing the Pen icon next to it.

The profile page also displays the player's statistics. These statistics include:

- Number of locations (fire icon): Displays the total number of virtual fire locations completed.
- Distance traveled (map): Displays the total distance traveled between locations.
- Time spent (clock): Displays the total time spent playing.

Figure 15.13: My Profile Page

The profile page also lets the player change up their active equipment for extinguishing fires. The player can choose between the water hose, foam, and fire truck. The foam and fire truck is more effective than the default water hose, but can not be chosen and has a lock icon on them until they are unlocked at levels 5 and 8.

The Log Out button at the bottom of the page logs the player out of the application when pressing it.

15.7 Progress page

The Progress page seen in Figure 15.14 displays the player's current level progress in the level system. The progress bar at the top of the page illustrates the player's progress towards the next level, the exact number of XP obtained, and XP needed for the next level.

The scrollable content below the progress bar contains information about the different levels and the rewards obtained on these levels. The circle representing the player's current level will be bright red, the levels below the current level will be light red, and the levels yet to be unlocked will be gray.

Figure 15.14: Progress Page

15.8 In-game tutorial

The game tutorial seen in Figure 15.15 will be displayed when the player logs into the game for the first time and can also be accessed later by pressing the Tutorial button on the about page. The tutorial contains a set of slides showcasing and describing different parts of the game. The player can navigate between these slides by pressing the "next" and "previous" buttons at the bottom of the page.

Figure 15.15: Tutorial Page

15.9 About page

The about page, seen in Figure 15.16, is accessed by pressing the Question Mark icon in the top menu bar. The About page contains a brief explanation of the game, a Tutorial button, and credits. The tutorial is accessed by pressing the Tutorial button, and will let the player be able to go through the game tutorial again.

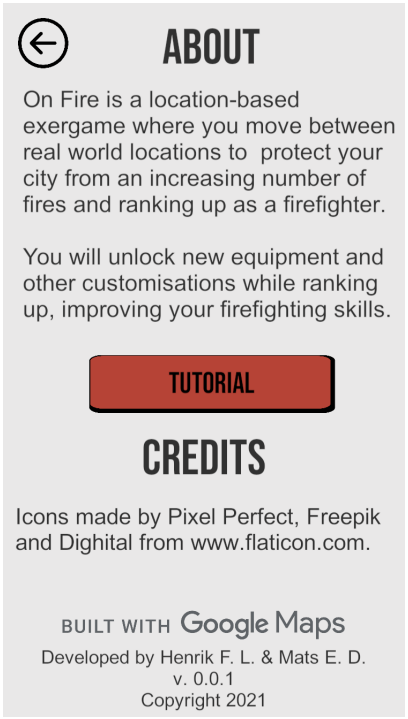

Figure 15.16: About Page

15.10 Leaderboard

The leaderboard page, seen in Figure 15.17 and Figure 15.18, is accessed by pressing the "Leaderboard" button in the main menu. The game provides two types of leaderboards, one table table listing the top 10 players ranked based on XP, and the other listing the top 10 players based on total distance traveled.

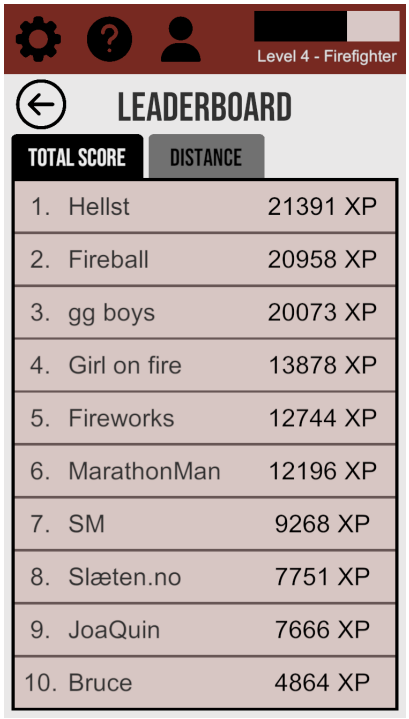

Figure 15.17: Total score leaderboard

Figure 15.18: Total distance leaderboard

15.11 Summary

This chapter has provided a walkthrough of the game prototype, including the different pages and how to navigate between them. The prototype includes a complete menu system with standard application features such as settings and an about page. In addition to playing the game, the application also provides functionality for viewing your stats, including distance traveled, time spent running, and the number of fires extinguished. These stats can be compared to friends on the social page or used to determine the players' placement on the global leaderboards. This chapter has also described how to play a game of Fire Run, showcasing its different parts, including navigating and relocating using the provided map and extinguishing the fires by controlling the water jet

in the mini-game. The players will receive feedback about their game when finishing a game, which includes XP gained, distance traveled, fires extinguished, and time. The XP rewards are calculated depending on the players' game progress, difficulty, and duration. Additionally, how how the game is built up by several locations retrieved from Google's API and how these are chosen depending on the players' location and preferences are also described.

16 Game enjoyment

This chapter will explain how the On Fire exergame concept developed in the specialization project utilizes the different concepts and elements from the theories presented in Chapter 12. Using these theories will contribute to making the game enjoyable and engaging while motivating the players to exercise. Some aspects of the finished prototype used for testing showcased in Chapter 15 will deviate from the concept and will later be described in Part IV.

16.1 GameFlow

On Fire utilizes the different elements of GameFlow to make the game more enjoyable, and some elements are more relevant than others. *Challenge* is one of the most important elements of this game concept. The main challenge in a typical game session is navigating efficiently to the next fire location and extinguishing it before the time runs out. The game's difficulty is dynamically adjusted to the player's physical fitness and their in-game progress reflected by their experience level to challenge the players appropriate to their perceived skills. This is crucial to maintain the players' interest in the game and motivate them to exercise while playing. This is highlighted as the golden rule of Flow by Csikszentmihalyi and Csikzentmihaly (1990). The game will also provide the players with a tutorial teaching them how to play the game, and a skill development platform showcasing the different rewards for leveling up, for example, new game modes and more efficient equipment to handle the increased difficulty as the player levels up.

Further on, On Fire is a location-based game, which includes controlling the in-game character by moving in the real world. Therefore, the game must be responsive to the player's movement with a high enough accuracy. Hence, the player feels in *control* of their character's movement in the virtual world. This will be handled by using Google Maps Platform. The other controls in the games will be following industry standards, for example, controlling the camera as in Pokémon Go. Additionally, the game will have an intuitive and minimal interface throughout the game, removing distractions and focusing the player's attention on the relevant aspects.

The game will capture the player's initial attention by presenting them with the overall *goal*, combined with the context and background story to make it clear and meaningful. These elements will be integrated into the tutorial, providing a reason for taking on a firefighter's challenges. The overall goal will be to reach the highest character level by protecting the city from an increasing number of fires. The players will see their progress towards this goal represented as a ladder of levels as shown in Figure 15.14. The players will be continuously provided with *feedback* both in-game and after each game based on their performance. This feedback will encourage the players to push themselves further physically.

Different aspects of *social interaction* will be implemented in the game. The biggest one is the ability to add friends, allowing the players to follow each other's progress and compare themselves with each other. This will create a social community to motivate the players to exercise and play, driven by competition. Another competition-driven motivation aspect of the game is the inclusion of a global leaderboard, giving the players extra motivation to fight for the top positions.

The *immersion* and *concentration* dimensions of the GameFlow models are less relevant in the case of On Fire, as it is necessary for the players to be constantly aware of their surroundings when playing. The players must jump in and out of the game world to navigate safely in the real world. However, these dimensions will not be completely irrelevant. Connecting the fires to real-world locations and utilizing augmented reality to visualize them will make the game experience feel more realistic and familiar, enhancing the immersion. The game will also use music, sound effects, and visual effects to make the game more immersive and create an engaging atmosphere.

16.2 DualFlow

The *attractiveness* dimension of the DualFlow model is described and modeled using the GameFlow model described in Section 16.1. It similarly covers the psychological aspect of the game, emphasizing the importance of an appropriate balance between perceived challenge and player skills for the players to reach a psychological Flow.

As mentioned in the prestudy, *effectiveness* is seen as the physiological dimension of exergames. The effectiveness focuses on adjusting the intensity of the gameplay's exercise elements to fit the player's fitness level. On Fire will do this by dynamically adjusting the intensity of the game sessions by regulating the distance between each location and the time limit for navigating and completing the tasks. This will provide the players with a running session adapted to their physical fitness, preventing physiological failure and deterioration, making them reach physiological flow. The players will also be rewarded appropriately for their performance to their level of challenge to motivate all players to push themselves physically.

16.3 Challenge, Fantasy, and Curiosity

This part will describe the game concept of On Fire using the model presented by Thomas W. Malone, which includes the three categories challenge, fantasy, and curiosity. Firstly, Malone highlights the importance of introducing uncertainty around the game's outcome to provide a sufficient amount of challenge. Malone presents four ways to achieve this. The concept of On Fire uses this theory in the following way:

1. **Having different difficulty levels:** As mentioned in Section 16.1 the game adjusts the difficulty according to the player's physical condition. As On Fire is an exergame, it adjusts the difficulty by changing the distance to the next location or the countdown time.

2. **Multiple levels of goals:** The concept does this in multiple ways: On a higher level, the game rewards the players across game sessions by having a level system with rewards including new equipment and game modes. The multiple fires in each game represent a sub-goal, which applies to all game modes. In the game modes Fire Run and City Rescue, the overall goal is to complete the game by extinguishing all fires, while Marathon will present this goal as improving your personal record or outperforming friends.

3. **Hiding information:** On Fire does this in multiple ways, one of these being that the intensity of the fire is determined by the time used to travel to the location.

By doing this, the player will not know the fire's severity until they arrive at the location. As Fire Run and Marathon only show the next fire's location, it hides information about how many sub-goals remain, where they are located, and the time limit for completing the next task.

4. **Introducing randomness:** The concept introduces randomness to the game by randomly selecting the locations that the player must travel to. It could be a shorter distance with less time, requiring a sprint, or a greater distance with more time, leading to more low-intensity activity. The game could also introduce randomness by having a variety of possible tasks that can be given at the next location.

The next category presented by Malone is *fantasy* and the two different types of fantasy. On Fire mainly uses *extrinsic fantasies*, where the player's skill affects the game's fantasy and not the other way around. This will be described by looking at three aspects of the game: The first one being the rewards given to the players depend on the time used to complete the assignments given in the game, the faster the player manages to extinguish a fire, the higher the reward. The second aspect is that the intensity of the fires depends on the time used by the player to travel to the location, making the fantasy dependent on the navigational and physical skills of the player.

The third and final aspect is that some fires are more intense than others and must be prioritized in the City Rescue game mode. This requires the player to use logical and navigational skills to plan a route that will prioritize the more intense fires and minimize the distance traveled. Thus the fantasy is affected by the player's skill because buildings may burn down if they do not possess the required physical, logical or navigational skills.

The final category of Malone's model is *curiosity*, which is further divided into two categories: Sensory curiosity and cognitive curiosity. *Sensory curiosity* involves the sensory stimuli which are often provoked using audio and visual effects. On Fire provides sensory curiosity by making the game's situations and tasks more realistic using audio and visual effects. Placing graphical representations of the fires on the map will most likely trigger the player's curiosity as it enhances the connection between the game and real-world

locations. The proposition of using AR technology in the gameplay to make the fires appear on structures in the real world also provides sensory curiosity. Sound effects of fire and music can also contribute to this during gameplay.

The game also provides *cognitive curiosity*, which is the user's motivation to structure and complete their knowledge. On Fire does this by hiding information, especially by hiding the location and countdown timer for the next assignment in Fire Run and Marathon. To create additional cognitive curiosity in between games, the leveling system illustrates the rewards given at certain levels but does not describe them in detail. This is to trigger the user's curiosity and motivate them to play the game to unlock these rewards to see what they include. The fact that these rewards are represented using graphics can also be seen to create *cognitive curiosity*. This is because the user will most likely get more satisfaction from unlocking new equipment rather than just receiving a stat boost on their existing equipment.

16.4 Summary

This chapter describes how the different theories of enjoyment presented in Chapter 12 are utilized in the concept of On Fire to contribute to making the game enjoyable and engaging while motivating the players to exercise. This chapter shows that On Fire utilizes several theories, including GameFlow, DualFlow, and Malone's Challenge, Fantasy, and Curiosity. The most relevant elements from each theory are described in detail, for example, challenge, feedback, control, and social aspects from GameFlow. Effectiveness from DualFlow and randomness, information hiding, fantasy, and curiosity from Malone's Challenge, Fantasy, and Curiosity. The connections between the elements of the theories and the concept of On Fire are presented and discussed, including the less relevant elements, for example, concentration and immersion from the GameFlow model.

Part IV

Development

The development part describes the process of developing the On Fire prototype and includes a review of the chosen technologies used to realize the application. Furthermore, the concept is divided into a set of functional requirements used as guidance in the development process. This part will also include a brief description of the architecture and how the functional requirements, combined with the chosen technologies and quality attribute requirements, influenced the choice of the application's architecture. The part will conclude with an evaluation of the development process and how the chosen technologies, functional requirements, quality attribute requirements, and architecture resulted in the finished On Fire prototype.

17 Development methodology

This chapter provides a more detailed description of the *Design and Creation* strategy in Oates (2005) model of the research process. A graphic representation of the development process can be seen in Figure 17.1.

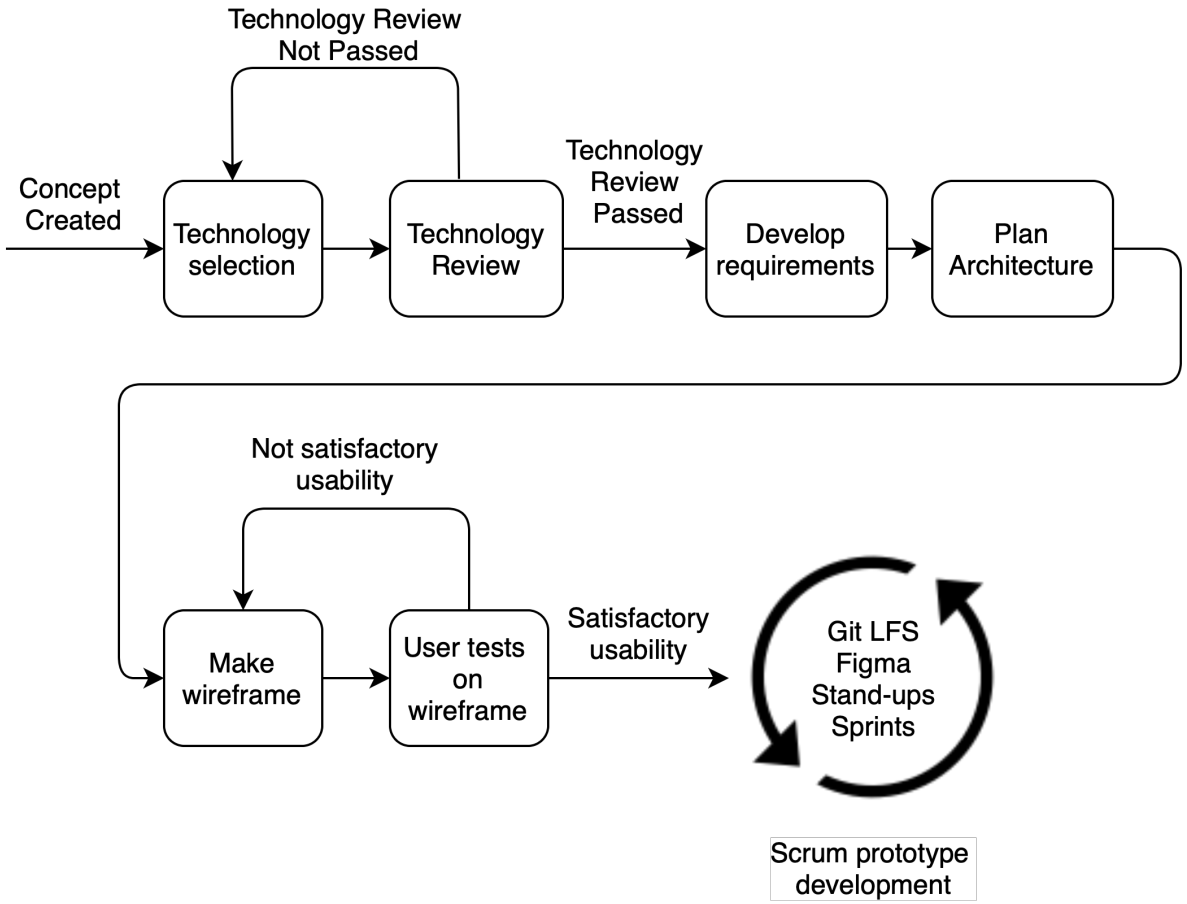

Figure 17.1: Development Methodology

After developing the On Fire concept, a selection of technologies was chosen to implement the prototype. Further on, a technology review was performed to verify that these technologies were suitable for the intended purpose. For a detailed description of the technology review, see Chapter 18. When all technologies were tested and verified, the group determined functional requirements and quality attributes for the prototype. Functional requirements present a prioritized set of requirements for the prototype's content, these are presented in Chapter 19. The quality attributes present critical properties of the prototype that is focused on during development. See Chapter 20 for more details.

After defining the functional requirements and quality attributes, the group developed the architecture of the application. The architecture describes where each part of the prototype should be implemented and how the different elements would interact.

After defining the architecture, the development of the prototype began. Before implementing the prototype presented in Chapter 15, the group developed a wireframe using the digital tool Figma. Figma provides a solution for making wireframes of the user interface with clickable elements. This wireframe was used to perform user tests. The feedback from these tests was used to change the user interface until it provided a satisfactory usability level. The user interface resulting from the wireframe testing was used as a template when implementing the prototype. Multiple digital tools and frameworks were utilized to make this process as efficient as possible. When writing the source code for both the server and client, Git was used for version control, allowing multiple developers to collaborate. Git Large File storage was also used to handle a large number of images, audio files, etc., during the client application development.

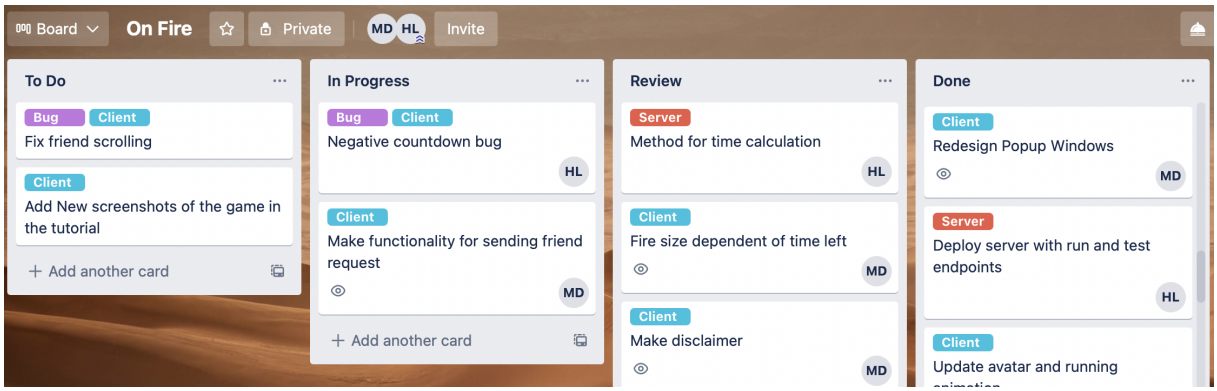

Figure 17.2: Trello Kanban board

To make the development process as efficient as possible, the students used elements from the Scrum framework. The most central of these elements was utilizing a digital Kanban board, by using Trello, to structure the development tasks (see Figure 17.2). This tool helped plan the development process and assign tasks to the different developers. The tasks were organized in multiple lists, including “To Do”, “In Progress”, “Review”, and “Done”. This helped the group communicate what needed to be done, what each

developer was currently working on, and if any work needed to be reviewed by another developer. The group also utilized Scrum elements like daily stand-ups and sprints.

18 Technology review

This chapter will present the proposed technology stack of the chosen game concept, which is the collection of technologies used to develop the prototype. Each technology will be tested and reviewed to ensure that it can be used as intended.

18.1 Mobile application

The On Fire concept is intended to be played on mobile devices, which influences the choice of technology to some extent. Based on experience and research, the group identifies two main ways of developing the client application, a web- or native application. When considering these two options, the group chose to develop a native application as it can be developed for Android and iOS and generally provides better support for location-based services, which is a central part of the application.

18.2 Unity

Unity is a cross-platform game engine tool for developing video games, including support for mobile platforms such as Android and iOS. It includes functionality for developing three-dimensional, two-dimensional, virtual reality, simulations, and augmented reality games. It has a mixture of drag and drop and C# programming interface making it a highly extensible and flexible platform (Unity, 2020), a picture of the Unity editor is shown in Figure 18.1. Unity is one of the most popular gaming engines, and more than 50% of all new mobile games are created in Unity, including Pokemon Go which shares a lot of similar functionality with the concept of On Fire (Wingfield, 2016).

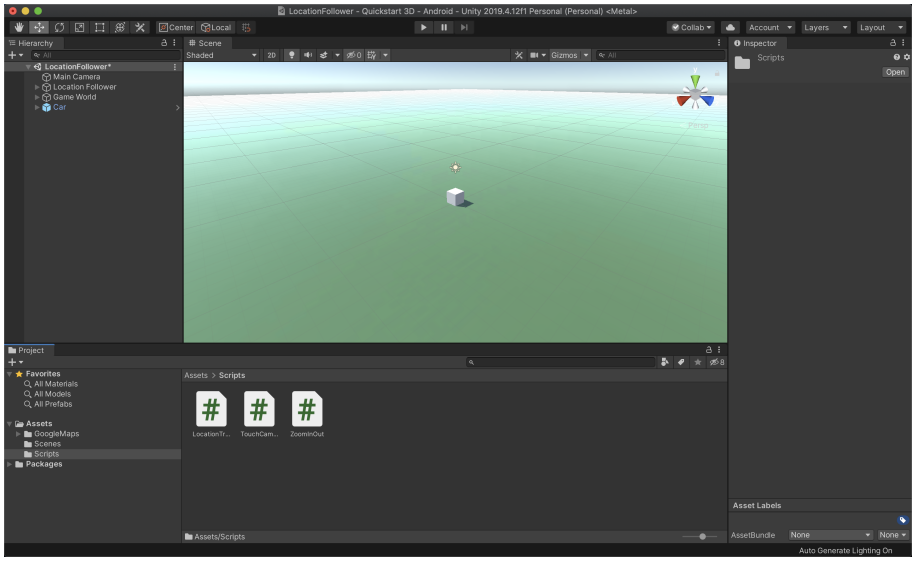

Figure 18.1: Unity Editor

None of the students had any experience with using Unity and therefore performed a quick test to get to know the platform and see if it is a good solution for developing the game. This test was relatively short and consisted of setting up Unity for development, as well as making a simple application and building it to both a runnable Android APK and iOS application.

The most challenging part of this test was understanding Unity's key concepts and how the game engine works. However, it was easy to find information about Unity and its concepts because of Unity's thorough documentation and large community, including online forums and tutorials. The building of the application was a straightforward process, using Unity's Internal Build System that allows building for both Android and iOS. Building for iOS involved building the project in Apples' Xcode and then installing it on a device running iOS. When building for Android, Unity used the Android SDK to produce an APK. This APK was then installed and tested on an emulator in Android Studio.

18.3 Google Maps Platform

The Google Maps Platform is a set of APIs, SDKs, and services bringing the real world to users with static and dynamic maps covering 99% of the world (Google, 2020a). This platform also provides Gaming Services for Unity that can be used to develop location-based mobile games. These games are constructed from Google Maps geospatial data and rendered at runtime by the Unity Game engine, thus further utilizing Unity's advantages. The platform is made up of two main components, Maps SDK for Unity and The Playable Locations API (Google, 2020b).

The Maps SDK for Unity allows the developer to create real-world mobile games by providing a set of tools, services, and assets extending Unity's development environment. The SDK provides access to geospatial data from the Google Maps database, which retrieves, handles, and generates the game world based on the player's physical location at run-time by utilizing Unity's customizable and extensible GameObjects (Google, 2020c). The Playable Locations API serves collections of geographical points contained within a geographical area that satisfies Google's player safety and appropriateness for gameplay criteria (Google, 2020d).

Google's gaming services were also tested to understand how it works and see if it is suitable to develop the Fire Run concept. The test consisted of developing a MVP of the essential player location functionality in the On Fire game. The Maps SDK was used to generate the game world according to the position of the player's phone and further move the player avatar according to changes in the location of the phone, illustrated as a cube in Figure 18.2. It was also implemented functionality for: The camera to follow the avatar in the game world. Pan around the avatar by swiping. Zooming in and out by pinching the phone's screen. The emulator in Android Studio was used to test the functionalities by simulating the phone's location and movement between two locations.

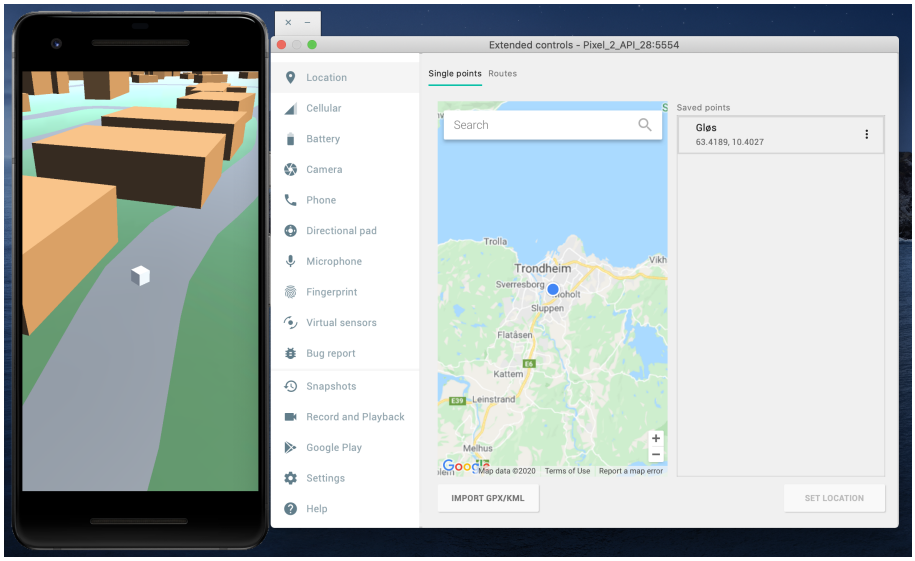

Figure 18.2: Player location MVP and location simulator

The player location functionality was implemented using a small set of GameObjects and two C# scripts, made possible by the built-in game mechanisms in Unity and extensions included in the Maps SDK. The Maps SDK also consists of a basic example, making it easy to start and get to know the platform. The Playable Locations API is a great tool for generating fires in random locations near the player's position in the game, while also ensuring that these locations are appropriate, safe, and reachable for the player in the real world. The combination of Unity's powerful game engine and Google Maps Platform Gaming Services, including their extensive geospatial data, makes it an excellent tool for developing location-based mobile games. Therefore, will it be used to develop the On Fire concept.

18.4 Firebase

Firebase is a platform developed by Google that provides a range of different cloud-based services. These services include Cloud Firestore and Realtime Database, both providing database solutions hosted online. Some of the other services provided by the Firebase platform include user authentication, hosting web applications, and running backend code. Google provides SDKs for running all of these services in Unity, which is a significant advantage for this project.

18.4.1 Cloud Firestore

One of Firebase's most valuable services for this project will be the database solutions because it provides a simple and scalable way of storing data. The requirements of the concept were considered when choosing which database to use. On Fire will mainly require storing information about the users, their results, and progress in the game. It will not require more advanced communication with the database, primarily because it will not require transferring significant amounts of complex data. Based on this and the fact that the students had previous experience with Cloud Firestore, it was chosen for this project. Firebase's user authentication service will also be used to manage users and user authentication.

