Master's thesis

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AR Games for Motivation, Socialisation, and Physical Activity

Master's thesis in Computer Science, Informatics
Supervisor: Alf Inge Wang
June 2022

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Abstract

In recent years a larger part of everyday life has become digital. We now live in an age where people are able to both study and work fully remote. In parallel with this, world obesity rates and time spent on video games are increasing. Exergames could potentially be a useful tool in battling the worrying trend.

This study started by going through some principles of game enjoyment and immersion, studying existing technologies related to exergames and reviewing existing exergames. The knowledge gained through the pre-study was then applied to an existing game in the development stage, called BitPet, where we conceptualized and proposed a number of new features in order to incentivise users to increase their level of physical activity and socialization. A feature was then selected and developed.

The testing period lasted two weeks, where the new feature and existing game was available to users through their mobile device.

Through two surveys, one before and one after the aforementioned testing period, we found results on how users experience the use of augmented reality in games, stay motivated for playing games, to which degree an exergame should demand exercise of the user, as well as how games better can facilitate social interactions between users.

Sammendrag

De siste årene har en større del av hverdagen blitt digital. Vi lever nå i en tidsalder hvor mennesker kan jobbe og studere "fully-remote". Parallelt med dette øker også både verdens fedme og tid brukt på videospill. Exergames kan potensielt være et nyttig verktøy for å kjempe mot den bekymringsfulle trenden.

Studiet startet med å gjennomgå noen prinsipper for spillglede og fordypning, studie av eksisterende teknologier relatert til treningsspill samt gjennomgang av eksisterende exergames. Lærdommen oppnådd gjennom forstudiet ble deretter brukt på et eksisterende spill i utviklingsstadiet, kalt BitPet, hvor vi konseptualiserte og foreslo en rekke nye funksjoner for å motivere brukere til å øke nivået av fysisk aktivitet og sosialisering. En funksjon ble deretter valgt og utviklet.

Testperioden varte i to uker, hvor den nye funksjonen og det eksisterende spillet var tilgjengelig for brukere via deres mobile enhet.

Gjennom to spørreundersøkelser, en før og etter den overnevnte testperioden, fant vi forskjellige resultater som viser indikasjoner til hvordan brukere opplever AR i spill, hvordan brukere holder seg motiverte i spill, i hvilken grad treningsspill bør kreve trening av brukeren, og til slutt hvordan spill bedre kan fasilitere for sosialisering mellom brukere.

Acknowledgments

We would like to give a special acknowledgment to our thesis supervisor Alf Inge Wang, at Department of Computer Science (IDI) at The Norwegian University of Science and Technology (NTNU) for his continued encouragement, support and helpful knowledge through weekly meetings during our project.

Thanks to the BitPet team who have allowed us to work on their project and has been helpful and available throughout the project, helping out with technical and practical questions related to BitPet, even during challenging times in their home country of Ukraine. Without their help, developing our new feature would've been close to an insurmountable task in the given time frame.

We would also like to thank the study hall Gamle Fysikk, particularly room 353, which has provided us with a fantastic working environment throughout the pre-project and thesis period.

Lastly, we would like to thank everyone who participated in the questionnaires, who tested the game and those who participated in interviews.

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Part I

Introduction

In the following part, we will discuss the grounds on which the thesis itself is based. Among this is the motivation for the project task, the project task as presented to us upon choosing the assignment, and the research goals and methodology we will apply to learn more about the task in question. In addition, a readers guide will follow.

1 Project Task and Context

The assigned project and its description is as follows:

[Game Technology] AR Games for Motivation, Socialisation, and Physical Activity

"In this project, the goal is to develop an game concept that will motivate the users to socialize and being physical activity using Augmented Reality. This project is part of a larger project with the goal of commercialising a concept."

The project is a part of *TDT4900 - Computer Science, Master's Thesis* for 5th year Computer Science students and *IT3920 - Master In Informatics, Master's Thesis* for 5th year Informatics students, at The Norwegian University of Science and Technology (NTNU) as the final course for the Computer Science and Informatics studies respectively. The thesis is a continuation of *TDT4501 - Computer Science, Specialization Project* and *IT3915 - Master in Informatics, Preparatory Project*, where the theory gathered from the previous project will be used as a foundation for further work. This thesis will focus on development and testing of a new concept on the existing game BitPet in order to answer the research goal mentioned in Section 3. The testing consists of letting players use our version of the BitPet-application for a limited amount of time and gather data about their experiences, which can be used by the BitPet team in order to commercialise a new concept.

2 Motivation

World obesity rates are high and the trend leans towards obesity increasing globally. As of 2016, 44 percent of the world population is considered obese, and we need new ways to battle the ticking time bomb that is worldwide obesity. [1].

A study conducted between 2017-2019 showed that obesity levels among youth in our study city Trondheim, based on BMI, continues to grow, which is a worrying trend [2]. In addition a report released by the NPD Group in 2011 showed that 91 percent of kids aged from 2-17 years actively played video games [3]. Introducing exercise through video games, often called exergames, is therefore a possible countermeasure to battle the obesity wave. The idea of combining exercise and video games is nothing new, but as technology has advanced, it has opened up for more seamless and interactive combinations.

In addition to the motivation stemming from health risks and physical health concerns, there are also motivations related to gaming and getting knowledge and experience within our field of work. Application development has in recent years increased in popularity [4] and has become a way to streamline distribution of software to target groups. We are both students who have played video games throughout our childhoods, and have throughout our studies gotten experience within development. Applying this knowledge to real-world problems, while being able to experience our childhood dreams of making video games is a motivational factor for the team. We are both entering full-time jobs in a relatively sedentary field after our studies. Staying active and keeping healthy is becoming a bigger priority, and needs to become a part of our everyday lives.

3 Research Goal, Questions and Methods

In the following section we will discuss the research goal, questions and methods for achieving said goal.

3.1 Research Goal and Questions

This project will utilise the "Goal, Question, Metric" (GQM) research approach, as proposed by Caldiera and Rombach [5]. The GQM research approach focuses on a top-down approach of finding metrics by which to rate the success of a research question. As it is quite easy to find certain metrics in software development, somehow managing to filter these out by starting from a more abstract goal, is how GQM approaches research.

From our project task and context as described in Section 1, we have derived the following research goal.

Research goal: *To develop and prototype a minigame concept, which utilizes AR and GPS to facilitate socialisation and exercise, and which increases motivation for the users*

From this, it is important to decompose our goal into more manageable and concrete questions, as the GQM research method demands. These questions should have well defined metrics, so that after proceeding with our studies, we should be able to answer them concretely.

RQ1 *How does the use of augmented reality affect the users immersion and experience of the game?*

While immersion may be a difficult metric to assess, it has been suggested that immersion can be analyzed both subjectively and objectively [6]. We believe augmented reality is a great tool for tackling user immersion, but it is important that we understand how immersion can be used, and how augmented reality affects this immersion.

RQ2 *What is the optimal distribution between physical activity and gaming in order to maximize the players enjoyment?*

This question emphasizes the importance of making the game enjoyable, even when introducing the exercising part. By answering this question, we can make sure we find the correct intensity for the physical aspects of our exergame. The answers retrieved from this question will help us plan new features and evaluate existing ones.

RQ3 *What factors contribute to the players motivation for playing a game?*

There are multiple ways people become interested in playing games. Thoroughly examining exactly what makes games affect the players' motivation will be essential for creating our

own game prototype. It could be that motivation between types of games varies wildly, so we need to look at motivation in the context of our concept.

RQ4 *How can games facilitate social interaction between users?*

As we intend to motivate users to socialize and exercise, it is very important that we in some way tackle how games can facilitate this social interaction. This interaction must be handled both for players playing alone, and in groups. It could be that the facilitation varies widely depending on the size of the group playing.

3.2 Research Methods

We will base our research strategy on Oates' research model presented in Figure 1. However, we disregard the first step from review to questions, as we believe our research questions can be explored quite a lot through literature review, and consider that one of our research strategies. Furthermore, we will design and create a new concept, which will lay the grounds for further work. In the following thesis, the concept will allow us to generate more data on our research questions. This will be done through interviews and questionnaires. The test subjects will also be allowed to experiment with the game in order to make up an opinion and simulate a real-world user. Some methods we believe could be beneficial for us, such as questionnaires which we have divided into pre-test questionnaires and post-test questionnaires.

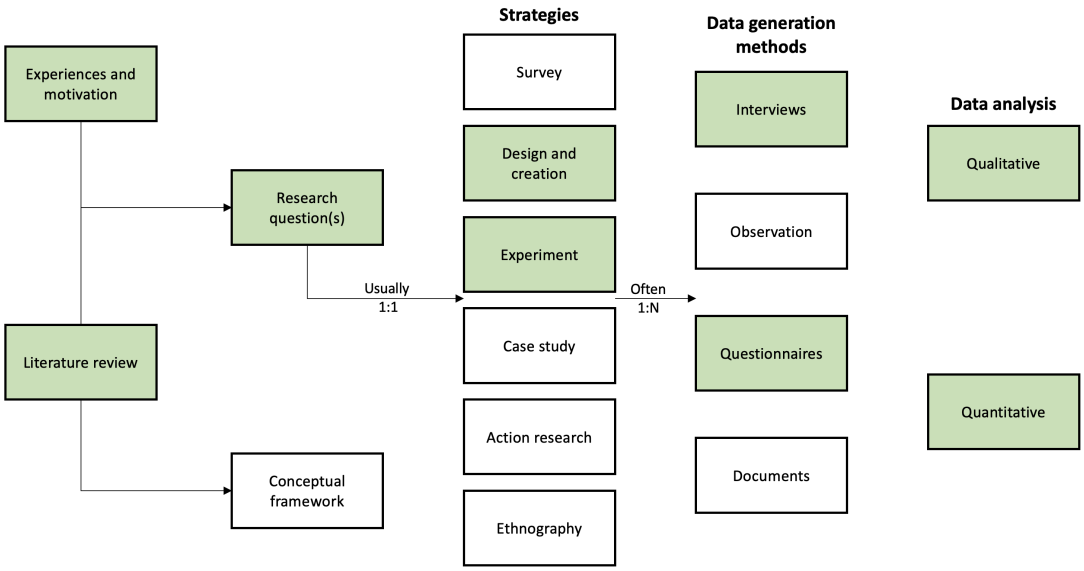

Figure 1: *Oates' research model, an overview [7]. Here highlighted are the strategies, generation and analysis methods used in this project.*

3.2.1 Literature Review

We will explore the aforementioned research questions through performing a literature review on the relevant subjects. Among these subjects we find augmented reality, exergames, gaming as a social tool, game development strategies, game enjoyment and more. Through this literature review we will, among other things, contextualise what has already been researched, identify issues with current research/find gaps in current knowledge and suggest theories which will guide our research based on the knowledge we find [7].

3.2.2 Data Generation and Strategies

After completing our literature review, the first operation to perform will be the design and creation of a new feature for BitPet (see Section 14). This feature will be designed and created with the knowledge gained in our literature review, and furthermore a group of people will test the feature in an experiment.

In order to gather data about the gameplay and our subjects, two questionnaires were used, a pre-test questionnaire and post-test questionnaire. The pre-test questionnaire was taken before the experiment begun and was used to map previous experience with the post-test questionnaire which was taken after the experiment had concluded. The questionnaires aimed to gather both qualitative and quantitative data and includes both fields with a fixed set of options, a series of statements where the subjects from a likert-scale ranging from strongly disagree to strongly agree. In addition to the mentioned question-types the questionnaires also include a free-text field where the subjects can write any additional information or feedback. The questionnaires are presented in Section 21.1.

There are several pros and cons that comes with using questionnaires in order to collect data. A questionnaire is for instance easy to develop, though hard to develop in a way that gathers valuable data [8]. Because of this fact, questionnaires will be combined with other sources of data collection, namely interviews.

The interviews used during research were meant to uncover data and opinions that a questionnaire and collected data did not cover. The way we structured these interviews was in a semi-structured matter where a couple of open-ended questions were presented at the start of the interview and followed up with probing questions as proposed by Adams *et al.* [9]. The objective was to gather qualitative data. The structure is described in Section 21.3.

As our research is based on a mobile game, BitPet, which is meant to be played on mobile devices, experimenting is an important part of our strategy. We are developing a new feature for the existing game, and allowing users to test and experiment with the new feature is the basis for our post-test questionnaire in addition to us getting feedback from their gameplay. The testing period will span

a period of two weeks, where users are free to play as much or little as they wish. The collected data will be used in order to map and correlate with the questionnaire answers and analyzed in order to find trends and segment our testers into different independent groups. Mann-Whitney will be used in order to find out whether there is a statistically significant difference in the dependent variable for two independent groups [10].

3.2.3 Summary of Research Methods

In the previous sections, we have presented the Oates' research model, and highlighted the different research methods which will be used in this thesis. The most important research strategies and data generation methods have been presented, along with how these strategies and methods will be used in the context of this thesis.

4 Report Outline and Reader's Guide

This chapter provides a brief overview of the content of the different parts in the report.

Part 1 - Introduction

The introduction part introduces the task, context, motivation and research questions for this project.

Part 2 - Prestudy

The prestudy goes through theories of enjoyment, augmented reality, an introduction to physical activity and its benefits, games and social interaction and an introduction to exergames including a review of existing exergames. Finally an overview of existing mobile phone and gaming technologies is presented.

This part is mostly based on work done in the pre-project [11], with some additions.

Part 3 - Concept

In the concept part, BitPet is introduced along with proposed new features of the game, further, the technology used to build the application is mentioned briefly.

This part is mostly based on work done in the pre-project [11], with some additions.

Part 4 - Development

The development part will go over functional and non-functional requirements for the proposed concept, as well as software architecture. Finally, this part will describe the results of the development period.

Part 5 - Experiments and Data Generation

In this part, our experiments and tools for data generation are presented. This comprises a pre-test questionnaire, a post-test questionnaire and interview questions.

Part 6 - Results and Discussion

In the sixth part, results from the previous part are presented. Furthermore, these results are interpreted and discussed in accordance with our research questions.

Part 7 - Conclusion and Further Work

The final part contains a summarised conclusion of the discussion, in which we answer our research questions, presented in the introduction part. Finally a description of how the work performed in the master's thesis can be used for further work.

Part II

Prestudy

This part is largely based on the corresponding part of the pre-project [11].

In the following part we will provide the reader with an extensive overview of relevant theory, frameworks and concepts. The prestudy should therefore lay the grounds for knowledge and vocabulary needed to properly assess the concepts and future work of the project. In this part, theory on the following is presented: status of physical activity in the world, different theories/frameworks of game enjoyment, augmented reality, social interaction and exergames, and lastly mobile phone technologies in the context of exercise and games.

5 Physical Activity

Physical activity is, according to WHO, defined as: *"any bodily movement produced by skeletal muscles that requires energy expenditure. Physical activity refers to all movement including during leisure time, for transport to get to and from places, or as part of a person's work. Both moderate- and vigorous-intensity physical activity improve health"*, and the recommended amount of physical activity per week for a healthy adult is between 150-300 minutes per week [12].

Throughout human history, physical exercise has been an essential part of our survival. Gathering food, resources, fending off rivals and escaping threats used to be a part of everyday life [13]. In recent times, however, where everything is readily available with a click of a button, or a short trip to the store and survival is not purely based on whether a hunting trip is successful or not, the immediate need for physical activity has diminished. An attempt to simulate the differences in physical activity in everyday life was performed by Egger et. al in 2001, where calculations based on body weight and energy expenditure showed estimated a difference of walking a distance of 16 kilometers per day [14].

Physical activity however still remains an important factor of human health and numerous studies have been performed in order to prove this. The effects of physical exercise was put under the microscope in a study by Warburton et. al in 2006, which concluded in that there is an indisputable correlation between physical activity and prevention of numerous diseases. The largest health benefit was found when studying groups which usually had lower levels of physical activity [15].

The global pandemic, COVID-19 has lead to people isolating themselves, and has for many, changed everyday life. The impact of isolation on physical activity levels was investigated in Spain, where the outbreak ran rampant at times. Results from the investigation showed both an increase in sedentary time, and also a decrease in time spent on physical activity [16].

6 Malone's Theory of Enjoyment

In their paper from 1980, Malone [17] described characteristics of what makes computer games fun. These characteristics were emphasized in games with educational uses, but the author states that these principles are useful in several applications of games. These essential characteristics, as stated by Malone are: *Challenge, fantasy and curiosity.* These characteristics are explained further in their respective sections.

6.1 Challenge

Malone describes challenge as an essential part of enjoying games, and notes the following: *"In order for a computer game to be challenging, it must provide a goal whose attainment is uncertain".* From this, multiple concepts are brought up.

1. *Goals*: Malone asserts that not all goals are made equal, and should follow some basic principles.
    - The goal should be obvious
    - Should the environment not feature built-in goals, the users should be able to generate their own goals of appropriate difficulty
    - The best goals are generally practical or fantasy goals, and should not be the simple act of using a skill
    - Feedback towards goals are essential
2. *Uncertain outcome*: If the outcomes of any experience are obvious, they are generally not interesting. To combat this, Malone provides four ways of combating this obviousness of an outcome.
    - *Variable difficulty level*, be that determined automatically, chosen by the player, or determined through the opponent's skill level
    - By providing *multiple levels of challenges or goals*, games may provide obvious outcomes, but simultaneously a difficult challenge. For example, a level may be quite simple for a player, but feature a timed goal as well, allowing the player to challenge themselves by beating a certain time
    - *Hidden information*, where the game selectively gives players new information or skills, provoking the players' curiosity as well. An example where this is used thoroughly is the metroidvania genre. Here, players frequently acquire new skills, allowing them to backtrack and execute new movements, or use their newly acquired knowledge to understand how an earlier section could be played.

- The final possibility is *randomness*, where the outcome is quite simply, random. In this case, players are not able to be certain no matter what. Malone states that many gambling games generally succeed simply from this principle alone.

3. *Self-esteem*: Lastly, Malone states that self-esteem is key in understanding how goals and challenges are captivating. Overcoming, or not overcoming, challenges and goals directly target the players' self-esteem. As such, carefully balancing the challenges players face, and also varying difficulty level in some manner, is of upmost importance, according to Malone [17].

6.2 Fantasy

Malone also states that fantasies are an important part of making players enjoy games. Fantasies allow developers to use symbols of varying degrees of social or physical impossibility, ranging from somewhat believable, to completely void of believability. They further separate fantasies into two different kinds, *extrinsic* and *intrinsic* fantasies. These fantasies differ in how they relate and interact with the players' skills, and they are visualised in Figure 2.

Extrinsic fantasies are described as fantasies where the player skill affects the fantasy, but not vice versa. An example of this would be a race-car going along a race track, and progressing through the track by fixed amounts, based on the players performance in some objective. The objective is completely domain-independent, meaning the objectives could be things like spelling, arithmetic, button coordination etc. Additionally, the player does not necessarily learn anything from their right or wrong answers, simply that the answer is right or wrong. Because of this domain independence, and the uni-directional relationship between skill and fantasy [17] describes these fantasies as extrinsic. *Intrinsic fantasies* on the other hand, are categorised by a bi-directional relationship between skill and fantasy. This allows the player to learn through immersing themselves in the fantasy. For example, if the race-car didn't move fixed amounts, but moved based on how close the player was to the right answer, the player learnt something from their mistake, by judging the movement of the car.

