Master's thesis

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

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Implementing and Evaluating a Friend System in the Mobile Exergame BitPet

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

Adolescents worldwide are currently failing to be as physically active as recommended while simultaneously experiencing an increase in mental health issues. Exergames, video games that promote physical activity, have shown the potential to improve both their players' mental and physical health. To tackle public health issues, we have developed and evaluated a new feature for the augmented reality- and GPS-based mobile exergame BitPet, a game where players care for, interact with, and fight virtual pets. We have reviewed existing literature on health recommendations, game design, and video games to explore what makes exergames effective. Our conclusion is that effective exergames ensure long-term player retention and balance their difficulty with players' fitness levels. After playtesting and analyzing BitPet, we found that the application's biggest challenge was its lack of social features. Based on these analyses, we conceived eight new feature concept ideas for BitPet.

One of these ideas, a friend system with an activity feed, was developed and integrated into the game after user interface prototyping and an in-depth study of the code. The feature concept was evaluated with an experiment and subsequent analysis of the generated qualitative and quantitative data. Twenty test subjects tested the system over ten days. Our results show that the feature had a positive but limited effect on players' physical and social activity and a moderately positive impact on their motivation. The results also show that BitPet could benefit from even more features for social interaction. Furthermore, the analysis shows the feature concept as an excellent basis for further development, including the other features we conceived.

Sammendrag

Verdens unge når ikke anbefalingene om fysisk aktivitet, samtidig som de opplever en økning i psykiske helseproblemer. Aktive videospill (exergames), videospill som fremmer fysisk aktivitet, har vist seg å ha potensiale til å forbedre spillernes mentale og fysiske helse. For å motvirke folkehelseproblemene har vi utviklet og evaluert en ny utvidelse til det utvidet virkelighet- og GPS-baserte mobile aktive videospillet BitPet, et spill hvor spillerne tar vare på, samhandler med og kjemper mot virtuelle kjæledyr. Vi har gjennomgått eksisterende litteratur om helseanbefalinger, spilldesign og videospill for å finne ut hva som gjør aktive videospill effektive. Vi har konkludert med at effektive aktive videospill sikrer at spillerne spiller spillet over lengre tid og tilpasser vanskelighetsgraden til spillernes fysiske form. Etter spilltesting og analyse av BitPet, fant vi at applikasjonens største utfordring var mangelen på sosiale funksjoner. Basert på disse analysene utarbeidet vi åtte ideer til utvidelser til BitPet.

En av disse ideene, et vennesystem med en aktivitetsstrøm, ble utviklet og integrert i spillet etter prototyping av brukergrensesnittet og en grundig gjennomgang av koden. Utvidelsen ble evaluert med et eksperiment og påfølgende analyse av de kvalitative og kvantitative dataene som ble generert. Tjue testpersoner testet systemet i løpet av ti dager. Resultatene viser at utvidelsen hadde en positiv, men begrenset effekt på BitPet-spillernes fysiske og sosiale aktivitet, og en moderat positiv innvirkning på motivasjonen. Resultatene viser også at spillet kan dra nytte av enda flere muligheter for sosial interaksjon. Analysen viste også at utvidelsen var et godt utgangspunkt for videre utvikling, blant annet de andre ideene vi hadde.

Acknowledgements

This project would not have been possible without the excellent guidance and support of Alf Inge Wang at the Department of Computer and Information Science at the Norwegian University of Science and Technology (NTNU), who has served as supervisor for this thesis and its prestudy. Thank you for your excitement, insights, regular support, and blazingly quick responses to our emails.

It would also have been unfeasible without everyone who volunteered to test our feature concept. Your willingness to spend time helping us and our project is greatly appreciated and has proven invaluable.

A final thank you goes out to all those who have supported us in other ways, particularly our four classmates who have shared room 303 at the Old Physics Building with us for the past year.

Contents

List of Figures

List of Tables

Part I

Introduction

This part introduces the project and the context within which it was written. After reading the introduction, the reader should have an understanding of the project task, the motivation behind it, its goal, the research questions associated with the specified goal, and finally, the research methodology with which the project is conducted. There is also a reader's guide that outlines the different parts of this paper.

1 Project Task and Context

This project is part of *TDT4900 - Computer Science, Master's Thesis* at The Norwegian University of Science and Technology (NTNU). It is a direct continuation of *TDT4501 – Computer Science, Specialization Project*. The project task remains the same as was specified then:

In this project, the goal is to develop an [sic] game concept that will motivate the users to socialize and be in physical activity using augmented reality. This project is part of a larger project with the goal of commercialising a concept.

The project will involve a study of existing theory, game concepts and technology, design and development of a game concept (both front-end and back-end) and an evaluation of the concept involving real users.

Front-end will be developed in Unity.

This project requires two students.