Testing Cloud Firestore required setting up a new Firebase project and then adding Cloud Firestore to this project, using Firebase's web console. The goal of the test was to read and write data to the Cloud Firestore from an Android application built in Unity.

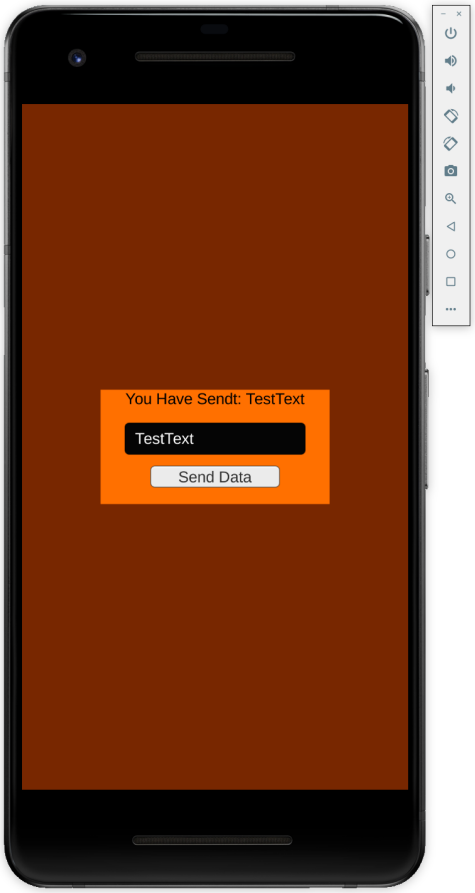

Figure 18.3: Firebase Test

The test involved significant configuration and troubleshooting in getting the Cloud Firestore SDK for Unity to function. As soon as this was resolved, the SDK was intuitive and easy to use with Unity. The main reason for this is the detailed documentation on how to use the SDK, which Google provides through their web page. The application developed to test the SDK was simple and contained an input field, button, and informational text (see Figure 18.3). Data was sent to the database by entering text in the input field and pushing the button. It was possible to quickly verify that the data had arrived by viewing the content of the Cloud Firestore from the Firebase console in a web browser. Reading data from the

database was tested by simply reading data using the SDK and printing the result to Unity's debug console. The tests revealed that both reading and writing data from the Cloud Firestore worked as intended in Unity. Therefore, Cloud Firestore will be used to develop the game concept.

18.4.2 Firebase Functions

Additionally, as the finished prototype will be a more complex application than the ones made in the technology tests, it may be advantageous to have the more resource-demanding code running on a server instead of on the client application. Firebase provides a service called Firebase Functions for hosting server-side code. It is beneficial to use this service as it has direct access to the Cloud Firestore and user authentication services. It can also be combined with Express.js, a Node.js web framework designed for developing APIs. This was tested by deploying simple code written in Express.js to Firebase Functions. The code provided a REST API that gave access to data retrieved from Cloud Firestore. Code running locally then used this API to get data from Cloud Firestore, resulting in a successful test. Based on the nature of Firebase Functions and the test performed, it was chosen to handle On Fire's resource-demanding logic and operations.

18.5 Summary

This project's proposed technology stack will mainly consist of the technology presented in this chapter, depending on the tests' results. The proposed solution for making the graphical user interface (GUI) and gameplay elements of the game concept is the Unity game engine. By performing simple tests of the set-up and building of Android applications using Unity, the group concluded that the Unity game engine is a suitable solution for developing the GUI and gameplay. Thus, the other technologies will have to be compatible with Unity, making this a part of the test for every other technology in the stack.

Since the game concept is heavily location-based, the group decided to use the Google Maps platform to handle most of the concept's location-aware aspects. An additional advantage of using the platform is that it provides the Google Gaming Service for Unity,

which offers many graphical solutions for map rendering in 3D space suitable for the On Fire game concept. The platform Gaming Service was tested by making a simple location-aware Android application using Unity. The test application was successful and therefore was the Google Maps Gaming Service added to the technology stack. To handle the synchronization and storage of the application data, the Cloud Firestore was proposed. This solution offers a cloud-based database that can be accessed using a SDK for Unity. The Cloud Firestore was tested by making a Unity application that reads and writes data to the database. This test was also successful, and the Cloud Firestore will therefore be part of the technology stack. Finally, Firebase Function was chosen to run server-side code, based on a successful test.

19 Functional requirements

The functional requirements describe the application's functionality. They are derived from the On Fire game concept presented in Chapter 14 and prioritized based on their importance. Each requirement listed in Table 19.1 is labeled with either high, medium, or low priority. The developers will use this list to prioritize what to implement first to make the game as enjoyable as possible. Requirements labeled with high priority are functionality that is important for the game to function as planned. Medium priority is functionality that will significantly improve the players' enjoyment but is not essential for playing the game. Requirements labeled with low priority are functionality that would be nice to have to increase the players' game experience even further.

ID	**Requirement**	**Priority**
FR1	The player should have access to an in-game menu.	High
FR2	The player should be able to edit the settings of the application.	Medium
FR3	The application should include music and sound effects.	Medium
FR4	The player should be able to view the rules of the game and a tutorial.	High
FR5	The player should be able to start a new game.	High
FR5.1	The game should start from the player's current location.	High
FR6	A game should display a map of the real world.	High
FR6.1	The map should display the player's current location on the map.	High
FR6.2	The map should display the location of in-game tasks (fires etc.)	High
FR7	A game should include several assignments.	High
FR7.1	An assignment should include a task given at a specific location, including both the relocation and the completion of the task.	High
FR7.2	The game should provide a countdown displaying the time left to complete the current assignment.	High
FR7.3	A task should be unlocked when the device is within reach of the task's location.	High
FR7.4	Tasks will require the player to complete a mini-game, e.g., extinguish fires.	High

FR7.5	The game should provide a new assignment after the player has completed an assignment, if available.	High
FR7.6	The game should end when all assignments are completed, or the countdown timer runs out.	High
FR8	The game should include different types of tasks.	Low
FR9	The game should reward the player after finishing assignments and games.	High
FR9.1	The rewards should be determined by the time spent on assignments and if all assignments were completed.	Medium
FR10	The game should include the Fire Run game mode.	High
FR10.1	The difficulty of assignments in Fire Run should be based on the player's physical health.	Medium
FR10.2	Each new assignment should be more challenging to complete than the previous one.	Medium
FR10.3	The number of assignments should be finite.	High
FR11	The game should include the Marathon game mode.	Medium
FR12	The game should include the City Rescue game mode.	Low
FR13	The player should be able to rank up.	High
FR13.1	The player should rank up based on awards gained from playing the game.	High
FR13.2	When ranking up, the player should get access to new game features, such as game modes, cosmetics, and equipment.	Medium
FR13.3	The game should provide the player with information about their performance and progression.	Medium
FR14	The game should allow the player to add and remove friends.	High
FR14.1	The game should allow the player to see their friend's stats and character.	High

Table 19.1: Functional Requirements

20 Quality attribute requirements

Quality attribute requirements describe non-functional properties of the application that ensure its quality for different stakeholders. When developing the On Fire application, the group focused on usability, modifiability, and performance as the main quality attribute requirements. Tactics and architectural patterns were used to ensure that the application meets these quality attribute requirements. A more detailed description of these can be found in Chapter 21. Several scenarios have been defined for each quality attribute requirement to test the chosen tactics and patterns' success.

Usability

The main stakeholders for usability are the users of the application, focusing on making the application as user-friendly as possible. This is done using well-known elements in the user interface such as progress bars to display level progress and familiar icons, such as a gear icon for accessing the settings page. The user interface also minimizes the number of clicks necessary to navigate the application. Additionally, a tutorial has been included to inform the users about how the application works. The tutorial will be displayed when the user first opens the application, it can also be replayed at a later stage. Different elements in the application also have information buttons that the user can use to get more information about these elements. The scenario for this quality attribute can be seen in Table 20.1.

ID	U1
Source	User
Stimulus	Wishes to play the Fire Run game mode for the first time.
Artifact	Application
Environment	Run time
Response	The user is introduced to the game and how to play it.
Response Measure	Five minutes

Table 20.1: Scenario U1

Modifiability

The primary stakeholder of the modifiability quality attribute requirement is the developers of the application. An application with good modifiability enables the developers to change or add parts of the application as efficiently as possible. The Model View Controller pattern was used to increase the application's modifiability by separating the system parts. The application also used the Template pattern. The scenarios for this quality attribute can be seen in Table 20.2 and Table 20.3.

ID	M1
Source	Developer
Stimulus	Wishes to add a new type of equipment used for fire extinguishment to the game.
Artifact	Client-side source code
Environment	Design time
Response	The new equipment is implemented and tested in an in-game task.
Response Measure	Five hours

Table 20.2: Scenario M1

ID	M2
Source	Developer
Stimulus	Wishes to modify how the locations in a Fire Run is determined.
Artifact	Server-side source code.
Environment	Run time
Response	Desired changes successfully implemented and deployed to the server.
Response Measure	Less than two minutes of server down-time.

Table 20.3: Scenario M2

Performance

The performance quality attribute requirement look at how the application system performes, this can be measured in server downtime, response time, etc. The architecture of the application and the technologies used is critical to ensure good performance. The group have therefore used the Model View Controller and Server-Client patterns. An example of how this effects the performance can be seen in the distribution of tasks between server and client. Code demanding a lot of processing power is run server side to relieve the device running the client application, thus speeding up the overall processing time. The scenarios for this quality attribute can be seen in Table 20.4 and Table 20.5.

ID	P1
Source	Client
Stimulus	Start new Fire Run server request.
Artifact	Client and server
Environment	Run time
Response	The server handles the request, gives the correct response and the game is started in the client.
Response Measure	Less than five seconds.

Table 20.4: Scenario P1

ID	P2
Source	Client
Stimulus	Save game data after finished Fire Run.
Artifact	Client and Firebase database.
Environment	Run time
Response	The database saves the data and gives the correct response.
Response Measure	Less than two seconds.

Table 20.5: Scenario P2

21 Architecture

This chapter will describe the implemented architecture of the On Fire prototype. The architectural patterns are chosen to meet the functional requirements and quality attributes described in Chapter 19.

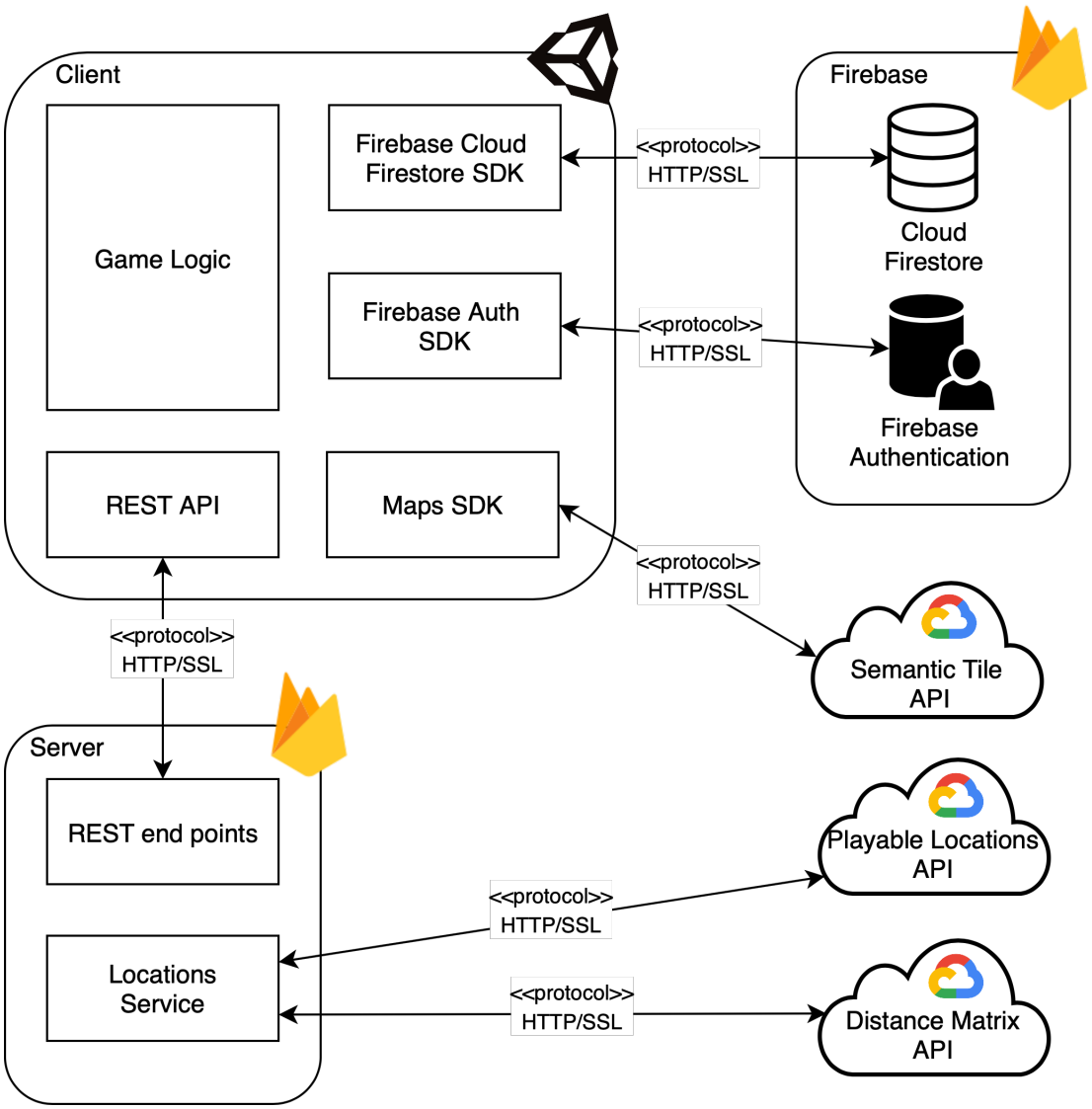

Figure 21.1: On Fire prototype architecture

21.1 Client-Server

The Client-server architecture (see Figure 21.1) is implemented to relieve the client from the most resource-demanding tasks, as the task of creating a new game of Fire Run. The creation of games is handled in the Location Service, showcased in Figure 21.1. It consists

of fetching locations from Google's Playable Locations API and further estimate distance and time between these locations using Google's Distance Matrix API. The client-side of the application consists of the application built in Unity. This is where most of the game logic is handled and where the players interact with the game. The server serves as a representational state transfer (REST) API using Express.js web framework for building REST APIs. The REST API is deployed and hosted on Firebase Cloud Functions, which provides direct access to the Cloud Firestore database and enables the client to communicate to the server through HTTP.

21.2 Database-as-a-service (DBaaS)

DBaaS is implemented using Firebase Cloud Firestore, a NoSQL cloud database without the need for a server to deploy and maintain (serverless) (Google, 2020). Cloud Firestore organizes data in collections of documents and is used to store all data about the players, their games, and statistics. The client communicates directly to this service through the Firestore Unity SDK, illustrated in Figure 21.1.

21.3 Model View Controller

Model View Controller is an architectural pattern splitting the application into three components: Model, View, and Controller. This pattern introduces an abstraction level, increasing cohesion and lowering the coupling, which further increases the client's modularity. The MVC architecture is implemented within the client-side of the application. The implementation was straight forward as many of MVC's properties are already present when using Unity's game engine. Where Unity already separates and structures how views are implemented.

The Model part is implemented as simple classes representing the data of a particular object or concept, such as the player, game, fire, equipment, etc. The View part of MVC is the most Unity-specific, where the views derive from Unity's base class MonoBehavior, which offers life cycle functions and other hooks for input and output functions to display

and update the graphics to the player. The Controllers are responsible for the game logic and bind the model and view together. It listens to the model's events and tells the view to update accordingly and vice versa.

21.4 Other design patterns

The architecture includes several additional design patterns. One of the creational patterns implemented is the *singleton pattern*, which lets the entire client application access the singleton class instantiation. This is used to handle game and player logic. Another creational pattern used is the *template methods pattern*, which uses a combination of abstract and non-abstract methods in a superclass to enable easy implementation of functionality in a subclass. Both creational patterns contribute to increasing the modularity of the system. The client also utilizes Unity's *sequential game loop pattern* for updating and rendering the views.

21.5 Summary

The architecture used to implement the On Fire prototype is primarily based on the Client-Server, Database-as-a-service (DBaaS), and Model View Controller (MVC) patterns. Client-Server is used to run the most resource-demanding code server-side to relieve the client, DBaaS is used to store data between game sessions, and MVC is used to structure code in the client. Other design patterns such as singleton, template methods, and sequential game loop are also used.

22 Evaluation

This chapter includes evaluation of the functional requirements, quality attribute requirements, technologies and architecture.

22.1 Functional requirements

Table 22.1 provides an overview of which functional requirements were implemented in the prototype. The requirements that are marked as not implemented or partially implemented are commented below the table.

ID	Requirement	Priority	Implemented
FR1	The player should have access to an in-game menu.	High	Yes
FR2	The player should be able to edit the settings of the application.	Medium	Yes
FR3	The application should include music and sound effects.	Medium	Partly
FR4	The player should be able to view the rules of the game and a tutorial.	High	Yes
FR5	The player should be able to start a new game.	High	Yes
FR5.1	The game should start from the player's current location.	High	Yes
FR6	A game should display a map of the real world.	High	Yes
FR6.1	The map should display the player's current location on the map.	High	Yes
FR6.2	The map should display the location of in-game tasks (fires etc.)	High	Yes
FR7	A game should include several assignments.	High	Yes
FR7.1	An assignment should include a task given at a specific location, including both the relocation and the completion of the task.	High	Yes
FR7.2	The game should provide a countdown displaying the time left to complete the current assignment.	High	Yes

FR7.3	A task should be unlocked when the device is within reach of the task's location.	High	Yes
FR7.4	Tasks will require the player to complete a mini-game, e.g., extinguish fires.	High	Yes
FR7.5	The game should provide a new assignment after the player has completed an assignment, if available.	High	Yes
FR7.6	The game should end when all assignments are completed, or the countdown timer runs out.	High	Yes
FR8	The game should include different types of tasks.	Low	No
FR9	The game should reward the player after finishing assignments and games.	High	Yes
FR9.1	The rewards should be determined by the time spent on assignments and if all assignments were completed.	Medium	Yes
FR10	The game should include the Fire Run game mode.	High	Yes
FR10.1	The difficulty of assignments in Fire Run should be based on the player's physical health.	Medium	No
FR10.2	Each new assignment should be more challenging to complete than the previous one.	Medium	Yes
FR10.3	The number of assignments should be finite.	High	Yes
FR11	The game should include the Marathon game mode.	Medium	No
FR12	The game should include the City Rescue game mode.	Low	No
FR13	The player should be able to rank up.	High	Yes
FR13.1	The player should rank up based on awards gained from playing the game.	High	Yes
FR13.2	When ranking up, the player should get access to new game features, such as game modes, cosmetics, and equipment.	Medium	Yes

FR13.3	The game should provide the player with information about their performance and progression.	Medium	Yes
FR14	The game should allow the player to add and remove friends.	High	Yes
FR14.1	The game should allow the player to see their friend's stats and character.	High	Yes

Table 22.1: Functional Requirements Evaluation

When developing the prototype, all functional requirements with high priority were implemented, and the majority of the ones with medium priority. The decision on which of the functional requirements with medium priority that was going to be implemented was based on what would provide the best user experience in the prototype. Therefore, the group chose not to implement any other game modes than the Fire Run. Thus FR11 and FR12 were not implemented. This was done to ensure that Fire Run would be as robust and complete as possible. The same argument also explains why there were not implemented any other tasks than fire extinguishment, as FR8 suggests.

Further on, the difficulty of assignments in the prototype is not based on the players' physical health (FR10.1). This was not prioritized because it would require the user to perform several test runs before the correct difficulty had been set. As the prototype was going to be tested over two weeks, this would take too much time. Additionally, the group wanted to present the players with an option to regulate the physical strain of their exercise. The chosen solution allows users to select each game's difficulty, ranging from walks (easy) to intense intervals (hard).

22.2 Quality attribute requirements

This section presents tests performed on the quality attribute requirements presented in Chapter 20.

U1: The user wishes to play the Fire Run game mode for the first time.	
Date	13.04.21
Environment	Run time
Stimuli	Wishes to play the Fire Run game mode for the first time.
Expected response measure	Five minutes
Observed response measure	Four minutes
Evaluation	Success
Comment	The user logged in and was forced to go through the game tutorial. This took about two minutes, and the user could easily understand the game's essence and navigate through the application.

Table 22.2: U1 Quality attribute requirement test

M1: Add a new type of equipment used for fire extinguishment to the game.	
Date	05.03.21
Environment	Design time
Stimuli	Wishes to add a new type of fire extinguishment equipment to the game.
Expected response measure	Five hours
Observed response measure	Two hours
Evaluation	Success
Comment	A new equipment type was added by implementing the equipment template and adding to the menu selection.

Table 22.3: M1 Quality attribute requirement test

M2: Modify how the locations in a Fire Run are determined.	
Date	13.04.21
Environment	Run time
Stimuli	Desired changes successfully implemented and deployed to the server.
Expected response measure	Less than two minutes of server downtime.
Observed response measure	No server downtime.
Evaluation	Success
Comment	Firestore Functions features an execution guarantee, where the old instance will continue to run until the newly deployed one is executable.

Table 22.4: M2 Quality attribute requirement test

P1: Start new Fire Run server request.	
Date	13.04.21
Environment	Run time
Stimuli	The server receives the request and gives the correct response.
Expected response measure	Less than five seconds
Observed response measure	3.8 seconds on average
Evaluation	Success
Comment	The server handles the resource-demanding task of generating the locations and estimating the time and distance between them.

Table 22.5: P1 Quality attribute requirement test

P2: Save game data after finished Fire Run.	
Date	13.04.21
Environment	Run time
Stimuli	The database saves the data and gives the correct response.
Expected response measure	Less than two seconds
Observed response measure	0.4 seconds on average
Evaluation	Success
Comment	The client communicates directly with the Cloud Firestore service through the Firestore Unity SDK, lowering response time.

Table 22.6: P2 Quality attribute requirement test

All quality attribute tests were successful, which indicates that the patterns used in the architecture are successful.

22.3 Technology and architecture

The choice of technologies, together with functional requirements and quality attribute requirements, heavily influenced the architecture. Going into this project, both group members had experience with programming and software engineering, including mobile device development. However, none of the group members had any previous experience in developing mobile applications using Unity's game engine. Because of this, the group spent a significant amount of time learning how Unity worked to be able to take advantage of its capabilities. The development of the game in Unity went better than expected, and no major issues occurred during the development, except for some minor bugs. The choice of developing On Fire using Unity also influenced the selection of other technologies and architecture. One of these technologies is the Google Platform's Gaming Solution, used to implement the location-based functionality. The Maps SDK and APIs were initially cumbersome to configure as it was still in a beta phase. Still, after decoding the provided

examples and documentation, it turned out to be a good tool for styling and dynamically loading the map in 3D space.

The client was implemented using the Model View Controller (MVC) architectural pattern as a modifiability tactic, separating the different MVC concerns to increase the cohesion and lower the system's coupling. This made it a lot easier to debug the client and maintain the code structure as the complexity grew. The implementation of MVC was an easy process as Unity already separates the views and provides hooks for controlling them. The system's modularity was also successfully tested (see M1 Table 22.4 in Section 22.2) by implementing a new equipment for extinguishing fires in the game. This test was successfully completed in about two hours, compared to the expected five hours.

Both members of the group had previous experience using the Firebase platform, and it was quickly chosen after the successful test of compatibility with Unity through their Unity SDKs. Cloud Firestore was chosen as the database in a Database-as-a-Service (DbaaS) architecture. This was to allow the client to communicate directly with the database after establishing an initial connection. Firebase Functions was also chosen as the server's host to relieve the client from the most resource-demanding tasks in a Client-Server architecture. The server was implemented as a REST API using the Express.js web framework. The server's main purpose is to provide the data needed to start a new game in the client. This involves fetching locations from Google's Playable Locations API and estimate the time and distance between using Google's Distance Matrix API based on the specific player's position and preference on difficulty and duration. Using a Client-Server architecture to run the more resource-demanding code to set up a Fire Run game in the server turned out to be a good choice, as this most likely significantly shortened the processing time needed to start a game of Fire Run. The performance was also validated in the performance tests P1 and P3 in Section 22.2.

22.4 Summary

This chapter has provided a detailed evaluation of the functional requirements, quality attribute requirements, architecture, and technology used to develop the On Fire prototype. The evaluation of the functional requirements reflects that the essential parts of the application have been successfully implemented. The majority of the additional functionalities described has also been implemented, except for some low and medium priority requirements. The entirety of the tests performed on the quality attribute requirements was successful; this indicates that the technology, architectural patterns, and -strategies were a good fit for this application. Hence, the development of this prototype is deemed successful as the resulting prototype fulfills most of the functional requirements while using technology and architecture that satisfies the quality attribute requirements.

Part V

Experiment and Data Generation

This part describes the experiment performed on the On Fire prototype. This includes the test procedure and the data generation methods used to collect data from the experiment.

23 Experiment design

This chapter presents the experiment performed using the On Fire prototype by looking at its purpose, design, test population, ethics, reliability, and validity. The purpose of conducting the experiment is to answer the following research questions:

RQ4: *How do the theories of enjoyment contribute to the players' motivation, engagement, and enjoyment of the exergame?*
The Experiment will gather data about the players' enjoyment, motivation, and engagement when playing On Fire to investigate how and if the measures taken from the theories of enjoyment have contributed to making it an enjoyable game.

RQ5: *Does the exergame have a positive effect on the players' motivation for- and level of physical activity?*
The experiment will also investigate the actual and perceived physical effect of On Fire, and how the game motivates the users to exercise.

23.1 Experiment design details

This section describes the experiment performed concerning the *Experiment strategy* described by Oates (2005). The experiment included collecting different types of data from multiple sources, ensuring triangulation of data. The first data collection was performed through the pre-test questionnaire, which collected data about the test users' demographics, gaming experience, and physical activity. This questionnaire was distributed using Microsoft Forms (see Appendix A).

After all of the users had answered the pre-test questionnaire, the On Fire application was distributed using Apple's TestFlight. TestFlight is a system used for beta testing iOS applications by allowing the developers to give specific users access to their application without publishing it on the App Store (Apple, 2021). When invited, the test users could download the application using the TestFlight iOS application. The TestFlight application functions similarly to the App Store, but users can only download applications they

are invited to test. Using TestFlight allowed the developers to efficiently distribute the On Fire iOS application and publish updates when bugs occurred.

When the application was distributed to all test users, they had access to the application throughout the test period, which lasted 19 days. The users used the application on their own initiative, with the only requirement being that they played at least one game to be able to give feedback after the test period. During the test period, a selection of test users was observed while playing a Fire Run. During the observation, the users wore a Polar Ignite heart rate monitor to record their workout's physical strain. After the session, the test users were interviewed about their gameplay experience.

After the test period ended, the test users answered the post-test questionnaire also distributed using Microsoft Forms (see Appendix B). This questionnaire contained some similar questions to the pre-test questionnaire to see if there are any changes in the users' physical activity levels. The questionnaire also collected data about the users' perceived game enjoyment, motivation, engagement, and physical activity. In addition to the data collected through questionnaires, observations, and interviews, usage data from the database were also analyzed to boost data triangulation further.

23.2 Experiment population

The experiment population had a total of 20 participants, where all of them took part in playing On Fire on their own initiative. Four of them also participated in being observed while playing a Fire Run session, including being interviewed afterwards. The different experiment participants were selected for ensuring different ages and genders with different physical fitness and motivation to be represented.

The experiment participants were recruited from the group members' network, including family, friends, and classmates. They were initially contacted and recruited over social media and email. All further communication with the participants, such as the distribution of the application and questionnaires, was done using email.