Malone believes that intrinsic fantasies offer more for players in general than extrinsic. An example of why, is how the behaviour in the fantasy can teach players more about the objective through analogues to the real life world. The fantasy can indicate how a skill can be used in the real world, hopefully immersing the player more, and teaching them more at the same time.

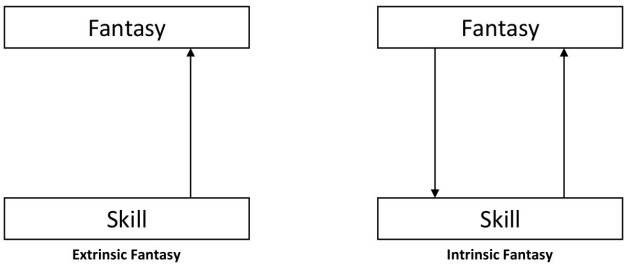

Figure 2: *Visual representation of how different fantasies relate to player skill* [17]

6.3 Curiosity

Finally, Malone believes that curiosity is a central category for enjoyment of games. They describe curiosity as "the motivation to learn, independent of and goal-seeking or fantasy-fulfillment". As long as the environments players are put into feature novel and interesting things to explore, while also staying comprehensible, Malone believes these environments pique the curiosity of people playing the game. The player should be able to expect some parts of their environment, but hopefully, they are sometimes surprised by the events taking place.

They further separate curiosity into sensory and cognitive curiosity. *Sensory curiosity* is curiosity brought upon by sensory stimulation, like auditory and visual effects. These effects can be decorative, enhance fantasies, reward the player and represent information in some other way than words or numbers. *Cognitive curiosity* may be thought of as the want, or need, for people to fill their gaps in knowledge through exploration. If players are nearing the end of solving some quest, their cognitive curiosity might drive them even further into solving said quest, fulfilling their knowledge base. Cognitive curiosity may further be enticed by providing the player with inconsistent knowledge, making players feel a stronger need to structure their knowledge in some way.

6.4 Summary

Malone's Theory of Enjoyment is a theory created with learning games in mind, but which has applications for games which do not have a learning element. The theory splits enjoyment of games into three categories: challenge, fantasy and curiosity. Within these categories there are certain criteria and characteristics which Malone believes one should follow. Following the guidelines of this theory will hopefully make for more enjoyable games.

7 Flow

Flow was a term coined by Csikszentmihalyi [18] to describe the state of optimal experience, when you are thoroughly concentrated and immersed in whatever you are doing. Csikszentmihalyi described flow as "a state of concentration so focused that it amounts to absolute absorption in an activity". Many different frameworks for describing flow in games have been created as a result of Csikszentmihalyi's work, some of which we will present in the following sections.

7.1 GameFlow

Basing their work off Csikszentmihalyi's flow state, Sweetser and Wyeth [19] created a framework called GameFlow for describing this flow-like state in a game context. The framework can be used to describe how a game gives players enjoyment through playing, and uses the same eight flow elements, but translated into elements that make sense in a game setting. These new game elements were found using existing literature in game theories, and then mapped to the original flow elements [19]. This mapping may be seen in Table 1. Notice that social interaction is not a part of the original flow criteria. Social interaction was still added to the GameFlow framework, as it featured numerous times in games literature. For example, a study by Brand [20] in 2012 showed that among a survey of 1252 Australian households, 70% of people who play games, enjoy doing so with others. Due to the strong presence of social interaction in games literature, it was added to the GameFlow framework.

GameFlow Element	Original Flow Element
The Game	A task that can be completed
Concentration	Ability to concentrate on the task
Challenge/Player Skills	Perceived skills should match challenges and both must exceed a certain threshold
Control	Allowed to exercise a sense of control over actions
Clear goals	The task has clear goals
Feedback	The task provides immediate feedback
Immersion	Deep but effortless involvement, reduced concern for self and sense of time
Social interaction	n/a

Table 1: *This table displays the mapping between the new GameFlow elements, created through literature analysis of game theory, and original flow elements, from* [18].

These GameFlow elements are described further by Sweetser and Wyeth:

- Concentration: Games should require concentration and the player should be able to concentrate on the game
- Challenge: Games should be sufficiently challenging and match the player's skill level
- Player Skills: Games must support player skill development and mastery
- Control: Players should feel a sense of control over their actions in the game
- Clear Goals: Games should provide the player with clear goals at appropriate times
- Feedback: Players must receive appropriate feedback at appropriate times
- Immersion: Players should experience deep but effortless involvement in the game
- Social Interaction: Games should support and create opportunities for social interaction

In order to properly evaluate games, the elements, in addition to these short descriptions, have a few criteria. For example, the criteria under the "Clear Goals" element are as follows: "Overriding goals should be clear and presented early" and "Intermediate goals should be clear and presented at appropriate times". Criteria are ranked on a scale from 1 to 5, where 1 is the worst performance,

and 5 is the best. In addition, criteria may be ranked a 0, which entails that the criteria is not applicable. After ranking these two criteria you average the two scores, and are left with a final "Clear Goals" score. Doing this with all GameFlow elements, and averaging these, you are left with a total GameFlow score for a game. The total GameFlow score can give you a sense of how enjoyable a game is, and how much of a flow state it induces in its players. The score allows you to compare games of similar genres, to which degree they are enjoyable, and for which reasons. All criteria are presented in Table 2 [19].

Element	Criteria
Concentration	• Games should provide a lot of stimuli from different sources • Games must provide stimuli that are worth attending to • games should quickly grab the players' attention and maintain their focus throughout the game • Players should not be burdened with tasks that don't feel important • Games should have a high workload, while still being appropriate for the players' perceptual, cognitive, and memory limits • Players should not be distracted from tasks that they want or need to concentrate on
Challenge	• Challenges in games must match the players' skill levels • Games should provide different levels of challenge for different players • The level of challenge should increase as the player progresses through the game and increases their skill level • Games should provide new challenges at an appropriate pace
Player Skills	• Players should be able to start playing the game without reading the manual • Learning the game should not be boring, but be part of the fun • Games should include online help so players don't need to exit the game • Players should be taught to play the game through tutorials or initial levels that feel like playing the game • Games should increase the players' skills at an appropriate pace as they progress through the game • Players should be rewarded appropriately for their effort and skill development • Game interfaces and mechanics should be easy to learn and use

Control	• Players should feel a sense of control over their characters or units and their movements and interactions in the game world • Players should feel a sense of control over the game interface and input devices • Players should feel a sense of control over the game shell (starting, stopping, saving, etc.) • Players should not be able to make errors that are detrimental to the game and should be supported in recovering from errors • Players should feel a sense of control and impact onto the game world (like their actions matter and they are shaping the game world) • Players should feel a sense of control over the actions that they take and the strategies that they use and that they are free to play the game the way that they want (not simply discovering actions and strategies planned by the game developers)
Clear goals	• Overriding goals should be clear and presented early • Intermediate goals should be clear and presented at appropriate times
Feedback	• Players should receive feedback on progress toward their goals • Players should receive immediate feedback on their actions • Players should always know their status or score

Immersion	• Players should become less aware of their surroundings • Players should become less self-aware and less worried about everyday life or self • Players should experience an altered sense of time • Players should feel emotionally involved in the game • Players should feel viscerally involved in the game
Social interaction	• Games should support competition and cooperation between players • Games should support social interaction between players (chat, etc.) • Games should support social communities inside and outside the game

Table 2: *This table displays the mapping between the new GameFlow elements, created through literature analysis of game theory, and original flow elements, from Csikszentmihalyi's flow.* [19]

While GameFlow is a rather old framework, it still seems to hold up as a good framework for assessing the enjoyment of a game. Of course, some metrics may be difficult to assess in an objective and general manner. For example Shin [21] states the following: "The meaning of immersion depends on the users' idiosyncrasies, and the influence of immersion substantially depends on the users' contexts such as their pre-existing conditions and personal traits". Meaning that for example the criteria regarding immersion is dependent on the user in question. To somewhat circumvent issues like these, more specialized versions of the GameFlow framework are created, which we will look at in the following sections.

7.2 Pervasive GameFlow

Pervasive games are games which are not confined to the virtual world of a video game, but rather incorporate the physical and social aspects of the real world [22]. As genres and types of games may directly affect the eight elements of GameFlow, attempts to better define the GameFlow criteria for these types of games are made. Jegers stated that it is of great importance to clarify how the elements of gameflow deal with unanticipated factors in pervasive games, and as such, created an updated framework specifically for these pervasive games.

Jegers found three major characteristics of pervasive games that had to be included in the GameFlow framework somehow:

- *Mobile, or place-independent gameplay*: Instead of limiting game design to specific environments, consoles and time-restricted sessions, game designers are now able to use portable consoles and mobile phones to their assistance. This allows pervasive games a greater degree of freedom over traditional games.
- *Social interaction between players*: Pervasive games tend to make extensive use of players in the design process. By using the players, and drawing on massively multiplayer solutions or small scale interactions, pervasive games often focus on making the social interaction between players the core of the gameplay. Creating social communities give rise for new goals and challenges created by said communities. The authors note, however, that these social interactions aren't exclusive to pervasive games, but the extent to which some pervasive games use them is unique.
- *Integration of the physical and virtual worlds*: While uncommon in computer gaming, the integration of these worlds are common in pervasive games. Either by placing virtual objects at physical locations, or enhancing physical locations with virtual information.

From this, Jegers created the new GameFlow framework, for pervasive games. The new criteria are exactly the same as in the original GameFlow framework, but with a few added criteria for each element. These new pervasive criteria may be seen in Table 3 [22].

Element	Criteria
Concentration	• Pervasive games should support the player in the process of switching concentration between in-game tasks and surrounding factors of importance
Challenge	• Pervasive games should stimulate and support the players in their own creation of game scenarios and pacing • Pervasive games should help the players in keeping a balance in the creation of paths and developments in the game world, but not put too much control or constraints on the pacing and challenge evolving
Player Skills	• Pervasive games should be very flexible and enable the players' skills to be developed in a pace set by the players
Control	• Pervasive games should enable the players to easily pick up game play in a constantly ongoing game and quickly get a picture of the current status in the game world (in order to assess how the state of the game has evolved since the player last visited the game world)
Clear goals	• Pervasive games should support the players in forming and communicating their own intermediate goals
Feedback	• No new criteria

Immersion	• Pervasive games should support a seamless transition between different everyday contexts, and not imply or require player actions that might result in a violation of social norms in everyday contexts • Pervasive games should enable the player to shift focus between the virtual and physical parts of the game world without losing too much of the feeling of immersion
Social interaction	• Pervasive games should support and enable possibilities for game oriented, meaningful and purposeful social interaction within the gaming system • Pervasive games should incorporate triggers and structures (e.g. quests and events, factions, guilds or gangs) that motivate the players to communicate and interact socially

Table 3: *The new criteria added for each GameFlow element in the pervasive GameFlow framework.* [22]

From Table 3 we see that a lot of new criteria has been added when the game is pervasive. All of these criteria may be connected in some way to the three major characteristics of pervasive games that Jegers mentioned in their paper. A common factor of the criteria is the seamless transition of game and real world.

Interestingly, some articles suggest that pervasive exergames are effective at reaching out to groups which generally play exergames less. Exergames are games which use video games for an exercise activity [23], which we will discuss further in Section 11. Wang and Skjervold [24] did a survey on 2191 Pokémon Go players, and their findings suggest that active gamers, as well as sedentary groups, tended to increase their physical and social activity when compared to less active games and more athletic groups. This suggests that it might possible to increase the physical and social well-being of parts of the population using well-designed pervasive exergames.

7.3 DualFlow for Exergames

Basing their work on Malone's theory of enjoyment, Csikszentmihalyi's flow theory, and Sweetser and Wyeth's GameFlow theory, Sinclair *et al.* [23] created a new flow framework for assessing the success of Exergames, called *DualFlow*

The framework is based on two main, interrelated dimensions for achieving success in an exergame: *effectiveness* and *attractiveness*. Effectiveness is thought of as meeting exercise requirements based on your fitness and the intensity of the exercise, and attractiveness is essentially the balance of challenge and skill, much inspired by GameFlow and Malone's theory, compelling the players to exercise for the recommended amount of time. The DualFlow model is presented in Figure 3. As we can see, both dimensions have two axes for determining the success of the dimension. In both dimensions, a fine balance between the two axes is necessary to achieve the goal of flow state. For attractiveness, if you do not find said balance between challenge and skill, the game could induce unwanted feelings. For example, if the players skill exceeds the provided challenges, players tend to become bored. As for effectiveness, the same holds; too intense exercise when compared to the players' fitness level, will result in failure.

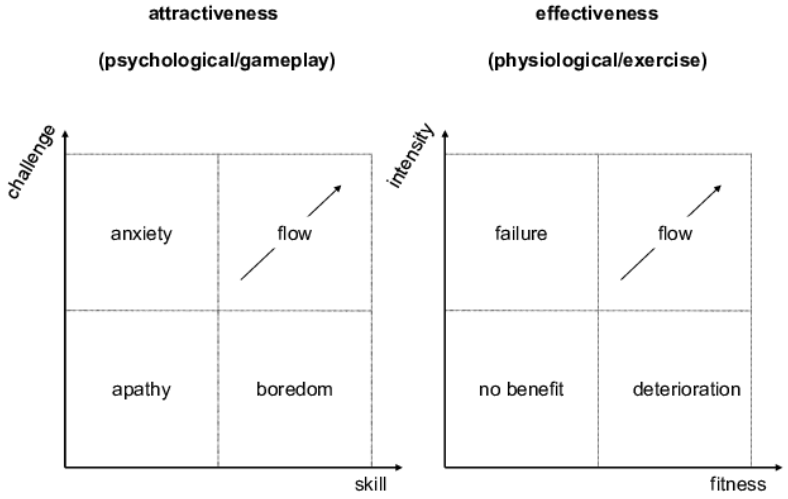

Figure 3: *Model for visualising the DualFlow between attractiveness and effectiveness of the game and exercise* [23]

7.4 Summary

In the previous sections we looked at different flow frameworks for enjoyment in games, namely GameFlow, pervasive GameFlow, and DualFlow. All of these frameworks are applicable for exergames, one of the focuses of this report. DualFlow was also specifically created for exergames. We can see that all frameworks share some common features, as they're based on the same concepts. Specifically though, the concept of balancing challenge in games seems to be present everywhere. As this is a core concept in all the frameworks, it will be important to keep in mind for our concept development. We also see that depending on the type of game, like if the game is an exergame or a pervasive game, one has to consider new challenges, like the seamless transitions from game

world to real world, or physical challenge in games.

8 The Magic Circle

This section discusses the magic circle, which is a concept briefly introduced by Huizinga [25] in Homo Ludens. Although the concept has received criticism, Stenros [26] discussed some of the critisicsm and elabortated on the term further in his article, *In Defence Of The Magic Circle*. It is a fixed boundary with its own set of physics and rules, and is a virtual world contained within the real world. The magic circle was applied to digital media and games by Salen *et al.* [27], where it is defined as the place where a game takes place, and every game takes place in a magic circle. An important part of the magic circle is the mindset of the players during gameplay and the will to adhere to certain rules of a game. An example is the game of chess, where the goal is capturing and defeating the opponents king. Even though the goal is quite straightforward, a player cannot win by simply pushing the opponents king over, but must use their pieces on their turn appropriately until they either win or lose. This attitude and mindset was coined by Suits [28] as the *lusory attitude*.

Pervasive games explore the limits of the magic circle in three different dimensions, temporal, spatial and social to elevate gameplay experiences and is meant to augment the gameplay [29].

8.1 Summary

As a game begins, the player enters into a magic circle. The magic circle can contain its own rules and physics and can require the player to adapt a certain mindset. Pervasive games uses the magic circle by expanding the real world in spatial, temporal and social dimensions. Although the concept has been criticised throughout the years, it is for many still a big part of game design terminology.

9 Augmented Reality

For the following section, it is important to keep in mind that both authors are aware of the concept of pervasive games in general, as they have been mentioned in Section 7.2. For this project however, we specifically want to focus on augmented reality, and its position in gaming, as we believe this to be the most relevant type of pervasive gaming. In the following sections we will present our definition of augmented reality, how it has been applied throughout history, and then look at augmented reality in gaming specifically. For augmented reality in gaming, we believe linking it up with pervasive GameFlow gives interesting insight into how augmented reality affects the feeling of flow.

9.1 Definition and Applications

Augmented reality, or AR, may be defined in many ways. Before the term itself was created, the concept we know of today was created in the 1950s, by Morton Heilig, a cinematographer. He created the "Sensorama", a cinema experience which takes in all senses [30]. The original definition of AR was coined by Thomas and David [31], in order to describe a heads-up display headset (HUDset) for use at a manufacturing site for Boeing aircraft assembly. This is a rather strict definition, as the authors demanded the use of a HUDset. In order to broaden what technologies could be used, Mekni and Lemieux [32] defines AR as systems that have the following characteristics:

- The system must combine the real and virtual space
- The system must be interactive in real time
- The system must be registered in 3D

To separate what AR means when compared to virtual reality (VR), a helpful illustration by Looser *et al.* [33] is presented. Figure 4 illustrates the mixed-reality continuum. Instead of attempting to define AR as one specific concept, Looser *et al.* [33] states that it is a lot more simple to define it as a broad part of a continuum. In this continuum, augmented reality is closer to the real environment we live in, but in some way virtualized. It is not, however, a completely virtual environment, as the real environment around you is still a key part of this new "reality".

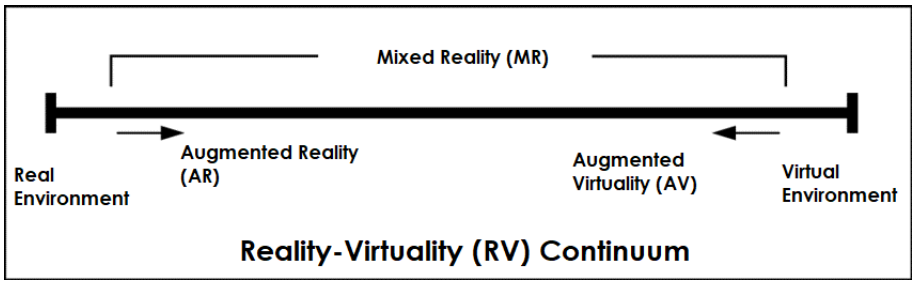

Figure 4: *The mixed-reality continuum. On the far left, we see the real environment, and by contrast, the far right is a completely virtual environment. Augmented reality is often defined as being somewhere closer to the real environment, but changed in specific ways.* [33]

AR has throughout history, since its "conception" in 1992 [31], had a wide range of applications. These applications span education, manufacturing, military, museums, and many more [34] [31] [35] [36].

9.2 Augmented Reality in Games

The most important AR application for this pre-study is how AR has been used in games. As such, we will in the following sections discuss a brief history of AR in games, before inspecting the literature in how augmented reality affects immersion and flow in games.