The concept will be developed for BitPet, an augmented reality exergame for iOS and Android where you care for, interact with, and fight different virtual pets. The specialization project dealt with the literature of existing theories, game concepts, and technology. Additionally, it presented the selected idea that will be designed and implemented into BitPet in this project. The project's final phase involves testing and evaluating the proposed game concept.

The project is part of The Game Technology for Health (GT4H) at NTNU. As their website describes, "*the GT4H Network brings together knowledge and expertise about serious gaming for health benefits from different research groups across Departments and Faculties at NTNU. The aim of the network is to connect researchers and professionals both within and outside NTNU that develop or use game technology for health, in order to deliver high quality research and advance our knowledge at the best value possible*" [62].

2 Motivation

People are less physically active than both Norwegian and international health guidelines recommend. Over a quarter of the adult population worldwide is less physically active than recommended [54]. For adolescents aged 11–17 worldwide, 81% fail to reach the Norwegian Directorate of Health's recommended 60 minutes of moderate- to high-intensity daily activity [58] [31]. A lack of regular physical activity can potentially have grave consequences for those affected. Rhodes et al. conclude that regular physical activity has a preventative effect on at least 25 chronic medical conditions, with the risk reduction typically being between 20% and 30%. In other words, increasing physical activity levels can have a massive positive effect on public health.

Mental health is also a great societal issue. Around 15–20% of Norwegian youth experience significant symptoms of depression, with 5% of these experiencing symptoms severe enough to be considered diagnosable depressive illness [46]. Ung-HUNT is a decennial survey tracking the mental health of youths aged 13–19 in Nord-Trøndelag and, later, Trøndelag. Comparing the latest three Ung-HUNT surveys shows that the percentage of boys experiencing depressive symptoms has increased from 10.1% to 16.5% from the 1995–1997 survey to the 2017–2019 survey, while the increase in girls was even more dramatic, increasing from 20.9% to 44.5% [72]. The same trend can be seen in the United States and worldwide [79] [65].

Playing video games that encourage physical activity has the potential to function as regular physical exercise [56]. We seek to utilize the smartphones that, in recent years, have become tightly integrated into our daily lives and find how exergames can help counteract the great scale of physical and mental health issues experienced by people worldwide. Furthermore, we want to explore how exergames can best help people increase their levels of physical activity and how games can be designed to help prevent depressive symptoms in their users.

The rapidly declining mental health in teenagers is an important issue to the us. We were both teenagers in the period that has thus far shown the greatest increase in mental health issues according to the Ung-HUNT survey. Our perception of the recent public debate about children and adolescents using smartphones is that the zeitgeist is very much *not* on the side of smartphones and techno-optimism. We wish to counter this narrative and explore the positive possibilities smartphones provide, as we have experienced the communities gaming can build, especially exergames. Both of us have been avid players of the augmented reality- (AR) and GPS-based exergame Pokémon GO and have experienced the prominent positive effects it had on our mental and physical health. Many others have done the same [80].

We wish to develop a concept for BitPet to increase physical and social activity in children and youth, ensuring healthier lives and futures. The next chapter presents the research goal formulated from this wish, and its accompanying questions.

3 Research Goal and Questions

The Goal, Question, Metric (GQM) method will be employed to define and frame the research in this project [9]. This method serves as a top-down framework for conducting research, assisting researchers in deconstructing broad objectives into focused questions and measurable metrics. The following goal has been established for this project:

Goal *Develop and evaluate a feature concept for BitPet that enhances physical or mental health.*

We aim to enhance physical or mental health by promoting physical and social activity in BitPet's players. Six specific research questions (RQs) with corresponding metrics have been formulated to accomplish this goal. The questions have been established by decomposing the overarching goal into smaller parts. Thus, each question addresses a different facet of the overall objective.

RQ1 *What factors contribute to the effectiveness of exergames?*

RQ1 intends to identify the pivotal factors to consider when designing exergames. These games face the unique challenge of balancing workout efficiency with fun. Before incorporating new elements into an existing exergame, it is crucial to recognize the characteristics contributing to its success or lack thereof. Discovering these mechanics and design principles allows us to utilize them in our concept.

RQ2 *How can BitPet be improved to encourage physical and social activity?*

RQ2 explores what alterations could be made to BitPet to further develop one of its overarching goals, increasing physical and social activity in players. We can discover what aspects are currently lacking by playtesting the game and examining other games with similar goals.

RQ3 *How should the proposed feature be implemented and integrated into the existing application?*

RQ3 focuses on modifying an existing game with new features. It encompasses the technologies utilized in the application along with the architectural patterns. Furthermore, it focuses on the methodology and process of bringing the concept to fruition.

RQ4 *How does the new feature affect player activity?*

RQ4 concerns player patterns. It investigates how the feature affects players' physical, social, and in-game activity. Observing their physical and social activity will aid in evaluating the concept's success. Moreover, identifying usage patterns in-game will help inform future development.