23.3 Ethics and privacy

It was necessary to get formal consent from the experiment participants as the experiment involved user testing and gathering different kinds of data about them, their usage, and opinions about the game. Therefore, an agreement contract describing the experiment had been prepared, which the users also had to sign (see Appendix C). The contract describes the purpose of the experiment, the data gathered from them and how it will be used in the research, as well as their rights to withdraw their consent, insight into their data, and to send a complaint to the Norwegian Data Protection Authority about the processing of their personal data. Two agreement contracts were formed, one for the participants only taking part in the experiment and the other for those participating in the experiment, observation, and interview.

The personal information gathered was stored separately from other data and linked to the participants using a random ID to ensure their anonymity and security. The IDs were stored on an encrypted server only accessible for the researchers and used by the participants to log into the application and answer the questionnaires.

Furthermore, when conducting research in Norway, it might be necessary to apply for permission from a government committee or agency. Norwegian Centre for Research Data (NSD) is such an agency. Therefore, the project was reported to NSD, applying for their permission to start the experiment and gather data from the experiment participants. The application was approved and assessed to be in accordance with the privacy legislation (see Appendix D).

This research project aims to research the physical effects of On Fire and can be considered as health research. Therefore, an application was sent to the Regional Committees for Medical And Health Research (REK) to assess whether this project needs their approval or not. REK's response to the application implied that this project could be carried out without further ethical assessment of REK (See Appendix E).

23.4 Reliability and validity

Familiarity bias

Familiarity bias refers to the phenomenon where people opt for the more familiar options, even though it often results in a less favorable outcome. The results of the experiment might have been influenced by familiarity bias as the participants were recruited from the group member's network and were either friends, family or classmates. Thus, they might have felt inclined to give more positive feedback than they genuinely felt, which would influence the experiment's results. A measure taken to prevent this familiarity bias was to tell the participants to be as honest as possible when providing feedback, being interviewed, and answering the questionnaires.

The Hawthorne effect

The Hawthorne effect is referred to by researchers as to when results may depend or be influenced by the fact that the subjects in a study have been aware of them receiving attention in an experiment (Merrett, 2006). Therefore, it is taken into account for unexpected outcomes as the observation participants were aware of them being part of an experiment and observed. The participants were asked how it felt to be observed and if they thought it affected their performance in any way. By doing this, it is possible to be somewhat aware of the extent of the Hawthorne effect.

23.5 Summary

The experiment performed on the On Fire prototype is done to answer research questions RQ4 and RQ5. The experiment was performed by distributing the prototype to 20 test users using Apple's TestFlight for a test period lasting 19 days. The test users were recruited from the developers' personal network, focusing on creating a diverse test population. A downside to recruiting from the developers personal network is that familiarity bias may occur. Before downloading the prototype, each test user answered a questionnaire. During the 19 days, the test users used the prototype on their initiative. A selection of users was observed during- and interviewed after a game session. After the test period, each test user answered another questionnaire. Several measures were taken to ensure the test participants privacy, including applying to NSD and encrypting personal information.

24 Data generation

This section will describe the *data generation methods* from Oates' model used to collect data from the experiment performed on the On Fire prototype. This includes interviews, observations, and questionnaires.

The *interviews* performed will be semi-structured, involving a set of predetermined questions while also allowing the interview object to focus on what they think is important by making the interview seem more like a conversation Longhurst (2003). The *observations* will be overt, meaning that the research participants know that the researcher(s) are watching them Oates (2005). The observations used in this project will be done with a complete observer, which is described as the researcher being "present in the setting either overtly or covertly, observing everything that occurs, but takes no other part in the proceedings" (Oates, 2005, p.209).

The *questionnaires* used in the experiment contain various questions and statements, with different types of response formats. The response format in all statements is structured as a *Likert's scale* from "totally disagree" to "totally agree". The multiple-choice format gave the participants the option to choose one or more given responses or develop their own responses. The participants gave a text answer and were encouraged to structure them as whole sentences when given questions with a text response format. The number format works similarly but restricted users to only using numbers in their response. The binary question format forced participants to choose one of two options and were often structured as yes/no questions.

Some of the questions also have branches of sub-questions, meaning that the questionnaire will change according to the responses to specific questions. Thus, some questions only appear if they are relevant to the participant.

24.1 Pre-test questionnaire

The pre-test questionnaire includes sections about demographics, gaming experience, and physical activity. Its primary purpose is to understand the participants' relationship with gaming and physical activity going into the experiment. The data from this questionnaire will be compared with data collected in the post-questionnaire and used to see interesting correlations of the different results.

Demographics

This section collects data about the demographic of the participants, including their age, gender, and user ID.

Gaming experience

The gaming experience section is used to map the participants' relationship with gaming. The questions in this section are described in Table 24.1

ID	Question	Format
Q1	About how many hours a week do you play video games?	Number
Q2	What kind of video games do you play?	Multiple Choice
Q3	Which platforms do you play video games on?	Multiple Choice
Q4	Do you have any previous experience with video games involving physical activity?	Binary
Q4.1	Name the game(s)	Text

Table 24.1: Gaming experience questions

Physical Activity

The participants were presented with nine questions, with sub-questions (see Table 24.2) and two statements (see Table 24.3) to map their relationship and motivation for physical activity.

ID	Question	Format
Q1	About how many hours a week do you exercise?	Number

Q2	About how many hours a week would you like to exercise?	Number
Q3	Do you perform running exercises?	Binary
Q3.1	About how many times per week do you run?	Number
Q3.2	What kind of running exercise do you perform?	Multiple Choice
Q4	What other exercise do you perform?	Multiple Choice
Q5	Do you go for walks/hikes in your spare time?	Binary
Q5.1	About how many times per month do you go for walks in the city/rural area?	Number
Q5.2	About how many times per month do you go for hikes in nature?	Number
Q6	Are you a member of a gym/exercise facility?	Binary
Q6.1	About how many times a week do you exercise in this facility?	Number
Q7	Do you regularly perform a specific sport?	Binary
Q7.1	Are you part of a team/organization?	Binary
Q7.2	About how many times a week do you perform this sport?	Number
Q7.3	Name the sport	Text
Q8	Do you exercise alone or with others?	Multiple Choice
Q9	Do you use any of the following digital equipment in your exercise?	Multiple Choice

Table 24.2: Physical activity questions, pre-test

Statement S1 and S2 are general statements about the participants' physical motivation and will be compared with similar statements in the post-test questionnaire. The participants were asked to respond to what extent they agreed to them, from strongly disagree to strongly agree.

ID	**Statement**
S1	I often find it hard to motivate myself to exercise
S2	My workouts are as intensive/effective as I would like

Table 24.3: Physical activity statements, pre-test

24.2 Observations and interviews

Each observation and interview will be performed on a single test subject at a time. When starting observations, the only instruction that the test subject will be given is to start the recording on their provided heart rate monitor and to complete a Fire Run game. Meaning that the test subjects are free to choose the difficulty and duration of the game as they wish. One researcher will then follow the subject around using an electric scooter. The researcher will not interact with the test subject until the Fire Run is finished, telling the subject to stop the recording on their heart rate monitor.

After completing the Fire Run game, the researcher who conducted the observation will be joined by the other researcher to help transcribe the interviews. The semi-structured interview is designed to ascertain subjective responses from the participants regarding their experience in the observation. A set of 10 questions is predetermined, focusing on the test object's experience based on enjoyment, motivation, and physical effect. The questions are formulated in a conversational and informal tone. They are structured to get the participants to respond with their own words. The participants are free to respond to these open-ended questions as they wish, and the interviewer might elaborate on these questions. The data collected are considered qualitative data and are comparable as all participants are asked the same questions in the same order.

The interview is estimated to take about 20 minutes to complete and is performed after a quick break after the observation in order for the participant to lower their heart rate. The interview will begin with instructions and clarification about the purpose of the interview and the research. The test subject will also be reminded about their anonymity and to be completely honest as a measure taken to prevent familiarity bias. Both group members will participate in the interviews, one performing the interview while the other observes and takes notes.

24.3 Post-test questionnaires

The post-test questionnaire will be distributed at the end of the test period and includes the sections enjoyment, motivation, and physical effect, all tied up to research questions RQ4 and RQ5. The questionnaire also includes technical questions and open text questions to uncover additional thoughts and opinions. The data generated from this questionnaire will be the primary source of quantitative data, in addition to the interviews and observations.

Demographics

This part only collects the User ID of the test user. This is to be able to link their answers to the pre-test questionnaire.

Physical Activity

This section focuses on mapping the user's physical activity during the test period and On Fire's effect on their physical activity. This is done by providing the test user with eleven questions (see Table 24.4) and seven statements (see Table 24.5 and Table 24.6). Q1 and Q2 are similar to the questions in the pre-test questionnaire. This is to compare the physical activity and motivation for physical activity before and after the test period.

ID	Question	Format
Q1	About how many hours per week did you exercise during the test period?	Number
Q2	About how many hours per week would you like to exercise?	Number
Q3	What combination(s) of duration and difficulty did you enjoy the most?	Multiple Choice
Q4	What combination(s) of duration and difficulty gave you the best workout?	Multiple Choice
Q5	How did your difficulty preference develop during the test period?	Multiple Choice

Q6	How did your duration preference develop during the test period?	Multiple Choice
Q7	How did On Fire affect your physical activity?	Text
Q8	What do you think of the running exercise produced by On Fire?	Text

Table 24.4: Physical activity questions, post test

S1 and S2 in Table 24.5 are the same as the statements in the pre-test questionnaire, this is to compare the answers.

ID	**Statement (... during the test period)**
S1	I found it hard to motivate myself to exercise
S2	My workouts were as intense/effective as I would like
S3	I rather played Fire Run than other ways of working out.

Table 24.5: Physical activity statements 1, post-test

ID	**Statement**
S4	The game motivated me to exercise
S5	I got a good running exercise from playing the game
S6	I forgot that I was working out while playing the game
S7	I would use this game instead of traditional running exercises in the future

Table 24.6: Physical activity statements 2, post-test

Game enjoyment

Game enjoyment tries to figure out what made the game enjoyable for the player. The statements in Table 24.7 are aimed at producing data that can evaluate the usage of the theories of enjoyment in the prototype.

ID	Statement
S1	I found the gameplay enjoyable
S2	I enjoyed navigating to the next fire using the map
S3	I enjoyed playing the fire extinguishment mini-game
S4	The fire extinguishment mini-game challenged me
S5	My skills at extinguishing fires improved during the test period
S6	The fire icons in the top left corner helped visualize my progress in extinguishing the fires
S7	The smoke effect helped visualize my progress in extinguishing the fires
S8	It was challenging to navigate to the fire's location using the map
S9	I felt in control of the movement of my character
S10	The music and sound effects made the game more enjoyable
S11	The graphics on the map (character, fire animation, and map) improved my gameplay experience.
S12	The fact that I could not see where all the fires were located increased my motivation to keep playing
S13	The goal of playing a Fire Run was clearly defined
S14	I felt in control of the water jet when extinguishing fires
S15	The fact that I could see my friends progress made the game more enjoyable
S16	I understood how to play the game after completing the tutorial.

Table 24.7: Game enjoyment statements

The questions in this section (see Table 24.8) try to find out how the player interacted with the app, any problems encountered, and some open questions to collect qualitative data about their experience.

ID	Question	Format
Q1	Did you replay the tutorial at a later stage?	Binary
Q2	Were there parts of the game/application that you did not understand?	Binary
Q2.1	Name what you did not understand:	Text
Q2.2	Did you find help with this problem on the About page or in the Tutorial?	Binary
Q3	Did you add friends in the application?	Binary
Q3.1	Did you add friends found by looking at the leaderboard?	Binary
Q4	Which part(s) of the application did you enjoy the most?	Text
Q8	Which part(s) of the application did you enjoy the least?	Text

Table 24.8: Game enjoyment questions

Game motivation and engagement

The section aims to collect data about how the different elements of the application affected the players' motivation to play the game. This was done using statements (see Table 24.9 and Table 24.10).

ID	Statement (... motivated me to keep playing the game)
S1	The level system
S2	The ability to unlock new equipment
S3	Using newly obtained equipment
S4	The ability to unlock new map themes
S5	Using newly obtained map themes
S6	The ability to view my stats on my profile page
S7	The ability to compare my stats with the stats of friends
S8	The ability to climb the "total score" leaderboard and compete against other players
S9	The ability to climb the "distance" leaderboard and compete against other players

S10	Feedback on XP and stats after playing a game of Fire Run
S11	Trying new combinations of difficulty and duration
S12	Finding out where the next location is going to be located

Table 24.9: Motivation and engagement statements 1

ID	**Statement**
S13	The countdown motivated me to push myself
S14	The change in countdown color and music when time is running out increased my motivation
S15	The feedback on XP gained after extinguishing a fire motivated me to keep playing
S16	Viewing my stats motivated me to exercise outside of playing the game
S17	Time seemed to go faster than usual when playing the game
S18	My goals were clearly defined when playing a Fire Run
S19	The fact that a Fire Run was divided into multiple locations made it easier to find the motivation to complete a game

Table 24.10: Motivation and engagement statements 2

This part also contained a single question: "What element(s) of the application motivated you the most to play the game/exercise?"

Additional questions

This section focuses on collecting data on any technical issues, cheating, and external factors that may have affected the test users' performance during the test period. The questions used for this are listed in Table 24.11.

ID	**Question**	**Format**
Q1	Did you experience any technical problems?	Binary
Q1.1	Describe the problem(s)	Text

Q2	Did any external factors prevent you from playing the game as much as you would like to?	Multiple Choice
Q3	Did you cheat at Fire Run?	Binary
Q3.1	How did you cheat?	Text
Q3.2	Why did you cheat?	Text
Q4	Do you have any additional comments about the application?	Text

Table 24.11: Additional questions

24.4 Usage data

Usage data will also be collected from the database. This will be done by making database queries that collect and calculate data from Firebase Firestore to give insight into how On Fire has been used during the test period. The data is considered quantitative data and includes the distance traveled, time spent playing, games completed, fires extinguished, etc.

24.5 Summary

This chapter presents the three different data generation methods that have been used to collect data from the experiment. Interviews are the first data generation method used. These will be semi-structured and performed in context with the second data generation method, the observations. The observations will be overt, which implies that the participants know that they are being observed. During the observations, the participants will play a game of Fire Run. They will also wear a heart rate monitor to record data about the physical strain of playing a Fire Run.

The third and final data generation method is the questionnaires, which will be divided into pre-and post-test questionnaires. These questionnaires will focus on collecting data on the applications' performance and effect on the users' physical activity, motivation, game enjoyment, and engagement. In addition to the data generations described above, a script will collect usage data from the application's database.

Part VI

Results

This part will present qualitative and quantitative data collected from the questionnaires, observations, interviews, and application usage data. All of this data is collected from the experiment described in Part V. The data will be used to look at how On Fire performs with focus on physical activity and the theories of enjoyment.

25 Demographics

20 participants were recruited to the experiment from the researchers' network. The experiment consisted of them downloading On Fire to their mobile phone and playing it on their own initiative. They also answered two questionnaires (see Chapter 24), one at the beginning of the experiment and the second at the end. This chapter will present the demographic of the participants and their relationship to gaming and exercise. This data is gathered from the pre-test questionnaire.

25.1 Gender and age distribution

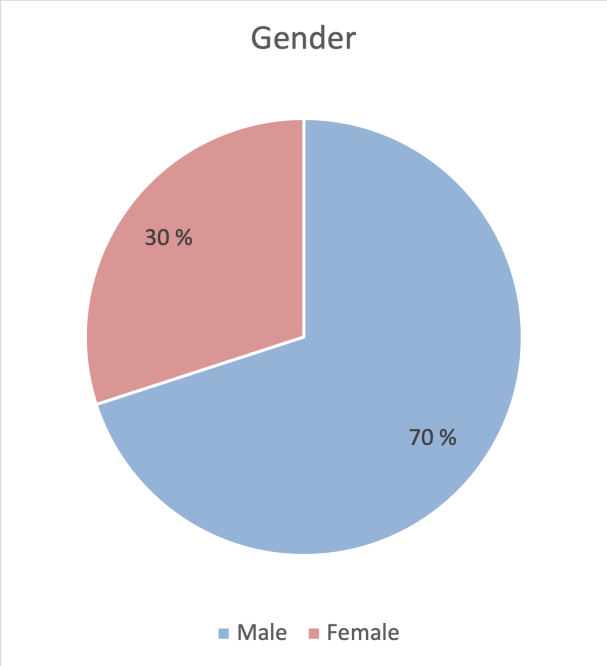

Figure 25.1: Gender distribution

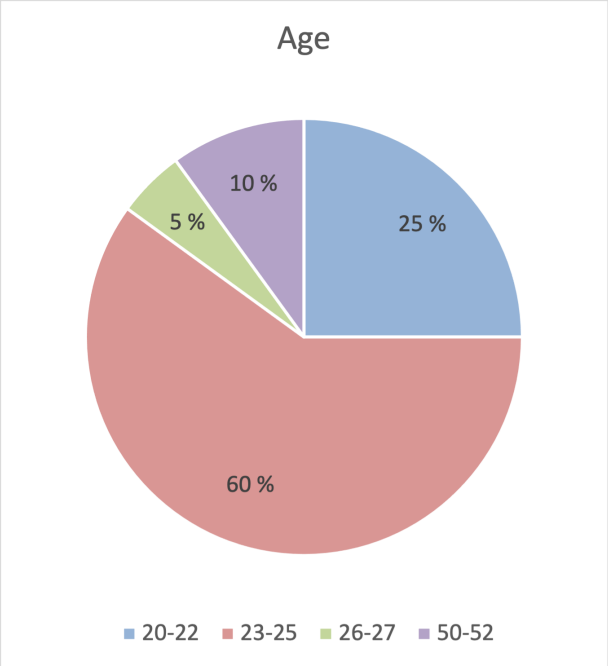

Figure 25.2: Age distribution

Out of the 20 participants, 14 were male and 6 female as illustrated in Figure 25.1. Figure 25.2 illustrates the age distribution of the participants, wheres most of the participants are in the age range of 23 - 25 years old.

25.2 Gaming relationship

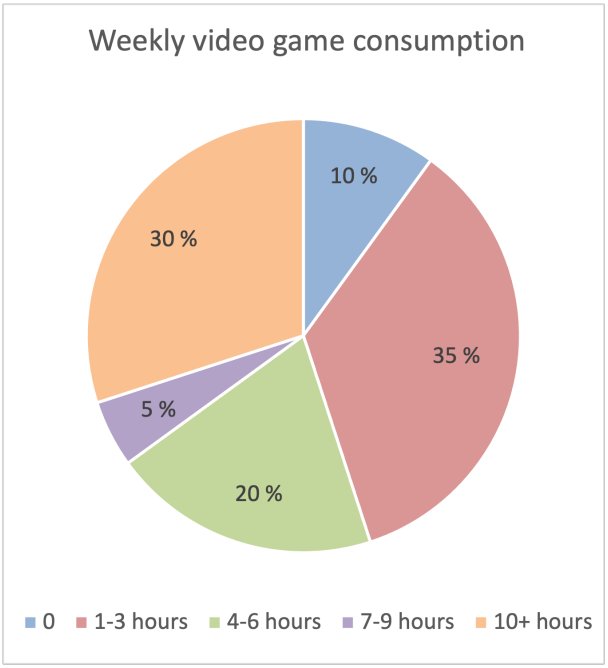

Figure 25.3: Weekly video game consumption

Figure 25.3 illustrates how much the participants usually play video games per week. The figure shows that 10% do not play video games, 55% play 1-6 hours, and 30% play 10 or more hours a week.

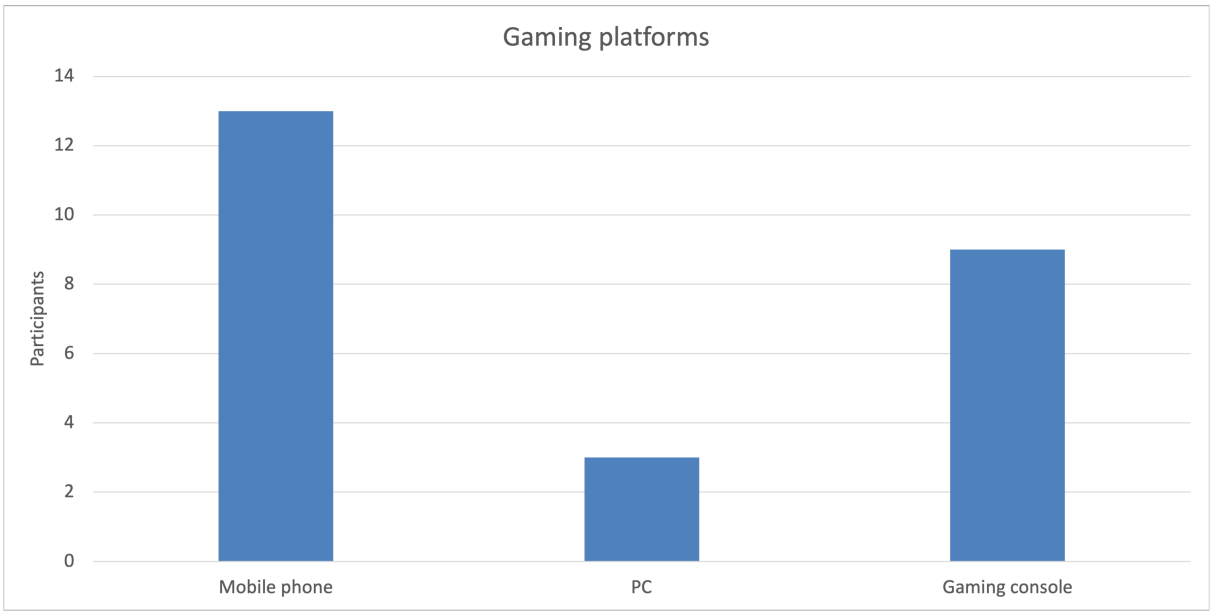

Figure 25.4: Gaming platform usage

Figure 25.4 illustrates what gaming platforms the participants usually use and shows that 13 of the participants play games on their mobile phone, 9 on various gaming consoles, and 3 on PC. 90% of the participants also reported to have previous experience with exergames, and most of these mentioned Pokemon Go as an example. Some other mentions are Wii Sports, EyeToy, Pedal Tanks, and Ring Fit Adventure.

25.3 Exercise relationship

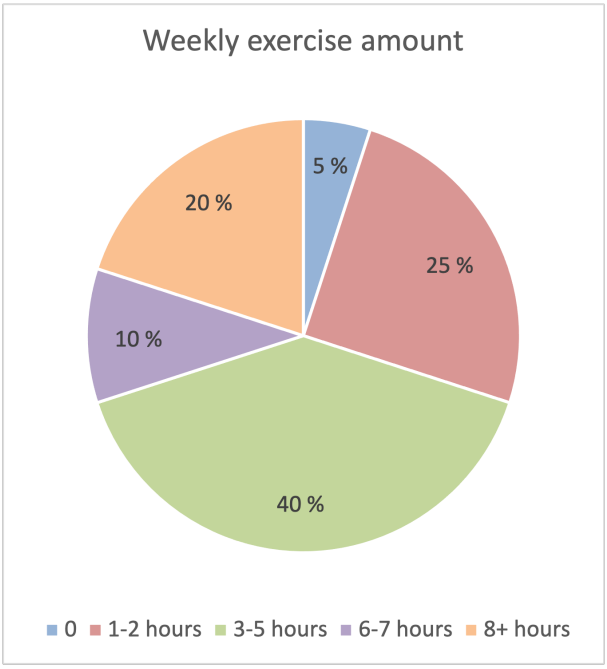

Figure 25.5: Weekly exercise amount

Figure 25.5 shows how much the participants usually exercise per week before the test period. 5% do not exercise at all, 25% exercise 1-2 hours, 40% exercise 3-5 hours, and 30% report that they exercise 6 or more hours a week.

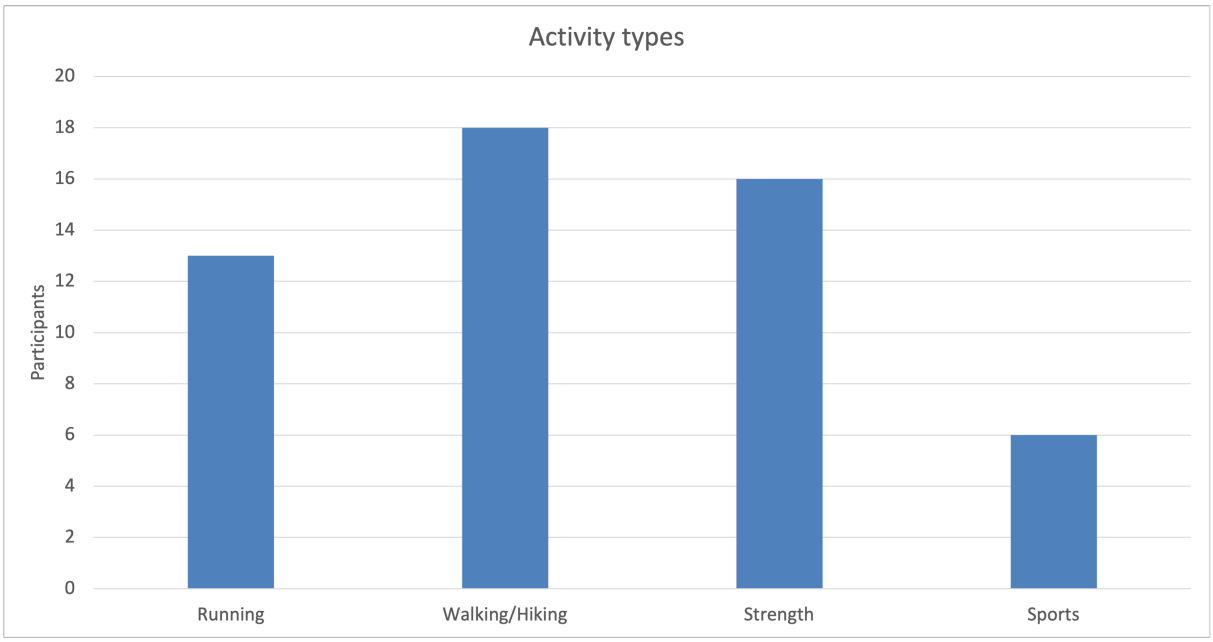

Figure 25.6: Activity types

Figure 25.6 illustrates what types of exercises the participants are performing. 65% of the participants perform running exercises, 90% go for walks/hikes, 80% perform strength exercises, and 30% perform specific sports, for example, rugby, football, tennis, or squash.

26 Physical activity

This chapter will present the physical activity data collected from the data generation methods during the On Fire test period. The statistical significance will be checked for some of the data, using either a T-test or a Mann-Whitney test. A resulting p value lower than 0.05 from these tests will be considered significant.

26.1 Usage data

The usage data section presents different quantitative data about the experiment participants' usage of On Fire retrieved from the Firebase Firestore database. This includes the distance traveled, time spent running, number of games and fires completed, and the distribution of the difficulty and duration of the games. The usage data provide insight into each participant's actual exercise amount using On Fire.