9.2.1 Brief History of Augmented Reality in Games

AR in gaming surfaced already in 2000, when Thomas *et al.* [37] created ARQuake, pictured in Figure 5. Their application modeled the physical world as a Quake 3D model. Information in the game was displayed with spatial context in our physical world. ARQuake, being the first game of its kind, laid the grounds for future AR gaming. The first mobile phone AR game was released in 2005, a game called AR-Tennis [38]. However, it would still take a long time before these AR games were as accessible and good as they are today. Not until recently, with Pokémon GO, has AR gaming been in the mainstream gaming scene [39].

Figure 5: *ARQuake setup. A player wears augmented reality goggles, and may then see the Quake UI integrated with the real world.* [40]

9.2.2 Immersion, Flow and Augmented Reality

As mentioned in Section 2, GameFlow is a framework for describing how well a game lends itself to "flow state" for the player. AR, depending on the context and scale, tackles many of these GameFlow elements. AR and VR gaming is a highly engaging activity. It may induce a many different emotions like flow, immersion, disassociation and absorption. Shin [21] said the following: *"It has been argued that advanced AR systems are not just traditional games with better pictures and sound. Instead, they provide a whole new experience by giving the viewer a sense of sociability and presence"*. In fact, for many, a primary reason for playing these kind of games in the first place is the pleasure of immersing oneself in a world which, depending on how you frame it, does not exist [21]. Because of this, we believe concentration, control and immersion stand out as especially relevant. If we look at the pervasive GameFlow criteria, we find a few criteria which AR tackles directly. The following two criteria in immersion directly tackle the challenges one might face for AR games:

1. Pervasive games should support a seamless transition between different everyday contexts, and not imply or require player actions that might result in a violation of social norms in everyday contexts

2. Pervasive games should enable the player to shift focus between the virtual and physical parts of the game world without losing too much of the feeling of immersion

For item 1, flow is affected when players have to perform something in-game that would otherwise not conform to societal norms. As mentioned in Section 6, fantasy is very important for players to enjoy games, but when creating AR games, it is important to not let this fantasy affect the player in a way in which they have to behave too peculiarly in a public space. Item 2 states that flow is

affected when players when the focus of the player has to shift between the virtual and physical parts of the game. For games like Pokémon Go (more on this in Section 12.4), how players shift between looking at their mobile phone in AR space, and how they then proceed to interact with the real world, has to be seamless to keep the players immersion strong. So while the fantastic nature of AR can lend itself to higher rates of immersion, as noted in [6], it is important to balance fantasy with real world, to not break the created immersion.

While AR may induce extra feelings of flow given the implementation is correct, this will not be the case for everyone. Weibel *et al.* [41] showed that players' tendencies to be immersed in mixed-reality environments were positively correlated with willingness to try, openness to exploration and extraversion. As such, one cannot automatically assume your game will feel more immersive or induce more flow just because it is an AR game, which will be important to keep in mind forward.

9.3 Summary

Augmented Reality/AR, a part of pervasive games, can be defined in different ways. Using the mixed-reality continuum, we can define AR as some virtual where our real world is only somewhat virtualised. AR has different uses in different areas, but are also used widely for games, especially after the release of Pokémon Go, which made AR gaming mainstream. AR can assist users in immersing themselves in a game world, but developers are faced with new challenges to not break said immersion. In addition, it seems the case that users are predispositioned to being immersed in AR worlds in general, and developers must not expect the use of AR to immerse every user in the same way.

10 Games and Social Interaction

From having to gather physically in groups of friends to play video games, to being able to play with strangers across the globe at a moments notice, it is clear that video games have evolved a lot over time and allow for greater interaction through evolved technology.

One of the benefactors from the evolved technology is the way players can communicate and interact with each-other. Some games have added features where you can add other players to a friend list and communicate and play together. With some games even going as far as implementing voice chats, the difference between online and offline interactions is growing smaller.

Attempts at trying to measure how friendships are formed have been performed over the years. One of the attempts tried to investigate if it was possible to compute the required amount of hours need to form and strengthen a friendship. The study showed that spending leisure time, with activities such as watching TV or playing video games together could be a factor in the formation of friendships [42]. Hall and Merolla has also performed another study which suggests that having frequent social interaction leads to a better well-being and less loneliness [43].

Pokémon Go has since its release been the focal point of several research projects. One study conducted by Wang in 2021 investigated how playing the game impacted different social groups physically and socially. The results interestingly enough showed that the game contributed to increased time spent on both physical activity and social activity even for sedentary groups [24]. Location-based games such as Pokémon Go allow for the social interaction to happen both in the physical and digital plane which according to a study by Laato *et al.* [44].

10.1 Summary

Games have changed throughout the years, from having to sit in the same room to being able to play with people across the world, and with it, the social dynamics have changed. Social interaction remains a large part in the prevention of loneliness and the mental health of people. Location-based games allow for interaction both in the physical and digital plane and promotes social interaction greatly.

11 What are Exergames?

Physical activity is widely recognized as an important aspect of a healthy lifestyle, and can contribute to a decrease in risk of high blood pressure, cardiovascular diseases and obesity [45]. A study conducted in 2010 by Warren et al. showed that when comparing individuals with differing levels of physical activity, cardiovascular diseases had significantly higher occurrences in sedentary participants [46].

The term exergames has been used extensively during research articles, but finding an universal definition for the word is not a simple task. An attempt was made in 2010 where exergames was proposed to be defined as a combination of exertion and video games, including other forms of physical activity such as flexibility training, strength exercise and balance training [47].

Exergames can be used to replace the time spent sedentary playing computer games with physical exercise, and can be an important tool in order to introduce healthy habits among the population [48].

According to a study conducted by Marc Prensky in 2001, games are a potentially the most engaging past-time in the history of mankind [49], which makes it ideal to combine with other activities.

There are many different kinds of exergames with varying degrees levels of interaction and rules, varying from commanding users to a location to being able to share your workouts.

12 Existing Exergames

In this section a selection of successful existing exergames will be reviewed and presented. The games were chosen based on a few different factors. Mostly, it is important for us to draw inspiration from games which were successful, as these games have done something well. Novelty in technology and use of augmented reality were also important factors.

12.1 Dance Dance Revolution

Dance Dance Revolution (DDR) is a game based around rhythm and music by Konami. Participating players move their feet to specific locations with relation to the music. A score is then given based on how precise and timed the movement is [50]. It has both a single player mode and versus mode, where you can challenge your friends. Life is determined by a Dance Gauge which increases whenever a note is hit with the correct timing, and decreases whenever a note is badly timed or missed completely. If the Dance Gauge is empty, the game ends. DDR started out as an arcade game (Figure 6), but has since its first release been made available on consoles and PC. The game hit 6.5million units sold in 2003 [51].

Figure 6: Dance Dance Revolution Super NOVA 2

A 6-week study was conducted on 27 healthy adults, which resulted in a significant decrease in mean BMI among the group [52]. Studies have also been performed on fourth grade children showed that children reported higher self-efficacy and enjoyment during play than when compared to aerobic dance [53]. A feasibility study with the objective of measuring sedentary screen time and time spent in physical activity while playing DDR suggested that the game could slightly reduce sedentary screen time and increase time spent in physical activity [54].

12.2 Just Dance

Just Dance is a rhythm-based game developed by Ubisoft and was released for the first time in 2009. Since its release it has since become a series consisting of 12 games [55]. The game revolves around mimicking the movements of an in-game avatar, where scores are based on how well you danced. In addition to movements, some dances also require the player to mimic poses to earn bonus point. The game is pictured in Figure 7.

Figure 7: Just Dance

To measure the effect Just Dance had on physical activity, a study was conducted on overweight and obese adolescent girls for a period of 12-weeks. The study participants reported an increase in physical activity throughout the experiment, although the accelerometry did not measure any difference before and during the experiment [56]. An experiment based on Just Dance on kinect did however increase the attention span of college students over a two week period which points to the game possibly being beneficial in improving the attention span of college students [57].

12.3 Strava

Strava is a tracking service mostly used in combination with cycling or running. It was initially released in 2009, but has grown steadily in features and popularity since [58]. It also has an in-built achievement system and allows users to compete with their friends or post updates about their workouts. Not only can you track and share your workouts, but elements such as personal best and progress over time is also available to users. An example workout is shown in Figure 8. Strava aims to be the go-to social media platform for sharing exercises and tracking progress.

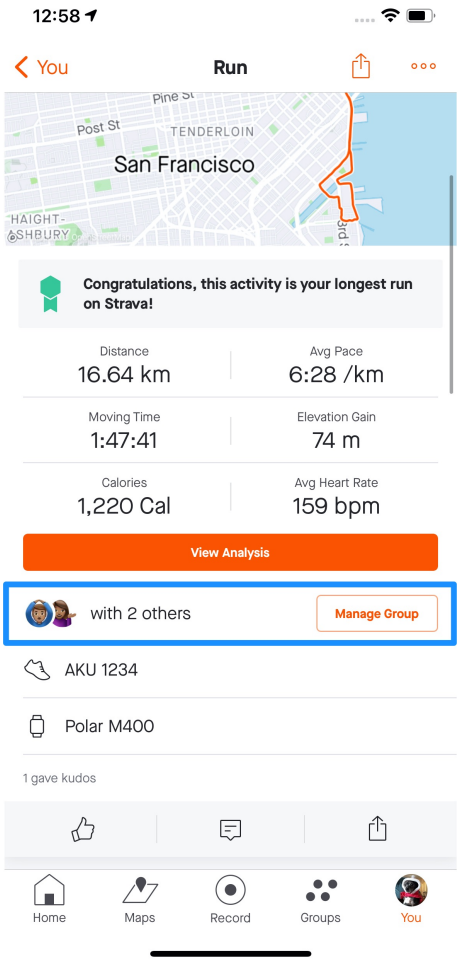

Figure 8: Strava: Example workout

The application in itself is very simple, you start by beginning to track a workout, and end it whenever you are finished. You can then choose to post it publicly, privately or discard it. Strava has over 76 million users and has amassed over one billion workouts since its release [58].

A study performed in 2017 showed that cyclists experienced an increase in motivation, frequency and intensity because of the competition aspect of applications such as Strava [59].

12.4 Pokémon Go

Pokémon Go was released in 2016 and is a collaboration project between Niantic and Nintendo and has since become one of the most successful mobile games of all time. It is an augmented reality game with the player's GPS location as one of its core features. Players have the role as a pokémon trainer where the main objective is to catch pokémon or "catch them all". Pokemon are generated on the map, and players are able to encounter them by being in, or moving to the same area. Pokémon are caught using expendable items available for purchase, pokéballs during an encounter (displayed in figure 9).

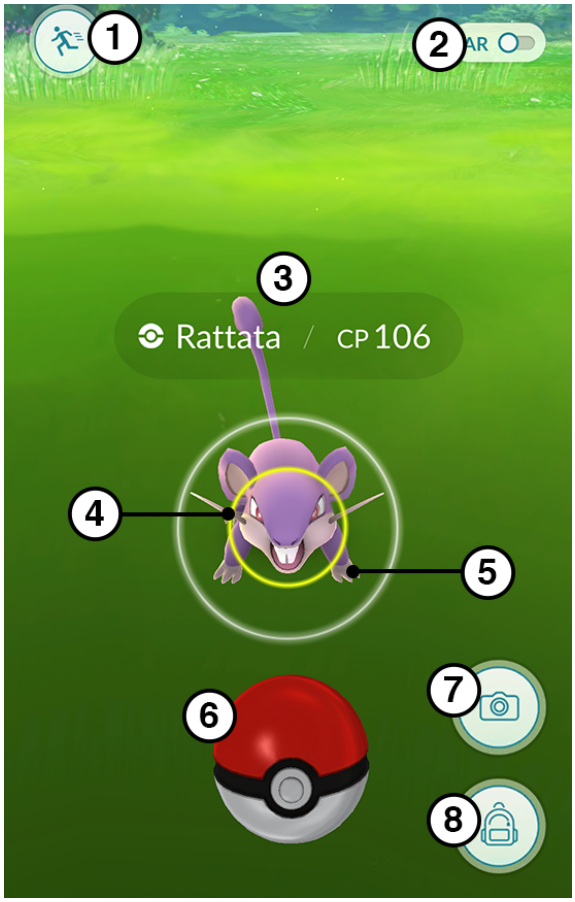

Figure 9: Pokemon Go: Pokemon Encounter

After catching a pokémon it can be used for Player-versus-Player (PvP) or allow them to battle against other pokémon in gyms, which are point-of-interest locations scattered across the map. Players are able to level up and train their pokémon by using in-game currency gained by visiting points-of-interests, catching more pokémon or walking in order to gain rewards. The game in its free-roam mode is showcased in Figure 10.

Figure 10: Pokemon Go: Free-roam mode

A literature review performed by Wang in 2021 showed that playing Pokemon Go brought significant health benefits during active play, increasing time spent on physical activity [60]. Another study conducted LeBlanc and Chaput showed that Pokémon Go substantially increased exercise levels short span, and eager users increased their activity level by more than 25 percent [61]. The game has since its initial release in 2016 kept up its popularity with 2020 being a record year. As of 2021, the application has made over $5 billion revenue in five years [62].

12.5 Harry Potter: Wizards Unite

Wizards Unite was an AR game developed by Niantic and Warner Bros based on the wizarding universe of Harry Potter created by J.K. Rowling. The game along with the partnership was first announced in 2017 [63], but was officially launched for beta in 2019. The game allowed users to cooperate on different missions and battle enemies by drawing spells on their screen. Although Pokémon Go and Wizards Unite shared many similar concepts, the game did not reach the same popularity and was ultimately shut down in 2022 [64].

Figure 11: Wizards Unite: Gameplay

A study by Laato performed on early adopters for the game, showed that mild exercise levels increased for the first week, similar to what was observed for other AR games. A large amount of study participants also reported that they played the game in social settings, which suggests that the game contributed to both physical exercise and socialisation [65].

12.6 Playpulse

Playpulse originally started out as a part of a master thesis in 2015, but due to purchase requests after trying out the prototype, the team decided to move the product moved from the lab to production [66]. Playpulse is an exercise bike that includes a custom game controller which allows users to input commands into games, pictured in Figure 12.

Figure 12: Playpulse One

In a study with the goal of answering whether playing games can get you fit performed in 2020, it was concluded that even though Playpulse is enjoyable, it did not have any long term effects on the test group [67].

12.7 Wii Fit

Wii Fit is an exercise game released by Nintendo in 2007. The game is playable on the Wii-console and comes with a balance board which enables users to interact with the game through different motions [68] with the goal of combining exercise and strength, balance, flexibility and general fitness. This is done by engaging the users through different kinds of gameplay, such as playing football, hula-hooping and more, where the user gets to pick the type of exercise they want. Since its release, it has since become a major commercial success and had sold over 20 million units as of match 2021 and is one of the most popular games sold on the Wii [69]. The game is pictured in Figure 13.

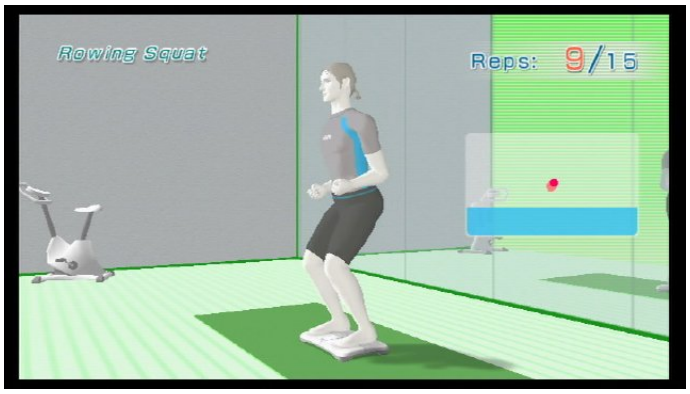

Figure 13: Wii Fit

A study conducted on ten women in the age range 30-58 years old, where the participants played the game for 1 hour each week in a 10 week period. The results showed an increase in both balance and lower limb strength, but no significant change in weight or other parameters [70].

12.8 Zombies, Run!

In Zombies, Run! The player is one of the few remaining humans after a zombie apocalypse has taken over the world. In order to save humanity, the player has to run to different outposts to save survivors and gather supplies (Figure 14). The exergame was released in 2012 by British studio Six to Start [71] and uses audio to narrate the story to the player.

Figure 14: Zombies run

A research project labeled the Zombie Trial was performed in 2015 to test whether smartphone exercise applications could increase physical activity levels in a test group. The results showed promising although not conclusive results, where motivation was seemingly increased, but with no significant change in activity levels [72].

12.9 Zwift Cycling

Zwift Cycling is a multiplayer cycling game that enables users to compete, train and ride in an artificial environment (Figure 15). The harder the player pedals, the faster the virtual player goes. In order to play all you need is a cycle, roller, Bluetooth measurement tool and a device to display the game. The game allows you to challenge your friends and compete in real-time virtual races with the ability to ride in different real-world locations from your own living room.

Figure 15: Zwift

Although not much research related to the effect of Zwift Cycling on exercise motivation exists, there are several studies on the use of virtual reality on stationary bike machines. A study performed by Zeng *et al.* showed that applications of VR on exercise machines lead to a higher degree of enjoyment for the user [73].

12.10 Summary

In this section a select existing exergames have been selected and reviewed. The games presented has had varying degrees of commercial success, but all serve as a source of inspiration for further work. There is also a difference in what role physical movement is a part of the gameplay, where some games such as Strava chooses to simulate real world cycling trips, other games uses physical exercise as a way to increase your progress or obtain certain rewards. Pokemon Go is the standout example among the games and has similarities to BitPet, which our research will be based on.

13 Mobile Phone Technology for Exercise and Gaming

The tools available for mobile phones has changed quite a lot since mobile phone games started surfacing. Among the first popular games for mobile phones, Snake for Nokia's 6610 phone [74], pales in comparison to today's mobile phone gaming. The Nokia 6610 had a resolution of 128x128 pixels and featured no WLAN, no Bluetooth and no GPS [75], all of which are common features for today's mobile phones. In fact, one is now able to play games like Fortnite, cross platform, in real time, online, on mobile devices like phones. These new technologies also assist users in other areas than games, such as mobile health apps. These mobile health apps use many of the new technologies in order to ease users' health tracking, like tracking sleep patters, body composition, setting goals, tracking calories and more [76]. In addition to the phones themselves, many tools like smart watches have been created, also assisting in these different areas of health. A common example is the fitbit, an electric wearable fitness watch developed by the company with the same name [77]. A fitbit model is pictured in Figure 16. In this section, we will look at a few of the technologies that make mobile phone gaming and these health apps possible, and how the technologies enhance user experiences and possibilities.

Figure 16: *Fitbit model. The fitbit utilises different sensors and wireless technology to benefit fitness and health, by tracking bodily metrics* [77].

13.1 Location and GPS

Modern phones employ many different ways of tracking your location to varying degrees of certainty. Among these, we have mobile signal tracking from cell towers and cell site simulators, Wi-Fi and Bluetooth tracking, and some might even use leaked location data from apps and websites [78]. Using these different techniques, real time location on a map is possible, depending on signal strengths and similar. For pervasive games, the use of mobile location is quite common. A few of the games listed in Section 12 contained location awareness to varying degrees. To achieve pervasiveness in games, using location can be a simple way of connecting the real world to a fictional one. In Pokémon Go, for example, the player character is always located at the location of the phone, and certain points of interests are connected to real world points of interests. Strava

is also a good example of a health app where precise location is necessary, so the user may receive a proper map of where they have been running.