RQ5 *How does the new feature affect player motivation and retention?*

RQ5 evaluates how the change affects a crucial challenge for exergames, keeping players motivated and regularly returning to the game. Keeping players invested is essential to successfully promote physical or social interaction over a longer period. Thus, our feature should aim to increase motivation and retention.

RQ6 *How do the players perceive the new feature?*

RQ6 regards our last major area of concern, how players experience the new feature. It will focus on improvement areas for the concept and suggested features from the subjects who tested it. The feedback can help explain other results and suggest future modifications.

The following chapter outlines the research methodology used to answer the above questions.

4 Research Methodology

This project's research methodology is based on Oates' research process model [51]. The previous chapters detailed the scoping phase by pinpointing the motivation behind the project, the research goal, and the research questions. With these defined, a literature review will be performed to aid in deciding appropriate strategies and data generation methods. The results will be analyzed to derive insights and answer the research questions. This paper represents the final phase of the research model, dissemination, where the findings and conclusions are presented through a report. The forthcoming sections will further describe how Oates' research model will be applied to this project. Figure 4.1 also gives an overview of the chosen strategies, data generation, and data analysis methods.

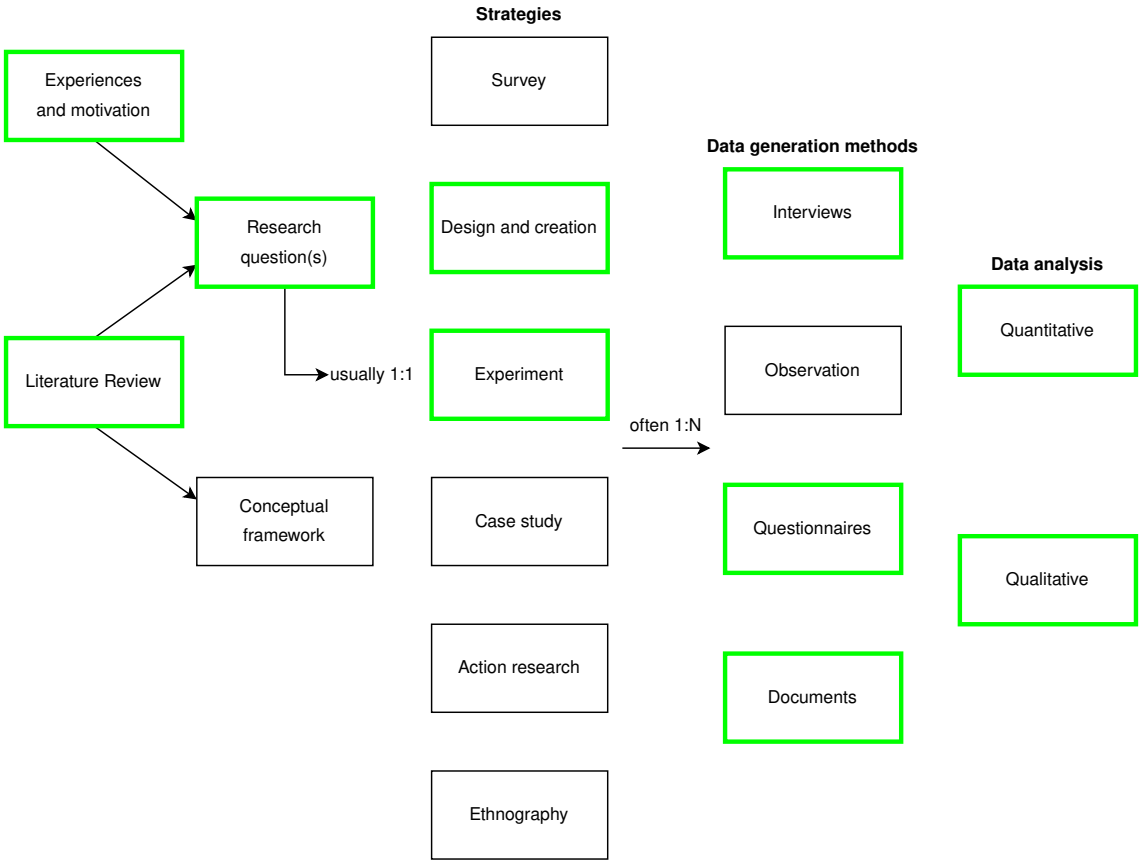

Figure 4.1: Oates' Research Model With the Chosen Strategies and Methods Highlighted.

4.1 Literature Review

A literature review will be performed to gather the existing knowledge of and literature on the topics essential to the project. The process consists of searching for and synthesizing relevant articles within the project's fields, including, but not limited to, exergames, augmented reality, and game design theory. In the case of BitPet, the literature also includes relevant documentation regarding technical solutions and patterns that the application utilizes. By inspecting prior literature, one can also identify trends in results and the methodologies of other authors. Furthermore, one can discover what domains still need to be improved in coverage [23]. This knowledge contributes to refining and deciding upon the final research questions as it becomes clearer what knowledge remains unanswered. The synthesized knowledge is presented in the next part, Part II.