26.1.1 Distance traveled

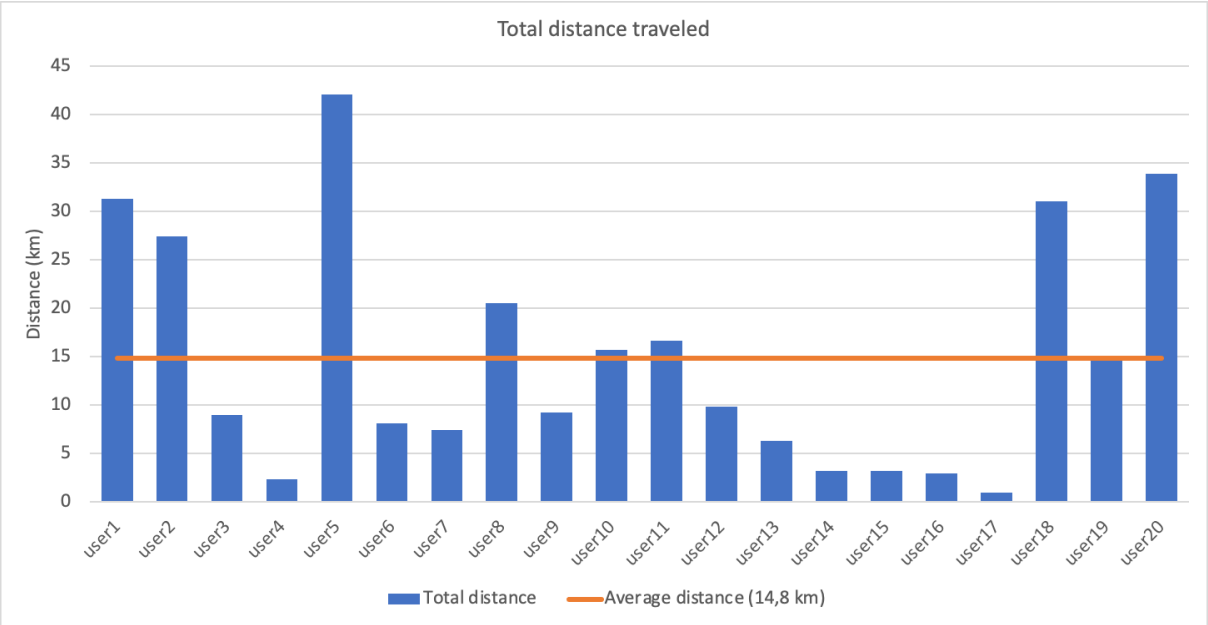

Figure 26.1: Total distance traveled

The game tracked and stored the distance traveled while playing Fire Run. The total distance traveled in kilometers per participant is illustrated in Figure 26.1. The figure shows that five participants have traveled over 25 km, the majority between 5 km and

15 km, and five less than 5 km. This gives an average distance of 14.8 km, highlighted as the orange line in Figure 26.1. The combined distance traveled is 295 km.

26.1.2 Time spent running

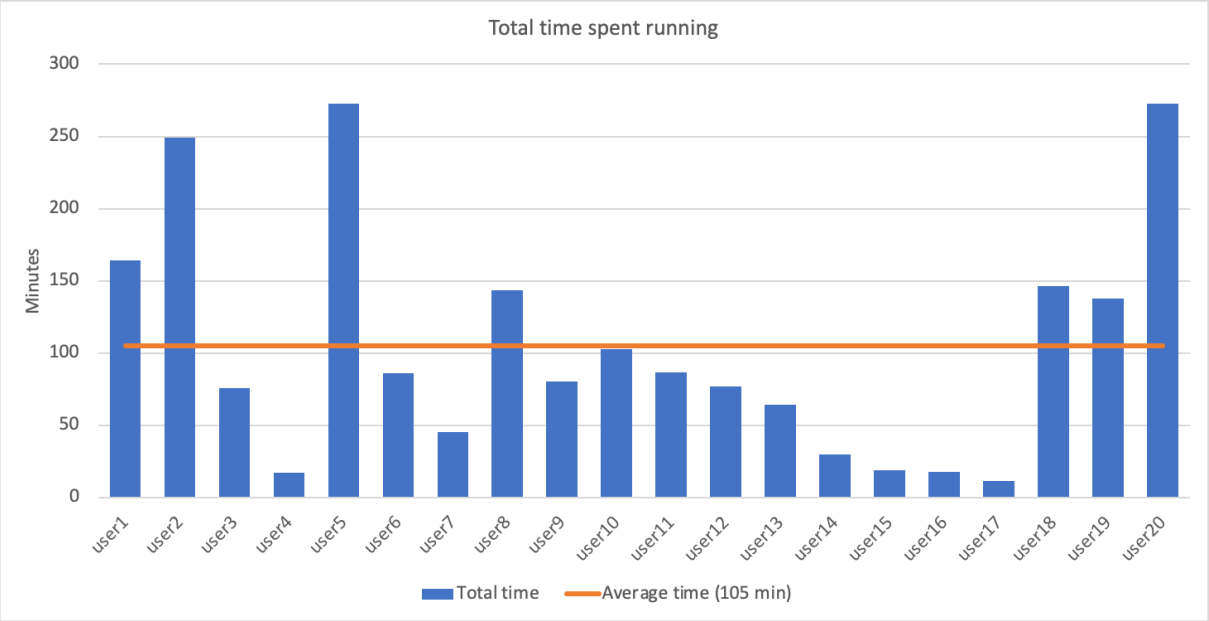

Figure 26.2: Total time spent running

Figure 26.2 illustrates the total time spent playing Fire Run per participant, which includes the time used to navigate, relocate to and extinguish the fires. This data does not include the playtime in between the Fire Run games. The figure shows that 35% of participants have a total playtime of over 2 hours, 35% between 1 and 2 hours and 30% below an hour, which gives an average of 105 minutes, highlighted as the orange line in Figure 26.2.

26.1.3 Amount of games

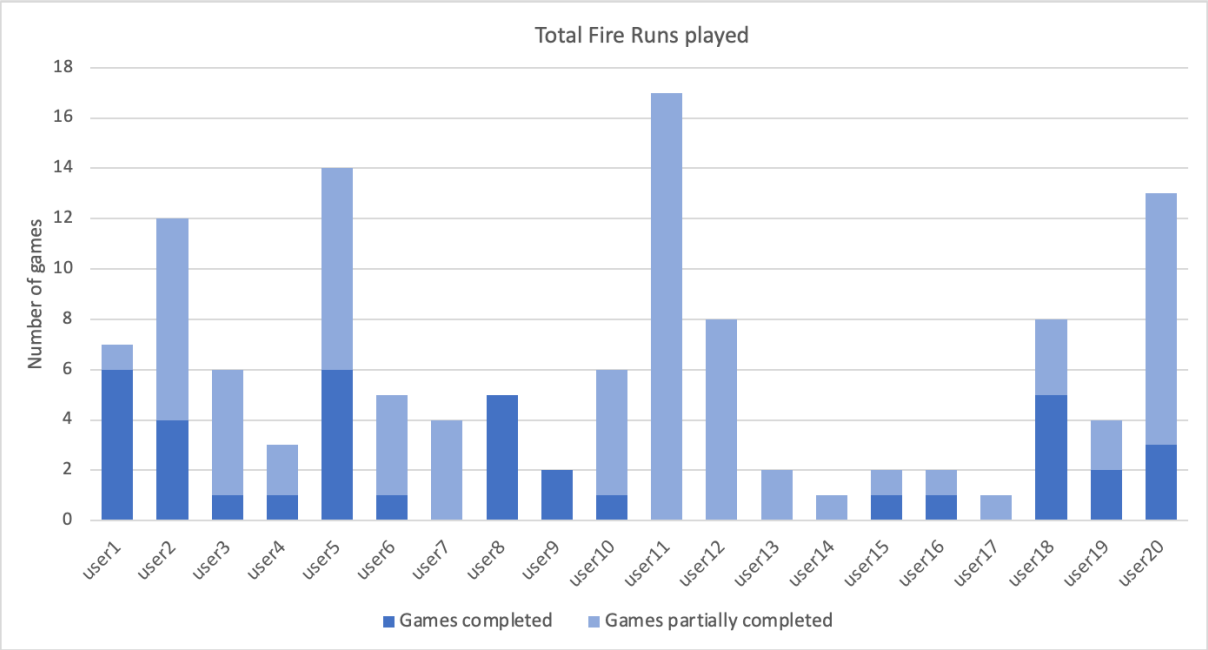

Figure 26.3: Amount of games

Figure 26.3 shows how many games of Fire Run each participant has played, where at least one location is completed. It also illustrates the distribution of games completed against partially completed. A game is completed if the player were able to extinguish the fire at all locations given in a Fire Run. The amount of locations given depends on their chosen game duration, where short duration gives five locations, medium gives seven, and long provides ten. The figures show that all players have played at least one game as they were told to do, and 90% of them have played further on their own initiative. It also shows that 70% of the participants have managed to complete at least one game. The average number of Fire Run games played is 6.1.

26.1.4 Completed locations

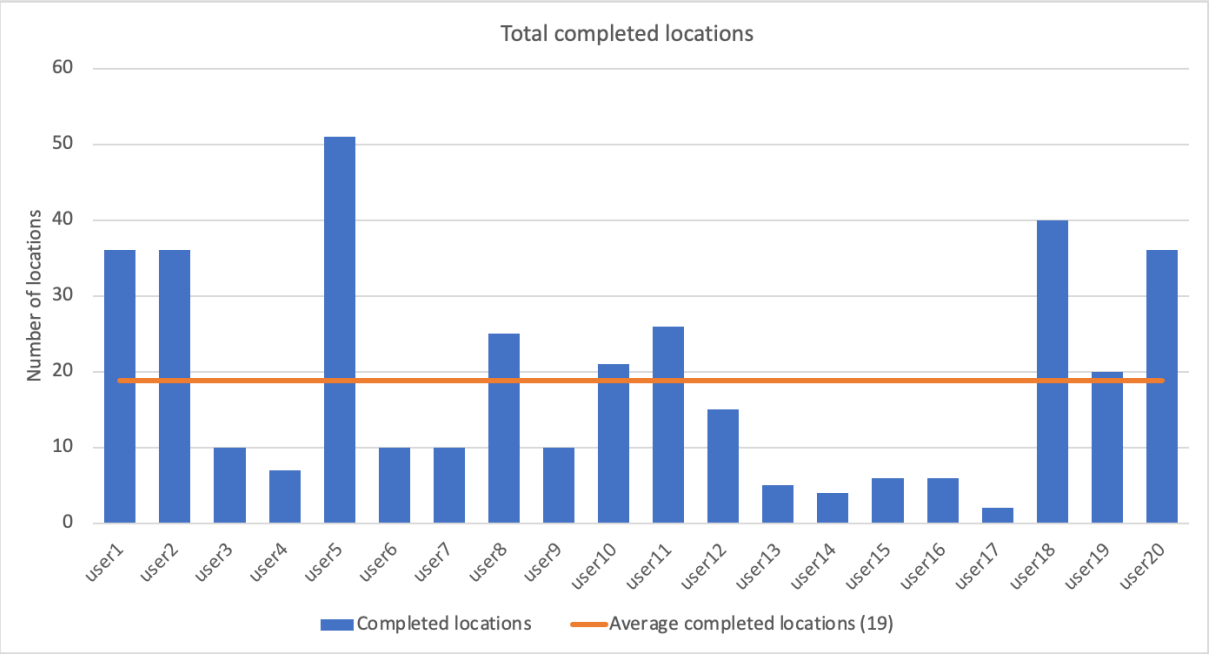

Figure 26.4: Completed locations

The total locations completed are connected to the amount of Fire Run games played and completed. Figure 26.4 gives an insight into how many running stretches, varying from 300 meters to 1200 meters each participant was able to complete in time. The average number of completed locations is 19.

26.1.5 Difficulty and duration

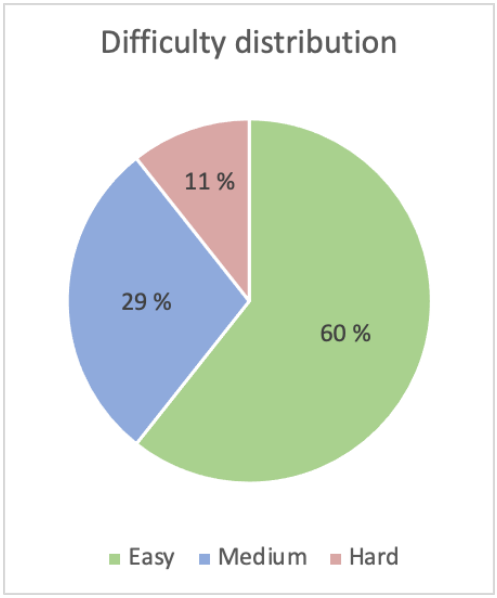

Figure 26.5: Difficulty distribution

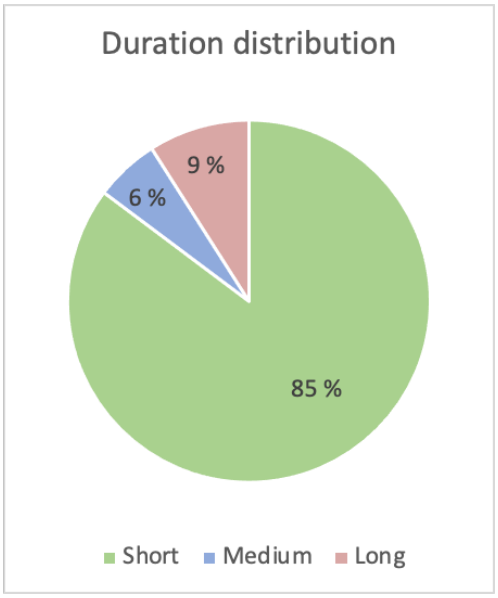

Figure 26.6: Duration distribution

Figure 26.5 illustrates the distribution of the difficulties in all played games of Fire Run, revealing easy to be the most popular difficulty. Furthermore, Figure 26.6 shows the distribution of the durations in all games of Fire Run, revealing that 85% of the games played was with the short duration (five locations). From this, it is possible to see that the participants varied more with difficulty than duration. However, all possible combinations of difficulty and duration have been played by at least one player. The post-test questionnaire also collected data about which combination of duration and difficulty provided the best workout. This was a multiple choice question where each participant could choose 1-3 alternatives. Analysing each individual answer produced the following percentages of duration and difficulty included in peoples selections:

- **Short duration:** 75%
- **Medium duration:** 20%
- **Long duration:** 30%
- **Easy difficulty:** 50%
- **Medium difficulty:** 45%
- **Hard difficulty:** 30%

26.2 Change in physical activity

This section will present, and compare, the data collected from questions and statements related to physical activity from the pre-test and post-test questionnaires. This gives insight into how the participants' level of- and motivation for physical activity have changed over the experiment period.

26.2.1 Change in exercise hours per week

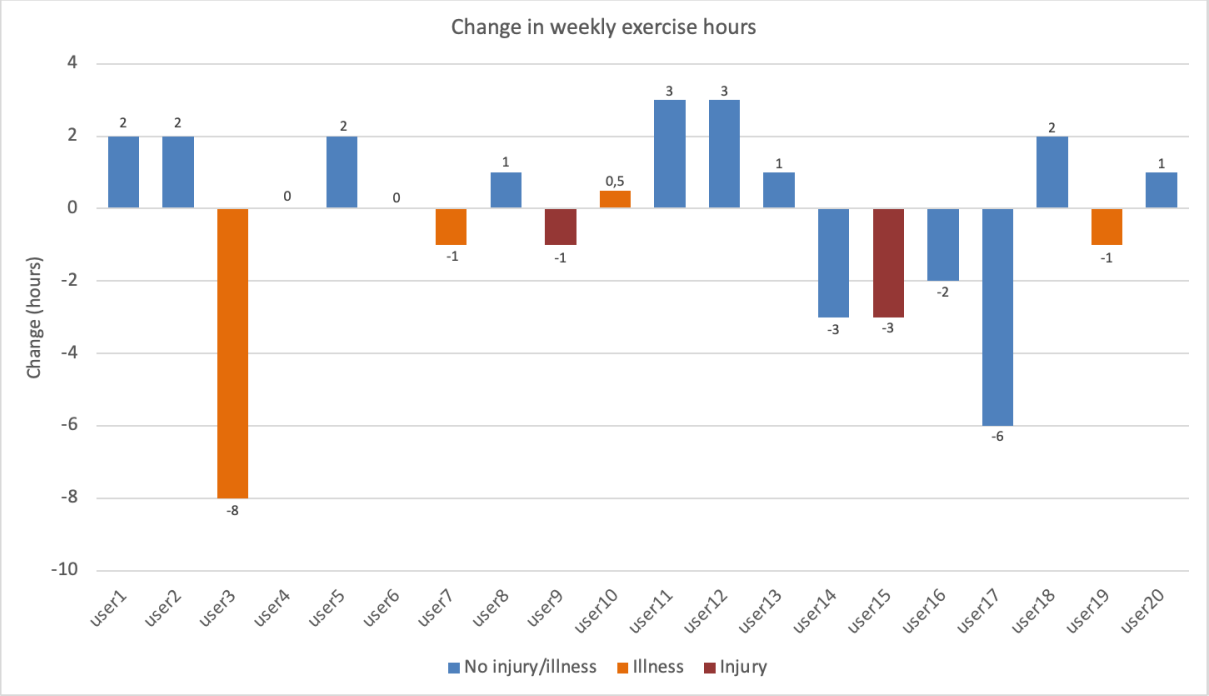

Figure 26.7: Change in weekly exercise hours

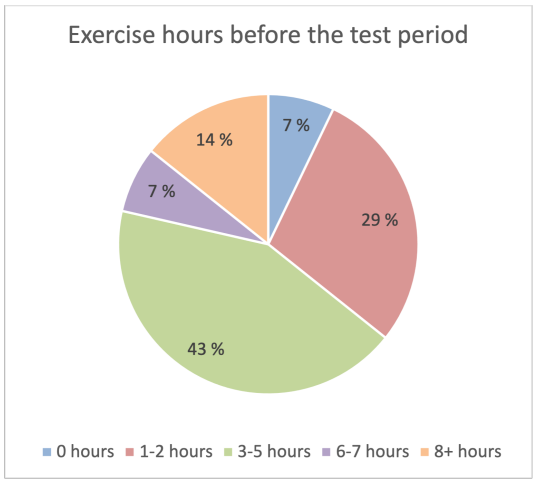

Figure 26.8: Exercise hours pre-test

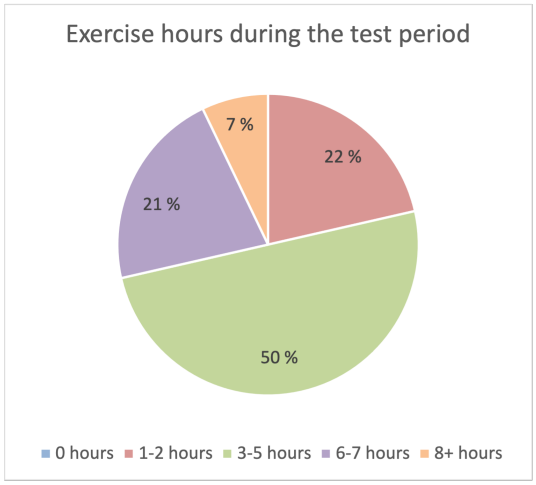

Figure 26.9: Exercise hours during test

The participants were asked how many hours per week they exercise before the test period and during the test period. Figure 26.7 illustrates the change in exercise hours for each participant. 50% of the participants have increased their amount of exercise, 10% have no difference, and 40% have decreased their exercise amount. It is also worth noticing that 62.5% of the participants with a decrease in exercise amount have been injured or ill during the experiment. The response distribution among those not suffering injury or illness before the test period is illustrated in Figure 26.8 and during the test period in Figure 26.9. The statistical significance for the change in exercise hours among the users without injury or illness was checked using a T-test with n=14. This resulted in a two-tailed p=0.628243, which indicates that this is not statistical significant as it is above 0.05. However, the standard deviation changed from 2.718 to 1.869.

26.2.2 Change in the difference between exercise amount and ambition

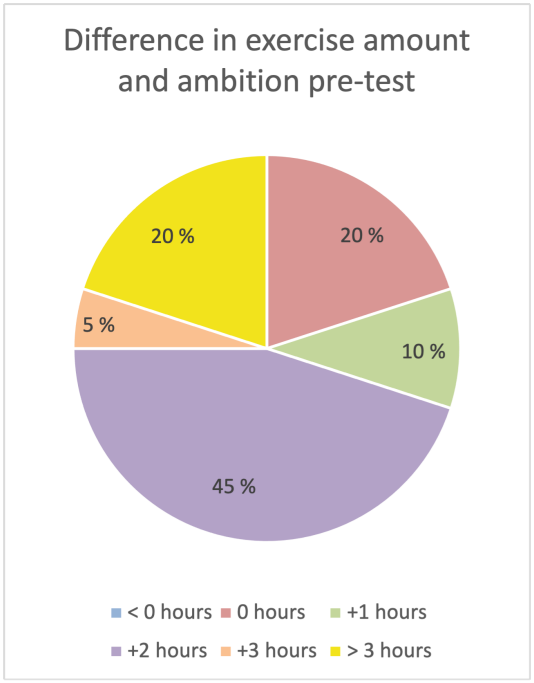

Figure 26.10: Pre-test exercise ambition

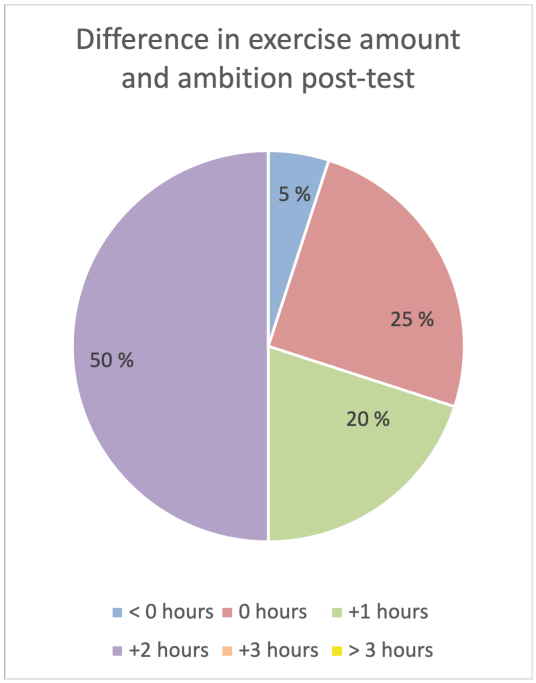

Figure 26.11: Post-test exercise ambition

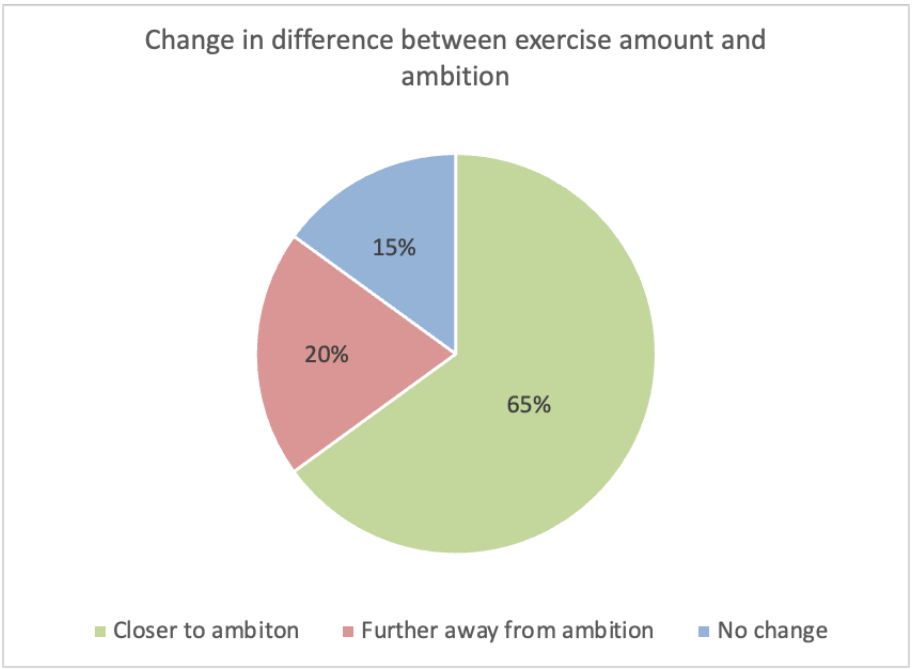

Figure 26.12: Change in difference between exercise amount and ambition

The participants were asked about how many hours a week they would like to exercise in both the pre-test and post-test questionnaires. The answer to this question was compared

to their actual exercise amount before and during the experiment. Figure 26.10 illustrates the difference between their exercise amount per week and their ambition to exercise before the experiment. The figure shows that 20% are satisfied with their exercise amount, while 25% want to increase this amount by three or more hours each week. Figure 26.11 illustrates the same comparison during the test period and shows that 5% exercised more than their ambition, 25% are satisfied with their exercise amount, and 0% wanted to exercise three or more hours more than they did during the experiment. Figure 26.12 illustrates the change in the difference between the participants' exercise amount and ambition, which shows that 65% were more satisfied with their exercise amount during the experiment than before.

26.2.3 Change in motivation and intensity satisfaction

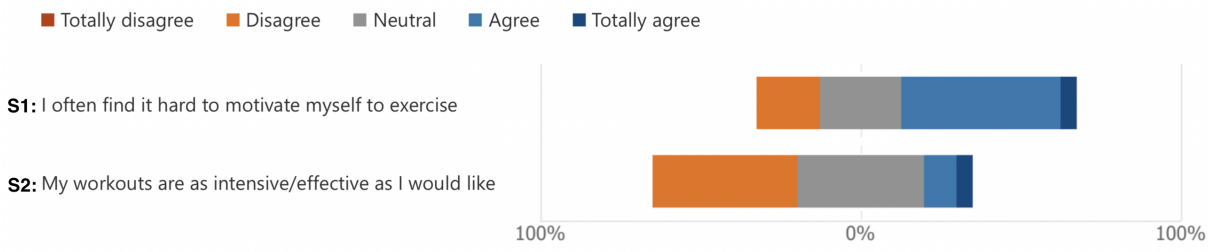

Figure 26.13: Physical activity statements, pre-test

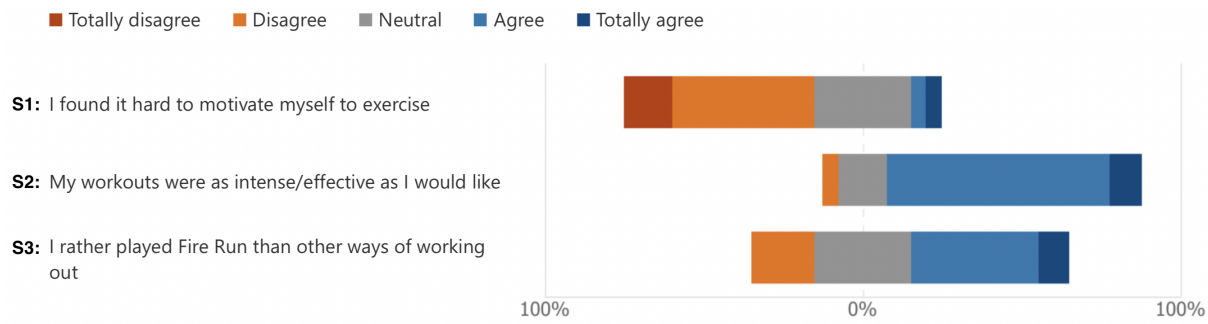

Figure 26.14: Physical activity statements, post-test

Statement S1 and S2 were responded to using Likert's scale in both questionnaires. The response distribution from the pre-test questionnaire is illustrated in Figure 26.13, and from the post-test questionnaire in Figure 26.14. The response distribution in S1 has moved from mostly agreeing to finding it hard to motivate themselves to exercise before the experiment to disagree to the same during the test period. The *median values* of the

answers were checked to confirm this, before the test the median was Agree and after the median was Disagree. A *Mann-Whitney test* was performed with n1=20 and n2=20 to check if this is a statistically significant change. The test resulted in p=0.0016, which concludes that the change in S1 is *statistically significant*.