13.2 Sensors

As phones have evolved, so have the different types of sensors available in the phone. Many of these are not necessarily relevant for games, but in the following section we will present a few of the sensors that could impact how a game can be developed for mobile platforms.

- *Accelerometer & Gyroscope*: The acceleromoter and gyroscope in a phone is mostly used for the same thing: Orientation. The gyroscope adds additional information by being able to track rotation and shift as well as orientation of phone. Using these two orientation sensors allows a phone to get an output of orientation that is accurate and responsive, instead of using them separately which results in poorer accuracy or responsiveness [79]. For games, this technology can be used for a multitude of different game fantasies. An example is how to accurately represent an in game characters orientation in the real life world, as we can see in Pokémon Go. Another different example is using the gyroscopes tilt orientation to accurately control a game object in space, by controlling the "surface" the object is on.

- *Microphone*: The sensor which truly makes a mobile phone what it is. While there exists different types of sensors as microphones, it is generally used to detect and measure loudness of different analog sounds, and digitizing these. Microphones are used for a few different purposes in both general phone accessibility and for games. For example, phones use these microphones to make users be able to make calls, or use voice commands in digital assistants like the iPhone's Siri assistant. For games, microphones can also be used for in game communication, or to interact with the game fantasy. An example of this is the early access horror game, Phasmophobia [80], in which players can communicate with the in game ghosts using a microphone, to make them interact with you.

- *Proximity Sensor / IR Sensor*: The proximity sensor makes use of infrared light to detect the proximity of an object in relation to the phone. Generally it is used for when the user is making calls, and it can then lock the screen to prevent the users ear from touching the phone screen [79]. This technology is a bit more limited than microphones and the orientation sensors, but it can still be used for some game fantasies. An example is a "fake" scanner of sorts, which asks the user to put their phone close to a certain object so it can scan the phone. The game could then use the proximity sensor in tandem with a camera to assess the proximity to said scanner.

- *Magnetometer*: Smartphones are also equipped with a magnetometer, which is used as a digital compass. When your phone opens a compass or uses any map which orients itself in relation to north, the phone uses the magnetometer and Earth's magnetic field to which

which way is north. In addition, the magnetometer can detect nearby metals [79]. While the compass isn't particularly interesting other than being a compass, the metal detection can be used in different fantasies. An example is where a user has to find some sort of fictional metal, and the game only accepts it when the phone is in proximity of a metal with a certain magnetic strength.

There does exist different types of sensors for phones, but these were picked as the most widely accessible and most useful for game fantasies. The examples chosen as game fantasies for the sensors are not exhaustive. Using these sensors, clever game developers may surely figure out a lot of different interesting game concepts.

13.3 Summary

Mobile phone technology has been steadily improving for many years now, and this does not seem to be a trend which is stopping at this point in time. New phones have access to sensors and other technologies which makes things which previously were not possible with phones, possible. Phones are now able to precisely locate themselves using GPS, Wi-Fi and Bluetooth, they can track orientation, sense magnetic fields and more. These different technologies allows users and developers alike to enjoy new experiences through their phones, like games using sensors in clever ways, or improving the users health by tracking goals and similar.

Part III

Concept

This part is largely based on the corresponding part of the pre-project [11].

This part discusses proposed game concepts which utilizes AR and GPS to increase socialisation, motivation and exercise for the player, as described in the project task in Section 1.

14 BitPet

Our research will be based on an existing game called BitPet. The game will be used in order to gather data, and our developer contributions will be added on on top of the game.

BitPet is an augmented reality location-based game from an idea by Alf Inge Wang based on research in co-located social engagement using game technology [81]. The game is based around unlocking and training up your pets and collecting rewards while using the entire world as its map, with the purpose of improving people's physical and mental well-being in a fun and social way. The game has drawn inspiration from multiple sources, and can be described as a sort of mixture between Nintendogs, Tamagotchi and Pokémon Go. You have to take care of your pets frequently, making sure to keep them happy, well fed and exercised. If you do not, your pets will perform worse in battle, and might die, in which case you will have to start over with that pet. BitPet uses health tracking like steps to complete missions which gives the player rewards based on activity. The game is focused on finding a fun balance of physical activity and in game goals. A depiction of many of the different pets in the game may be seen in Figure 17.

Figure 17: *Some of the pets you can collect in the game BitPet.*

BitPet uses coins as its in-game currency which can be earned through completing missions, battles or by purchasing from the in-game store. These coins can then be used in order to purchase new pets or decorate and upgrade your base. The game is still under development and is not available to the public yet.

15 Our Concept

To find a suitable concept, several proposals are presented and discussed in the context of BitPet. Afterwards, one of the concepts will be chosen and later implemented in the game. These concepts were created during the pre-project period, and some concepts lacked insight into the BitPet ecosystem as a result, allowing us to dismiss a few proposals easily after learning more about the current systems status.

15.1 Proposal 1: Shared Missions

The game has the ability to perform daily missions in order to gain rewards for the user and its pets. A feature that could be implemented is being able to share different missions, where the players need to work together in order to reach the same milestones and share progress along the way. A large part of the game is based on pets being generated on a map, which at the current moment is individual for each player. Implementing this change would involve sharing the same pets on the map between players. This would allow for more social interaction between the different players which as mentioned in Section 10 leads to an increase in well-being and decrease in loneliness.

15.2 Proposal 2: Mark Territory

Marking of territory could be implemented on the map. This means that players are able to place markers by placing their pet on select locations on the map, which could grant them rewards corresponding to how long the area has been marked. Other players could be able to see who controls parts of the area, giving more interaction between players and incentivise users to pursue new areas of the map, potentially increasing physical activity.

15.3 Proposal 3: Streak Features

A concept that has been successfully implemented in other games, is the daily retention or streak concept, which rewards players for returning to the game. This can either be connected to the existing daily missions feature by increasing the reward size according to amount of the days the player has returned to the game, or create a new feature which implements the concept. With the goal of increasing user motivation, increased user retention could be a useful tool.

15.4 Proposal 4: Minigame

Having the option to partake in minigames with other players when near each other could function as an add-on to the existing game features and would allow players to interact in a more dynamic

way. Rewards for winning the minigames could be in-game currency or cosmetic items. Depending on the type of minigame we would like to introduce, this could add many motivating factors for users. If the minigame is repeatable, it could be a good way for players to farm in-game currency.

15.5 Proposal 5: Players on the Minimap

When exploring the world and seeing the minimap, players should be able to see each-other on the map while walking around. They could be displayed as their pets and would allow users to see when others are playing nearby. Making the playing of BitPet a group activity could possibly increase both social interaction and physical activity, which is good for both GameFlow and DualFlow. It will, however, demand that the map is refactored from client side to server side.

15.6 Proposal 6: Pet Interaction

More tailored interaction between the different player' pets is a concept that could be interesting for BitPet as a game. Different kind of pets would have different animations or options depending on who they meet. It could contribute to the game enjoyment aspect of the game.

15.7 Proposal 7: Integration with Niantic lightship

Niantic recently released an ARDK called Lightship [82] which includes out-of-the-box features that could improve both the developer experience and user experience of BitPet. After discussing with Mathias Grønstad, CEO of BitPet, it was mentioned that the implementation of Niantic's Lightship instead of the current Google AR Core SDK, would potentially help performance and apparently ease the implementation of many different AR features. This integration would not directly tackle the project task, but rather assist in tackling this in the future. The refactoring would probably be time consuming and difficult.

15.8 Discussion and Choice of Concept

For the choice of concept, it was important that the choice we took was one taken with the rest of the BitPet team, which would ensure that our work was in line with the teams' vision and needs for BitPet as a product. In addition, we wanted the new concept to be quite relevant to the thesis, allowing us to increase our ability to discuss and reflect on our research missions and goals. The BitPet game was already able to test some of these, but with our new concept we want to directly tackle a few of them. Lastly, we wanted the concept to be something that we actually believed was a good feature for the game. Even though some concept might help us with the thesis, it might not actually fit the BitPet ecosystem. Therefore, we wanted something we "believed" in.

Due to the reasons above, a few of the the proposals were quickly dismissed at the start of the thesis period. Proposal 7, while interesting for the BitPet development team, would pose little to no change for users, and would unfortunately not contribute to any of our research proposals. The same reasons are given for dismissing Proposal 6. Furthermore, Proposals 2 and 4 were dismissed as a result of wanting to avoid potential 3D modeling. The team was aware of the potential time consumption modeling may provide, especially as the team did not have experience in any modeling software.

With the dismissal of the earlier proposals, only 1, 3 and 5 are were left for possible implementations. Players on minimaps were already in the works by the time the project was begun, and therefore we decided the best way forward was to somehow attempt to implement both concept 1 and 3. In the following part we will describe how the feature has been implemented.

Part IV

Development

This chapter contains information about the BitPet software architecture, functional- and non-functional requirements and our development contributions to the project.

16 Functional Requirements

In Table 4 we can see the proposed functional requirements for Proposal 1, Shared Missions, and with added streak functionality to account for Proposal 3. Most of the requirements relevant to Proposal 1 has been given a high priority, whereas Proposal 3 is considered slightly lower priority. In the table, the following three priorities are given: Low, meaning the feature is nice to have, meaning it may provide a good user experience or provide a nice statistic for business related data, but is not essential for the feature to work as intended. Medium, meaning the requirement is not essential, but it would be preferable to implement and not simply a quality of life improvement for the user or team. High, meaning the requirement is of utmost importance, and should be prioritized above any other priority requirement, these requirements are essential for the feature to work as intended.

ID	Requirement	Priority
FR1	The user should be able to open a mission menu for shared missions	High
FR1.1	The user should be able to view a list of different types of shared missions	High
FR1.2	The user should be able to re-roll mission if they do not like it	Low
FR2	The user should be able to choose a mission based on a textual description of the mission	High
FR3	The user should be able to choose a partner for a shared mission upon accepting a mission	High
FR4	The user should be able to make progress on a mission if the mission is started	High
FR5	The user should be able to progress a shared mission alone if the mission allows it	Medium
FR6	The user should be able to receive a reward upon mission completion	High
FR7	The user should be able to receive more demanding shared missions of the same type if they have already completed a shared mission	Medium
FR8	The user should be able to do shared missions as a daily task	High/Medium
FR8.1	The user should be rewarded for doing daily shared missions on a streak, with increasing bonuses	Medium
FR8.2	Upon completing a certain number of days in a row, the user should be rewarded with an extra bonus	Low
FR8.3	Upon completing a certain number of days in a row, the user should be able to share them and their partners feat on social media	Low
FR9	The user should be able to abandon a mission if they don't want it anymore	Medium
FR10	The user should be able to view the progress of their current mission	High

Table 4: Functional requirements for the new feature to be added to BitPet, allowing for shared missions between players

17 Non-Functional Requirements

The following non-functional requirements were discussed internally in the team and agreed upon all team members.

In Table 5 the requirements for the system are displayed. As all the requirements shown were important for the testing phase of the project, they were all deemed critical. Because the development to be done was going to be on an existing system, system requirements were prioritized

over quality attributes as the main goal of the experiment was to gather data. Requirement NR1 was added in order to support the number of test users that signed up for the experiment in-case they were all to play concurrently, and NR4 was added as it was critical that our version of the application did not interfere with the main BitPet application.

ID	**Requirement**
NR1	The system must be handle a minimum amount of 25 concurrent users
NR2	The system must be available to test on both iOS and Android mobile devices
NR3	The system must be able to have an up-time of 90%
NR4	Data stored during the testing period must be handled in a separate database

Table 5: Non-functional requirements for BitPet during the testing period

18 Software Architecture

The following section describes the architecture of the front and back end applications. While both applications share the same main architectural pattern in Model-View-Controller, there are some differences which will be explained. This pattern allows for separation of concerns, which greatly improves modifiability of code, often at the expense of complexity. This is done by decoupling views from models such that changes to one object can affect others, without having to know the details about the implementation or state of other objects [83, p.14-16].

18.1 Front End Architecture

The client side of the application is developed using Unity. Unity is a cross-platform 2D/3D engine and framework which enables developers to develop and design entire applications. Using Unity allows developers to easily use and create assets and animations as well as use C# to manage object interaction and logic [84]. The Unity framework is built with the architectural pattern Entity Component System in mind. Every object in the game world is built upon the empty entity GameObject, which may have multiple different components added to them, which in turn interact through systems. Unity offers a lot of different components by default, and the systems which interact on them are black-boxed behind the Unity framework. However, developers are free and able to create their own components and systems which interact with the game world. For BitPet, Model-View-Controller has also been used, but a slightly modified version. This version of MVC makes use of Mediators, Commands and Signals as well. Mediators work by listening to signals sent from views, in turn firing new command-signals, which can change the state of the model through controllers. The client side model is however often directly changed using a command, without the use of a controller. While this greatly increases complexity, and the logic flow may be hard to follow at times, this comes with the benefit of improved modifiability and decoupling, as mentioned.

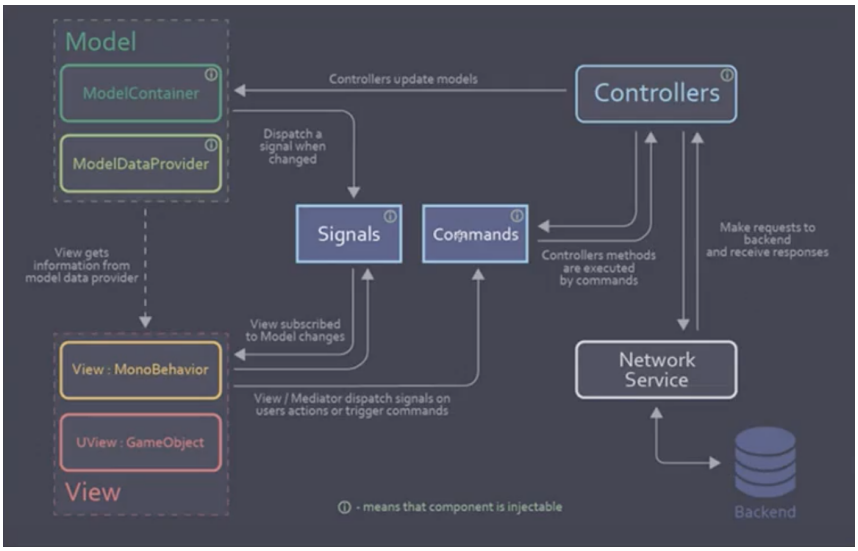

Figure 18: Client application flow

18.2 Back End Architecture

The server is written in Ruby and uses the server-side framework Ruby on Rails. The framework allows developers to define the database structure through the use of the structured Model-View-Controller architectural pattern. As shown in Figure 19 concerns are separated into Models, Views and Controllers.

As Ruby on Rails can be used to create a full-stack application, the full extent of the framework is not used for the back-end server, as views are not used, due to the client side being rendered in Unity. However, models and controllers are used as normal. The models are mapped to the database entities, and controllers are used for business logic like CRUD on the entities themselves. Most entities are automatically created using a Rails Model, and some are created automatically without models, like the schema-migrations table.

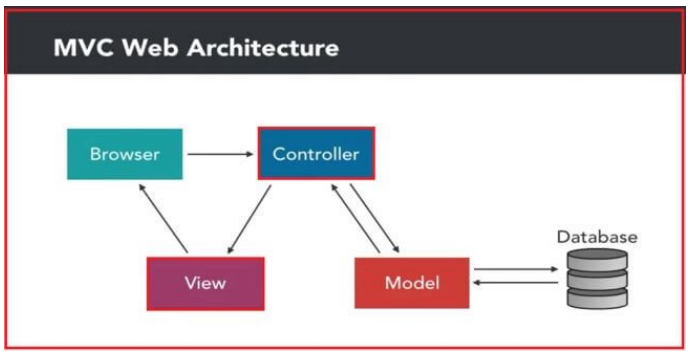

Figure 19: Model-View-Controller architecture used by Ruby on Rails [85]

19 Development Results

In order to create the new feature of shared missions, development had to be done both on the server side and client side. In the following section we will look at the final state of the changes done to the application. In addition to changes to the application, the processes for hosting and deployment of the application are described.

19.1 Implementation of Functional Requirements

In Table 6 we can see an overview of the functional requirements described in Section 15, and whether or not the requirement was implemented in the end. Due to time constraints, mostly as an effect of the relatively large system we were presented with, not all functional requirements were able to be added. The streak function was one of the proposed concepts with added functional requirements we did not have time to implement, which we think would have been helpful for retaining players. However, due to the way mission rewards were already implemented, it would require too much refactoring of code, and was deemed outside our time frame. Still, users are given a new shared mission every day, irrelevant of their current shared mission count.

ID	Requirement	Implemented?
FR1	The user should be able to open a mission menu for shared missions	Yes
FR1.1	The user should be able to view a list of different types of shared missions	Yes
FR1.2	The user should be able to re-roll mission if they do not like it	No
FR2	The user should be able to choose a mission based on a textual description of the mission	Yes
FR3	The user should be able to choose a partner for a shared mission upon accepting a mission	Yes
FR4	The user should be able to make progress on a mission if the mission is started	Yes
FR5	The user should be able to progress a shared mission alone if the mission allows it	No
FR6	The user should be able to receive a reward upon mission completion	Yes
FR7	The user should be able to receive more demanding shared missions of the same type if they have already completed a shared mission	No
FR8	The user should be able to do shared missions as a daily task	Partly
FR8.1	The user should be rewarded for doing daily shared missions on a streak, with increasing bonuses	No
FR8.2	Upon completing a certain number of days in a row, the user should be rewarded with an extra bonus	No
FR8.3	Upon completing a certain number of days in a row, the user should be able to share them and their partners feat on social media	No
FR9	The user should be able to abandon a mission if they don't want it anymore	No
FR10	The user should be able to view the progress of their current mission	Yes

Table 6: Overview of which of the functional requirements were implemented

19.2 Implementation of Non-Functional Requirements

The system requirements were given in Table 5. Although some users reported bugs related to gameplay, no one faced problems related to the system going down. NR1 was related to supporting 25 concurrent users, but the experiment ended up only having 17 users. Therefore we cannot conclude that it was completed as further testing is needed. During the experiment, there was downtime related to maintenance on the Heroku Platform, but NR3 was still completed. The overview of the non-functional requirements and whether they were completed or not is given in Table 7.

ID	Requirement	Completed?
NR1	The system must be handle a minimum amount of 25 concurrent users	-
NR2	The system must be available to test on both iOS and Android mobile devices	Yes
NR3	The system must be able to have an up-time of 90%	Yes
NR4	Data stored during the testing period must be handled in a separate database	Yes

Table 7: Non-functional requirements for BitPet during the testing period

19.3 Endpoints

In Table 8 we can see the new endpoints added to the BitPet back end. Most of the shared mission endpoints share a similar URL to that of their normal mission counterpart, but had to be somewhat duplicated in order to properly handle the extra logic needed for shared missions. In addition to new shared mission endpoints, a few users endpoints were added to be able to invite users to missions, as well as being able to update all relevant missions.