A critical assessment of the sources used is of utmost importance when conducting a literature review. This paper will chiefly refer to research papers, though sometimes articles or other websites

are cited for information that is not research-centric. Google Scholar search engine will be utilized to ensure the search covers the vast majority of research on relevant topics. The number of references, research methodologies, conflicts of interest, etc., will also be considered to evaluate the credibility and relevance of the articles found.

4.2 Strategies

The strategies applied are heavily correlated with the provided project task. The task, in combination with the research questions, inspired the choice of two strategies: *Design and Creation* and *Experiment* as defined by Oates. *Design and Creation* focuses on creating information technology (IT) artifacts that can either contribute to knowledge itself or be a vehicle for something else that contributes to knowledge. The focus can also be on the software creation process and not the final product [51, Ch. 8]. In the case of this project, the product will mainly be a vehicle for the ensuing experiment, though the creation process will also be considered. A detailed account of the experiment can be found in Part V.

4.3 Data Generation Methods

Three data generation methods will be used to collect quantitative and qualitative data during testing. *Method triangulation*, using more than one data generation method, will allow the findings to be corroborated and questioned by comparing data from different methods [51, Ch. 3]. The chosen methods are *Questionnaires*, *Interviews*, and *Documents*.

Participants will receive questionnaires before and after testing the concept. The questionnaires will help collect demographic information on all the participants and their habits and experiences with the game without requiring considerable effort. Some participants will also be selected for interviews to elaborate on the questionnaires after the test period. Finally, the game will generate logs to observe the players' behavioral patterns. These documents are researcher-generated, "*put together solely for the research task, and would not otherwise have existed*" [51, p. 233].

The data generated can be divided into two categories: *quantitative* and *qualitative*. *Quantitative* data is "*based on numbers. It is the main type of data generated by experiments and surveys*", while *qualitative* data "*includes all non-numeric data [...] found in such things as interview tapes, researchers' diaries, company documents, websites, and developers' models.*" [51, p. 245] [51, p. 266]. The questionnaires will generate quantitative data, e.g., for demographics and usage, and qualitative, e.g., text answers about personal experiences. Interviews will provide more qualitative data that substantiate the questionnaire data. Meanwhile, the player logs will generate additional quantitative data. The collected data is presented in Part VI.

4.4 Summary

This chapter outlined the research methodology that will be utilized to achieve the project's research goal. It is based on Oates' research model, and will use the *Design and Creation* and *Experiment* strategies. The strategies will use method triangulation with *Questionnaires*, *Interviews*, and *Documents* data generation methods. Prior to using these strategies, a literature review will be performed to gain an understanding of the state of relevant research. The ensuing chapter provides a reader's guide to the different parts of this report.

5 Reader's Guide

This chapter gives a brief overview of the different parts of the paper.

Part I - Introduction
This part provides context for the project. It gives an overview of the research goal and questions the paper sets out to answer and the methodology used to achieve this. It should prove helpful to readers interested in the project's purpose or motivation.

Part II - Prestudy
The prestudy introduces various concepts related to the project task, along with related research and articles. In particular, it focuses on exergames, mental and physical well-being, social games, and game design theory. It is suited for readers unfamiliar with these topics or who are curious about learning more.

This part is based on the pre-project but has been modified and expanded since then [17].

Part III - Concept
The concept part describes the different feature concepts we propose to add to BitPet. Furthermore, it ranks the various features and presents the final one. The final feature is relevant to all readers, as it is the basis for the following parts. The other features are relevant to the later discussion and could prove interesting for readers enthusiastic about game mechanics and design.

This part is based on the pre-project but has been modified and expanded since then [17].

Part IV - Development
The development part describes the process of designing, implementing, and hosting the final feature concept. The user interface chapter should be approachable for most readers and suited for those who want to see the final mockups and learn about the process. The frontend and backend chapters are relevant for readers familiar with software development who wish to learn about the technical details.

Part V - Experiment and Data Generation
This part outlines the experiment and the data generation methods used. It presents the process for the experiment, the questionnaires used, the interview methodology, and considerations regarding the experiment's validity. The part is suitable for readers who want to understand how the results have been produced.

Part VI - Results
The results part condenses the data collected throughout the experiment into various graphs and quotes. The results are split into four chapters: demographics, general usage, feature usage, and additional results. Readers interested in detailed information about how the feature performed are recommended to read this part.

Part VII - Discussion
This part discusses how the feature concept fared based on the results from the experiment. Each research question is discussed in light of these results. Additionally, the validity of the experiment as a whole is also discussed. It should prove helpful to readers interested in a comprehensive evaluation of the feature concept.