Furthermore, in S2 45% of the participants responded that they were not satisfied with the intensity of their workouts, and only 15% percent were satisfied before the experiment. However, during the experiment 80% of the participants were satisfied with the intensity, and only 5% disagreed with the statement. When checking the *median value* of the answers, the value was Nautral in the pre test and Agree in post test. Indicating that more users were pleased with the intensity of their workouts during the test. The statistical significance of this change was also tested with a *Mann-Whitney test* which resulted in a p value of 0.0001, concluding that the change in S2 is *statistically significant*

When investigating what each participant responded to S1 in both questionnaires and comparing the responses, it revealed that 75% of them found it easier to find the motivation to exercise, 20% found it harder, and 5% had no change. The same was done to S2's responses, which also revealed that 75% of the participants were more satisfied with the intensity of their exercises during the experiment. Figure 26.14 does also include S3, which shows that 50% would rather play this game than other ways of working out. 20% disagreed and 30% were neutral to the statement.

26.3 On Fire's physical aspects

This section will showcase the participants' responses to some statements and questions about On Fire's physical activity aspects gathered from the post-test questionnaire. This is to determine how On Fire has contributed to their level of and motivation for physical activity.

26.3.1 Statements

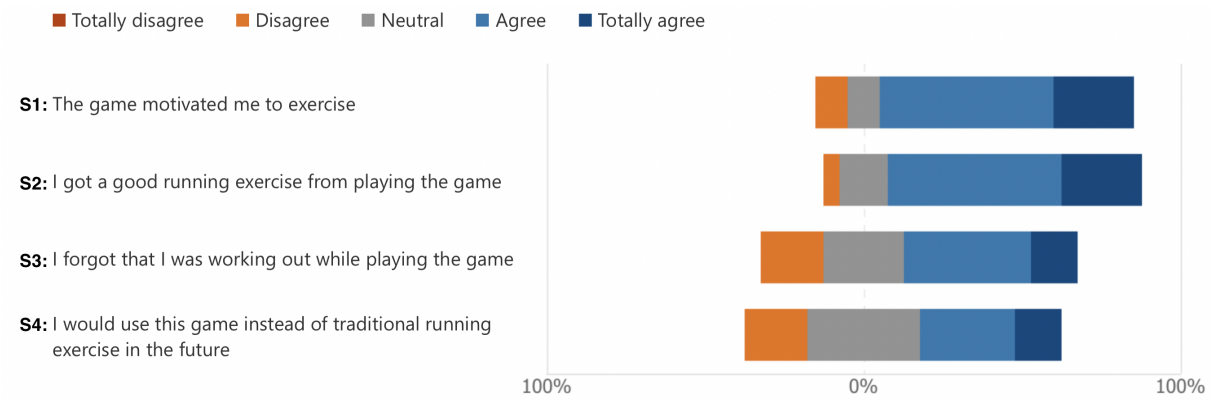

Figure 26.15: On Fire's physical aspect statements

Figure 26.15 illustrates the distribution of responses using Likert's scale in the statements regarding On Fire's physical aspects. The majority either "agreed" or "totally agreed" with all statements. The distribution of these answers are:

- **S1:** 80% either "agreed" or "totally agreed" to On Fire motivated them to exercise, while 20% either "disagreed" or were "neutral" to the matter.
- **S2:** 80% either "agreed" or "totally agreed" to them getting a good running exercise from playing the game. 5% "disagreed", and 15% were "neutral".
- **S3:** 55% either "agreed" or "totally agreed" to forget that they were exercising while playing the game, 20% disagreed, and 25% were neutral.
- **S4:** 45% either "agreed" or "totally agreed" to use this game instead of traditional running in the future, while 20% disagreed and 35% were neutral.

26.3.2 Quotes

This section will present quotes from two questions given in the post test questionnaire. The majority of the answers were positive, with some exceptions. Both are represented in the quotes below.

How did On Fire affect your physical activity?

- *"Fire Run gave me some extra exercise in addition to my routine training, it made me active in periods where I would otherwise be inactive"*
- *"On Fire made me jog outside, something I do very rarely. My cardiovascular fitness improved slightly, which has motivated me to continue running in the future"*
- *"The game motivated me to run a lot more than I usually do. It was also nice to change up the difficulty and duration to fit what running exercise I wanted to do that day. It was a nice addition to my routine exercises."*
- *"I became more active and motivated to go outside, even when the weather was poor and cold."*
- *"For me, this kind of physical activity (running) is not what motivates me to get in shape."*

What do you think of the running exercise produced by On Fire?

- *"The game gave a different experience than a normal workout. It tended more towards an interval workout. I would not use the on fire app for all my workouts, but I believe it could be a nice switch of contexts for interval exercises."*
- *"The pace required on Hard difficulty provided me with a perfect pace for pushing myself, resulting in very good running exercise."*
- *"The different difficulties really fitted my pace. Hard when I wanted to run, medium when jogging and easy if I wanted to go for a walk. I also really enjoyed that the game provided different running routes each time, giving my running exercises a bit of variety."*

- *"It caused a lot of running back and forth. I feel that I would get a better workout if the locations would be arranged in a circle, so that you do not have to run back the way you came."*

Several of the quotes received from the second question included notes on how the quality of the exercise would be improved if the locations were arranged so that you do not have to run back and forth.

26.4 Results related to subgroups

This section presents differences in physical activity between selected subgroups in the test population. The subgroups are formed based on answers given in the questionnaires, and the physical activity data are collected from the application database.

26.4.1 Gaming relationship and On Fire exercise

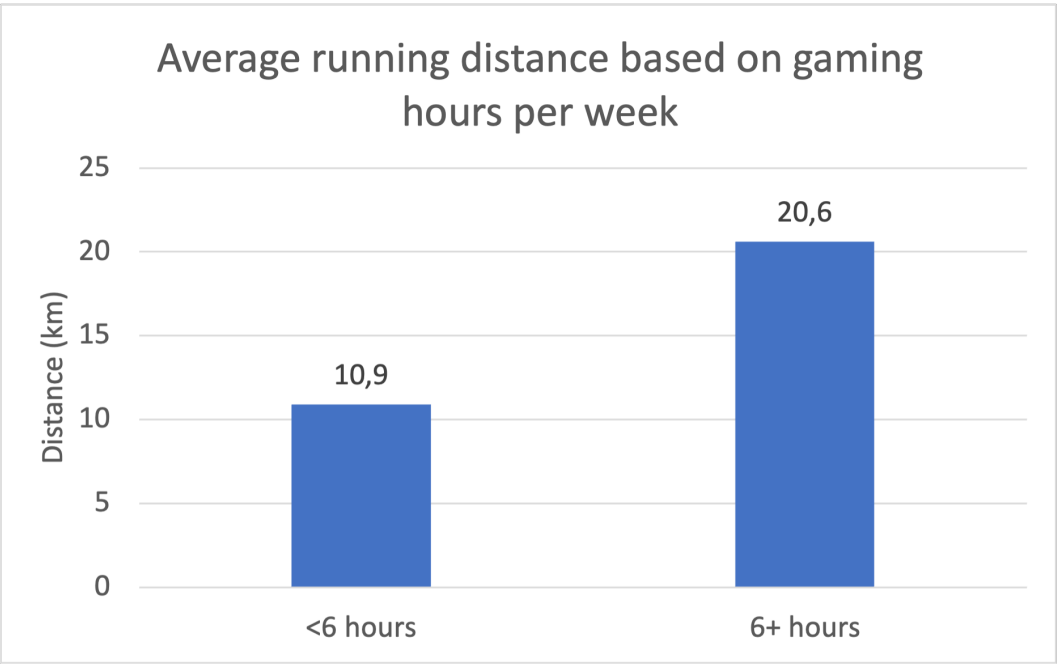

Figure 26.16: Average On Fire running distance and gaming relationship

Figure 26.16 illustrates the average distance traveled by the participants, grouped by weekly gaming consumption. The first group plays less than six hours a week (60% of test population) and the other group plays six or more hours a week (40% of test population). Figure 26.16 shows that the group that plays more video games have ran an average of 20,6 km, while the participants that play less video games ran an average of 10,9 km. A *T-test* was performed to check the statistical significance of the difference between the two groups, with n1=12 and n2=8. This test resulted in a one tailed p=0.0411595, which concludes that the result is *statistically significant*.

To see if there is any connection between the statements presented in Figure 26.15 and the participants' gaming relationship, the median and average values of the answers for

these groups were calculated. Additionally, the statistical significance of the difference between the answers was checked using a *Mann-Whitney* test with n1=12 (less than 6 hours of gaming) and n2=8 (6+ hours of gaming). Table 26.1 presents the data for these two groups, with m representing the median value, avg representing the average of the answers, and the p-value from the Mann-Whitney test. The values from the Likert's scale is converted to numbers where 1 represents totally disagree and 5 represents totally agree. Statement S2 have a p value lower than 0.05, therefore it is a *statistically significant* difference between the answers of the two groups. None of the other statements can be considered statistically significant, but S1 with a low p-value indicates that the gamers are more motivated to exercise by the game.

ID	**Statement**	**Subgroup**	**m**	**avg**	**p**
S1	The game motivated me to exercise	Non gamers	4	3.75	0.0708
		Gamers	4.5	4.25	
S2	I got a good running exercise from playing the game	Non gamers	4	3.67	**0.017**
		Gamers	4.5	4.5	
S3	I forgot that I was working out while playing the game	Non gamers	4	3.5	0.484
		Gamers	3.5	3.5	
S4	I would use this game instead of traditional running exercise in the future	Non gamers	3	3.25	0.1977
		Gamers	4	3.63	

Table 26.1: Gaming relationship and statements

26.4.2 Exercise relationship and On Fire exercise

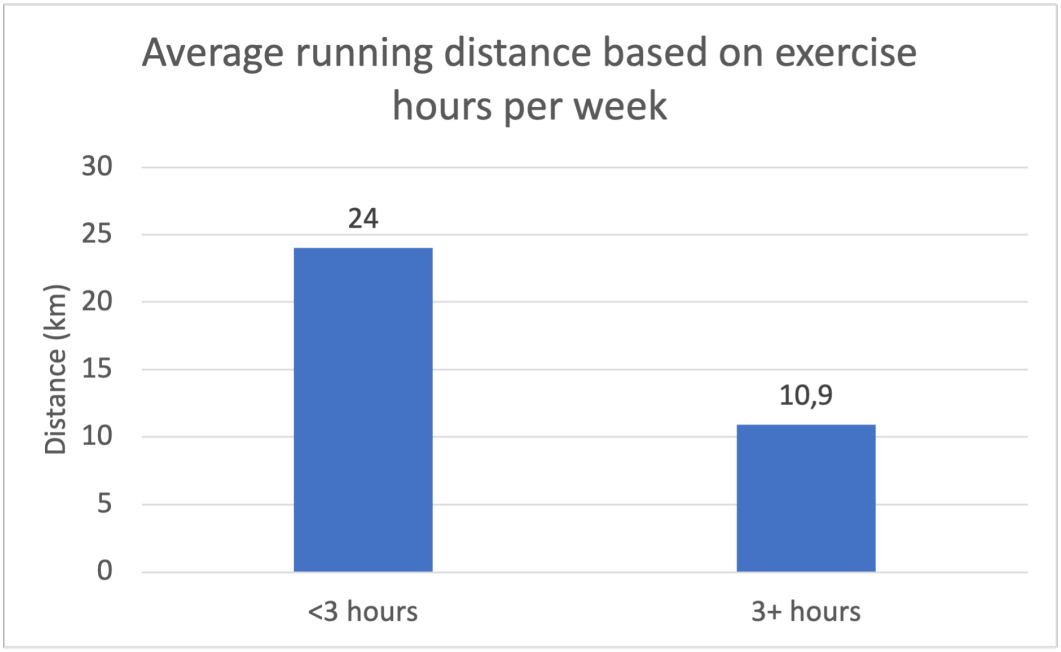

Figure 26.17: Average On Fire running distance and pre-test exercise amount

When researching physical activity in Chapter 6 in the prestudy, it was discovered that the recommended amount of moderate physical activity for people aged 20 to 64 is 150 minutes a week. Based on this, those who have three hours of weekly exercise (180 minutes) or above will be considered physically active. Figure 26.17 illustrates the average distance traveled by participants divided into two groups based on their weekly exercise amount. The first group exercise less than recommended (30% of test population) and the other group exercise more than the recommended minimum amount (70% of test population). The participants with a low exercise amount ran an average of 24 km and the participant that exercise regularly ran 10.9 km on average. When performing a *T-test* on this result with n1=6 and n2=14 a one tailed p=0.0118705 was found, which tells us that this result is *statistically significant*.

The answers given on the statements presented in Figure 26.15 by these two groups were compared to look for any statistically significant differences. These were tested using a Mann-Whitney test with n1=6 (less than 3 exercise hours) and n2=14 (3+ exercise hours). Table 26.2 contains values for median (m), average (avg), and p-value from the *Mann-Whitney* test (p). These values are converted from the Likert's scale to numbers

where totally disagree equals 1 and totally agree equals 5. S4 is the only statement with a *statistically significant* difference between the answers of those who are active and those who are not.

ID	**Statement**	**Subgroup**	**m**	**avg**	**p**
S1	The game motivated me to exercise	Inactive	4	4.33	0.1515
		Active	4	3.79	
S2	I got a good running exercise from playing the game	Inactive	4	4.33	0.1515
		Active	4	3.86	
S3	I forgot that I was working out while playing the game	Inactive	3.5	3.83	0.2297
		Active	4	3.36	
S4	I would use this game instead of traditional running exercise in the future	Inactive	4	4.17	**0.0162**
		Active	3	3.07	

Table 26.2: Exercise relationship and statements

26.5 Observations

This section will present the physical activity data produced by the observations and interviews.

26.5.1 Observation 1

Test participant data:

- Age: 23
- Gender: Male
- Reported exercise hours per week, pre-test: 5
- Regularly performs running exercise: Yes
- Injury/Illness during the test period: No

Data collected from fitness tracker:

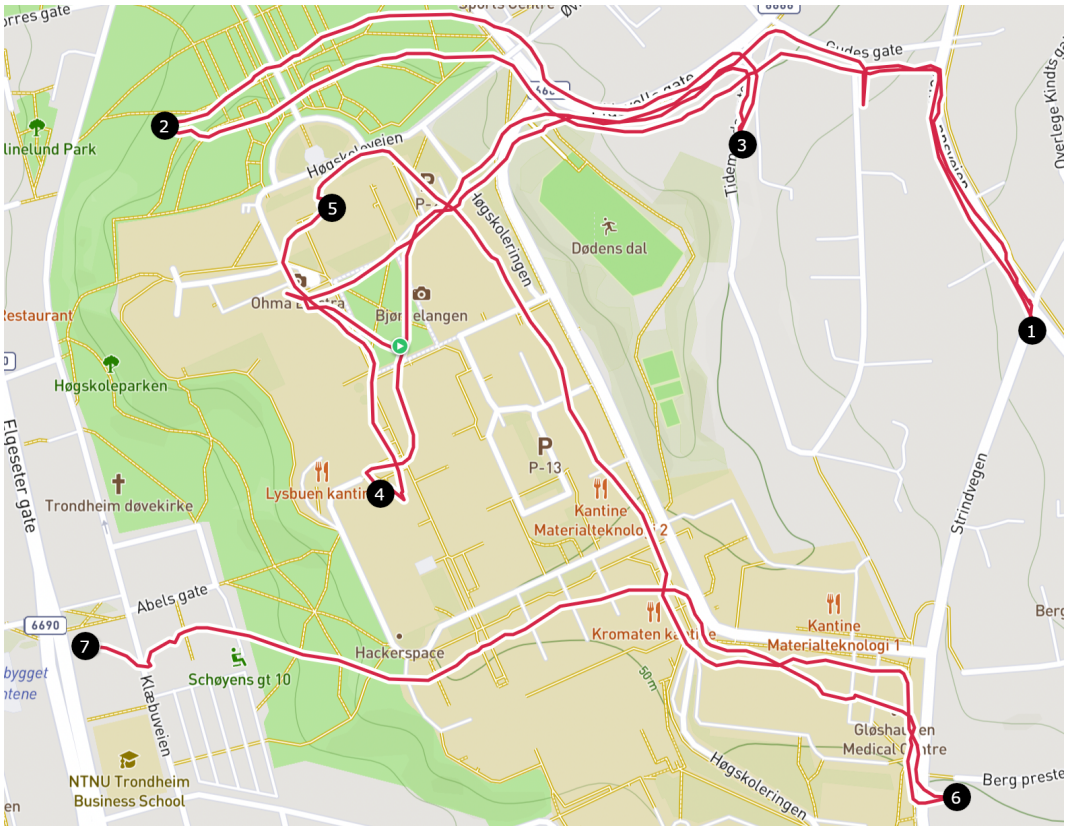

Figure 26.18: Observation 1: Route map

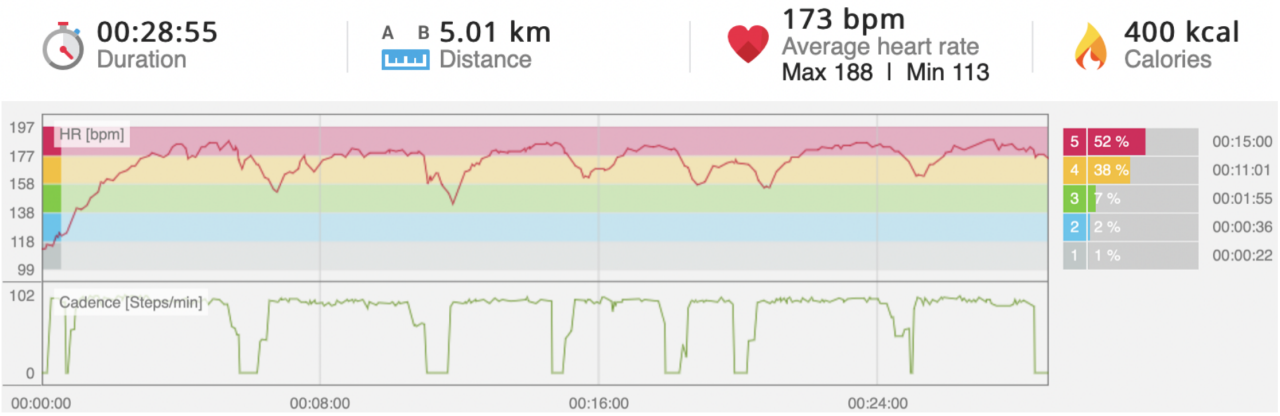

Figure 26.19: Observation 1: Fitness tracker data

Exercise information:

- Fire Run difficulty: Hard
- Fire Run duration: Medium
- Average pace recorded: 05:46 min/km

This Hard-Medium Fire Run produced a high-intensity, interval running exercise. The heart rate graph (see Figure 26.19) reflects this, recording 52% of the time spent in the top heart rate zone and an average heart rate of 173 bpm. The player kept a steady running pace throughout the session. It is also possible to see a clear connection between the dips in heart rate and the cadence, indicating that the players' heart rate slows down when stopping to play the fire extinguishment mini-game. All declines in cadence except for the first minor drop is related to the fire extinguishment task.

When arriving at a new location, it was observed that the player did not completely stop moving for longer periods while extinguishing the last 2-3 fires. The cadence also reflects this. When asked about this in the interview the player said that this was to avoid getting lactic acid when the muscles cool down as this could cause problems for further running as the muscles would stiffen.

26.5.2 Observation 2

Test participant data:

- Age: 24
- Gender: Male
- Reported exercise hours per week, pre-test: 4
- Regularly performs running exercise: Yes
- Injury/Illness during the test period: No

Data collected from fitness tracker:

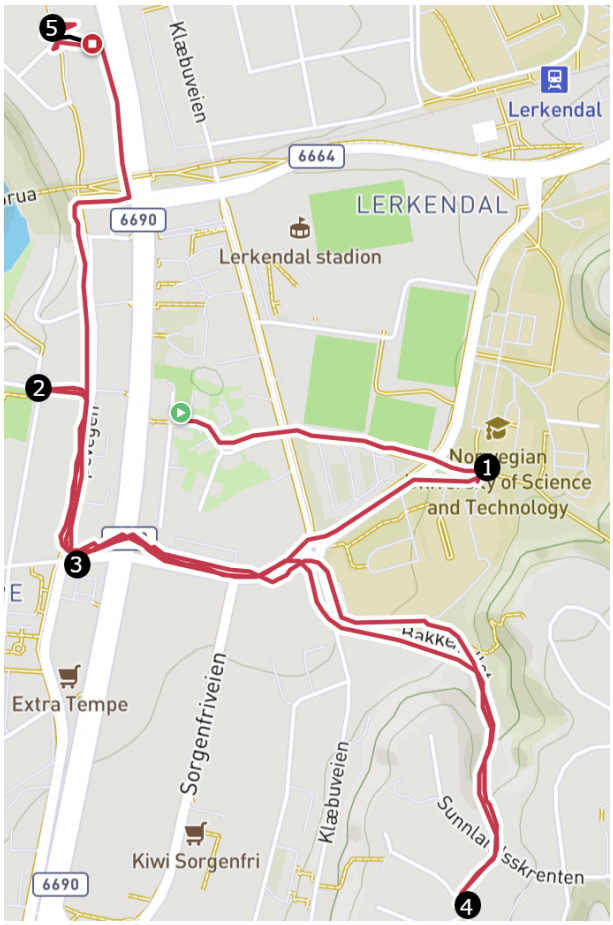

Figure 26.20: Observation 2: Route map

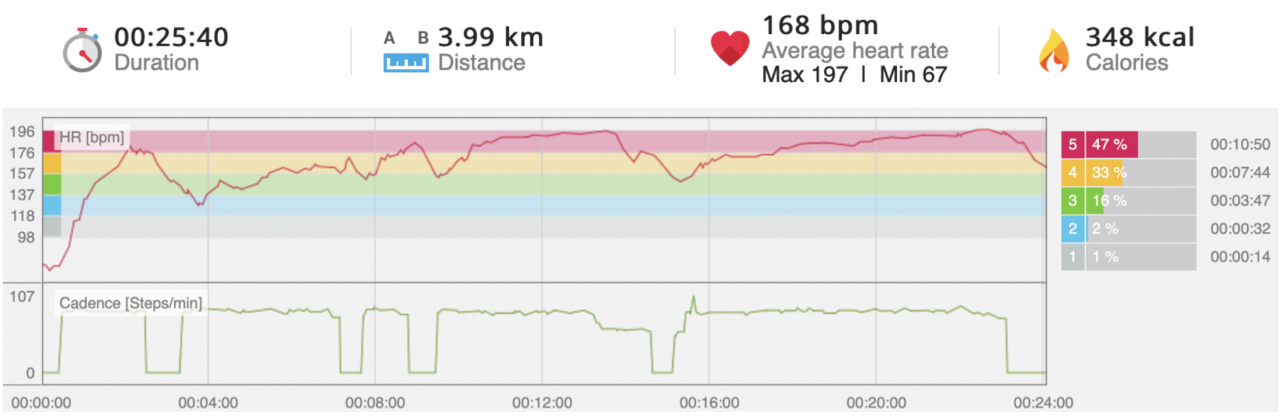

Figure 26.21: Observation 2: Fitness tracker data

Exercise information:

- Fire Run difficulty: Hard
- Fire Run duration: Short
- Average pace recorded: 06:25 min/km

The heart rate data and calorie expenditure show that this Fire Run produced a high-intensity workout. The heart rate graph (see Figure 26.21) shows that the user was in the two highest heart rate zones for most of the test. Similar to the other observation made on the Hard difficulty, there is a strong correlation between the heart rate graph and cadence. When the player stopped to extinguish the fires (cadence reached zero), the player's heart rate declined until he started running again. The player also keeps a stable level of cadence when moving between locations. Combined with the observations made, this implies that the player ran at a steady pace.

When observing this test, it was clear that the test subject was running at maximum capacity for most of the Fire Run, especially between locations four and five. This is also reflected by the heart rate graph, as it was constantly close to the max between these two locations. The key observation made was that the player purposely used longer time to extinguish the fires when being tired. When asked about this in the interviews, the player said he did this to get a longer break before receiving the next location.

26.5.3 Observation 3

Test participant data:

- Age: 22
- Gender: Female
- Reported exercise hours per week, pre-test: 2
- Regularly performs running exercise: No
- Injury/Illness during the test period: No

Data collected from fitness tracker:

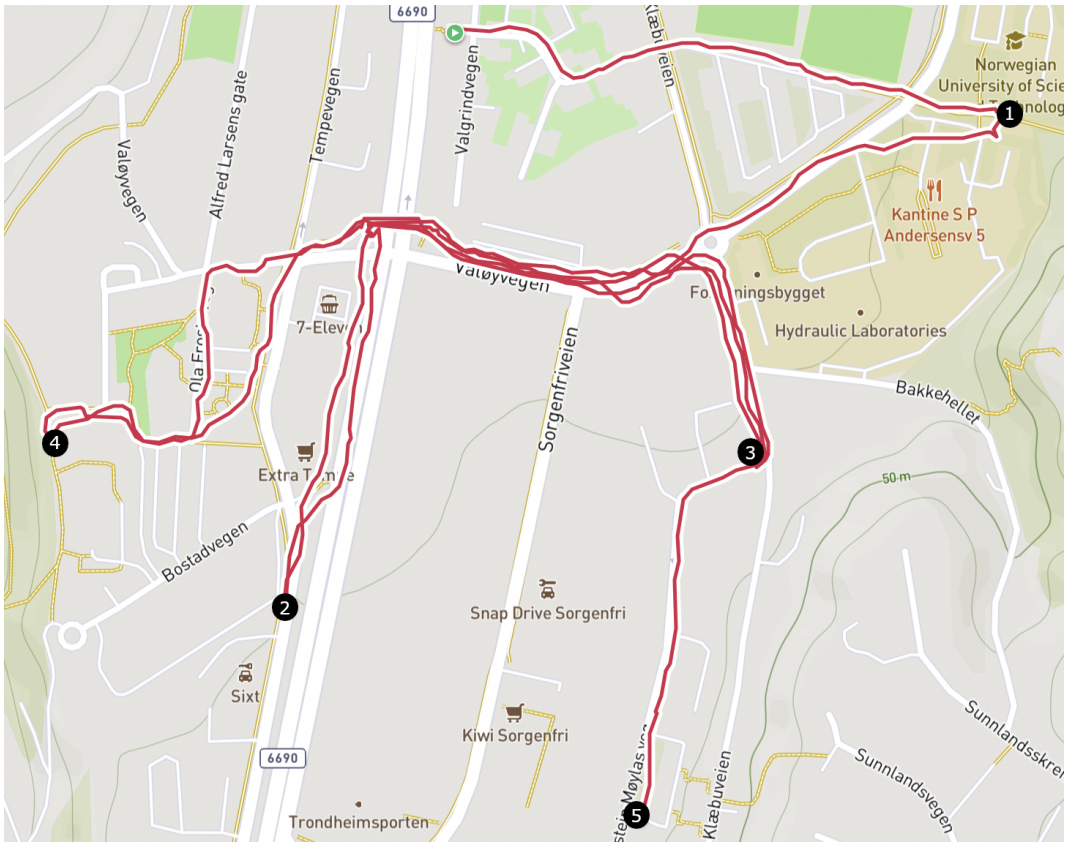

Figure 26.22: Observation 3: Route map

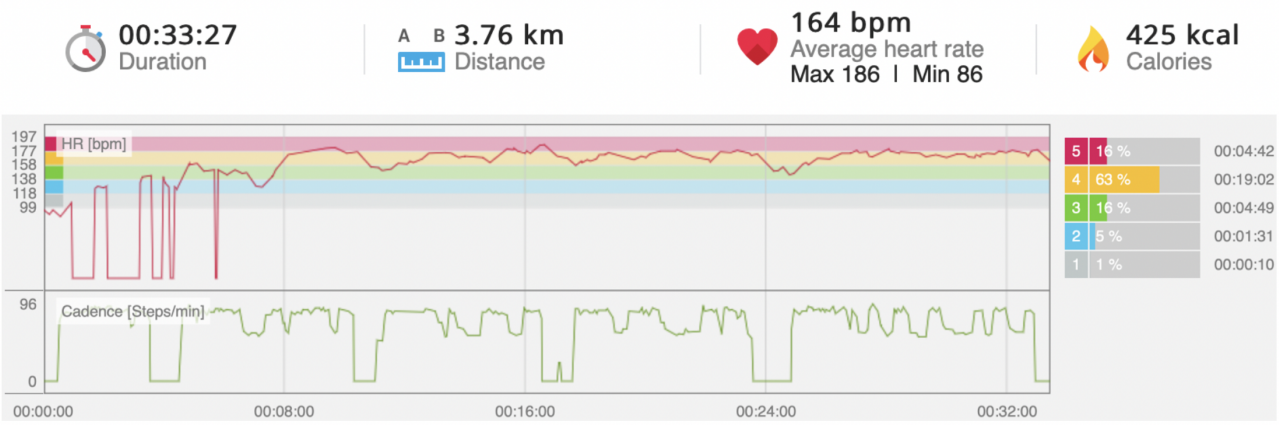

Figure 26.23: Observation 3: Fitness tracker data

Exercise information:

- Fire Run difficulty: Medium
- Fire Run duration: Short
- Average pace recorded: 08:53 min/km

This Medium-Short Fire Run produced a physically demanding running exercise for the test user, which does not regularly run and has a relatively low exercise amount per week. The cadence graph (see Figure 26.23) implies that the user often changed its running pace when moving between locations. This was verified by the observations, where the player was observed altering between running and walking. The apparent dips in heart rate at the start of the graph is due to a poor connection between the watch and the user. When looking at most of the graph that has not been affected by this, it is possible to see correlations between zero cadence and decreasing heart rate. During the observations, the observer noticed that the player seemed to experience increasing difficulties completing the fire extinguishment mini-game as her heart rate increased.