HTTP Verb	URL	Functionality
GET	`/shared_missions?role=[]`	Get all shared missions. Optional query parameter role can be either inviter or invitee, which filters the missions based on whether or not you are the inviter or invitee
PUT	`/shared_missions/:id/accept`	Accepts specified shared mission. Only possible if the user that accepts the mission is the invitee
PUT	`/shared_missions/:id/invite`	Invites a user to the specified shared mission
PUT	`/shared_missions/:id/claim`	Claim rewards for a shared mission. If either the invitee or inviter claims the reward, the mission is claimed for both
POST	`/shared_missions/action_made`	Progresses all missions with the same target type as the action made. Updates both inviter and invitee missions
POST	`/shared_missions/generate_missions`	Generates shared missions for all users
GET	`/users/id_on_name`	Gets a user id based on a name input
GET	`/users/name_on_id`	Gets a username based on an id input
GET	`/users/users_on_action`	Gets a list of user ids which share a mission with the user based on an action type.

Table 8: New endpoints to the BitPet back end

19.4 New and Changed Models

Some of the models that were already present had to be adjusted to allow for shared missions. In addition to this, some new models were created. Firstly, the mission type model had to be adjusted to add a new boolean field called *is_shareable*. This field was added to easily add new missions without necessarily allowing them to be shareable. As such, adding new missions does not require more effort compared to before the change, which is important for modifiability. Should this field not have been added, every new mission type must somehow be able to be shared with another player, which restricts possible mission types. A new model was also added: the shared_mission model. While similar to the regular mission model, called *user_model*, there are some key differences. Firstly, the mission is connected to two user IDs, one for the inviter and one for the invitee. Secondly, a new boolean field was added called *accepted*, to track whether or not the invitee has accepted the mission.

19.5 Docker

Docker is a way to package applications or programs in a container that can contain all necessary software in order to run them. This essentially means that instead having to download several programs in order to run a program, one can in some cases rely on running Docker instead [86]. Docker-compose is a way to declare container configuration using YAML-syntax and allows users to spin up containers with a single command [87].

In addition to adding new functionality to the existing application, we also added Docker in order to more easily develop locally without having to install a dedicated database on your machine. This was done by using Docker-compose in order to spin up a database. Because we added changes and migrations to the existing database schema, this allowed us to rapidly setup and tear down database instances while we both were able to develop locally. We also considered dockerizing the back end of the server, but opted not to as we did not encounter any problems with it during local development.

19.6 Deployment and Distribution of the Application

To distribute our version of the application without affecting the existing BitPet environment several steps were needed.

19.6.1 Deployment of Server

Heroku is a cloud platform or Platform-as-a-Service (PaaS) which enables rapid delivery and deployment of code to end-users. It contains compute power (dynos), managed databases and a container registry readily available for developers [88].

Our solution uses a number of services from Heroku showcased in Table 9. The deployment is handled through Github actions, and automatically updates whenever our production branch is updated.

Service	**Tier**	**Usage**
Dyno	Hobby developer	Run and expose BitPet back end
Heroku Postgres	Hobby developer	Store user and game data
Heroku Scheduler	Standard	Periodically update Firebase certificate
Redis To Go	Nano	Store Firebase certificate for authentication

Table 9: Heroku services used during deployment

The reason we chose Heroku as our cloud provider was because of the ease of setup, in addition to

having all the services needed for testing. As mentioned in Section 17 the back end only needed to support the users in testing, and therefore did not require any form of auto-scaling or load balancing.

19.6.2 Distribution of Application

In order to test the application, the front end of our application was distributed to both iOS and android mobile devices. For Android, Unity has built-in features in order to build, bundle and minimize the application which we used in order to generate an APK-file used to run the application [89]. For the iOS version of our application, we firstly built the project using Unity in order to generate a X-code project, which was then used to build a runnable build distributed through TestFlight [90]. The app was then made available for users to download by using a project code in the TestFlight application.

19.7 Shared Mission Views

In the following section, we will present the most important in-game views that are relevant to our contributions.

Before we started work on the game, functionality for user and step missions were already implemented, in a common *mission panel*. This mission panel, which may be seen in Figure 20 contains every mission the user is currently on, be those missions special user missions, common user missions or step missions. In this panel, the dark grey/black missions are the steps missions, the grey missions are the special user missions, and the blue missions are the common user missions. The mission items are not interactable unless a mission is finished, but when a user has finished a mission, they can claim the mission rewards with the *Claim* button, as shown for the daily diamond mission.

Figure 20: Mission panel view with common user missions, which were implemented before this thesis

The mission panel, showing only shared missions and their different states, may be seen in Figure 21. This was the feature we implemented in the game. Shared missions have some more interactability, which can be seen through the different states shown in the figure. From top to bottom: A mission may be new, and the user may invite a different user, using the mission invite popup view as shown in Figure 22. A mission may be accepted by the other user, and the mission item will then state which user you are currently sharing that mission with. A mission invite may have been sent, but currently not accepted or declined, in which the item will state that the invite is pending. Lastly, a mission invite may have been sent to the logged in user, and the user may then choose between accepting a mission, or declining it. Declining a mission will remove it from the panel, and accepting it will make it visually identical to the second mission item in the mission panel. Of course, shared missions may also be claimed when finished, but such an item is not presented here. When claiming shared missions, the mission is claimed for both users and promptly removed from the mission panel.

Figure 21: Mission panel view with shared user missions, and the different states a shared mission may be in

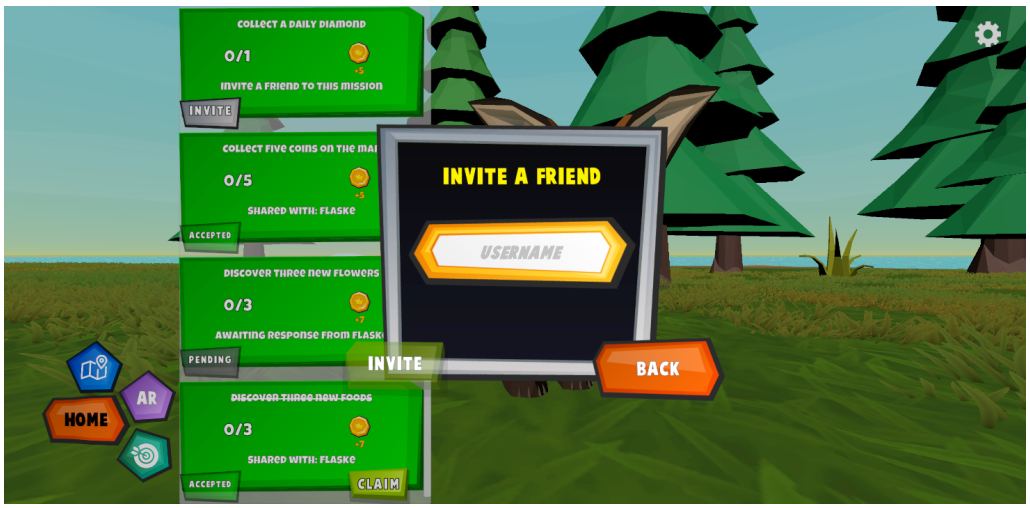

Figure 22: Mission invite popup view, used when inviting other users to your shared missions

Part V

Experiment and Data Generation

In this part the authors will present the different methods used to generate data for further analysis. The experiment proposed is presented, and furthermore questionnaires and an overview of the interview process is described.

20 Experiment

The experiment aimed to answer the research goal and questions presented in Section 3 through the use of gathering and analyzing data.

The testing of the game was conducted over a two week period, where the BitPet application with our developed feature was distributed among the test users. Android users downloaded the application through downloading an APK-file, while iOS users gained access through the TestFlight application [91]. After downloading the application, the game was available for play during the entire testing period, where users chose how much they wanted to play and engage with the game. As the game was under development, users received a disclaimer about possible bugs and missing features in the distributed application.

21 Data Generation

21.1 Questionnaires

Questionnaires were used in order to gather data about the subjects and gameplay as mentioned in Section 3.2. The questionnaires consisted of a mix of closed questions where the options ranged from two to multiple, statements ranging from completely disagree to completely agree and also open-ended questions. Combining multiple choice questions with open ones makes up a semi-structured format which has the benefit of us getting loads of information without having to cope with large amounts of editing or transcriptions [8]. During the questionnaire design, questions were mapped to their related research question.

21.1.1 Pre-test Questionnaire

The pre-test questionnaire aims to gather data about the demography, video game experience and physical activity of its test subjects. The questionnaire consists of questions for the subject to answer and statements for the subject to agree/disagree with. The data will be used in conjunction with the post-test questionnaire and will be analyzed for results. In addition to the normal questions, an optional question with a free text field was added to gather qualitative data.

21.1.2 Demographics

This part covers the name, gender and age of the participant and will be used to segment the data. The name is also used in order to keep track of which users answered the questionnaire.

ID	**Question**	**Format**
BQ1	What is your name?	Text
BQ1.1	What is your gender?	Multiple Choice
BQ2	What is your age?	Multiple Choice

Table 10: Questions related to demographics

21.1.3 Video Game Experience

In this section, the questionnaire aims to find out how familiar is with video games. Video games that involve physical activity are emphasized. The questions are described in table 15.

ID	Question	Format
BQ3	How often do you play video games?	Multiple Choice
BQ4	Have you played games involving physical activity previously?	Binary
BQ5	Name the game(s) involving physical activity	Text
BQ6	Have you heard about Pokemon Go or Tamagotchi	Multiple Choice

Table 11: Questions related to video game experience

21.1.4 Physical Activity

The subjects are to answer questions related to physical activity in order to find out how often they exercise and the preferred way to exercise. The related questions are shown in table 17

ID	Question	Format
BQ7	Approximately how many hours do you spend in physical activity in a week	Number
BQ8	How many hours in a week do you wish to exercise?	Number
BQ9	What kind of exercise do you perform?	Text
BQ10	Do you prefer exercising alone or with others?	Binary
BQ11	Do you have any form of entertainment while walking?	Multiple Choice
BQ12	Do you use the aid of any digital equipment in your exercise?	Multiple Choice

Table 12: Questions related to physical activity

Different statements related to motivation are presented to each subject. The statements are shown in Table 13.

ID	Statement
BS1	I find it easier to motivate myself when I work out with others
BS2	When working out I usually have a clear goal in mind
BS3	I wish I worked out more
BS3.1	I get bored easily during exercise

Table 13: Questions related to physical activity

21.1.5 Socialisation

The subjects are presented four new statements related to socialisation and interaction with other people.

ID	Statement
BS4	I am comfortable in the presence of people I know
BS5	I am comfortable in the presence of people I don't know
BS6	I prefer being social over being alone
BS7	I wish to meet new people

Table 14: Questions related to physical activity

21.1.6 Post-test Questionnaire

The post-test questionnaire aims to gather data about the participants experiences during the test period. The questionnaire consists of questions for the subject to answer and statements for the subject to agree/disagree with. The data will be used in conjunction with the pre-test questionnaire and will be analyzed for results.

21.1.7 Test Basis

This part covers the information about the user, platform they used and will be used to map the pre-test questionnaire to the post-test questionnaire in order to correlate the data.

21.1.8 Gameplay

In order to evaluate the answers, the subject is to answer questions related to the overall experience and frequency of their play.

ID	Question	Format
AQ1	Did you get the opportunity to test BitPet?	Multiple Choice
AQ2	If no, why not?	Text
AQ3	How often did you play BitPet?	Multiple Choice
AQ4	What was the most fun about BitPet?	Text
AQ5	Did your pet die during the testing period?	Multiple Choice

Table 15: Questions related to experiences

A couple of statements were added in order to assess how the subjects experienced the actual gameplay.

ID	Statement
AS1	I cared about the well-being of my pet during gameplay
AS2	Playing BitPet was enjoyable
AS3	During testing, making progress was important to me
AS4	I would play BitPet again if it was available on app store/google play.
AS5	The use of augmented reality made me feel more immersed in the game
AS6	Watching pets interact with the real world made me more engaged with the game

Table 16: Statements related to experiences

21.1.9 Physical Activity

ID	Question	Format
AQ6	How many walks did you go for during the testing period?	Number
AQ7	How many walks did you go for in order to play BitPet during the testing period?	Number
AQ8	How many times did you exercise during the testing period?	Number

Table 17: Questions related to physical activity

Statements related to how BitPet affected physical exercise were added to find out if the users perceived the game to have an effect on their activity levels, and also give context to the interviews.

ID	Statement
AS7	Playing BitPet during the testing period made me more active
AS8	By playing BitPet walking did not feel like exercising
AS9	BitPet has too much exercise compared to play
AS10	BitPet has too much play compared to exercise

Table 18: Statements related to physical activity

21.1.10 Socialisation

Questions related to how the users interacted during their testing is given in Table 19.

ID	Question	Format
AQ9	Did you tell other people you played BitPet?	Binary
AQ10	If no, how so?	Text
AQ11	Did you play BitPet with other people?	Binary
AQ12	Did you meet new people while playing BitPet?	Binary

Table 19: Questions related to socialisation

Statements related to socialisation trying to figure out whether users would try recruiting friends to the game.

ID	Statement
AS11	I was ashamed of playing BitPet
AS12	Playing BitPet during the testing period made me more sociable
AS13	Playing BitPet made me talk to more people
AS14	I would tell my friends about this game

Table 20: Statements related to physical activity

21.1.11 Shared Missions

Shared missions is the newly developed concept meant to be tested on users. Therefore gathering data about experiences related to this is important.

ID	Question	Format
AQ13	Did you test the shared mission feature?	Binary
AQ14	If no, how so?	Text
AQ15	Care to elaborate?	Text

Table 21: Questions related to shared missions

Statements related to the shared missions feature were added in order to assess whether the feature had a positive impact on the gameplay. The statements focused on both the complexity and usefulness of the feature.

ID	Statement
AS15	shared missions were way too complicated
AS16	I enjoyed playing shared missions
AS17	shared missions had decent rewards
AS18	shared missions was a needed feature for the game
AS19	I had people to test shared missions with

Table 22: Statements related to shared missions

21.2 Mapping to Research Questions

An overview of which questions were related to which research question is given below.

21.2.1 Questions Related to Effect of Augmented Reality on Immersion (RQ1)

Questions used in order to answer *How does the use of augmented reality affect the users immersion and experience of the game?*:

Question ID	Relation
AS1	Assess whether the users were immersed enough to care about their digital pet
AS5	Assess whether the users gameplay was affected by AR
AS6	Assess whether the specific pet AR element made the game more engaging

Table 23: Mapping of questions related to RQ1

21.2.2 Questions Related to Optimal Distribution of Exercise in a Game (RQ2)

Questions used in order to answer *What is the optimal distribution between physical activity and gaming in order to maximize the players enjoyment?*:

Question ID	Relation
BQ7	Get a baseline value for the time spent in physical activity
BQ8	Get the ideal time spent in physical activity for the user
BQ9	Assess what kind of exercises the user usually spends time on
AS7	Assess whether the user perceived themselves as more active during the testing period
AS8	Assess whether the gameplay was perceived as play or exercise
AS9, AS10	Assess how the users experienced the distribution of gameplay versus physical activity

Table 24: Mapping of questions related to RQ2

21.2.3 Questions Related to Motivational Factors in a Game (RQ3)

Questions used in order to answer *What factors contribute to the players motivation for playing a game?*:

Question ID	Relation
BQ10	Assess whether the user prefers to work out alone or with others
BQ11	Assess whether the user uses a form of entertainment during physical activity.
BQ12	Assess whether the user uses any equipment during exercise
BS1	Assess whether the user is more motivated when working out with others
BS2	Assess whether the user has a goal as motivation during exercise
BS3	Assess whether the user wishes to work out more
BS3.1	Assess whether the user perceives exercise as entertaining
BS7	Assess whether the user can be motivated by meeting new people
AQ4	Assess what the most fun part about the gameplay was
AS2	Assess whether the user enjoyed the gameplay
AS3	Assess whether the user cared about making progress
AS16	Assess whether the added feature (shared missions) was enjoyable
AS17	Assess whether shared missions was worth the time invested
AS18	Assess whether the users perceived the added feature a a necessary one

Table 25: Mapping of questions related to RQ3

21.2.4 Questions Related to Facilitation of Social Interaction Through Games (RQ4)

Questions used in order to answer *How can games facilitate social interaction between users?*:

Question ID	Relation
BQ10	Assess whether the user prefers exercising alone or with other people
BS4	Assess whether the user is comfortable in the presence of people they know
BS5	Assess whether the user is comfortable in the presence of people they don't know
BS6	Assess whether the user prefers being alone over the company with others
BS7	Assess whether the user wishes to meet new people
AQ9	Assess whether the user reached out to friends during testing
AQ11	Assess whether the user played with others during the testing period
AQ12	Assess whether the user met new people during the testing period
AS11	Assess whether the user was comfortable with playing the game
AS12	Assess whether the game contributed to making the user more sociable
AS13	Assess whether the user talked to more people while playing
AS14	Assess whether the user would invite friends to play the game
AS19	Assess whether the user had friends to test the shared missions feature with

Table 26: Mapping of questions related to RQ4

21.3 Interviews

The interviews were as mentioned in Section 3.2 built in a semi-structured matter and consisted of mostly open-ended questions followed up by probing questions meant to give more context to the questionnaires. Our open-ended questions focused on the experimental developed feature, shared missions.

Starting the interviews by asking open-ended questions, then following up in a *general interview approach*, allowed us to build rapport and use probing questions to generate more data in an efficient matter. As the experience could vary between each of the interviewees, a less structured approach allowed for more flexibility while still allowing the interviewer to remain in the driving seat [92]. The questions are given below:

- *BitPet as a game is made with inspiration from Pokemon Go and Tamagotchi, among others, and aims to motivate players to socialize and train via the game. What parts of the game do you think are good motivators for this? Possibly which ones do you think are missing?*
- *Shared missions were a functionality that should directly address this issue. Do you think that the functionality was a good motivator? Had the game facilitated socialisation to the same extent without?*
- *Are there other similar games (Pokemon Go for example) that you experience as stronger facilitators? Why?*

The interviews were performed after the post-test questionnaire and were used in order to gather more qualitative data in relation to the experiment and their experiences. The answers to the interviews will be discussed in Section 23.

Part VI

Results and Discussion

This chapter will present the data gathered through the pre-test questionnaire, post-test questionnaire, the experiment and the interviews.

22 Results

The data gathered for this research project came from individual test users, consenting to answering two questionnaires in addition to answering data related to playing the game. The test period lasted a period of two weeks, with users having the option to submit their data after a week of gameplay.

22.1 Test Users

This section will describe the test users and how they were grouped as a result of their differences. In addition, how analysis was performed on these different binary groups is presented.