Part VIII - Conclusion and Further Work
The final part concludes the findings of the project in a summary. It also presents future work that proceeds this thesis. The conclusion should interest readers who want to read our final thoughts and an overview of the answers to the research questions. Readers who wish to learn about what work remains undone should also consult the further work chapter.

The next part presents the accumulated knowledge from the prestudy.

Part II

Prestudy

The ensuing part presents relevant theories, concepts, and terms from literature, and an overview of BitPet. The part is a summary of a conducted literature review. It covers general physical and mental health recommendations, theory related to game design, augmented reality and relevant technologies, exergames and their effects, social games and their effects, existing social- and exergames, and finally BitPet and its technical implementation. This part is based on a previous project report written as a part of *TDT4501 - Computer Science, Specialization Course* [17]. Some alterations and additions have been made since the project's initial delivery.

6 Physical and Mental Well-being

Preventing physical and mental ailments and illnesses is a goal for anyone wishing to lead a healthy life. This chapter aims to collect the most reputable and relevant knowledge available about preventing and counteracting physical and mental health issues.

6.1 Recommendations for Physical Exercise

According to the Norwegian Directorate of Health, adolescents aged 6 to 17 should participate in at least 60 minutes of moderate- to high-intensity physical activity daily [31]. Recommendations also include limiting screen time, but games that promote physical or social activity are exempted.

Adults aged 18 to 65 should also be regularly physically active. Naturally, each individual should adapt the activity level to their physical shape. Still, the general recommendation is 150 to 300 minutes of moderate-intensity physical activity weekly to live a healthy life. One can reduce the suggested time if some or all of it involves high-intensity physical activity. Moderate-intensity physical activity encompasses exercise activities in which you run slightly out of breath, such as walking fast. High-intensity physical activities entail running seriously out of breath, such as running.

Any physical activity is beneficial, even if one does not reach the recommended goals. In particular, individuals with the lowest physical activity levels are the greatest beneficiaries of increasing physical activity.

6.2 Recommendations for Better Mental Health

Mental health is a complex and multi-faceted field, partly because there are many mental health illnesses and ailments to consider. We have therefore limited our focus to depression. Depression and anxiety are the most common mental health illness among children and adolescents in Norway [46]. 5% of Norwegian youth have a diagnosable depressive illness, but 15–20% experience significant symptoms of depression. Sund et al. similarly found in the Ung-HUNT survey that 16.5% of teenage boys and 44.5% of teenage girls experience depressive symptoms in 2017–2019, with the numbers increasing over the past few decades [72].

Santini et al.'s study presents a systematic review of the available knowledge on the association between social relationships and depression [59]. The clear consensus in the studies reviewed is that high levels of perceived and received emotional support highly correlate with the prevention of depression. The studies disagreed on whether friends can provide helpful social support, while all studies concluded that family can. A majority of studies concluded that vast social networks are important protective factors against depression, but it should be noted that some found no significant conclusion on this. Studies on the frequency of social contact found no consistent findings. The reviewed studies found that having diverse social networks, in that one's social network consists of family, relatives, and several networks of friends, had favorable effects on depression outcomes.

6.3 Summary

Physical health guidelines are clear about physical activity being incredibly beneficial, even if one does not reach the weekly recommended amount or intensity. General mental health guidelines are hard to define, but with the scope limited to depression, one can, with reasonable safety, assume that maintaining an extensive, diverse social network that can provide emotional support is beneficial. The next chapter will present various theories that aid in designing games and exergames.

7 Game Design Theory

Game design is "*the art of applying design and aesthetics to create a game for entertainment, educational, exercise, or experimental purposes*" [92]. This chapter explores theories on flow, player types, engagement, rewards, and enjoyment.

7.1 GameFlow

Flow, as defined by Csikszentmihalyi is "*a blissful psychological state of effortless concentration and enjoyment*" [13][14]. It is a feeling of complete immersion in an experience that any enjoyable activity can cause. Flow occurs when someone faces clear goals that require appropriate responses, or when a task is barely manageable for their given skill set. Most people experience flow, but only some experience it several times daily. It is rarer during free time than work, despite the widespread assumption that free time is easy to enjoy. The initial investment required to engage in flow-inducing activities makes people stray from them. This is usually against their interest, as these activities should be more enjoyable than engaging in passive activities with lower entry barriers.

Social interactions share many characteristics with flow. They prove incredibly fulfilling for humans and share many common traits with flow activities, mainly related to challenge, concentration, and use of skillset. Successful interactions include compatibility between the participant's goals and the willingness to commit to a mutual investment in these goals. These kinds of interactions can induce flow in their participants.