26.5.4 Observation 4

Test participant data:

- Age: 23
- Gender: Female
- Reported exercise hours per week, pre-test: 4
- Regularly performs running exercise: Yes
- Injury/Illness during the test period: Yes, sprained ankle

Data collected from fitness tracker:

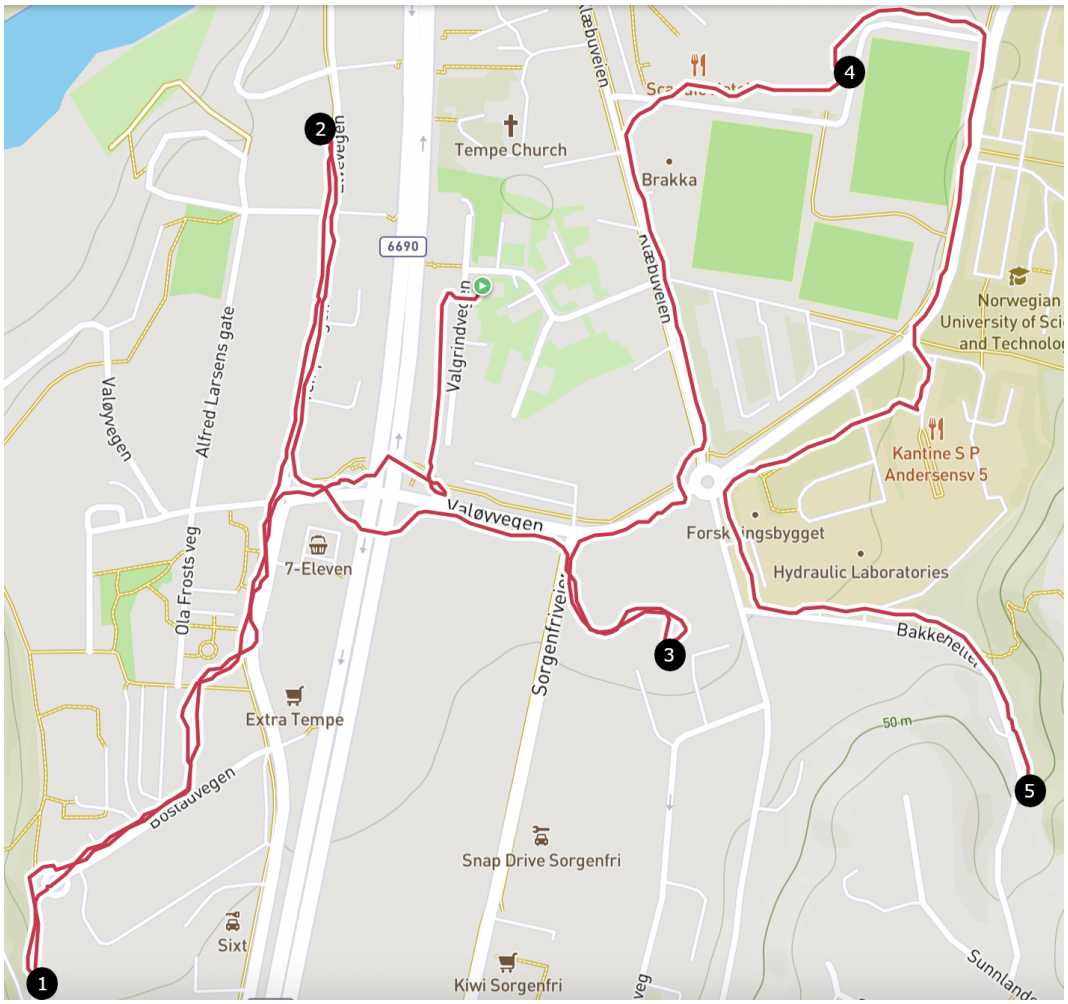

Figure 26.24: Observation 4: Route map

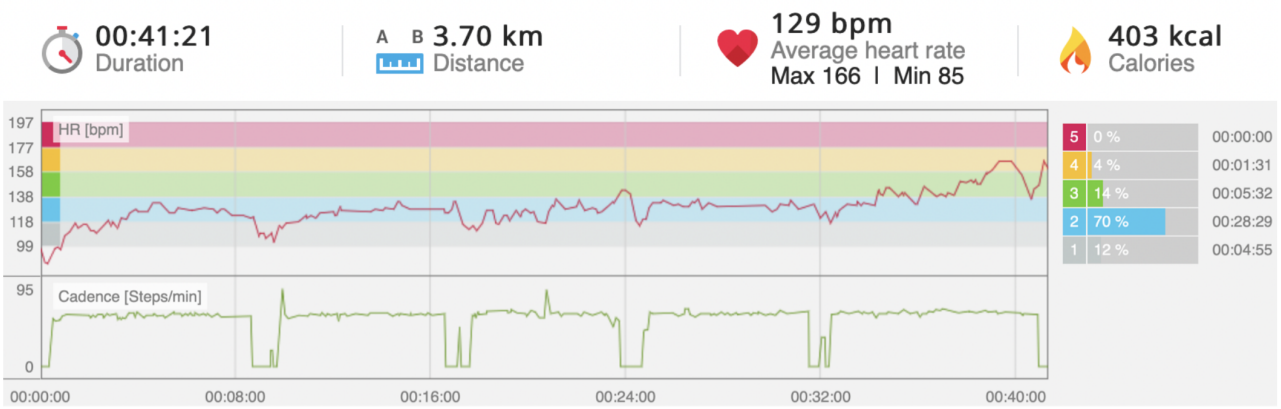

Figure 26.25: Observation 4: Fitness tracker data

Exercise information:

- Fire Run difficulty: Easy
- Fire Run duration: Short
- Average pace recorded: 11:10 min/km

This test user was unable to run because of a sprained ankle, presenting a good opportunity to test both the intensity and usability of Fire Run for those suffering injuries. The user kept a fast walking pace throughout the game, leading to an average heart rate of 129 and good calorie expenditure (see Figure 26.25). It is also possible to see some correlation between cadence and heart rate, as the heart rate slightly drops when the player is standing still. The reason for the heart rate not dropping more is that the heart rate primarily stayed in heart rate zone 2, which requires standing still for a more extended period of time than it takes to extinguish fires to be able to lower the heart rate at this level.

26.6 Interviews

This part presents the data collected from the questions concerning physical activity in the interviews conducted after the observations. The first of these questions ask the participants if the combination of difficulty and duration that they played on during the observation is their preferred combination. Three out of four participants confirmed that they preferred the combination chosen for the observation. The final participant, who ran a hard-medium Fire Run, partially agreed that this combination was his preferred one. He stated that: "*Hard is my preferred difficulty as it fits nicely to my running pace, but I like to vary the duration, depending on my daily physical shape*".

The second physical activity question of the interview asked the participants to describe how they perceive the physical aspect of On Fire and primarily focused on the intensity of the exercise. One of the participants had been injured during the majority of the test period. Therefore she had not been able to explore the intensity of On Fire's physical aspect fully. All of the other participants stated that On Fire provides them with a good intensity workout. One participant also pointed out that the fact that you can adjust the difficulty and duration increased the number of games that he played. His statement reflects this: "*I like the fact that you can choose the difficulty to regulate the intensity of the workout. Some days I want an intensive running exercise like today, but other days I only want to go for a walk*". All of the participants unaffected by injury stated that they had to push themselves at different points in the game to complete it. The participant playing on hard-short felt this game was incredibly intense and said: "*This workout was very intense, especially the hills to flame number four and the long run to the last location. But this kind of intensity is what I want from the hard difficulty*". Another participant also pointed out that elevation between locations may affect the difficulty of Fire Runs.

The final question regarding physical activity asked the participants if they would consider using On Fire after the test period. All participants replied that they would like to use the application after the test period, with one participant stating: "*Absolutely, kind of sad that I can not keep on playing the game. It has given me a boost in motivation for running, and I think I am going to struggle to find new motivation to maintain the level*

of running exercise I have had during the test period". However, the answers varied when asked how they would use the application in the future. One of the participants that ran on hard difficulty stated that he would use the application to go for walks, but not for higher intensity running exercise as running on asphalt hurts his knees and back. Another participant also pointed out that she would like to use the application to go for walks. Her statement reflects this: "*Yes, I would especially use it to go for walks in my neighborhood. It is fun to have something that gives you new routes to walk, as I often find it boring to go for the same walks every time*". The last two participants stated that they would like to use the application for complete running exercises in the future.

26.7 Summary

This chapter presents qualitative and quantitative data collected from the applications database, interviews, observations, and questionnaires. All of the data presented focus on the effect of the application on the users' physical activity. This include raw data as well as a selection of data connections

27 Enjoyment

This chapter will present the results associated with On Fire's enjoyment, including data gathered from the post-test questionnaire, observations, and interviews.

27.1 Enjoyment statements

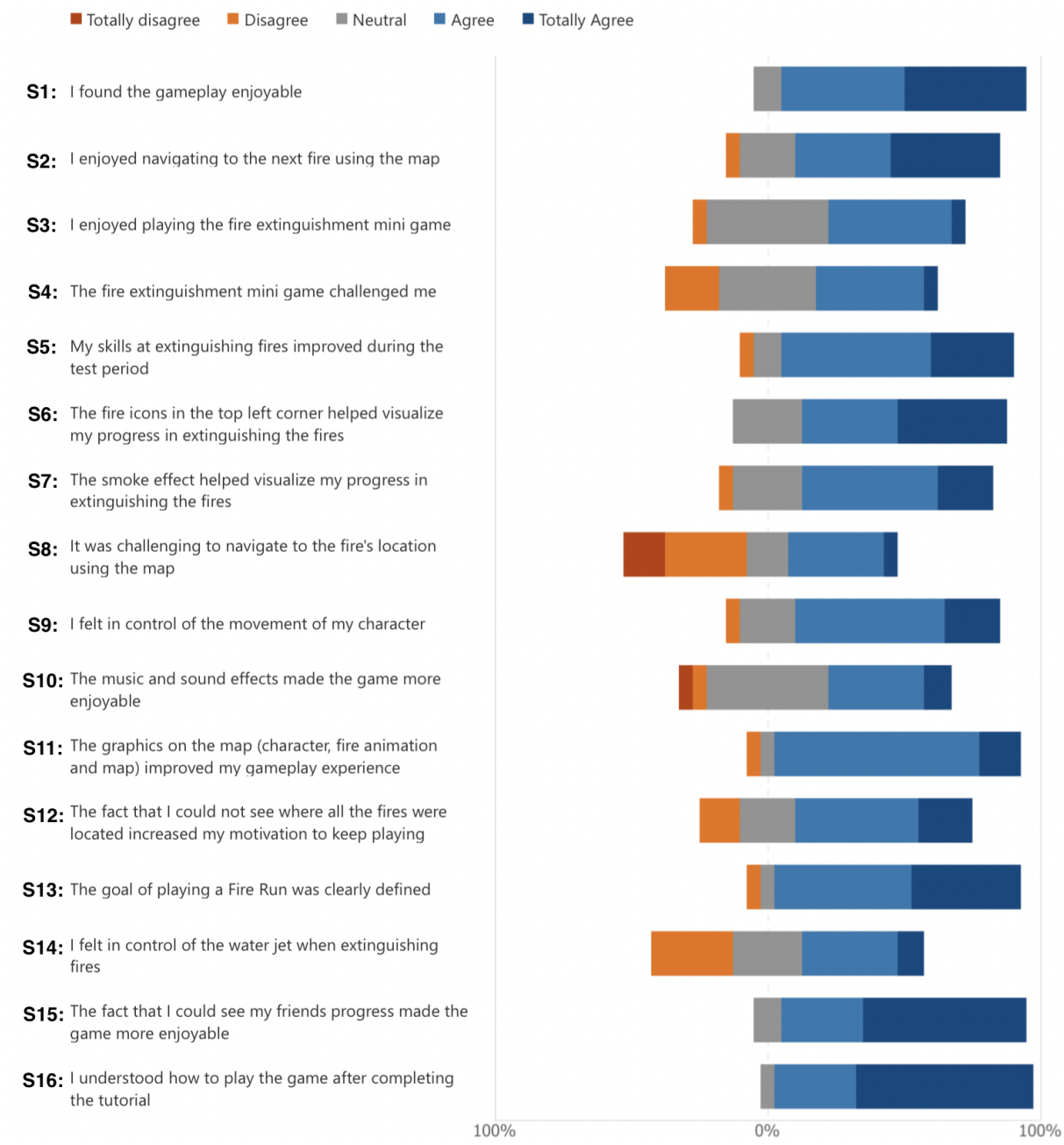

Figure 27.1: Enjoyment statements

Figure 27.1 visualizes the response distribution of the enjoyment statements in the post-test questionnaire, using *Likert's scale* ranging from "totally disagree" to "totally agree". It includes 17 statements, all stating different aspects of the game, to understand what contributed to the game's enjoyment. S1 reflects that most participants found the gameplay enjoyable, and the majority of the other statements mostly have positive answers. The statements that positively stand out by not having anyone disagree with them is S6 that reflect the importance of giving visual feedback in the form of the fire icons, S15 that indicates a strong social aspect in On Fire, and S16 that saw 95% of the users agreeing to understand the game after completing the tutorial.

However, some of the statements also had a significant amount of users disagreeing. S8 is the statement that received the most disagreements, which indicates that it was not as challenging to navigate to the fire's location as other parts of the gameplay. The second most disagreed statement is S14, highlighting an issue with controlling the water jet in the fire extinguishment task.

27.2 Quotes

The post-test questionnaire also included two open-ended questions, asking the participants what they enjoyed the most and least. A selection of the participants' answers to these questions are listed below:

Which part(s) of the application did you enjoy the most?

- *"To navigate using the map. It looked really nice (reminded me of Pokemon GO), and it was fun to plan out the best route to the fires. I also really enjoyed fighting for the top position on the leaderboard and unlocking new equipment."*
- *"I was really impressed with the mechanics and the graphics. That was really nice."*
- *"The game made the local community more motivating to explore. You walked several km without thinking that you did it in an environment, you would not normally have walked that much."*
- *"To compete against my friends! It was fun to have something to do together despite*

the fact that we lived far apart. I experienced it as a fun competition."

- *"The time aspect of the game, where you have to complete the task before the time runs out."*

Which part(s) of the application did you enjoy the least?

- *"The mini-game was alright, but extinguishing the fires became slightly monotone."*
- *"The fire extinguishment mini-game had a few bugs making it hard to hit the fires."*
- *"Some of the fires were far apart (25-30 minutes between the fires on easy-short), and the map could be a bit indistinct in residential areas with many similar homes."*
- *"That you can not play 2 and 2 together! It would have been fun to run with others too."*
- *"That you sometimes got a flame from where you just had been. It would motivate more if the fires could be picked in a circle."*

27.3 Additional enjoyment data

This section presents some additional data gathered from the post-test questionnaire associated with On Fire's enjoyment.

27.3.1 Difficulty and duration

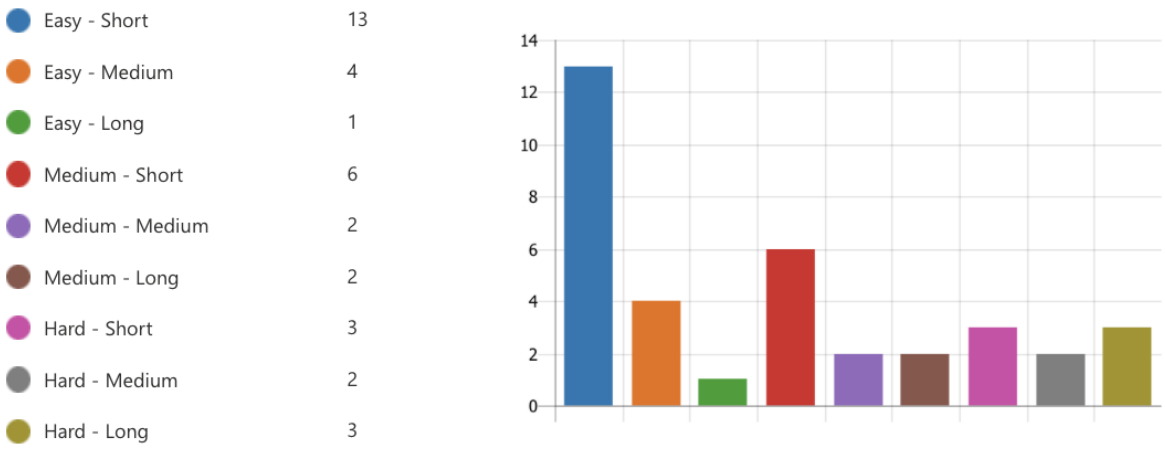

Figure 27.2: Most enjoyable combinations of difficulty and duration

The post-test questionnaire also collected data about which combination of duration and difficulty the participants enjoyed the most. This was a multiple-choice question where each participant could choose 1-3 alternatives. Figure 27.2 visualizes the selection of combinations, showing that 13 participants have included the easy short combination in their selection. Analyzing each individual answer produced the following percentages of durations and difficulties included in the participants' selections:

- **Short duration:** 85%
- **Medium duration:** 35%
- **Long duration:** 15%
- **Easy difficulty:** 70%
- **Medium difficulty:** 40%
- **Hard difficulty:** 25%

27.3.2 Social

14 participants added at least one friend during the experiment, and three of them also added new friends found by looking at the leaderboard.

27.3.3 Tutorial

S16 in Figure 27.1 shows that 95% either agreed or totally agreed to them understanding how to play the game after completing the tutorial. The participants were also asked if they did not understand any parts of the game, where all 20 participants answered no. However, three mentioned that they had to replay the tutorial at a later stage

27.4 Observations

When observing the participants playing a game of Fire Run, several strategies and patterns emerged. Every single participant had a similar approach when navigating to a fires' location. First, they took some time to figure out where the fire was located and plan a route to this location. After this, every participant closed their phone before running to the next fire (see Figure 27.3). Some even put it in their pocket while running. Every participant also opened the application from time to time to check whether they

were heading in the right direction.

Another common factor amongst the participants was that they started trying to press the fire on the map to start the fire extinguishment task when being too far away to do this. The participant then continuously pressed the icon while moving closer to the location.

Figure 27.3: Participant running

Figure 27.4: Participant at the location

Some participants spent conciderably more time orienting the map to determine where the fire was located, but no one was unable to find the fire's location. During the observations, it also became clear that some of the participants struggled with the sensitivity of the fire extinguishment controls (see Figure 27.4).

27.5 Interviews

This part will present answers received to the questions about On Fire's game enjoyment in the interviews. The first of these questions asked the participants which elements of the game that they enjoyed the most. Three of the participants replied that they enjoyed navigating to the next location the most and that it was especially enjoyable to try to

find the optimal route. Some participants also added that it was exciting to see where the subsequent fire was located. One participant also stated that the exercise produced by On Fire was perceived as less tedious than running on a treadmill, while still having the same level of intensity.

The second question asked the participants if they felt in control of their actions when playing a Fire Run. All of the participants initially answered yes to this question, but some had additional comments with requests regarding the game's controls. These included having the On Fire map automatically rotate to match the direction that the mobile device is facing to make the orientation easier, especially in urban areas where many buildings and streets look the same. Another comment highlighted that the controls became increasingly difficult as the screen became wet when playing in poor weather.

The third and final question asked if the participants had any struggles with the app. All of the participants reported that they had some issues with the fire extinguishment task. An example being one participant stating: "*Had some initial struggles with the controls when extinguishing the fires, but I am used to them by now. The fire extinguishing is also harder with a higher heart rate because my hands are shaking a bit*". The interviews also uncovered another issue as one of the participants played with the dark map theme on a sunny day. He stated: "*I played with the dark map theme on a very sunny day, and it was very hard to navigate because I could not see all the roads and buildings. I had to look at the map in the shadows to see clearly*".

27.6 Summary

This chapter has presented qualitative data from the observations and interviews, and quantitative data from the post-test questionionaire. This data is all associated with On Fire's enjoyment.

28 Motivation and engagement

This chapter will present the results associated with On Fire's motivation and engagement, including data produced by the post-test questionnaire and interviews. The observation data generation method will be excluded from this chapter as it is not possible to accurately observe the participants' motivation to play the game.

28.1 Motivation statements

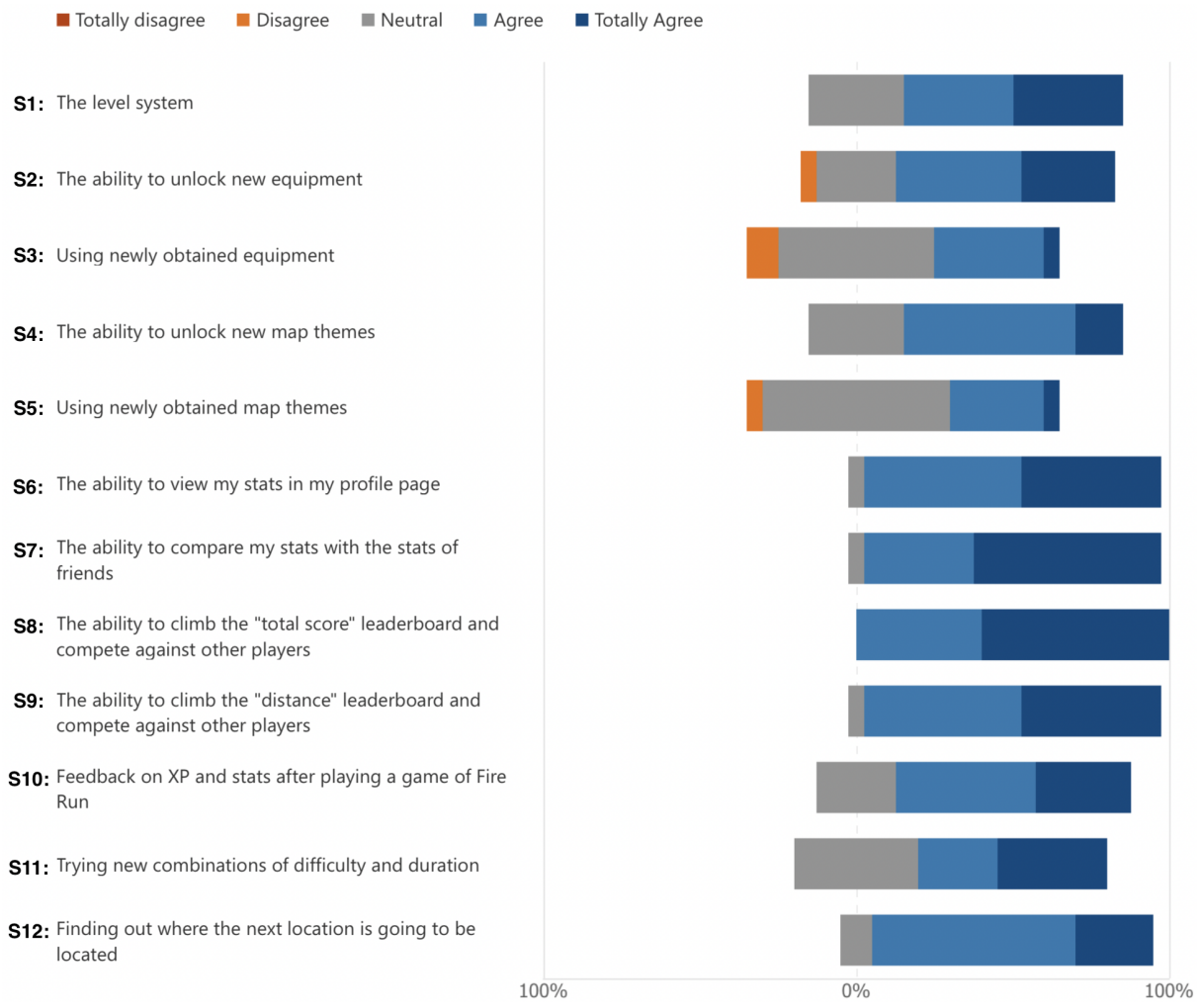

Figure 28.1: Motivation statements (... motivated me to keep playing)

The participants answered whether they agreed or disagreed with if the statements listed in Figure 28.1 motivated them to keep playing the game. Figure 28.1 also visualizes the response distribution to each statement. It includes statements about the leveling system, social aspects, feedback, and world exploration. The majority of the responses are

positive, with very few disagreements. By looking at the responses to statements S6-S9, it becomes apparent that viewing your stats and competing against other players using these stats was a significant motivational factor as most of the participants agreed or strongly agreed to these statements. Statements S1-S5 focus on the motivation provided by the leveling system. Although receiving very few disagreements, these statements have significantly more neutral responses than the statements focusing on the social aspects.

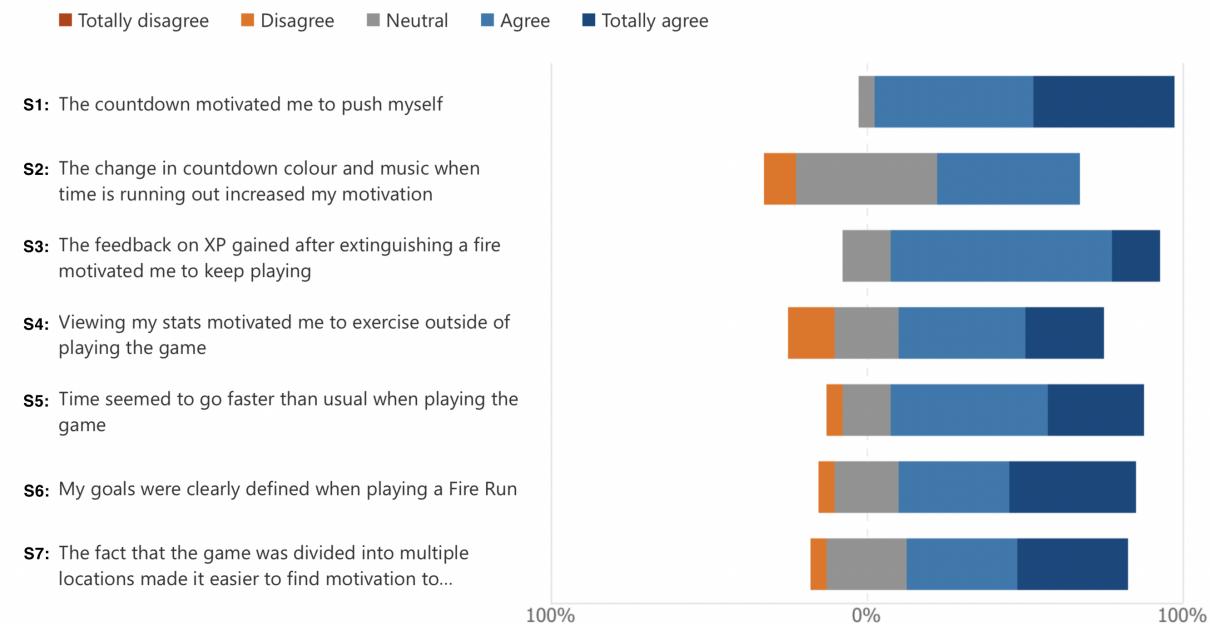

Figure 28.2: Additional motivation statements

Figure 28.2 illustrates the response distribution to some additional statements regarding the participants' motivation to play and to increase their performance. These statements cover aspects as the countdown, change in music, and progress feedback after each fire extinguishment. Similar to Figure 28.1 the responses to the statements are primarily positive, with few participants disagreeing. S1 and S3 received the highest degree of positive feedback. These responses indicate that the feedback on time left through the countdown timer and the feedback on progress during games was crucial for motivating the players. Contrarily, S3 received the most negative response. This response highlights that the change in countdown color and music had little effect on the players' motivation.