22.1.1 Groupings

During analysis, we chose to group the participants into three different binary groups according to three different factors: *gender*, *time spent on video games per week*, and lastly *time spent on physical activity per week*. All respondents identified as either male or female, as such this is the binary grouping for gender. The global weekly time spent on video games in 2021 was around 8.5 hours [93], and was used as a reference point when dividing the test users into the other binary group, *active gamer* and *casual gamer*. Lastly, Ipsos did a survey on 29 countries around the world on their exercise levels, and found a global average of 6.1 hours spent exercising per week [94], making the basis for our last binary group, *athletic*, above 6.1 hours spent exercising, or *sedentary*, below 6.1 hours spent exercising. We considered a grouping based on age, as age may be an indicator of, among other things, experience with mobile games and exercising through games. However, the age grouping in our survey only ranged from years 21 to 27, and was therefore considered too close to group by age.

22.1.2 Analysis

The results were then analyzed using the Mann-Whitney test. The Mann-Whitney test was used due to it being a non-parametric test between the distributions of two independent groups and it also allows for groups to be of non-equal sizes. As we are basing our groups based on a single attribute at a time, there is no risk of having individual subjects placed in two opposing groups at the same time, which is an important assumption in the Mann-Whitney test [10]. In Table 27 we can see the n for all different groupings. The Mann-Whitney test computes a value for P, which is the statistical probability that two groups are statistically the same. For our analysis we chose to include values below 0.1, where results between 0.1 and 0.05 were treated as implied statistical significant difference, while values below 0.05 were treated as statistical significant difference.

To perform the Mann-Whitney test we used the python module SciPy. The authors of the SciPy

module describes the module as following: "SciPy is a collection of mathematical algorithms and convenience functions built on the NumPy extension of Python. It adds significant power to the interactive Python session by providing the user with high-level commands and classes for manipulating and visualizing data." [95]. We decided to use this module as this let us perform every test programatically instead of manually. The code used to analyze the data may be found in Appendix D.

Grouped by	**Group**	**n** (pre-test)	**n** (post-test)
Gender	Male	14	12
	Female	8	5
Physical activity	Athletic	14	12
	Sedentary	8	5
Gaming activity	Active gamer	11	9
	Casual gamer	11	8

Table 27: Number of participants in the different groupings that were analyzed

In total 24 users registered for the testing period of the project. Out of these 24, 22 of them answered the pre-test questionnaire and 17 players logged into the game and played during the experiment, 20 answered the post-test questionnaire, but the answers of those who did not play the game have been removed, as every question was related to their experience with the game.

Note also that for every statement in the questionnaires, users were presented with a Likert scale ranging from 1-5 where 1 meant completely disagree and 5 meant completely agree. However, in the tables presented in the following sections, the different levels of agreement and disagreement have been summed for readabilities sake. The original rankings were used in the Mann-Whitney test however, which may result in the same percentages providing different P-values.

22.2 Pre-test Questionnaire

In the following section we will look at the data and results of the pre-test questionnaire as presented in Section 21.1.1. Firstly, data related to demographics and experience with video games and exercise are presented, furthermore, we will look at statistically significant results when comparing groupings in some of the statements.

22.2.1 Demographics

This section covers the age and gender distribution of our test users. The age distribution is displayed in Figure 23 and the gender distribution is displayed in Figure 24. The gender distribution

consisted of 63.6% males and 36.4% females giving us the two groups segmented by gender as mentioned in Section 22 with the male group being the larger one. Our users ranged from 21 to 27 years old covering the young adults segment.

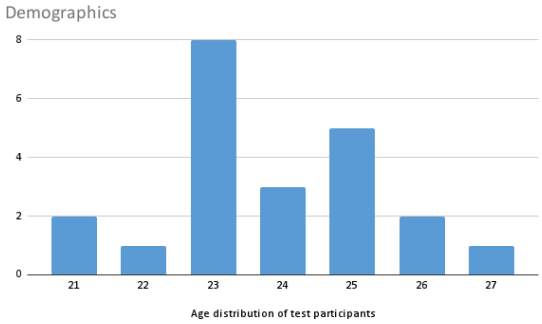

Figure 23: Age distribution uncovered from the pre-test questionnaire

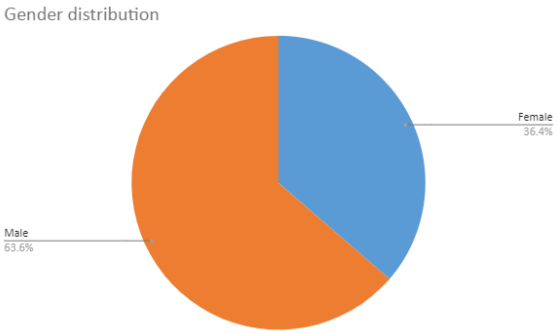

Figure 24: Gender distribution uncovered from the pre-test questionnaire

22.2.2 Video Game Experience

Out of all the participants that answered the pre-test questionnaire, 19 (86.4%) had previous experience related to games involving physical exercise (shown in Figure 25). When asked about which existing exergames they had heard of, all 22 participants answered Pokémon Go.

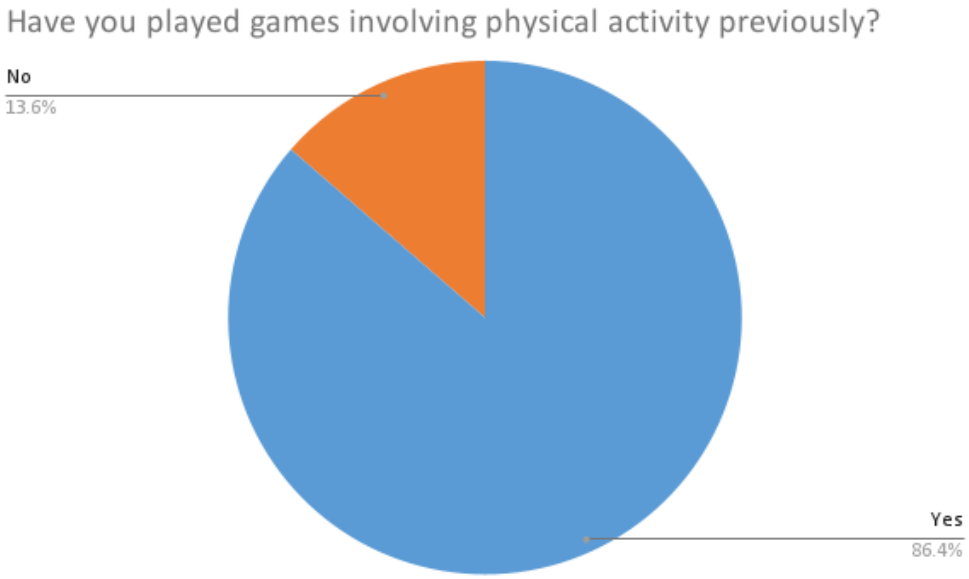

Figure 25: Experiences related to previous exergames

22.2.3 Physical Activity

In Table 28, 29 and 30 the statistically significant Mann-Whitney tests for statements involving physical activity are presented. Interestingly, between all groups there was a significant difference in how groupings perceived their motivation when exercising with other people. In addition, the athletic grouping tended to work out with clear goals in mind when compared to the sedentary group.

Statement	**Group**	**Disagree**	**Neutral**	**Agree**	**P**
I find it easier to motivate myself when I work out with others	Active gamer	9.1%	9.1%	81.8%	**0.058**
	Casual gamer	0%	45.5%	54.5%	

Table 28: Comparison of statistically significant physical activity related statements between the two groups; active gamers and casual gamers

Statement	**Group**	**Disagree**	**Neutral**	**Agree**	**P**
I find it easier to motivate myself when I work out with others	Male	7.1%	14.3%	78.6%	**0.046**
	Female	0%	50%	50%	

Table 29: Comparison of statistically significant physical activity related statements between the two groups; male, female

Statement	**Group**	**Disagree**	**Neutral**	**Agree**	**P**
I find it easier to motivate myself when I work out with others	Athletic	7.1%	7.1%	85.7%	**0.080**
	Sedentary	0%	62.5%	37.5%	
When working out I usually have a clear goal in mind	Athletic	14.3%	7.1%	78.6%	**0.008**
	Sedentary	62.5%	12.5%	25%	

Table 30: Comparison of statistically significant physical activity related statements between the two groups; athletic, sedentary

In Figure 26 we can see a distribution of how many hours per week the participants of the pre-test questionnaire exercised usually.

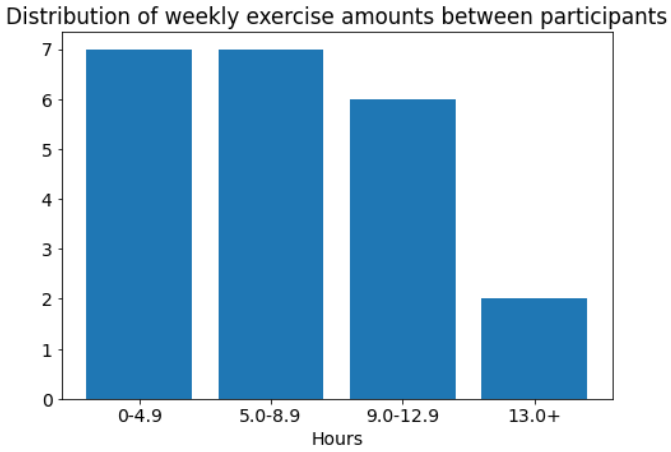

Figure 26: Distribution of weekly exercise amounts between all participants who answered the pre-test questionnaire

22.3 Post-test Questionnaire

In the following section we will look at the data and results of the pre-test questionnaire as presented in Section 21.1.6. The data has been sectioned based on which results that are related to a specific research question. Section 22.3.1 is related to RQ1 and RQ3, Section 22.3.2 is related to RQ2 and Section 22.3.3 is related to RQ4.

22.3.1 Gameplay

In Table 31 we see a table comparing the response of significant statements between the athletic and sedentary group. Every single sedentary participant agreed that they cared about the well-being of their pet, whereas this was mostly not the case for the athletic group.

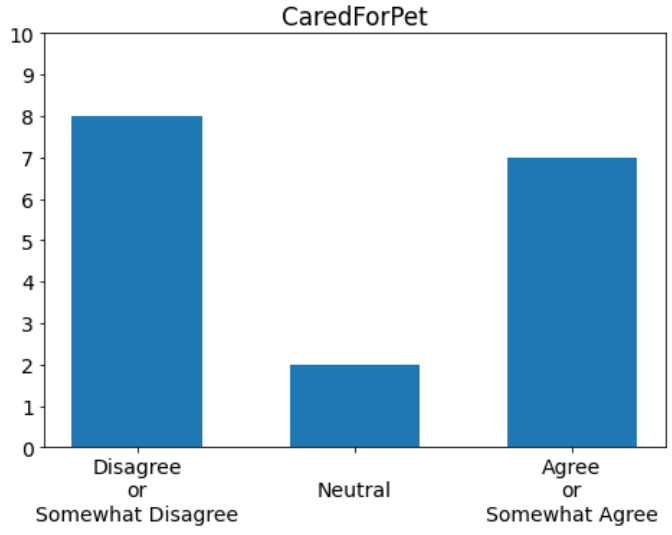

Figure 27: Distribution of AS1: I cared about the well-being of my pet during gameplay

Statement	Group	Disagree	Neutral	Agree	P
I cared about the well-being of my pet during gameplay	Athletic	66.7%	16.7%	16.7%	**0.050**
	Sedentary	0%	0%	100%	

Table 31: Comparison of statistically significant gameplay related statements between the two groups; athletic and sedentary

In Figure 28 and Figure 29 we see the distribution of participants who found themselves invested and engaged through the use of augmented reality, as well as seeing their pets interacting with the real world. We see that the userbase as a whole was very split on whether or not this felt engaging, but there was no significant difference between the groupings.

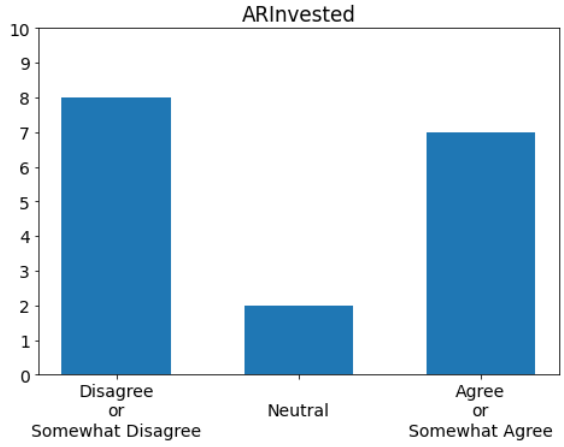

Figure 28: Distribution of AS5: The use of augmented reality made me feel more immersed in the game

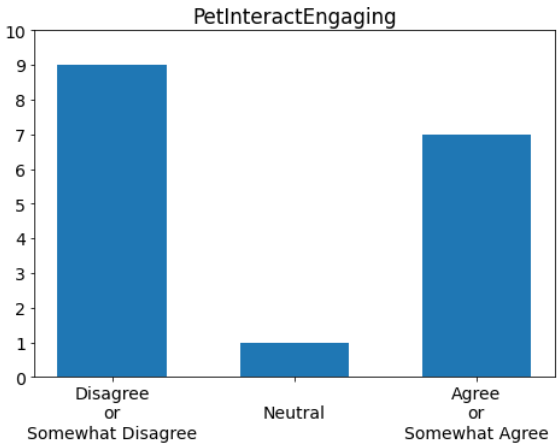

Figure 29: Distribution of AS6: Watching pets interact with the real world made me more engaged with the game

In the following graph, Figure 30 we see a distribution of the users who tested the shared mission feature we created for the game. As shown, very few users actually had a chance to test the feature. When asked why, most of the answers simply stated that they were not aware of the feature, and were not guided properly to the feature by in-game tutorials. In addition, a few of the users stated that they did not have anyone to test the shared mission feature with, as not everyone were able to get a partner for testing the game.

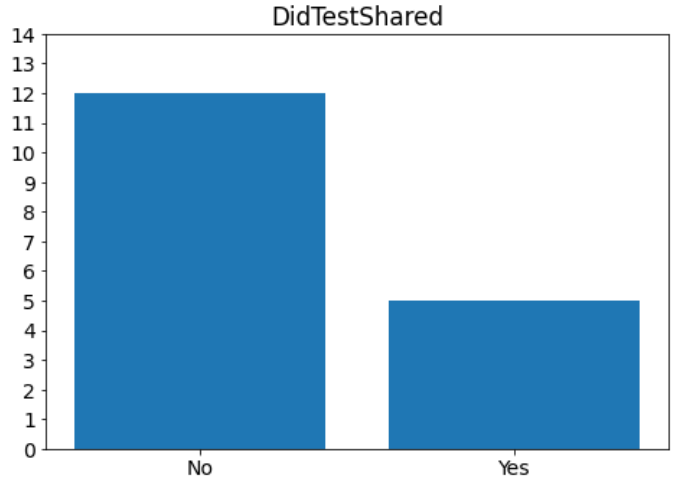

Figure 30: Distribution of AQ13: Did you test the shared mission feature?

In addition a question was added to track how users perceived and prioritised making progress during the testing period. The results are displayed in Figure 31.

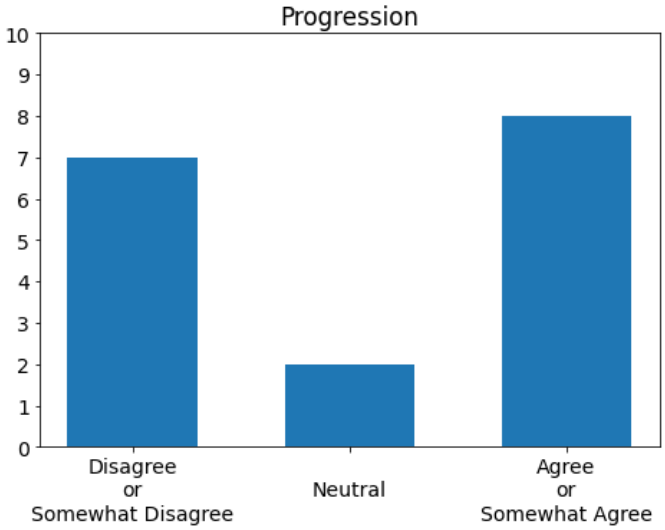

Figure 31: Distribution of AS3: During testing, making progress was important to me

22.3.2 Physical Activity

In Figures 32 and 33 we see how our testers felt about the relationship between the amount of exercise and amount of gameplay in BitPet. From the results, most users were either neutral or disagreed that the game contained too much exercise. In addition, the userbase was very split on whether or not there was too much gameplay when compared to exercise. There were no significant differences between the groupings when it came to these two statements.

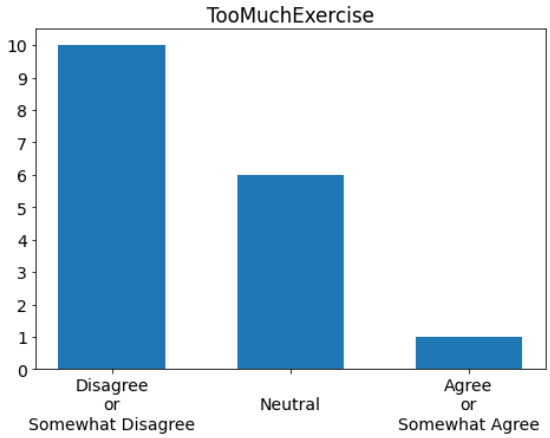

Figure 32: Distribution of AS9: BitPet has too much exercise compared to play

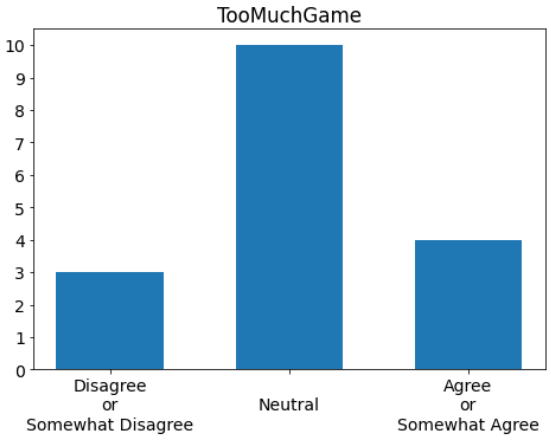

Figure 33: Distribution of AS10: BitPet has too much play compared to exercise

22.3.3 Socialisation

In Table 32 we can see that in general, the active gamers were somewhat less sociable while playing BitPet.

Statement	Group	Disagree	Neutral	Agree	P
Playing BitPet during the testing period made me more sociable	Active Casual	88.9% 62.5%	11.1% 12.5%	0% 25%	**0.042**
Playing BitPet made me talk to more people	Active Casual	88.9% 62.5%	11.1% 12.5%	0% 25%	**0.094**

Table 32: Comparison of statistically significant socialisation related statements between the two groups; active and casual gamer

Somewhat related to the results in in Table 32, we see that a majority of the player base felt embarrassed playing BitPet in Figure 34.