The eight core elements defined in flow are [14, p. 3]:

1. We confront tasks we have a chance of completing
2. We must be able to concentrate on what we are doing
3. The task has clear goals
4. The task provides immediate feedback
5. One acts with deep but effortless involvement that removes from awareness the worries and frustrations of everyday life
6. One exercises a sense of control over their actions
7. Concern for the self disappears, yet, paradoxically, the sense of self emerges stronger after the flow experience is over
8. The sense of duration of time is altered

Sweetser and Wyeth define GameFlow, a model of game enjoyment constructed based on the eight core elements of flow and how flow manifests itself in computer games [73]. It consists of eight core elements game developers should follow to ensure player enjoyment, derived from the original eight flow elements. They are as follows:

1. **Concentration:** Games should require concentration, and the player should be able to concentrate on the game
2. **Challenge:** Games should be sufficiently challenging and match the player's skill level
3. **Player Skills:** Games must support player skill development and mastery
4. **Control:** Players should feel a sense of control over their actions in the game
5. **Clear Goals:** Games should provide the player with clear goals at appropriate times

6. **Feedback:** Players must receive appropriate feedback at appropriate times
7. **Immersion:** Players should experience deep but effortless involvement in the game
8. **Social Interaction:** Games should support and create opportunities for social interaction

Sweetser and Wyeth argue that a game has to require *concentration* to be enjoyable and that the feeling of absorption into the game will scale along with the need to concentrate [73]. Complete absorption, the sense that the player has no extra energy for other activities, is achieved when all relevant skills the player possesses are necessary to complete a challenge. The player should pay attention to the game from the beginning until they put it away. Games should gradually increase the workload to induce this level of attention and concentration in the player, as long as it stays within the range of what the player can handle. All potential distractions, such as unimportant tasks or user interface elements not strictly related to the task, should be minimized. Concentration finds its root in the second core element of flow.

The *challenge* requirement, often considered the most important, entails that a well-designed game should meet a certain challenge threshold compared to the player's skill. The difficulty level should differ between players and should progress along with the game as they gain or improve skills. New challenges should not appear too frequently nor rarely, but keep a pace appropriate for the player. The theory behind this requirement relates back to the observation that flow occurs when a person can just about manage a task with their skillset. If too many skills stay unused, the player will experience apathy, while the opposite results in anxiety.

Player skills must be able to be developed and mastered for a game to meet the GameFlow requirements. The theory behind this core element is much the same as that of *challenge*, in that the player's skills must match the challenge so that skill levels meet the increasing challenges of the game. These skills' early development should occur quickly after beginning a new game. Tutorials should be immersive by themselves, for example, by taking place as the player plays the game. Players should receive appropriate rewards when developing skills so their interest is maintained. Controls and interfaces should adhere to industry standards so players can start playing the game effortlessly. If the game is hard to understand, it might provide in-game hints that do not break with the immersion of a simple manual or online guidance for the player.

The sixth core flow element directly maps to the *control* core element in GameFlow. Players should experience that their inputs into the game have an expected and appropriate response in-game so they feel control over their actions. This means that in-game actions must affect the world and have consequences in ways the player can notice. Having control over in-game actions must also, by extension, mean that the player has room to experience the game how they want and not be forced to play how the designers intended. As with player skills, Sweetser and Wyeth also make a few observations about successful user interfaces and controls [73]. Starting and stopping the desired game must be simple, including the ability to save the game at the player's will, allowing them to stop at any time.

Clear goals is another element of GameFlow that has a straightforward mapping to the core elements of flow, in this case, the third one. A game should have a major, overarching goal introduced early, with smaller goals introduced as the game progresses. The ability to enjoy the game depends on the player knowing what they have to achieve next. This also means the game must appropriately report goal progress to the user. This is the *feedback* requirement of GameFlow, which has a counterpart in the fourth core element of flow.

Sweetser and Wyeth state that to fulfill the *immersion* requirement, the player should "*experience deep but effortless involvement in a game*" [73]. Csikszentmihalyi describes both this deep, effortless involvement and how the sense of time is altered [14]. Both of these elements are reflected in the immersion requirement because the former often causes the latter to occur. When immersion happens, the world outside the game should become so secondary to the in-game world that the player feels as though they are an integral part of the game. Well-designed audio and narrative experiences are some important tools when designing immersive experiences.

The final requirement of GameFlow is *social interaction*. This requirement does not explicitly build upon the flow elements, but it has been identified as an undeniably strong cause of enjoyment.

Competition, cooperation, and connection are ways for multiple players to interact and therefore utilize humans' pleasure of mutual interaction to benefit the game. Supporting social interaction is not limited to in-game interactions but also includes support for real-life and out-of-game online interactions related to the game.

Table 16 in Appendix A provides a complete overview of detailed criteria for the eight core elements of the GameFlow Model.