28.2 Quotes

The post-test questionnaire included an open-ended question, asking the participants what elements of the application motivated them the most to play the game. A selection of these answers are listed below:

What element(s) of the application motivated you the most to play the game/exercise?

- *"To fight for a top position at the leaderboard! I had to check several times each day to see if the others had overtaken my spot. My goal was to unlock the foam equipment, which felt really rewarding to unlock just before the test period finished."*
- *"The leaderboard motivated me the most because you could see when other people had run and compete against them."*
- *"The Countdown in the corner while playing motivated me. Also being able to check other people's statistics and distance did also motivate me."*
- *"The competition against friends! It made me go out to play the game even though I did not want to exercise!"*
- *"Getting XP and as low time as possible motivated me the most."*

Ten of the participants mentioned that the leaderboard(s) motivated them to play the game in their response.

28.3 Interviews

The interviews only contained a single question about motivation, asking the participants what their primary motivation for playing On Fire was. Every participant identified the leaderboards as their primary motivation for playing the game, where the XP leaderboard seemed to be particularly motivating for the participants playing on higher difficulty levels. Several participants also said that comparing stats with friends was motivating, as it became an internal competition. This is reflected by the statement made by one of the participants: "*Me and a friend of mine, who was also taking part in this test period, have a competition to beat each other. He has almost 4000 more XP than me, so I have to step up my game this last week!*". The majority of the participants also said that the

exercise effect of playing the game was motivating in itself, especially running outside when the weather was nice. Some participants also identified the leveling system and unlocking new equipment as motivating factors.

28.4 Summary

This chapter has presented the results associated with the motivation to play On Fire, which includes quantitative data from the motivation statements, quotes gathered from the post-test questionnaire, and qualitative data from the interviews.

29 Additional results

This chapter will present some additional results gathered from the post-test questionnaire and interviews. It will include technical problems, cheating, external factor, and the extent of the Hawthorne effect.

29.1 Technical problems

The post-test questionnaire included the question: *"Did you experience any technical problems?"*. Seven said that they had experienced some sort of technical problem. When elaborating about their issue(s), most mentioned a bug in the fire extinguishment mini-game or occasional crashes when the game ran as a background task. One participant also mentioned that a completed Fire Run game did not get registered. This bug was later resolved and fixed during the test period.

29.2 Cheating

Two of the participants expressed that they had been cheating when playing Fire Run. One of them used a bicycle when navigating instead of running and explained it was because of an injured knee. The other described their cheating as an unintentional exploit of a bug, where it was possible to extinguish the first fire from the starting point. However, this bug was also quickly fixed during the test period.

29.3 External factors

Some participants expressed that they had been ill, injured, or that some other factors prevented them from playing Fire Run as much as they would like to. Among these factors, poor weather was mentioned the most. One of the participants also mentioned exams and school work as a factor in why he did not play as much as he wanted. The amount of different mentioned external factors are:

- 4 illness
- 3 injuries
- 11 poor weather

- 1 exam/schoolwork

29.4 Hawthorn effect

The four test subjects participating in the observation were asked about how it felt to be observed and if it affected their performance in any way. This was a measure taken to be aware of the extent of the Hawthorne effect. All participants expressed no issues about being observed, and one of them even said he completely forgot about it. Another mentioned that the effect was low because she knew the observer, and it would have been different if she did not know him. Three out of the four expressed that the observation did not affect their performance and one even stated: *"I usually run at my highest pace, so I do not feel the observation affected my performance"*. However, one of the participants said that the observation affected him to run a bit faster than normal.

29.5 Summary

This chapter has presented additional results from the experiment, focusing on technical issues, cheating, external factors affecting the application usage, and the Hawthorn effect.

Part VII

Discussion and Conclusion

This part will discuss the research question based on the findings made in this master's thesis. The discussion will further be used to conclude these research questions and the overall research goal. Additionally, potential further work will be presented.

30 Discussion

This chapter will discuss the research questions presented in the introduction.

30.1 Research question 1

RQ1: *How to make an exergame physically demanding while still being enjoyable to play?*

This research question highlights two important and enabling factors for exergames to contribute to the players' physical health: making the game physically demanding and enjoyable to play, to ensure the players continue to play and exercise regularly. The research question is divided into two parts: How to make an exergame enjoyable and how to make it physically demanding without harming the enjoyment. GameFlow, Malone's Fantasy, Challenge, and Curiosity, and DualFlow are all theories of enjoyment that present different important game design principles to make a game enjoyable. These theories were found and researched when conducting the literature research in the prestudy.

GameFlow is used to evaluate and design enjoyment in games and includes eight elements, each derived and somewhat related to Cziksentmilalyi's Flow elements. According to the GameFlow model, games must have a clear goal, giving them a reason to spend their time and to make an effort. The game should also grab the player's attention quickly and maintain their attention and concentration throughout the game. The players must be allowed to feel a sense of control over their actions and be aware of their progress and performance through different means of feedback. Games should also provide a platform for player-to-player interaction in the form of competition, cooperation, or connection.

Malone's Fantasy, Challenge, and Curiosity model describes that triggering the players' sensory and cognitive curiosity is essential for creating an engaging and enjoyable game. Cognitive curiosity is the motivation to structure their knowledge, and it can be triggered by introducing randomness and hiding information. Sensory curiosity involves different sensory stimuli from the game environment, often through sound and visual effects to enhance the players' fantasy and immersion. Provoking the players' fantasies is another crucial aspect to keep the player engaged within game sessions. Malone distinguishes

between intrinsic and extrinsic fantasies. Intrinsic fantasies, is when the player's skill and fantasy depend on each other, and extrinsic fantasies depend on whether the skill is used correctly.

One of the most important principles mentioned by all three theories is the provided challenges. The provided challenges should be connected to a goal, balanced with the players' skill level, and follow the players' skill development. This aspect applies to both the gameplay challenges and physical challenges, which is also the emphasis of the DualFlow model.

The Dualflow model is a framework constructed for optimizing and evaluating exergames. It consists of two interrelated dimensions of an exergame: its attractiveness for engaging and motivating the player to keep playing and its effectiveness of the exercise. The attractiveness dimension emphasizes the balance between challenge and skills and describes that psychological Flow is achieved when the game balances the perceived skill and perceived challenge appropriately. The effectiveness dimension highlights the importance of balancing the intensity of the exercise with the player's fitness to allow the player to reach a physiological flow, avoiding the players to enter a state of deterioration or feeling of failure.

30.2 Research question 2

RQ2: *How to develop a new exergame concept that contributes to improved physical health for its users?*

A part of this project's purpose and overall research goal was to develop a new exergame concept that improves the physical health of people lacking the motivation to stay physically active, and research question 2 highlights the challenge of this. From utilizing the study mentioned in RQ1, taking advantage of the technological possibilities, and taking inspiration from previously successful exergames, the concept of On Fire emerged.

When designing an exergame concept, it is essential to create a game concept that motivates physical activity. An excellent tool for this was to utilize existing knowledge about how to make a game engaging and enjoyable to ensure player retainment. This was done by actively using the theories of enjoyment when designing the game concept. DualFlow, which is a framework constructed for optimizing and evaluating exergames, is an excellent example.

Another key factor was to research previous successful exergames and their physical effect. A wide variety of exergames was explored, from Dance Dance Revolution, being one of the earliest ones, to Ring Fit Adventure, which was just released. This provided great inspiration and an understanding of what has previously contributed to their success. Pokemon GO and Zombies, Run! was significant sources of inspiration when designing the concept of On Fire, as Pokemon Go has shown to contribute significantly to people's physical health and motivation (Wang, 2021).

It is also important to take advantage of the technological possibilities when designing a new exergame concept. A wide variety of technologies has been used in the history of exergames, and new and exciting possibilities emerge from technological development all the time, for example, motion controllers, VR, AR, and other alternative controllers. Smartphones have also become a platform fit for games because of their powerful hardware, operating systems, big screens, and built-in sensors. Many recent successful exergames such as Pokemon Go, Zombies, Run!, and Run an Empire have taken advantage of this evolution. The On Fire concept did also take advantage of this as it was designed to be developed for mobile phones and to utilize location-aware technology to control the game, similarly as in Pokemon Go.

30.3 Research question 3

RQ3: *How to implement the exergame with satisfactory performance and usability, using existing technologies and methodologies?*

Before starting the implementation of the On Fire exergame concept, it was essential

to find and review relevant technologies. The prestudy had already researched potential technologies, some of which could be used to implement On Fire. One of the technologies chosen from this is the Google Maps Platform, used in both the client and server application. This platform provided proven technologies that helped raise the performance and usability of the application. The Maps SDK provided the map that the player used to navigate, which was also used to make the map in Pokemon Go. Using this increased On Fires usability, as several players had previous experience with Pokemon Go. The other technologies used, such as Unity and Firebase, were chosen based on previous experience and research. The technology review tested all of these technologies to ensure that they were a good fit for their purpose. This was beneficial as the group could be confident that the planned technology would work together, with minimal risks of unforeseen problems with interoperability.

After deciding which technologies to use, the group defined the functional- and quality attribute requirements. The functional requirements focus on what functionality the application should include and give each requirement a priority ranging from high to low. The quality attribute requirements focus on non-functional requirements such as usability, performance, and modifiability. After this, the group developed an architecture that would help meet the requirements. This architecture utilizes several patterns, all of which the developers had previous experience implementing. The first pattern is the Client-Server architecture, which separates different parts of the code by placing it in the client and server. This pattern helped increase the performance of the application by running resource-demanding code on the server. This both decreased the time needed to run the code and most likely lowered the battery usage of the mobile device, which is crucial for mobile games. The second pattern used is Database-as-a-Service (DBaaS), which utilized a NoSQL database running on Firebase Cloud Firestore. This further increased the application's performance by giving the client read and writing access to the database to store simple user data, as well as providing offline data persistence. The architecture also used several other patterns such as the model view controller (MVC), singleton, template method, and sequential game loop.

After determining the architecture, the implementation could begin. It was crucial to use a solid development methodology to ensure that the application would meet the requirements and have good usability and performance. Based on previous experience within software development, the group started by making a wireframe of the application's user interface. The group performed user tests with the wireframe through several iterations to ensure the usability of the application's user interface. When these tests reported that the user interface had a satisfactory level of usability, the programming of the application began. The testing and wireframing were beneficial for ensuring the application's usability, but the group could have performed additional iterations to further improve the usability.

The group used the Scrum framework during the development to organize the tasks and ensure progress. Based on the fact that only two developers worked on the prototype, some elements of the Scrum framework became redundant. However, the Scrum elements used were very beneficial when implementing the On Fire exergame concept, especially the Trello kanban board. The agile nature of the workflow provided by Scrum has been a vital resource for ensuring constant production and efficiency during the development process.

30.4 Research question 4

RQ4: *How do the theories of enjoyment contribute to the players' motivation, engagement, and enjoyment of the exergame?*

The theories of enjoyment were actively used in designing and implementing the concept of On Fire. All implementations of these theories were tested through the data generation methods in the experiment. This section will use the data and results from these data generation methods (presented in Part VI Results) to discuss research question 4.

30.4.1 Control

As On Fire is a location-based exergame, controlling the in-game character by moving in the real world. Thus, the game must be responsive and accurate to the player's movement to give the player a sense of *control*, which also applies to the control element of GameFlow. The players' feeling of control was tested in the post-test questionnaire, and 75% of the participants agreed or totally agreed to them feeling in control of their character. This gives reasons to believe that implementing similar controls as in Pokemon Go and using Google Maps Gaming Services have contributed and given the player a feeling of control when navigating using the map. However, the results about controlling the water jet in the fire extinguishment mini-game varied some more. 45% agreed or totally agreed to them feeling in control of the water jet, while 30% disagreed and 25% were neutral with the statement. Quotes from the post-test questionnaire and interviews identify this part of the application as troublesome. When asked about which part of the application they enjoyed the least, one participant stated: *"The fire extinguishment mini-game had a few bugs making it hard to hit the fires."*. This indicates that the lack of feeling of control in the mini-game could hurt the game's total enjoyment.

30.4.2 Goal

On Fire's *goal* is defined as: *"To protect your city from an increasing number of fires and to rank up to become the fire chief."* The goal was integrated into the tutorial, and the progress towards this goal was illustrated as a ladder of levels on the progress page. 90% of the participants agreed or totally agreed with the game having a clearly defined goal, which is, according to the GameFlow model, essential to give the players a reason

to spend their time and effort in the game. The goal of Fire Run is to extinguish all provided fires and is further structured into multiple levels of sub-goals by only providing the players with one fire at a time. Malone argues that having multiple levels of sub-goals is a way to make the game experience more uncertain for the players, triggering their curiosity and motivation to play. This was also confirmed in the experiment, where 70% agreed or totally agreed with the fact that the game was divided into multiple locations made it easier for them to find the motivation to complete the game.

The implemented level system also divides the game's overall goal into multiple sub-goals, rewarding the player as they rank up. These rewards included new equipment for extinguishing the fires and new map themes. No participant had a negative perception of the level system feature, and 70% agreed that it motivated them to keep playing the game. Statements regarding the ability to unlock new equipment and map themes had similar response distribution. However, the majority were neutral when asked if using the rewards motivated them. A reason for this may be that just a few participants unlocked new features in the test period. The level system should have been better adjusted to the short period of the test so that it was more manageable to unlock at least one new equipment and one new map theme. Nevertheless, the statements still leaned toward agreeing for most of the level system. Based on the answers from the statements above, the use of clear goals, rewards, and sub-goals gave the player a feeling of success and helped motivate them to play the game.

30.4.3 Social interaction

Different aspects of *social interaction* were implemented in the game, the biggest one being the ability to add new friends, allowing the players to follow each other's progress and compare themselves with each other. This feature was realized to be a significant contributor to the participants' enjoyment, engagement, and motivation. 90% answered that the fact that they could see their friends progress made the game more enjoyable, and a total of 95% agreed that the ability to compare themselves motivated them to keep playing the game. Other implemented competition-driven social aspects is the global score and distance leaderboards, which scored very high on motivation. 100% agreed or totally agreed that the ability to climb the score leaderboard motivated them, and 95%

agreed or totally agreed that the ability to climb the distance leaderboard motivated them. Similar results have been found in Wang and Lieberoth (2016) research of Kahoot, which presented that the point system and leaderboard had a significant positive effect on players' enjoyment, engagement and motivation. The leaderboards were also mentioned in 50% of the answers when asking what part of the application motivated them the most. Similar findings were also found during the observations and interviews. The first thing one of the participants did after finishing his game was to check the leaderboard. When asked about his motivation to play the game during the interview, he said: *"My main motivation for playing the game is to climb the total XP leaderboard. I am really pleased with myself after climbing two positions and reaching third place after this game session."*. The social aspects of On Fire have been revealed to create a social community around the game, strengthening the enjoyment, and be a significant contributor to the players' motivation.

30.4.4 Feedback

The GameFlow model argues that providing *feedback* is essential for the game's enjoyment. Therefore, multiple means of feedback were implemented, for example, feedback on XP and statistics after playing a game of Fire Run, in which 75% of the participants agreed or totally agreed to contribute to their motivation to keep playing the game. The game also provided feedback on XP gained after extinguishing each fire, which received an even higher score, where 85% either agreed or totally agree with it motivated them to play. Additional feedback was also implemented to let the player know their progress and performance during a game of Fire Run. The countdown timer was revealed to motivate the participants to push themselves physically while playing. 95% of the participants agreed that this feature motivated them, and a participant even mentioned it as the game's biggest motivator. The participants mostly agreed to the fire icons in the top right corner, and the smoke effect when hitting the fire with the water jet helped visualize their progress on extinguishing the fires. The results give reasons to believe that the provided feedback has been a success and a significant contributor to the participants' motivation and enjoyment.

30.4.5 Immersion

The *immersion* aspect from the GameFlow model was initially stated in the Chapter 16 to be less relevant as the players must be constantly aware of their surroundings when playing. However, 80% of the participants agreed to the statement: *"time seemed to go faster than usual when playing the game."*. 55% did even agree that they forgot that they were exercising while playing the game, indicating that the immersion effect was more present than anticipated. Some reasons for this could be the strong connection between the exercise and gameplay, the use of music, sound effects, and visual effects.

30.4.6 Challenge

One crucial aspect in designing and evaluating games mentioned by GameFlow, DualFlow, and Malone's Fantasy, Challenge, and Curiosity is the provided *challenges*. A game of Fire Run primarily includes two challenges; it requires the player to use logical and navigational skills to plan an optimal route, and the other is to control the water jet to extinguish the increasing fires. The level of challenge in Fire Run is primarily determined by the player's difficulty and duration selection and thus the physical challenge. A higher difficulty results in having less time to navigate, relocate and extinguish the fire. The participants perceived challenges were tested in the post-test questionnaire. 40% agreed that they found it challenging to navigate using the map, while 45% disagreed. A reason for the wide response distribution may be that the easy difficulty was the most popular one, which gave the participants more time to navigate to each location. The participants who played on medium or hard most likely found this feature more challenging as they had less time to navigate. An example of this was seen during the observation of the participant playing on medium difficulty. The participant navigated wrong at a location but realized this quickly. It resulted in her picking up the pace for a while to compensate for the lost time. She also later stated that she enjoyed the navigation part of the game, even though it was challenging. 75% of the participants agreed or totally agreed that they enjoyed the navigation challenge. Statements regarding the challenge of fire extinguishment received a different score. 45% agreed or totally agreed to the fire extinguishment mini-game challenged them, 20% disagreed, and 35% were neutral. Only 50% agreed to have enjoyed the fire extinguishment, which is probably because of a reoccurring bug when controlling the water jet.

Malone also argues that introducing *randomness* and *information hiding* to the challenges will make the game experience more uncertain for the players and provoke their curiosity. Randomization was implemented in the game by randomly selecting the locations that the player must travel to in a game of Fire Run received from Google's Playable Locations API. This feature received primarily positive feedback, and some stated that they enjoyed the variations of locations and exploring their local community. 90% agreed that finding out where the next fire is located motivated them to keep playing the game. However, the randomness could also result in running back and forth between locations, which a few participants mentioned when answering what they enjoyed the least. The randomness of locations worked as intended in most cases, triggering the players' cognitive curiosity. Still, the randomness could have been constrained to prevent running back and forth and other predictable patterns.

The effectiveness dimension in the DualFlow model highlights the importance of balancing the intensity of the exercise with the player's fitness. Fire Run was intended to have the intensity dynamically adjusted based on the player's performance but this was not implemented due to the short development period. Instead, the players could choose the difficulty and duration of their sessions themselves, which allowed them to experiment to reach their physical flow. This feature received good feedback, and a participant stated: *"I like the fact that you can choose the difficulty to regulate the intensity of the workout"*. 80% of the participant also agreed to them getting a good running exercise from playing the game. The user participating in the observations were asked about how they perceived the physical aspect of the game in the interview to see if the players were able to reach physical flow. One said, *"The game provides me with intense exercises and a rewarding feeling when I am able to push myself to finish a game"*, this indicates that the participant was physically challenged and achieved physical flow. Another users shared this point of view, which is reflected by the statement: *"I find medium difficulty it to be really adapted to my physical fitness, not too easy and not too hard"*.

30.4.7 Curiosity

Information hiding was implemented as a tactic to trigger the players' *cognitive curiosity* and provide uncertainty to the challenges. This was done in multiple ways, for example, by not revealing the locations and countdown times in a game before the player had completed the preceding location. Multiple participants mentioned this as a significant contributor to their motivation and enjoyment in the post-test questionnaire and interviews, and 90% agreed that finding out where the next fire is located motivated them to keep playing the game. No participant disagreed, and the remaining 10% were neutral to this feature, which indicates that this feature worked as intended. The game did not reveal any information about how the unlockable equipment and map themes worked or looked. This did not have as much of an effect as the hiding of locations. A reason for this could be that just a few participants unlocked the equipment and map themes during the test period.

On Fire provided *sensory curiosity* by making the game's situations and tasks more realistic using audio and visual effects. 90% of the participants agreed or totally agreed to the graphics including the running character, fire animation, 3D map, and others improved their gameplay experience. Only 5% disagreed to this statement. A participant even stated: *"I was really impressed with the mechanics and graphics of the game"* when asked about what they enjoyed the most. 45% of the participants agreed that the music and sound effects made the game more enjoyable. 45% were neutral to the statement, and only 10% disagreed. The observation gave different results regarding music, where three out of four of the participants listened to their own music rather than On Fire's music, which indicates that the implementation of sound effects and music did not contribute as much to the enjoyment, immersion, and sensory curiosity as intended. However, On Fire provided sensory curiosity, enhancing the connection between the game and real-world locations.

30.5 Research question 5

RQ5: *Does the exergame have a positive effect on the players' motivation for- and level of physical activity?*

30.5.1 Exercise intensity

During the 19 day test period, the 20 test users ran a combined 295km using the prototype, averaging 14.8km per user. Each user also spent an average of 105 minutes playing the game. The intensity of the physical activity produced by On Fire is based upon the player's running speed. The minimum required running speed is determined by the chosen difficulty. The easy difficulty requires walking (5km/h), medium requires a slow jog (7km/h) and hard requires running (10km/h). Although 60% of the games were played on easy difficulty and only 11% on hard, some kept a higher tempo than required by their chosen difficulty. This is supported by calculating the average running speed to be 8.5km/h based on average minutes spent running and distance traveled. This is somewhere between the pace required by the medium and hard difficulties.

It is possible to look at the observation performed on On Fire game sessions to indicate the average level of physical strain produced by a Fire Run, assuming an average running speed of approximately 8.5km/h. When converting the average running pace from 8.5km/h to approximately 7:03 min/km, it becomes clear that this is between what was recorded in observation 2 (see Section 26.5.2), which is 6:25 min/km, and observation 3 (see Section 26.5.3), which is 08:53 min/km. The average heart rate recorded from these observations is 168 bpm and 164 bpm. This implies that the average heart rate, for most of the test users in their 20's, most likely is in the range of 160-170 bpm. Assuming a heart rate max of approximately 200 for these users, it would place this average heart rate in the Hard heart rate zone, which equals 80-90% of heart rate max (160-190 bpm). Polar describes the effects of this level of cardiovascular exercise as: "If you train at this intensity, you'll improve your speed endurance. Your body will get better at using carbohydrates for energy and you'll be able to withstand higher levels of lactic acid in your blood for longer." (Polar, 2021, p.1).

30.5.2 Exercise effect and variations

The observations and interviews provided qualitative data about the applications' physical effects on the players during and in-between game sessions. All of the different difficulty levels were tested during the observations, giving insight into the different intensity levels that the application can provide. The heart rate sensors used during the observations provided graphs on both the heart rate and cadence (steps/min) throughout the game session. By comparing these graphs for each observation, a clear connection between the cadence and heart rate can be observed. When the cadence goes down close to zero, which means that the participant has stopped moving to extinguish a fire, the heart rate starts to decrease. On all of the observations, the heart rate decreased until the participant began running again, and the cadence increased. The connection between cadence and heart rate is especially prominent for the observations on higher difficulty levels. The increased correlation between cadence and heart rate on higher levels is most likely because these difficulties create a higher heart rate when running. This heart rate and cadence pattern indicate that On Fire successfully creates an interval running exercise when playing the game, especially on greater difficulty levels.

The two observations on hard difficulty had participants that regularly run and reported weekly exercise hours above the recommended minimum amount of moderate physical activity. Both participants spent most of the Fire Run above 80% of heart rate maximum, indicating a high-intensity running exercise. This proves that the application can provide high-intensity training for players who regularly exercise and perform running activities. This is also reflected by both participants stating that the hard difficulty offers an intense workout suitable for their physical condition during the interviews conducted after the observations. The observed Fire Run on medium difficulty was performed by a participant with physical activity levels below the recommended amount and who does not regularly run. The heart rate graph of this participant shows an average heart rate close to what was recorded on the high difficulty, but with more of the heart rate within 80-90% of heart rate max. This participant stated that she had started to run regularly using the app and that On Fire has increased her motivation to exercise, especially running. This is a strong indication that On Fire successfully adapts its required physi-

cal activity level to motivate users within a wide range of previous physical activity levels.

Users also seemed to like the fact that you could adjust the physical strain of the workout by changing the difficulty, with one statement saying: "*The different difficulties really fitted my pace. Hard when I wanted to run, medium when jogging, and easy if I wanted to go for a walk. I also really enjoyed that the game provided different running routes each time, giving my running exercises a bit of variety*". This indicates that users not only used the application for high-intensity training and that it could also be used to spend time in moderate physical activity. The physical effects of this kind of moderate activity can be seen in observation 4, which was conducted on an easy Fire Run. The participant in this observation struggled with a sprained ankle. She used On Fire as a tool to rehabilitate it with walks around the city. Despite moving at a considerably slower pace than the other observation and in lower heart rate zones, the participant burned more calories than observed at the hard difficulties.

30.5.3 Effect on subgroups

To further investigate the difference in the physical activity effect of On Fire on different subgroups of the test population, both the distances ran, and responses to statements were analyzed for select subgroups. The first of these divided the test population into those who play a lot of video games (6+ hours a week) and those who play a smaller amount of video games (less than 6 hours a week). A statistically significant difference between the distance run using the app was discovered for these two groups. Those who play less video games ran on average 10.9km using the app, and those who play more video games running an average of 20.6km. This is a clear indication that this kind of exercise may be more appealing to gamers, as their joy of playing video games can be used to motivate them to exercise. Similar results have been found in Wang and Skjervold (2021) research of Pokemon Go, which presented that Pokemon Go players got a more significant positive physical effect the more video games they had reported playing before playing Pokemon Go. Statement S2 in Table 26.1 also showed a statistically significant difference, where those who play more video games agreed to a greater extent when asked if they got a good running exercise from using the app. Statement S1 and S4 further indicated that the participants who regularly play video games were more motivated to

exercise by On Fire and more inclined to replace traditional running exercise with the app.

The second subgroup focuses on dividing the users into those considered physically active and those who are not. Physically active test users exercise three or more hours a week, while physically inactive users exercise less than this. When looking at the distance ran using On Fire, the inactive users ran an average of 24km, while the active users ran an average of 10.9km. This difference in running distance between these groups proved to be statistically significant. The fact that those who are considered physically inactive ran on average 24 km within 19 days is a strong indication that the On Fire concept may help those who struggle to find the motivation to exercise to become physically active.