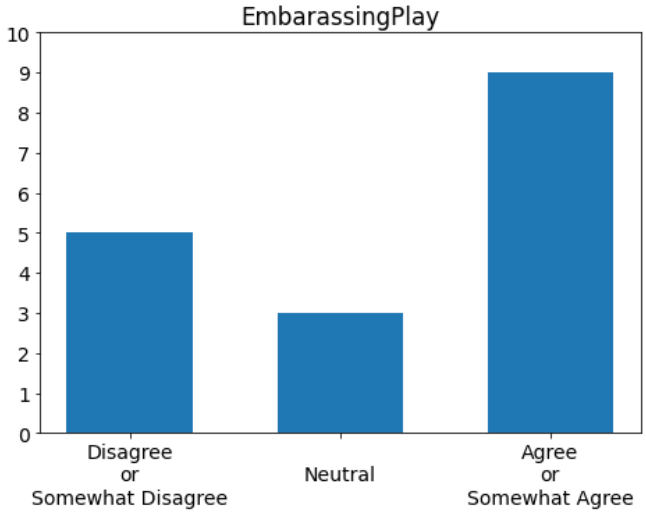

Figure 34: Distribution of AS11: I was ashamed of playing BitPet

22.4 Interviews

Out of the 20 participants in the post-test questionnaire, only 5 of them tested the newly developed concept, shared mission, extensively. After the experiment ended, a selection of 2 of these 5 participants were asked additional questions about the shared mission feature.

The participants of the interviews were asked what part of the game they found motivating, one participant talked about the interaction with the environment and being able to interact with their pet and pickup items from the map, while the other participant focused more on the challenge features, coin battle and pet battles. Both users also mentioned how owning territories was a fun aspect.

When asked specifically about the shared missions feature the users had mixed opinions, but both agreed that the concept was interesting if the game was more polished. One participant also mentioned how it was a missed opportunity to not have different objectives for the shared missions compared to the normal single player ones. One user also mentioned how it was hard to keep track of progress during missions, as you did not get any visual cues except for when you opened up the missions menu. The shared missions also lacked a way to get to know new people, as you had to know the username of existing players in order to play missions with them.

Both participants had previously played Pokémon Go and when asked whether a feature or part of Pokémon Go was a good facilitator for exercise and socialisation, one participant mentioned how Pokémon Go had different spawn rates for different areas, and incentivised playing in areas with a higher population, which lead him to meet new people more frequently.

22.5 Summary

This section started out by introducing the groupings used during presentation of the results in addition to our analysis method.

23 Discussion

The following section will discuss limitations we experienced during the experiment and data gathering phase, interviews of shared mission testers, as well as the different research questions presented in Section 3.

23.1 Limitations of Data Gathering

During the experiment we experienced some limitations to our data generation. These are discussed in the following sections.

23.1.1 Limitations with User Population

The number of users that ended up playing BitPet was 17, down from the original 22 participants who answered the pre-test questionnaire. While we got useful data from the participants, another consequence of a small user pool was that only a fraction of the users got to test out our newly developed feature shared missions, which may have affected our results. If there had been more users available to embark on shared missions with, we might have received more data related to shared missions. Interviews were used as a countermeasure in order to gain more data about shared missions along with general feedback.

In a production environment, the game would have a lot of different users to interact with when compared to this limited pool of users. This means that any feature which relies on cooperation or interactions between users were somewhat limited, simply because there were fewer players to do in-game objectives with.

In addition, the game was only tested with one age group, young adults. It is possible that these young adults test and interact with the game very differently compared with teenagers and children, as well as older people, due to the general difference in experience with games and mobile phone technology.

23.1.2 Limitations with BitPet

During testing of the application, several users reported a bug concerning a no-network modal, which some users reported as disruptive to their gameplay. Some users also reported that the game did not have enough content to fill the entire testing period, and as a consequence it might have led us into missing out on important data due to the fact that some testers stopped playing early during the testing period. In addition, multiple users mentioned that they did not know how to play the game, and the lack of a tutorial therefore made them confused as to how to progress at

all.

23.2 Interviews of Shared Mission Participants

During interviews we uncovered that the participants shared many of the same opinions about the shared mission feature, and therefore decided that interviewing 2 participants was adequate. The two participants also represented different binary groups as one of the participants belonged to the active gamer binary group, whilst the other belonged to the casual gamer group.

The participants both valued elements related to the AR aspect of the game and found them motivating. Their answers during the interviews are presented where relevant in the following discussion on research questions.

23.3 RQ1: Effect of Augmented Reality on Immersion

Original research question: *How does the use of augmented reality affect the users immersion and experience of the game?*

In Figure 29 from Section 22.3.1 we see that the participants had mixed conceptions about whether or not augmented reality made them feel more immersed in the game, as users either agreed or disagreed, with only a small fraction of the participants being neutral. This makes sense when considering some of the theory mentioned in Section 9.2.2, as immersion is affected by the users' willingness to try and explore, as well as their extraversion [41]. An interesting find was that the sedentary group reported data that indicated that they cared more about their pets as opposed to the athletic group (Table 31). In addition, the pervasive gameflow described in the same section, states that game should be able to shift the focus between the virtual and physical part of the game [22]. This meaning the transition between these states should be as smooth as possible. As many users experienced bugs relating to augmented reality and the map, as well as users being forced to use landscape mode on their phone for all scenes in the game, this flow state may have been broken for some. Breaking this flow state may have lead to an overall less positive experiences with the augmented reality sections of the game.

During the interviews described in Section 22.4 one participant answered *"collecting battles and fighting other pets in order to win the territory"* to the question about the most immersive part of the gameplay. Collecting coins heavily involves the use of augmented reality as you place your pet virtually on a real world surface and race against another pet in order to collect the most coins, and battling other pets uses the existing real world as the background. During development this feature was tested in Unity on desktop, which does not support augmented reality, making the depth perception in the game mode non-existent, completely removing the feeling of immersion when playing. Therefore, the use of a real world background, much like when catching Pokémon

in Pokémon Go, seems to improve the users immersion somewhat.

The results from the post-test questionnaire and interviews indicates that augmented reality affects users differently, having about as many users reporting that it contributed to the gameplay and immersion, while other users reported that it did not. No statistically significant differences between the groupings were found for how the use of augmented reality affected them.

23.4 RQ2: Optimal Distribution of Exercise in a Game

Original research question: *What is the optimal distribution between physical activity and gaming in order to maximize the players enjoyment?*

During the pre-test questionnaire it was uncovered that our users consisted of a lot of active individuals with previous experience from playing exergames. Out of the 17 users testing the game, 12 of them were in the athletic group, which may have affected our results. The distribution in Figure 32 is skewed in the direction where almost none of the users reported that the game had too much exercise compared to play, although no statistically significant difference was found in the answers from the athletic and sedentary group for this question. When asked about the amount of gameplay compared to exercise (Figure 33), most of the users answered neutrally, with a couple of more users agreeing. The results indicate that users could be comfortable with increasing the level of exercise, while being mostly neutral about the gameplay aspect.

In Section 22.4 one user said *"Pokémon Go had more content. There are loads of Pokémon and different locations had different probabilities of spawning different kinds of Pokémon, which incentivised traveling to different locations"*, which also suggests that the game lacked incentive for more exercise. They also noted that the locations you had to travel to made more sense in Pokémon Go, where in game gyms and points of interest are located at real life points of interest. If you give players multiple incentives to travel somewhere, the exercise may not be recognised as an incentive itself. This study did not generate enough data to be able to answer this question, but from the questionnaire data and interviews it is clear that there has to be more incentives for exercising than what is currently present in BitPet.

23.5 RQ3: Motivational Factors in a Game

Original research question: *What factors contribute to the players motivation for playing a game?*

During the post-test questionnaire a question related to the importance of progress was asked and given in Figure 31. Although there is only a slight favor for agree, the game was not a finished product, so the progress possible was limited, and some users also reported having nothing left to do before the testing period ended. Other findings from the questionnaires was that users in the active gamers group found it significantly easier to motivate themselves for a workout when working out

with others, while the casual gamer group was more neutral (Table 28). Another interesting find was that users belonging to the athletic group found it easier to motivate themselves for exercise when having a clear goal in mind, while the sedentary group was more neutral (Table 30). These results indicate that the different user groups favors different factors when it comes to motivation, but with a few common traits. Nearly none of the participants of the experiment reported that being with others was negative for their motivation.

During the interviews in Section 22.4 when asked about shared missions, one user reported that *"The missions need a better form of visualization of progress. It was hard to keep track of the remaining steps of the mission without having to go into the missions menu. The rewards were also not worth the time investment. The objectives were also very similar to normal missions, and I had no reason to play shared missions instead"*. This coincides well with how Game Flow as discussed in Section 7.1 states how important feedback and is for motivating players [19]. The interviewed participant belonged to the active gamer group, and as the data indicates, making progress was important. Having a more distinct separation between shared missions and normal missions could also possibly motivate more users to test the feature out. The comment about rewards was also interesting as it was mentioned in both interviews that they lacked incentive to test out the shared missions feature.

From Malone's theory of Enjoyment and Game Flow as presented in Sections 6 and 7.1 clear goals are a very important part of motivating players to play games [19] [17]. It was stated from multiple participants that they felt somewhat clueless and without an obvious progression system. The same participants felt that they were discouraged after a few playing sessions due to this lack of a goal, further exemplifying this need for a clear goal when playing.

The results from the questionnaires and interviews suggest that motivation is based on the individual, but we can extract a couple of suggested factors from our data. These are namely the sense of progress, playing with other people and having a clear goal.

23.6 RQ4: Facilitation of Social Interaction Through Games

Original research question: *How can games facilitate social interaction between users?*

From our research it seems that games facilitate this social interaction in a lot of different ways, with varying degrees of success. One of our findings suggests that a game must not simply provide a user with a way of interacting with other users, but incentivise this feature in different ways than the ones that do not provide social interactions. During one of the interviews, it was stated that the shared mission feature would be a lot more interesting if it provided the players with different types of missions that what are found in common user missions. They stated that missions which would otherwise be impossible to complete alone would be more interesting to share with a friend. Furthermore, the game must make it obvious how the player is able to actually do things in game

with other users. As an example, a few of our players experienced the shared mission invite as somewhat buggy, due to names being case sensitive, but the game not actually providing a difference in fonts between cases. This resulted in some players dismissing the feature as a whole, believing it to not work the way they thought it did. Another point made in one of the interviews was that the map provides a feature in which players are able to see other players in close proximity, however, the possibilities you have for interacting with them outside of this are quite limited. An idea that was presented was that users should for example be able to invite a player to a shared mission directly through the map, instead of having to learn their name and then write it. Another idea that was presented was one that is used in one of Nintendo's successful game series, Animal Crossing. In this game you are able to visit other players' islands which they have spent time decorating for themselves. Currently, the islands in BitPet are only available for the player themselves, without any way of sharing their time spent on the island.

As noted in Section 22.3.3, a majority of the players that played BitPet felt somewhat embarrassed or ashamed while playing the game. This will obviously halt how interested a player is in interacting with other users. The users that are playing the game should feel confident in sharing their experiences. It is possible this embarrassment would not be present in different age groups.

In conclusion, it seems that there are many ways of facilitating social interactions between users, but that one of the most important incentives is one which makes this social interaction give different rewards and experiences when compared to the single player experience, other than the fact that you are sharing it.

Part VII

Conclusion and Further Work

This chapter consists of the conclusion and further work after the research project ends.

24 Conclusion

This study had the research goal *To develop and prototype a minigame concept, which utilizes AR and GPS to facilitate socialisation and exercise, and which increases motivation for the users*, which was broken down into 4 research questions.

Creating and developing a new concept for an AR game is both interesting and challenging. In order to make the concept successfully, one needs to know users are affected by AR differently (RQ1), as the concept can not be overly reliant on AR itself, but has to provide a proper ecosystem around the AR features, in order for this to provide a good experience. Finding the optimal distribution between gameplay and physical activity in exergames or achieving DualFlow can be very challenging as users have different opinions based on their own personal preferences (RQ2), though having an incentive for increasing physical activity could have a positive effect. A well-designed feature needs to keep users motivated. Although motivation is individually based, our data indicates that giving users a sense of progress, a clear goal and enabling them to play with other people has a positive effect on motivation (RQ3). Facilitating for social interaction can be done by giving exclusive rewards and experiences for multiplayer content and by making it easier to make these available with by introducing players to new people (RQ4).

The results from the study indicates that the developed feature, shared missions has potential to increase motivation whilst facilitating for socialisation and exercise. It does however need more work in order to make it available to users, iron out bugs and errors and be more integrated in the existing games features.

25 Further Work

25.1 Shared Missions

If wanted by the BitPet team, the shared missions feature needs to be merged on their existing version of the project. During development and testing, we worked on a separate version of the project by forking, and the changes made by the BitPet team has happened in parallel with our development. During development we made several changes to the existing database schema and used a separate database for testing, making new migrations required.

During interviews a couple of feature requests were proposed. Some of these were a reworked way to invite users to shared missions, not requiring the inviting user to know the invitees username, changing the objectives of the missions and increasing the rewards. In addition a user wanted an easier way to track progress during missions which includes both shared missions and normal missions.

25.2 Future of BitPet

The testing period we have performed have given the BitPet team a lot of different feedback and potential feature developments for the future. While a lot of the feedback was related to bugfixes which potentially would be fixed regardless of the feedback given during this testing, some of the feedback did not relate to such bugfixes. An example of this is the need for a clear goal when playing the game, and giving players direction. A tutorial for how to play the game and its different game modes would be an essential part of the game. While one such tutorial was in the works before the testing period, it was not finished and ready for testing. This tutorial should be a focus going forward. In addition, further incentivising the social interaction of players could be a focus going forward. Be that through polishing shared missions, or for example the shared islands feature that one of the interviewees mentioned. While a lot of the testers did not enjoy the game in its current state, multiple users still believed that the game has potential, but requires polishing, refining and stronger interactions between the different parts of the game which are currently present.

While it is hard to tell how well the game will fare in the future, our testing has shown that the game has potential and some of the testers said they would happily play the game in the future if it was somewhat more polished. We wish the best of luck to the BitPet team in their future development, be that with or without our shared mission feature.

25.3 Further Experimenting

As mentioned in Section 23.1 there were a few limitations to the experiment performed. Some further work that could be performed to counteract these limitations are presented. Firstly, testing features with many different types of users. It would potentially be interesting to see how children and older adults interact with the game, due to their different experiences with mobile phone technology and games. Secondly, testing the game with a larger player base could make the experience of all features which demand some interaction between users more easily tested for the users, as there are more players to test it with. This could potentially solve some issues like people meeting new people who are also playing the game. Lastly, the game should be polished further before testing, due to the different bugs users experienced when playing. Among these bugs, multiple of them were experienced as immersion-breaking and provided a negative user experience, which may have affected the data we received regarding the general flow of the game.

Furthermore, it could be interesting to test newer features in BitPet, such as the ones presented in the previous Section. While there were some ideas presented, it is difficult to tell whether or not these features would provide a better gameplay experience for users without testing them on a larger scale.

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Appendix

A NSD Information

Vil du delta i forskningsprosjektet

AR Games for motivation, socialization and exercise

Dette er et spørsmål til deg om å delta i et forskningsprosjekt hvor formålet er å undersøke bruken av AR (augmented reality) i spill for å motivere brukeren, og å fasilitere for sosialisering og trening. I dette skrivet gir vi deg informasjon om målene for prosjektet og hva deltakelse vil innebære for deg.

Formål
Prosjektet skrives i forbindelse med en masteroppgave ved NTNU Trondheim, fakultet for informasjonsteknologi og elektroteknikk (IE), institutt for datateknologi og informatikk (IDI). Formålet med prosjektet er å undersøke hvordan AR spill kan virke motiverende for brukere, samt fasilitere for sosialisering og trening. Vi ønsker å undersøke hvordan spesifikke samarbeidsoppgaver påvirker den sosiale opplevelsen i spillet BitPet.

Hvem er ansvarlig for forskningsprosjektet?
Professor Alf Inge Wang ved IDI er ansvarlig for prosjektet.

Hvorfor får du spørsmål om å delta?
Du får spørsmål om å delta da du befinner deg i nettverket til en av prosjektets deltakere, og fordi du passer i målgruppen for eksperimentet.

Hva innebærer det for deg å delta?
Ved å delta i prosjektet er du med på et eksperiment som går over 2 uker. I starten ønsker vi å kartlegge dine tidligere erfaringer med liknende spill som BitPet ved bruk av et elektronisk spørreskjema. Videre vil du spille BitPet i større eller mindre grad over 2 uker. Når denne perioden er over, vil du svare på et elektronisk spørreskjema til.

Vi vil trekke ut et tilfeldig utvalg deltakere for nærmere intervjuer. Det er anledning for å på forhånd trekke seg fra dette utvalget, ved å ikke samtykke til intervjuet i erklæringen i bunn av dokumentet.

Dine svar fra spørreskjemaet blir registrert elektronisk. I tillegg vil informasjon du oppgir i mobilapplikasjonen bli lagret i en skytjeneste. Denne dataen vil bli slettet ved eksperimentets slutt, eller før dersom du ber om det.

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

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

Det er forfattere av masteroppgaven, samt veileder, som vil ha tilgang disse dataene.

For datalagring benyttes skytjenesten SharePoint, lagd av Microsoft. Informasjonen vil så ligge under NTNU som organisasjon og adgangsbegrenses. Mer om SharePoint og Microsoft sin behandling av din data her: https://docs.microsoft.com/en-us/sharepoint/safeguarding-your-data.

Persondata som vil lagres under bruk av appen er som følger:

- E-post, brukernavn, passord og registreringsdato i forbindelse med registrering
- GPS-posisjoner brukes fortløpende for å beregne logikk i spillet, men lagres typisk ikke, utenom ett tilfelle: Dersom du fullfører et oppdrag som baserer seg på å reise til et spesifikt sted, vil oppdragsdata, GPS posisjon, samt anonymisert bruker-ID lagres sammen som bevis på gjennomført oppdrag
- Antall skritt gått mens appen er åpen (per dag).
- Operativsystem på enhet
- Forrige innloggingsdato
- Vellykkede og mislykkede transaksjoner

Hva skjer med opplysningene dine når vi avslutter forskningsprosjektet?
Opplysningene slettes når prosjektet avsluttes/oppgaven er godkjent, noe som etter planen er senest 17. juni. Opplysningene vil anonymiseres når utvalget for intervjuer er valgt. Intervjuene vil ikke anonymiseres før de slettes.

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 IDI 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:

- Forfattere av masteroppgaven:
  - William Andersson – william.andersson@ntnu.no
  - Casper Feng – casperf@stud.ntnu.no
- Veileder:
  - Alf Inge Wang - alf.inge.wang@ntnu.no
- Vårt personvernombud: https://innsida.ntnu.no/wiki/-/wiki/Norsk/Personvernombud+NTNU

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

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

Med vennlig hilsen

Alf Inge Wang
William Andersson
Casper Feng
(Forsker/veileder)

Samtykkeerklæring

Jeg har mottatt og forstått informasjon om prosjektet *AR Games for motivation, socialization and exercise*, og har fått anledning til å stille spørsmål. Jeg samtykker til:

- □ å delta i elektronisk spørreundersøkelse
- □ å delta i eksperiment ved bruk av mobilapplikasjonen BitPet
- □ å delta i tilfeldig utvalgt intervju

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

---

(Signert av prosjektdeltaker, dato)

B Pre-test Questionnaire

BitPet spørreundersøkelse 1

Vi er William Andersson og Casper Feng, og vi studerer 5. året på henholdsvis informatikk og datateknologi ved NTNU. Dette er en spørreundersøkelse knyttet til masteroppgaven vår høsten 2022 og skal gjennomføres før testperioden med BitPet-spillet. Dette er første del av to spørreundersøkelser, hvor neste undersøkelse gjennomføres etter testperioden. Undersøkelsen består av spørsmål samt påstander og skal ikke ta mer enn 15 minutter å besvare. Hensikten med undersøkelsen er å danne et datagrunnlag før eksperimentet. Tusen takk for at du ønsker å delta!