7.2 Dual Flow

Sinclair et al. build on the flow theory but adapt it specifically to exergames with the Dual Flow model [66]. Compared to normal video games, exergames introduce another design challenge with *effectiveness*, the balance between physical intensity and the player's fitness level. Still, the games must also maintain the traditional balance between challenge and skill, defined as *attractiveness* by Sinclair. The model aims to keep the player engaged and achieving fitness goals simultaneously. The player may attain health benefits but not want to return to the game if it is not engaging enough. Thus, adaptability becomes a key feature of Dual Flow. The designer must consider that the player will become much more fatigued as the play session elapses than when playing a traditional video game. Thus, the game should try to follow the recommended structure of an aerobic exercise session:

- 5–10 minutes of low-intensity exercise
- Minimum 20 minutes of exercise at 77–90% of maximum heart rate
- 5 minutes of low-intensity exercise

Adaptability is also important in the context of a player's fitness level. Players who are more physically fit will have to complete more demanding challenges to reach the same recommended heart rate levels as those who are less active. The game should also consider the player's physical feedback, whether tired or nearing exhaustion, and adapt accordingly. One should note that it is not necessarily desirable for all exergames to push players to the edge of their physical capabilities. Some exergames might simply want to encourage more physical activity than sedentary playing does, for instance through walking outdoors. Thus, Dual Flow might not be as applicable to such games.

Figure 7.1 shows the two aspects that have to be balanced to comply with Dual Flow. The leftmost graph shows how attractiveness is achieved by balancing skill and challenge. If either axis is too high compared to the other, or both are too low, players will not achieve flow. Instead, they will either end up anxious, apathic, or bored. Similarly, the rightmost graph shows the same relationship but for effectiveness. If a correct balance is not achieved, the player ends up with failure, deterioration, or no exercise benefit.

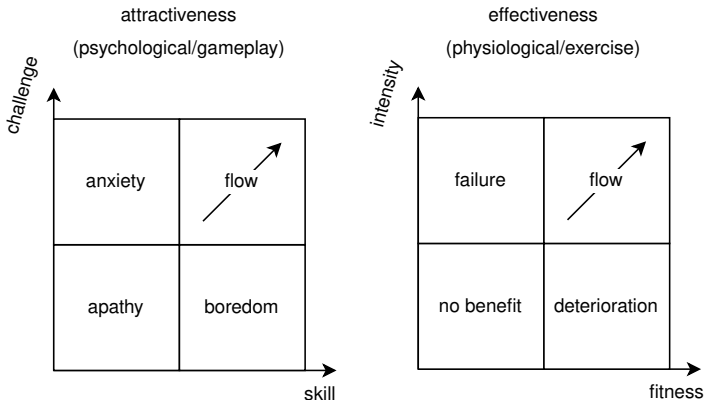

Figure 7.1: The Dual Flow model [66].

7.3 Player Types

A research area of considerable interest in game design is the notion of player types. As Hamari and Tuunanen note, games have continued to grow and business models have changed, leading to an increasing need to differentiate and segment players [30]. The authors identify psychographic and behavioral segmentation as the driving forces within game design. One classic example they mention is the distinction between casual and hardcore players, those heavily engaged and those casually engaged with a game. However, this is not a dichotomous classification and offers little aid when designing a game.

One of the most referenced player segmentations is Bartle's player types [7]. He introduces two axes on which to place players based on their preferences: *interaction* versus *action* and *player-* versus *world orientation*. The result is four types of players: **killer**, **achiever**, **explorer**, and **socializer**. Killers are focused on action and have a player focus, trying to dominate the others. Achievers also prefer action but concentrate on the game world. Explorers prefer interaction and exploring the world. Finally, socializers prefer social interaction within their game and have a player focus. Importantly, Bartle's segmentation follows scales instead of strictly separated categories. One can design game features to suit a specific audience using these types.

Yee has built on Bartle's framework but focuses on motivation and psychography rather than behavior [97]. He has identified three motivating factors for players: **Achievement**, **Social interaction**, and **Immersion**. Subfactors of achievement include progress and provocation, as well as power and domination. The social aspects are friends and collaboration, and helping and support. Finally, players with a high immersive motivation prefer exploration, the game fantasy, and immersing themselves within the story. Notably, his study focused on a Massively Multiplayer Online Role-Playing Game (MMORPG) audience, which does not necessarily align with fans of other game genres. For instance, the social features of single-player games are generally much more limited than in an MMORPG. Still, the motivations outlined apply to many contemporary games.

7.4 Player Engagement

An essential aspect of growing and maintaining a player base is to ensure satisfactory player engagement. We utilize Schoenau-Fog's term: "*the level of continuation desire experienced in the player*" [61]. The definition differs from motivation, which concerns why a player started playing a game initially. Through analyzing a survey on media technology students' thoughts on engagement, Schoenau-Fog identified a cyclic engagement process:

1. Players are initially motivated to play a game due to game-related or personal motivations
2. When they start playing, an objective is either set up or defined by the player, leading to activities to perform
3. Players can want to continue playing as long as they have not reached the objective
4. Through performing an activity, players can experience an affect. If positive, it can lead to sustained engagement and the start of a new cycle

The process comprises four components: *objectives*, *activities*, *accomplishments*, and *affects*. All can lead to a continued desire to play but also disengagement if they are missing or poorly implemented. For instance, achievements and unlockables are accomplishments that typically encourage engagement. If these payoffs are absent, the player may become disengaged.