On the other hand, the application did not seem to have as big of an impact on the people who are already physically active. When researching the physical effects of Pokemon Go, Wang and Skjervold (2021) found similar results. Their research found that users in the Low category of physical activity before playing Pokemon Go had a considerably higher increase in physical activity than those in the Medium and High categories. A possible explanation for the difference in On Fires' effect on physical activity between these two groups is that the physically active participants already have established workout routines and are less likely to substitute these with On Fire. However, several users with established workout routines stated that they found On Fire to be a refreshing addition to their exercise, which is reflected by the statement: "Fire Run gave me some extra exercise in addition to my routine training, it made me active in periods where I would otherwise be inactive".

Statement S4 in Table 26.2 backs up this assumption by finding statistically significant differences in the answers given by the two groups when asked if they would use On Fire instead of traditional running exercise. Where those who are inactive agreed to a greater extent. Statement S1 and S2 also had higher averages for the inactive users, indicating that they were more motivated to exercise by On Fire and perceived the exercise produced by the application as better than those who are physically active.

30.5.4 Changes in motivation and physical activity

The data collected also measured the change in physical activity from before the test period to during the test period. Out of the 14 participants who did not experience injury or illness during the test period, 65% increased their weekly exercise amount, with only 21% of users decreasing and 14% of users reporting no change. Those who experienced decreases in exercise amount exercised more than 7 hours per week before the test, making it likely that their decreasing exercise amount is not due to On Fire as it has proven to have less effect on those who are physically active. One of the most noticeable effects on exercise amount is that the percentage of participants considered physically active increased during the time they used On Fire, going from 64% before the test to 78% during the test period. These results strongly suggest that On Fire has helped increase the exercise amount for those considered inactive.

Statements S1 and S2 in Figure 26.13 and Figure 26.14 also collected data about the participants' motivation for physical activity and satisfaction with the intensity of their workout sessions. S1 asks the participants if they struggle to find the motivation to exercise, to which the median value of the answers given was agreed before the test period. However, when responding to the same statement during the test period, the median value changed to disagree. This change was confirmed to be statistically significant, making this a vital result suggesting that On Fire helped motivate the participants to exercise. S2 also reflects positive changes in the participants' answers. The median value of the answers is neutral when asked if their workouts are as intense as they would like before the test period. After the test period, the median value changed to agree. Performing a Mann-Whitney test also proved this change to be statistically significant, proving that most test users became more pleased with the effectiveness of their exercise during the On Fire test period. This result is most likely connected to the fact that 65% of the test participants reported that their exercise amount was closer to their ambition during the test period. With most users agreeing to statement S2 and thus being more pleased with the intensity of their workouts, their need for more hours of exercise may decrease.

31 Conclusion

This project aims to develop and evaluate a new exergame that will contribute to better physical health, especially for those struggling to find the motivation to be physically active.

To make an exergame that is physically demanding and enjoyable to play, it is essential to utilize the existing theories of enjoyment (RQ1). To successfully develop an exergame using these theories, it is vital to research and use aspects from previously successful exergames. Additionally, the exergame should use technologies that complement the concept to provide a good user experience and accurate detection of the users' physical activity (RQ2). When implementing the exergame concept, a suitable development methodology is essential. This project successfully did this by first performing technology reviews, developing functional and quality attribute requirements, and prototyping with user tests. Based on this, an architecture was defined utilizing well-known architectural patterns such as Client-Server, Model View Controller, and Database-as-a-Service. Finally, to effectively implement the application, the group used parts of the Scrum framework to organize the workload (RQ3).

GameFlow, DualFlow, and Malone's Fantasy, Challenge, and Curiosity were actively used when developing the concept and prototype of On Fire. The theories highlight the importance of sufficient challenge. Therefore, multiple features were implemented to balance and provide uncertainty to the challenges. The challenge of navigating and extinguishing the fires in Fire Run was determined by the player's difficulty and duration selection, which allowed the players to find their preferred combination and reach their physical flow. These features were tested and confirmed to contribute to the game's enjoyment and motivation. Additionally, the features for social interaction were identified as the game's most significant motivational factor. Other successful aspects contributing to the game's enjoyment, engagement, and motivation include feedback, control, cognitive curiosity, clear goal, and subgoals. 95% of the experiment participants agreed that the game was enjoyable, and 80% agreed that it motivated them to exercise. Based on these successful results, it is safe to conclude that On Fire is an enjoyable game, which also

motivates for physical activity (RQ4).

Considering On Fire's effect on the players' motivation for and level of physical activity, results show that 65% of the users increased their exercise amount, increasing the percentage of physically active users. There is also a statistically significant increase in the users' motivation for exercise and content with exercise intensity. Additionally, the estimated average heart rate experienced during a Fire Run is 80-90% of heart rate max, which is considered excellent cardiovascular exercise. The observations also reflects that On Fire provides a good exercise independent of running experience or physical shape, hard for experienced runners, medium for new runners, and easy for injury rehabilitation or walks. Additionally, statistically significant evidence proved that On Fire has a greater effect on both motivation for and level of physical activity for users who are considered physically inactive or regularly play video games (RQ5).

Based on the increase in motivation for and level of physical activity, it is concluded that On Fire successfully contributes to improving the physical health of its users by utilizing the theories of enjoyment, especially among those lacking the motivation to stay physically active.

32 Further work

On Fire has shown potential as an exergame, but just a limited prototype was implemented and tested due to time constraints. The concept can quickly evolve and expand to be a full-worthy exergame, and this chapter will go through what should be done next and some suggestions for new functionalities to improve the game's enjoyment.

The intended feature of dynamical adjustment of intensity to the player's performance level was not implemented in the prototype and should be implemented when developing it further. However, the game should also give the player the ability to override it and choose their difficulty, as this feature received very good feedback in the experiment. Cheating is a problem when developing exergames, which also is the case for On Fire. Therefore, measures for preventing cheating should be implemented, such as tracking movement speed to prevent players from using motorized vehicles like cars. It will also be implemented a variety of mini-game tasks other than extinguishing fires used in the prototype. The tasks should have a stronger connection to the location of the fire and utilize augmented reality to visualize the fires augmented in the real world to make the game experience feel more realistic and familiar. Other minor changes including improving the design, graphics, and sound are also important.

On Fire's social aspects were proven to be a massive contributor to the enjoyment, engagement, and motivation in the game. Multiple participants of the experiment also requested more social features for competing and cooperating. Some suggestions for additional social features are:

- Functionality for players to play Fire Run together. It gives the player the ability to invite friends to a game of Fire Run. The players would need to be at the same start location and receive the same tasks, allowing them to run together.
- Give the players the ability to challenge their friends to play the same Fire Run game as them. The challenged player must start at the same location and complete the same tasks as the challenger. The player with the lowest completion time wins.
- Give the players the ability to create a league with their friends and compete on

their own leaderboard over a limited or unlimited period.

Implementing all features requires a considerable amount of time and resources, but it is essential to make On Fire a fully-worthy exergame. All new features should go through extensive iterative testing with an even larger test population to ensure the functionality works as intended and contributes to the game's enjoyment.

Further on, higher quality and quantity of data could be produced by performing a new experiment on the On Fire prototype. This experiment would include more test participants testing the game over a more extended period. It would also be beneficial to have a more diverse test population, as this could uncover interesting effects on different subgroups of the test participants.

To generate revenue from the application, the game could provide in-game purchases of customization items, for example, map themes and character skins. To deal with the constant costs associated with using the Google Maps API's it would be beneficial to include ads to secure a constant income. Similar to other popular free-to-play games, On Fire could also provide extra rewards from leveling up for a limited time which can be unlocked by in-game purchase. An example of such a reward system is the *Battle Pass* in Call of Duty Warzone.

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Appendices

A Pre-test Questionaire

On Fire - Pre Test

* Obligatorisk

Demographics

1. User ID *

   Enter the user ID that was provided with the email

2. Age *

   Verdien må være et tall

3. Gender *

   - Male
   - Female
   - Other

Gaming experience

4. About how many hours a week do you play video games? *

Verdien må være et tall

5. What kind of video games do you play? *

- [ ] First person shooters
- [ ] Sports games (FIFA, NHL, etc.)
- [ ] Puzzle Games (Candy crush, Homescapes, etc.)
- [ ] Role Playing Games (RPG's)
- [ ] Idle Games
- [ ] Adventure Games
- [ ] Annet

6. Which platforms do you play video games on? *

- [ ] Mobile Phone
- [ ] PC
- [ ] Gaming console (Playstation, Xbox, etc.)
- [ ] Web browser
- [ ] Annet

7. Do you have any previous experience with video games involving physical activity? *

Examples: Pokemon Go, Ring Fit Adventure, Wii Sports, etc.

- ( ) Yes
- ( ) No

8. Name the game(s) *

involving physical activity.

Physical Activity

9. About how many hours a week do you exercise? *

Verdien må være et tall

10. About how many hours a week would you like to exercise? *

Verdien må være et tall

11. Statements *

	Totally disagree	Disagree	Neutral	Agree	Totally agree
I often find it hard to motivate myself to exercise	○	○	○	○	○
My workouts are as intensive/effective as I would like	○	○	○	○	○

12. Do you perform running exercises? *

- ○ Yes
- ○ No

13. About how many times per week do you run? *

Verdien må være et tall

14. What kind of running exercise do you perform? *

- [ ] Intervals
- [ ] Long runs
- [ ] Treadmill
- [ ] Sprint
- [ ] Annet

15. What other exercise do you perform? *

Apart from running

- [ ] Strength
- [ ] Sports
- [ ] Do not exercise
- [ ] Annet

16. Do you go for walks/hikes in your spare time? *

- Yes
- No

17. About how many times per month do you go for walks in the city/rural area? *

Verdien må være et tall

18. About how many times per month do you go for hikes in nature? *

Verdien må være et tall

19. Are you a member of a gym/exercise facility? *

- Yes
- No

20. About how many times a week do you exercise in this facility? *

Verdien må være et tall

21. Do you regularly perform a specific sport? *

- ○ Yes
- ○ No

22. Are you part of a team/organization? *

- ○ Yes
- ○ No

23. About how many times a week do you perform this sport? *

Verdien må være et tall

24. Name the sport *

25. Do you exercise alone or with others? *

- ☐ Alone
- ☐ With others

26. Do you use any of the following digital equipment in your exercise?

- [ ] Strava
- [ ] Heart Rate Sensors (Polar, Apple Watch, Fitbit, etc.)
- [ ] Exercise Games
- [ ] Annet

B Post-test Questionaire

On Fire - Post Test

* Obligatorisk

1. User ID *

   Fill inn the provided User ID

Physical Activity

2. About how many hours per week did you exercise during the test period? *

Both with and without using the game.

Verdien må være et tall

3. About how many hours per week would you like to exercise? *

Verdien må være et tall

4. Statements: *

... during the test period

	Totally disagree	Disagree	Neutral	Agree	Totally agree
I found it hard to motivate myself to exercise	○	○	○	○	○
My workouts were as intense/effective as I would like	○	○	○	○	○
I rather played Fire Run than other ways of working out	○	○	○	○	○

5. Statements: *

	Totally disagree	Disagree	Neutral	Agree	Totally agree
The game motivated me to exercise	○	○	○	○	○
I got a good running exercise from playing the game	○	○	○	○	○
I forgot that I was working out while playing the game	○	○	○	○	○
I would use this game instead of traditional running exercise in the future	○	○	○	○	○

6. What combination(s) of duration and difficulty did you enjoy the most? *

Please choose no more than 3 combinations

- [ ] Easy - Short
- [ ] Easy - Medium
- [ ] Easy - Long
- [ ] Medium - Short
- [ ] Medium - Medium
- [ ] Medium - Long
- [ ] Hard - Short
- [ ] Hard - Medium
- [ ] Hard - Long

7. What combination(s) of duration and difficulty gave you the best workout? *

Please choose no more than 3 combinations

- [ ] Easy - Short
- [ ] Easy - Medium
- [ ] Easy - Long
- [ ] Medium - Short
- [ ] Medium - Medium
- [ ] Medium - Long
- [ ] Hard - Short
- [ ] Hard - Medium
- [ ] Hard - Long

8. How did your difficulty preference develop during the test period? *

- ( ) Increasing difficulty
- ( ) Decreasing difficulty
- ( ) No change

9. How did your duration preference develop during the test period? *

- ○ Increasing duration
- ○ Decreasing duration
- ○ No change

10. How did On Fire affect your physical activity? *

Please reply with complete sentences.

11. What do you think of the running exercise produced by On Fire? *

Please reply with complete sentences.

Game enjoyment

12. Game enjoyment statements: *

	Totally disagree	Disagree	Neutral	Agree	Totally Agree
I found the gameplay enjoyable	○	○	○	○	○
I enjoyed navigating to the next fire using the map	○	○	○	○	○
I enjoyed playing the fire extinguishment mini game	○	○	○	○	○
The fire extinguishment mini game challenged me	○	○	○	○	○
My skills at extinguishing fires improved during the test period	○	○	○	○	○
The fire icons in the top left corner helped visualize my progress in extinguishing the fires	○	○	○	○	○
The smoke effect helped visualize my progress in extinguishing the fires	○	○	○	○	○
It was challenging to navigate to the fire's location using the map	○	○	○	○	○
I felt in control of the movement of my character	○	○	○	○	○

The music and sound effects made the game more enjoyable	○	○	○	○	○
The graphics on the map (character, fire animation and map) improved my gameplay experience	○	○	○	○	○
The fact that I could not see where all the fires were located increased my motivation to keep playing	○	○	○	○	○
The goal of playing a Fire Run was clearly defined	○	○	○	○	○
I felt in control of the water jet when extinguishing fires	○	○	○	○	○
The fact that I could see my friends progress made the game more enjoyable	○	○	○	○	○
I understood how to play the game after completing the tutorial	○	○	○	○	○

13. Did you replay the tutorial at a later stage? *

- ○ Yes
- ○ No

14. Were there parts of the game/application that you did not understand? *

- ○ Yes
- ○ No

15. Name what you did not understand: *

16. Did you find help with this problem on the About page or in the Tutorial? *

- ○ Yes
- ○ No

17. Did you add friends in the application? *

- ○ Yes
- ○ No

18. Did you add new friends found by looking at the leaderboard *

- ○ Yes
- ○ No

19. Which part(s) of the application did you enjoy the most? *

Please reply with complete sentences and elaborate why.

20. Which part(s) of the application did you enjoy the least? *

Please reply with complete sentences and elaborate why.

Game motivation and engagement

21. Statements: ... motivated me to keep playing the game: *

	Totally disagree	Disagree	Neutral	Agree	Totally Agree
The level system	○	○	○	○	○
The ability to unlock new equipment	○	○	○	○	○
Using newly obtained equipment	○	○	○	○	○
The ability to unlock new map themes	○	○	○	○	○
Using newly obtained map themes	○	○	○	○	○
The ability to view my stats in my profile page	○	○	○	○	○
The ability to compare my stats with the stats of friends	○	○	○	○	○
The ability to climb the "total score" leaderboard and compete against other players	○	○	○	○	○
The ability to climb the "distance" leaderboard and compete against other players	○	○	○	○	○
Feedback on XP and stats after playing a game of Fire Run	○	○	○	○	○

Trying new combinations of difficulty and duration	○	○	○	○	○
Finding out where the next location is going to be located	○	○	○	○	○

22. Other statements *

	Totally disagree	Disagree	Neutral	Agree	Totally agree
The countdown motivated me to push myself	○	○	○	○	○
The change in countdown colour and music when time is running out increased my motivation	○	○	○	○	○
The feedback on XP gained after extinguishing a fire motivated me to keep playing	○	○	○	○	○
Viewing my stats motivated me to exercise outside of playing the game	○	○	○	○	○
Time seemed to go faster than usual when playing the game	○	○	○	○	○
My goals were clearly defined when playing a Fire Run	○	○	○	○	○
The fact that the game was divided into multiple locations made it easier to find motivation to complete a game	○	○	○	○	○

23. What element(s) of the application motivated you the most to play the game/exercise? *

Please reply with complete sentences and elaborate why.

Additional questions

24. Did you experience any technical problems? *

For example, game crashes, GPS errors, or other bugs.

- ○ Yes
- ○ No

25. Describe the problems(s) *

26. Did any external factors prevent you from playing the game as much as you would like to?

- ☐ Illness
- ☐ Poor weather
- ☐ Corona restrictions
- ☐ Injury
- ☐ Annet

27. Did you cheat at Fire Run? *

For example, using motorized vehicles

- ○ Yes
- ○ No

28. How did you cheat? *

29. Why did you cheat? *

30. Do you have any additional comments about the application?

Please reply in complete sentences.

C On Fire - Agreement contract

Vil du delta i forskningsprosjektet

Exergames - Play to get fit

Dette er et spørsmål til deg om å delta i et forskningsprosjekt hvor formålet er å undersøke hvorvidt bruk av spill kan bidra til økt motivasjon for fysisk aktivitet. I dette skrivet gir vi deg informasjon om målene for prosjektet og hva deltakelse vil innebære for deg.

Formål
Dette prosjektet har som hensikt å undersøke hvordan spill kan brukes som en del av løsningen på problemet rundt økende inaktivitet i dagens samfunn. Prosjektet vil gjøre dette gjennom utvikling av et spill som inkluderer fysisk aktivitet, et slikt spill omtales som et exergame. For å teste om spillet har ønskelig påvirkning på brukernes fysiske aktivitet vil det bli gjennomført en testperiode, det er denne testen du vil bli spurt om å ta del i.

Forskningsprosjektet er en masteroppgave ved NTNU og en del av programmet Game Technology For Health (GT4H) som et bidrag til NTNU's forskning på exergames.

Hvem er ansvarlig for forskningsprosjektet?
Norges teknisk-naturvitenskapelige universitet (NTNU) er ansvarlig for prosjektet.

Hvorfor får du spørsmål om å delta?
Den primære målgruppen for prosjektet er mennesker som sliter med motivasjon til å holde seg fysisk aktive, i varierende grad. Det er ønskelig å se på hvordan din motivasjon påvirkes av bruk av spillet over en liten periode.

Hva innebærer det for deg å delta?
Hvis du velger å delta i prosjektet, innebærer det at du vil få spillet installert på din mobiltelefon. Spillet vil så være tilgjengelig for deg i en 2-ukers periode, hvor du bruker applikasjonen på eget initiativ i løpet av perioden. Før og etter denne perioden vil du fylle ut et spørreskjema, noen av spørsmålene i disse spørreskjemaene vil være like, men ikke alle. Hvert spørreskjema vil ta deg ca. 20 minutter å fylle ut.

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

Ditt personvern – hvordan vi oppbevarer og bruker dine opplysninger
Vi vil bare bruke opplysningene om deg til formålene vi har fortalt om i dette skrivet. Vi behandler opplysningene konfidensielt og i samsvar med personvernregelverket.

All data som vil bli samlet inn vil kun være tilgjengelig for prosjektgruppen og veilederen. Dette vil bli sikret ved at alle opplysninger vil bli kryptert. I tillegg til dette vil personopplysninger, som navnet og kontaktopplysningene dine vil bli erstattet med en kode som lagres på en egen navneliste adskilt fra øvrige data. Ditt navn og kontaktopplysninger vil kun bli brukt til å sende ut nødvendig informasjon til deg, som inkluderer spillet og spørreskjemaer.

Du vil ikke kunne gjenkjennes i publikasjonen, det vil kun publiseres oppsummeringer av- og ulike sammenhenger mellom flere av testdeltakerenes svar på spørreskjemaene og data knyttet til hvor langt man har løpt ved hjelp av spillet. Leverandør av spørreskjemaer vil være Nettskjema.no.

Hva skjer med opplysningene dine når vi avslutter forskningsprosjektet?
Opplysningene anonymiseres når prosjektet avsluttes/oppgaven er godkjent, noe som etter planen er 11 juni 2021. Ved denne datoen vil også dine personopplysninger og kobling til koden brukt i prosjektet bli slettet.

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

- innsyn i hvilke personopplysninger som er registrert om deg, og å få utlevert en kopi av opplysningene,
- å få rettet personopplysninger om deg,
- å få slettet personopplysninger om deg, og
- å sende klage til Datatilsynet om behandlingen av dine personopplysninger.

Hva gir oss rett til å behandle personopplysninger om deg?
Vi behandler opplysninger om deg basert på ditt samtykke.

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

Hvor kan jeg finne ut mer?
Hvis du har spørsmål til studien, eller ønsker å benytte deg av dine rettigheter, ta kontakt med:

- NTNU: Alf Inge Wang på epost alf.inge.wang@ntnu.no
- Vårt personvernombud: Thomas Helgesen på epost thomas.helgesen@ntnu.no

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

- NSD – Norsk senter for forskningsdata AS på epost (personverntjenester@nsd.no) eller på telefon: 55 58 21 17.

Med vennlig hilsen

Alf Inge Wang,
(Veileder)

Mats Elias Davidsen og Henrik Finnerud Larsen
(Student)

Samtykkeerklæring

Jeg har mottatt og forstått informasjon om prosjektet *Exergames - Play to get fit*, og har fått anledning til å stille spørsmål. Jeg samtykker til:

- □ å delta i testperiode av aktuelt spill
- □ å delta i spørreskjema før og etter testperiode

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

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(Signert av prosjektdeltaker, dato)

D NSD Application

Behandlingen av personopplysninger er vurdert av NSD.

Vurderingen er: Det er vår vurdering at behandlingen av personopplysninger i prosjektet vil være i samsvar med personvernlovgivningen så fremt den gjennomføres i tråd med det som er dokumentert i meldeskjemaet den 19.03.2021 med vedlegg, samt i meldingsdialogen mellom innmelder og NSD. Behandlingen kan starte.

DEL PROSJEKTET MED PROSJEKTANSVARLIG
Det er obligatorisk for studenter å dele meldeskjemaet med prosjektansvarlig (veileder). Det gjøres ved å trykke på "Del prosjekt" i meldeskjemaet.

MELD VESENTLIGE ENDRINGER
Dersom det skjer vesentlige endringer i behandlingen av personopplysninger, kan det være nødvendig å melde dette til NSD ved å oppdatere meldeskjemaet. Før du melder inn en endring, oppfordrer vi deg til å lese om hvilke type endringer det er nødvendig å melde:
nsd.no/personverntjenester/fylle-ut-meldeskjema-for-personopplysninger/melde-endringer-i-meldeskjema Du må vente på svar fra NSD før endringen gjennomføres.

TYPE OPPLYSNINGER OG VARIGHET
Prosjektet vil behandle alminnelige kategorier av personopplysninger frem til 11.06.2021.

LOVLIG GRUNNLAG
Prosjektet vil innhente samtykke fra de registrerte til behandlingen av personopplysninger. Vår vurdering er at prosjektet legger opp til et samtykke i samsvar med kravene i art. 4 og 7, ved at det er en frivillig, spesifikk, informert og utvetydig bekreftelse som kan dokumenteres, og som den registrerte kan trekke tilbake. Lovlig grunnlag for behandlingen vil dermed være den registrertes samtykke, jf. personvernforordningen art. 6 nr. 1 bokstav a.

PERSONVERNPRINSIPPER NSD
vurderer at den planlagte behandlingen av personopplysninger vil følge prinsippene i personvernforordningen om:
- lovlighet, rettferdighet og åpenhet (art. 5.1 a), ved at de registrerte får tilfredsstillende informasjon om og samtykker til behandlingen
- formålsbegrensning (art. 5.1 b), ved at personopplysninger samles inn for spesifikke, uttrykkelig angitte og berettigede formål, og ikke viderebehandles til nye uforenlige formål
- dataminimering (art. 5.1 c), ved at det kun behandles opplysninger som er adekvate, relevante og nødvendige for formålet med prosjektet

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

DE REGISTRERTES RETTIGHETER
NSD vurderer at informasjonen om behandlingen som de registrerte vil motta oppfyller lovens krav til form og innhold, jf. art. 12.1 og art. 13. Så lenge de registrerte kan identifiseres i datamaterialet vil de ha følgende rettigheter: innsyn (art. 15), retting (art. 16), sletting (art. 17), begrensning (art. 18) og dataportabilitet (art. 20). Vi minner om at hvis en registrert tar kontakt om sine rettigheter, har behandlingsansvarlig institusjon plikt til å svare innen en måned.

FØLG DIN INSTITUSJONS RETNINGSLINJER
NSD 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). Nettskjema er databehandler i prosjektet. NSD legger til grunn at behandlingen oppfyller kravene til bruk av databehandler, jf. art 28 og 29. For å forsikre dere om at kravene oppfylles, må dere følge interne retningslinjer og eventuelt rådføre dere med behandlingsansvarlig institusjon.

OPPFØLGING AV PROSJEKTET
NSD vil følge opp ved planlagt avslutning for å avklare om behandlingen av personopplysningene er avsluttet. Lykke til med prosjektet!

Kontaktperson hos NSD: Jørgen Wincentsen Tlf. Personverntjenester: 55 58 21 17 (tast 1)

E REK Application

Region:	Saksbehandler:	Telefon:	Vår dato:	Vår referanse:
REK midt	Karoline Bjørstad Berget	73597509	02.03.2021	243951
			Deres referanse:	

Henrik Finnerud Larsen

243951 Exergames - Play to get fit

Forskningsansvarlig: Norges teknisk-naturvitenskapelige universitet

Søker: Henrik Finnerud Larsen

Søkers beskrivelse av formål:

Dette prosjektet har som hensikt å undersøke hvordan spill kan brukes som en del av løsningen på problemet rundt økende inaktivitet i dagens samfunn. Prosjektet vil gjøre dette gjennom utvikling av et spill som inkluderer fysisk aktivitet, et slikt spill omtales som et exergame. For å teste om spillet har ønskelig påvirkning på brukernes fysiske aktivitet vil det bli gjennomført en testperiode.

Forskningsprosjektet er en masteroppgave ved NTNU og en del av programmet Game Technology For Health (GT4H) som et bidrag til NTNU's forskning på exergames.

REKs vurdering

Vi viser til innsendt fremleggingsvurderingsskjema datert 12.02.2021. Henvendelsen ble behandlet av komiteens leder.

REK midt mener at prosjektet ikke fremstår som medisinsk eller helsefaglig forskning. Prosjektet omfattes derfor ikke av helseforskningslovens saklige virkeområde, og kan gjennomføres uten nærmere etisk vurdering av REK. Dersom det skal registreres personopplysninger, må prosjektet ha et selvstendig behandlingsgrunnlag, jf. personopplysningsloven. Behandlingsgrunnlaget må forankres i og avklares med egen institusjon.

Merknad

- Vi minner om at vurderingen er gjort med bakgrunn i de innsendte dokumenter og kun er å betrakte som veiledende, jf. forvaltningsloven § 11. Dersom du ønsker at det skal fattes et formelt enkeltvedtak etter forvaltningsloven, må du sende inn en full prosjektsøknad til REK. En prosjektsøknad blir komitébehandlet iht. oppsatte frister.Vurderingen er gjort på grunnlag av de innsendte dokumenter. Dersom du gjør endringer i prosjektet, kan dette ha betydning for REKs vurdering. Du må da sende inn ny søknad/framleggingsvurdering.
- Prosjektleder er ansvarlig for å påse at forskningsprosjektet oppfyller eventuelle krav nedfelt i andre lover enn helseforskningsloven, som for eksempel personopplysningsloven, forvaltningsloven og forskningsetikkloven.

REK midt
Besøksadresse: Øya Helsehus, 3. etasje, Mauritz Hansens gate 2, Trondheim
Telefon:73 59 75 11 | **E-post**:rek-midt@mh.ntnu.no
Web:https://rekportalen.no

- Vi gjør oppmerksom på at samtykket må være dokumenterbart i henhold til generelle forskningsetiske retningslinjer utarbeidet av De nasjonale forskningsetiske komiteene.

Vedtak

Ikke fremleggspliktig

Med vennlig hilsen
Vibeke Videm
overlege, dr.med.
leder, REK midt

Karoline Bjørstad Berget
seniorkonsulent, REK midt

Mats Elias Davidsen, Henrik Finnerud Larsen

On Fire - A Location Based, Cardiovascular Exergame

NTNU
Kunnskap for en bedre verden