* Obligatorisk

Introduksjon og Samtykke

Denne delen omhandler litt informasjon om det praktiske i forsøket samt for å bekrefte at det er greit at svarene som gis i denne undersøkelsen blir benyttet til videre forskning. Informasjon om hvordan dataen behandles ligger vedlagt i utsendt informasjonsskriv. Dersom du ikke har mottatt denne så ta kontakt. Du kan underveis i spørreundersøkelsen velge å avbryte når som helst, eller sende melding til kontaktpersonen (casperf@stud.ntnu.no) dersom du ønsker å trekke deg fra

1. Hva er ditt navn? *

2. Jeg samtykker til at jeg har mottatt og forstått informasjon om prosjektet samt fått anledningen til å stille spørsmål, trekke meg fra prosjektet til en hver tid og samtykker til: *

- [ ] at svarene mine i spørreundersøkelser kan bli brukt til analyse og videre forskning
- [ ] at jeg er villig til å delta i brukertesting hvor svarene mine blir brukt til analyse og videre forskning
- [ ] at jeg er villig til å delta i et intervju hvor svarene mine blir brukt til analyse og

3. Jeg samtykker til at mine opplysninger oppbevares og behandles inntil prosjektet avsluttes. *

- ◯ Ja, jeg samtykker
- ◯ Nei, jeg samtykker ikke

Demografi

4. Hvor gammel er du? *

5. Hva er ditt kjønn? *

- ◯ Mann
- ◯ Kvinne
- ◯ Annet
- ◯ Ønsker ikke å oppgi

Erfaring med videospill

6. Ca. hvor mange timer bruker du på dataspill hver uke? (Mobilspill, dataspill, konsoll og lignende) *

7. Har du tidligere spilt videospill som involverer en form for fysisk aktivitet? (f.eks Pokemon Go) *

- ◯ Ja
- ◯ Nei

8. Hvis ja til forrige spørsmål, kan du utdype hvilke(t) spill? *

9. Jeg har hørt om Pokemon Go eller Tamagochi *

- ◯ Jeg har hørt om Pokemon Go
- ◯ Jeg har hørt om Tamagochi
- ◯ Jeg har hørt om begge spillene
- ◯ Jeg har ikke hørt om noen av spillene

Fysisk aktivitet

10. Ca. hvor mange timer i uken er du i fysisk aktivitet? (gåtur, løpetur, trening eller lignende) *

11. Hvor mange timer i uken ønsker du å benytte i fysisk aktivitet? *

12. Hva slags type trening foretrekker du? *

13. Fortrekker du å trene alene eller med andre? *

- ◯ Alene
- ◯ Sammen med andre

14. Vil du utdype hvorfor du foretrekker å trene alene/med andre?

15. Benytter du deg av noe form for underholdning på gåturer? *

- [ ] Lydbok
- [ ] Musikk
- [ ] Videospill (f.eks Pokemon Go)
- [ ] Telefonsamtale
- [ ] Gåtur sammen med venner
- [ ] Jeg drar ikke på gåturer

16. Påstander om fysisk aktivitet *

	Helt uenig	Delvis uenig	Nøytral	Delvis enig	Helt enig
Jeg synes det er lettere å motivere meg selv når jeg trener sammen med andre	◯	◯	◯	◯	◯
Jeg har vanligvis et klart mål i tankene når jeg trener	◯	◯	◯	◯	◯
Jeg synes det fort blir kjedelig under fysisk aktivitet	◯	◯	◯	◯	◯
Jeg skulle ønske jeg trente mer	◯	◯	◯	◯	◯

Sosialisering

17. Påstander om sosialisering *

	Helt uenig	Delvis uenig	Nøytral	Delvis enig	Helt enig
Jeg er komfortabel sammen med folk jeg kjenner	◯	◯	◯	◯	◯
Jeg er komfortabel sammen med folk jeg ikke kjenner	◯	◯	◯	◯	◯
Jeg foretrekker å være med andre fremfor å være alene	◯	◯	◯	◯	◯
Jeg ønsker å møte nye folk	◯	◯	◯	◯	◯

18. Noe du vil tilføye?

C Post-test Questionnaire

BitPet spørreundersøkelse 2

Vi er William Andersson og Casper Feng, og vi studerer 5. året på henholdsvis informatikk og datateknologi ved NTNU. Dette er en spørreundersøkelse knyttet til masteroppgaven vår høsten 2022 og skal gjennomføres etter testperioden med BitPet-spillet. Undersøkelsen består av spørsmål samt påstander og skal ikke ta mer enn 15 minutter å besvare. Hensikten med undersøkelsen er å danne et datagrunnlag for videre analyser. Tusen takk for at du ønsker å delta!

* Obligatorisk

Testgrunnlag

1. Hva er ditt navn? *

2. Hvilken platform testet du BitPet med? *

- ◯ Android
- ◯ iOS

Erfaringer med BitPet

3. Fikk du testet BitPet under testperioden? *

- ◯ Ja
- ◯ Nei

4. Hvis nei, hvorfor ikke?

5. Hvor ofte spilte du BitPet? *

- ◯ Hver dag
- ◯ Flere ganger i uken
- ◯ Ukentlig
- ◯ Spilte ikke BitPet

6. Hva var mest morsomt under testingen av BitPet? *

7. Døde kjæledyret ditt under testperioden til BitPet? *

- ◯ Ja
- ◯ Nei
- ◯ Ikke relevant

8. Påstander knyttet til erfaringer med BitPet *

	Helt uenig	Delvis uenig	Nøytral	Delvis enig	Helt enig
Jeg synes det var gøy å spille BitPet	◯	◯	◯	◯	◯
Under testing var jeg opptatt av å ha en form for fremgang i spillet	◯	◯	◯	◯	◯
Jeg ville spilt BitPet igjen dersom det kom ut på App store/Google play	◯	◯	◯	◯	◯
Bruken av AR (Augmented Reality) fikk meg til å føle mer investert i spillet	◯	◯	◯	◯	◯
Å se kjæledyret interagere med den virkelige verden gjorde spillet mer engasjerende	◯	◯	◯	◯	◯
Jeg brydde meg om hvordan kjæledyret mitt hadde det	◯	◯	◯	◯	◯

Fysisk aktivitet

9. Ca. Hvor mange gåturer ble det i løpet av testperioden *

10. Ca. Hvor mange gåturer gikk du på i sammenheng med testing av BitPet i løpet av testperioden? *

11. Hvor mange ganger trente du i løpet av testperioden? *

12. Påstander knyttet til fysisk aktivitet *

	Helt uenig	Delvis uenig	Nøytral	Delvis enig	Helt enig
Under testperioden bidro BitPet til at jeg var mer aktiv	◯	◯	◯	◯	◯
Når jeg spilte BitPet føltes ikke gåturer ut som fysisk trening	◯	◯	◯	◯	◯
BitPet hadde for mye trening i forhold til spill	◯	◯	◯	◯	◯
BitPet hadde for mye spill i forhold til trening	◯	◯	◯	◯	◯

Sosialisering

13. Fortalte du andre om BitPet under testperioden? *

- ◯ Ja
- ◯ Nei

14. Hvis nei, hvorfor ikke?

15. Spilte du BitPet sammen med andre folk? *

- ◯ Ja
- ◯ Nei

16. Under testperioden førte BitPet til at jeg møtte nye mennesker *

- ◯ Ja
- ◯ Nei

17. Påstander knyttet til sosialisering

	Helt uenig	Delvis uenig	Nøytral	Delvis enig	Helt enig
Jeg synes det var flaut å spille BitPet offentlig	◯	◯	◯	◯	◯
Under testperioden førte BitPet til at jeg var mer sosial	◯	◯	◯	◯	◯
Under testperioden førte BitPet til at jeg snakket med nye mennesker	◯	◯	◯	◯	◯
Jeg kunne fortalt andre om BitPet	◯	◯	◯	◯	◯

Delte oppdrag

Spørsmål knyttet til delte oppdrag (shared quests).

18. Testet du delte oppdrag under testperioden? *

- ◯ Ja
- ◯ Nei

19. Hvis nei, hvorfor ikke?

20. Påstander knyttet til delte oppdrag (velg nøytral dersom du ikke fikk testet) *

	Helt uenig	Delvis uenig	Nøytral	Delvis enig	Helt enig
Delte oppdrag var for komplisert	◯	◯	◯	◯	◯
Jeg koste meg med delte oppdrag	◯	◯	◯	◯	◯
Jeg synes delte oppdrag hadde gode premier	◯	◯	◯	◯	◯
Jeg synes delte oppdrag var en nødvendig funksjonalitet i spillet	◯	◯	◯	◯	◯

Avslutning

Dette er slutten på undersøkelsen! Vi setter pris på alle tilbakemeldinger, og igjen takk for at du

21. Noe du vil tilføye? (Dette er siste spørsmål)

D Data Analysis Notebook

In [ ]:
```
import pandas as pd
from scipy.stats import mannwhitneyu

df = pd.read_excel (r'.\data.xlsx', sheet_name='Mann-Whitney')

group_male = df.loc[df['Gender'] == 'Mann']
group_male.name = "Male"
group_female = df.loc[df['Gender'] == 'Kvinne']
group_female.name = "Female"

group_gamer = df.loc[df['GameTime'] >= 8.5]
group_gamer.name = "Gamer"
group_casual = df.loc[df['GameTime'] < 8.5]
group_casual.name = "Casual"

group_athletic = df.loc[df['ExerciseTime'] >= 6.1]
group_athletic.name = "Athletic"
group_sedentary = df.loc[df['ExerciseTime'] < 6.1]
group_sedentary.name = "Sedentary"

binary_groups = [[group_male, group_female], [group_gamer, group_casual], [group_athletic, group_sedentary]]

agree = [4, 5]
neutral = [3]
disagree = [1, 2]

def percentage(part, whole):
    if (whole == 0):
        return 0
    return str(round((100 * float(part)/float(whole)), 1))
```

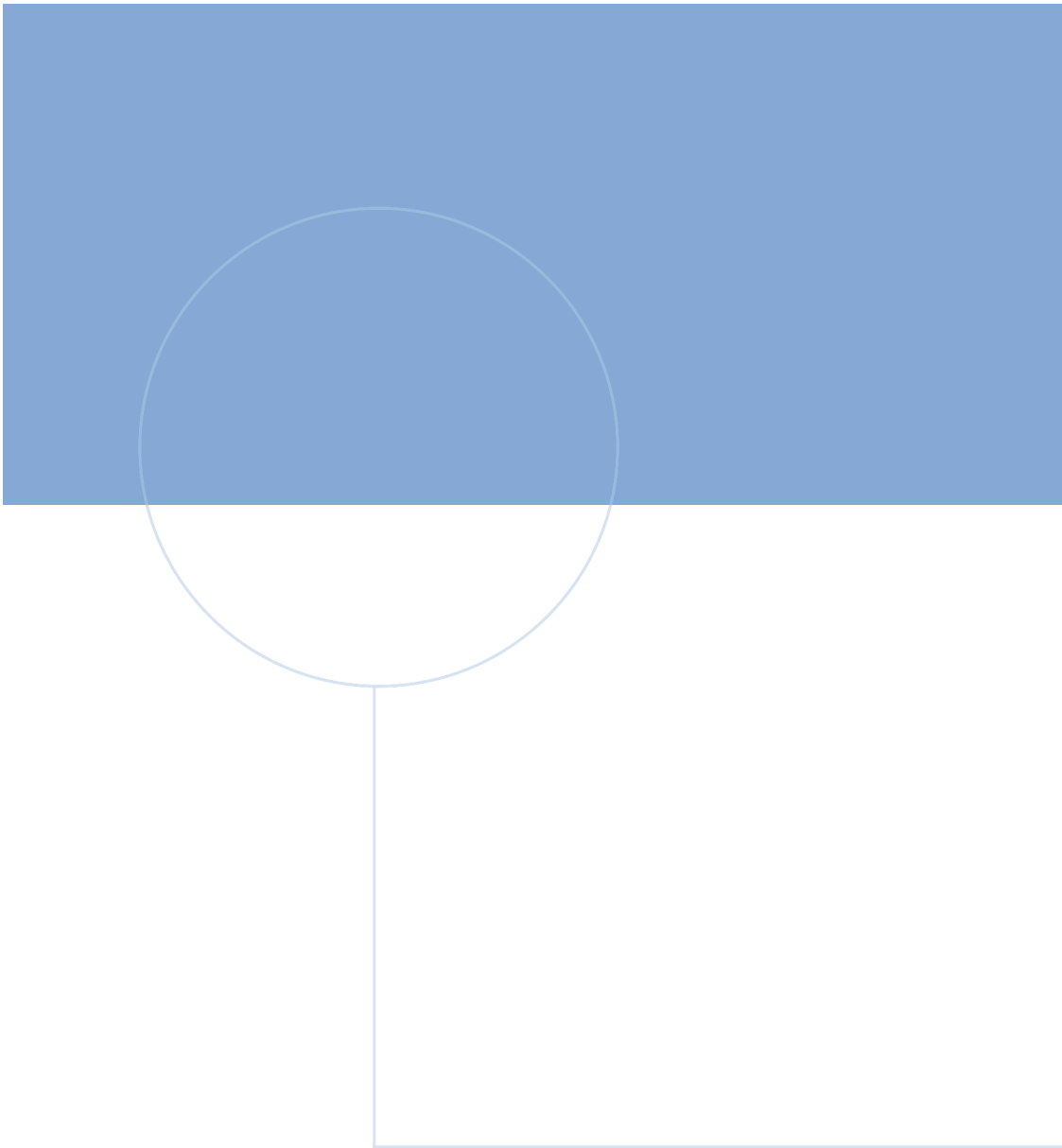
In [ ]:
```
for group in binary_groups:
    statements = df.loc[:, 'MotivationOthers':'TrainMore']
    for statement in statements:
        result = mannwhitneyu(group[0][statement], group[1][statement])
        if result.pvalue > 0.1:
            continue
        for g in group:
            num_agree = g.loc[g[statement].isin(agree), statement].count()
            num_neutral = g.loc[g[statement].isin(neutral), statement].count()
            num_disagree = g.loc[g[statement].isin(disagree), statement].count()
            print(g.name + ' ' + statement)
            print('Agree: ' + percentage(num_agree, len(g.index)) + '%, Neutral: ' + percentage(num_neutral, len(g.inc
        print(result)
    print('\n')
```

In [ ]:
```
df_cleaned = df.dropna()
df_cleaned = df_cleaned.loc[df_cleaned['CouldTest'] == 'Ja']

clean_group_male = df_cleaned.loc[df['Gender'] == 'Mann']
clean_group_male.name = "Male"
clean_group_female = df_cleaned.loc[df['Gender'] == 'Kvinne']
clean_group_female.name = "Female"

clean_group_gamer = df_cleaned.loc[df['GameTime'] >= 8.5]
clean_group_gamer.name = "Gamer"
clean_group_casual = df_cleaned.loc[df['GameTime'] < 8.5]
clean_group_casual.name = "Casual"

clean_group_athletic = df_cleaned.loc[df['ExerciseTime'] >= 6.1]
clean_group_athletic.name = "Athletic"
clean_group_sedentary = df_cleaned.loc[df['ExerciseTime'] < 6.1]
clean_group_sedentary.name = "Sedentary"

clean_binary_groups = [[clean_group_male, clean_group_female], [clean_group_gamer, clean_group_casual], [clean_group_a
```

In [ ]:
```
for group in clean_binary_groups:
    statements = df.loc[:, 'BitpetFun':'SharedMissionsNeccesary']
    for statement in statements:
        result = mannwhitneyu(group[0][statement], group[1][statement])
        if result.pvalue > 0.1:
            continue
        for g in group:
            num_agree = g.loc[g[statement].isin(agree), statement].count()
            num_neutral = g.loc[g[statement].isin(neutral), statement].count()
            num_disagree = g.loc[g[statement].isin(disagree), statement].count()
            print(g.name + ' ' + statement)
            print('Agree: ' + percentage(num_agree, len(g.index)) + '%, Neutral: ' + percentage(num_neutral, len(g.inc
        print(result)
    print('\n')
```

In [ ]:
```
import matplotlib.pyplot as plt

from IPython.core.display import display, HTML
display(HTML("<style>div.output_scroll { height: 66em; }</style>"))

plt.rcParams.update({'font.size': 14})

df_dropped = df.dropna()
df_cleaned = df_dropped.loc[df_dropped['CouldTest'] == 'Ja']

statements = df.loc[:, 'BitpetFun':'SharedMissionsNeccesary']
labels = ['Agree\nor\nSomewhat Agree', '\nNeutral', 'Disagree\nor\nSomewhat Disagree']

for statement in statements:
    num_agree = df_cleaned.loc[df_cleaned[statement].isin(agree), statement].count()
    num_neutral = df_cleaned.loc[df_cleaned[statement].isin(neutral), statement].count()
    num_disagree = df_cleaned.loc[df_cleaned[statement].isin(disagree), statement].count()

    data = [num_agree, num_neutral, num_disagree]

    fig = plt.figure()
    ax = fig.add_axes([1,1,1,1])
    ax.bar(labels, data, width=0.6)
    ax.set_yticks(range(0,11))
    ax.invert_xaxis()
    plt.title(statement)
    plt.show()

num_yes = df_cleaned.loc[df_cleaned['DidTestShared'] == 'Ja', statement].count()
num_no = df_cleaned.loc[df_cleaned['DidTestShared'] == 'Nei', statement].count()

data = [num_no, num_yes]

fig = plt.figure()
ax = fig.add_axes([1,1,1,1])
ax.bar(['No', 'Yes'], data, width=0.8)
ax.set_yticks(range(0,15))
plt.title('DidTestShared')
plt.show()
```

In [ ]:
```
fig = plt.figure()
ax = fig.add_axes([1,1,1,1])
labels = ['0-4.9', '5.0-8.9', '9.0-12.9', '13.0+']

low_exercise = df.loc[(df['ExerciseTime'] >= 0) & (df['ExerciseTime'] < 5), 'ExerciseTime'].count()
low_medium_exercise = df.loc[(df['ExerciseTime'] >= 5) & (df['ExerciseTime'] < 9), 'ExerciseTime'].count()
medium_high_exercise = df.loc[(df['ExerciseTime'] >= 9) & (df['ExerciseTime'] < 13), 'ExerciseTime'].count()
high_exercise = df.loc[df['ExerciseTime'] >= 13, 'ExerciseTime'].count()

data = [low_exercise, low_medium_exercise, medium_high_exercise, high_exercise]

ax.bar(labels, data, width=0.8)
plt.title('Distribution of weekly exercise amounts between participants')
plt.xlabel('Hours')
plt.show()
```



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