Several studies have found that social interaction and a feeling of belonging to a community are significant contributors to continued play in online games [18] [22] [78]. Furthermore, it is more likely that Mobile Multiplayer Games (MMGs) players play games due to social aspects and keep their interest when their in-game friends play with them [40]. Li et al. researched how social habits affected player groups' we-intention, the shared intention to continue playing a game. They conceptualize the notion of the social play habit, which consists of three subdimensions: *Inviting*,

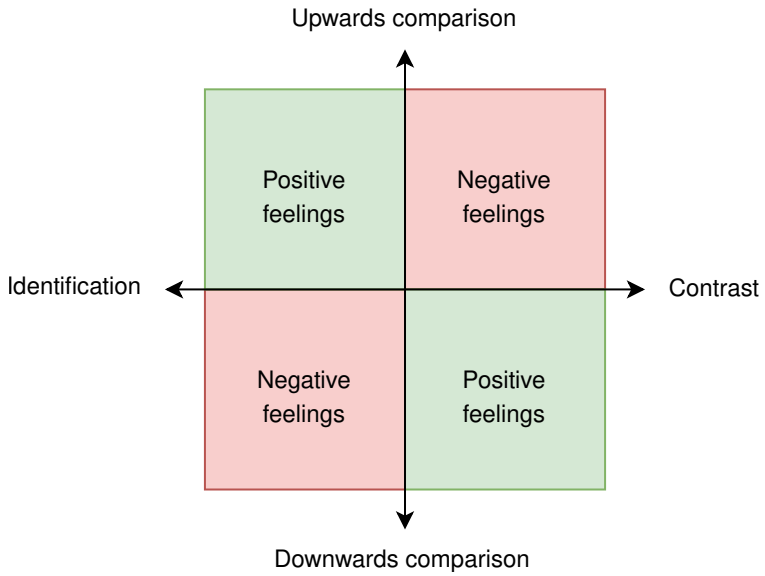

Figure 7.2: The General Effects of Social Comparison [18].

Playing, and *Sharing*. The habit forms when these social actions are repeatedly performed and automated. As a result, initiating new social actions becomes less effortful. Thus, they conclude that for an MMG to ensure success, its design should encourage a social play habit and promote the aforementioned social actions. To hasten the formation of this habit, one should make co-play desirable. One can, for instance, achieve this by providing rewards for playing with in-game friends.

Through social comparison and self-efficacy theory, Esteves et al. investigated how social comparison in social games affected continuation intention in players [18]. Social comparison theory states that people evaluate their opinion and abilities by comparing them with the views and skills of others. The direction of the comparison can be either upwards or downwards, depending on if the targets are perceived to be in a better or worse situation. Additionally, the comparison's effect can be either one of identification or contrast. Figure 7.2 illustrates the four possible quadrants that result from these two axes. Competitive settings generally promote contrast, whereas cooperative environments encourage identification. In general, upwards identification and downward contrast invoke positive feelings in the person performing the comparison, whereas upwards contrast and downward identification invoke negative feelings. Social comparison has been argued to be important in the development of self-efficacy, the belief that an individual has in their ability to meet situational demands or perform tasks [18]. In general, there are four influences for one's self-efficacy: enactive mastery experiences, social persuasions, vicarious experiences, and psychological and affective states.

Analyzing data collected from Farm Heroes Saga, Esteves et al. found that upward identification and downward contrast had a significant positive effect on players' self-efficacy and perceived enjoyment. At the same time, the remaining comparison types affected the variables negatively. Upwards identification had a more substantial impact on enjoyment, whereas downwards contrast affected self-efficacy more. Thus, encouraging these types of comparisons in the game design can increase players' intentions to continue playing. Suggestions include:

- Leaderboards.
- Notifying the player of achievements from similar players.
- Highlighting the similarities between a player and a top performer.

To avoid adverse effects from downward identification and upwards contrast, one can design the leaderboards so the player can more easily visualize the players they identify with.

7.5 Rewards

Rewards are a game design tool that can motivate players and encourage them to continue through less engaging video game sections. For instance, MMORPGs regularly reward players with experience points for doing so-called *grinding*, repeating monotonous tasks over an extended period. It is common to separate the type of reward into two categories: **intrinsic** and **extrinsic**. Intrinsic rewards solicit a feeling of reward simply from playing the game itself, whereas extrinsic rewards are actual physical or virtual awards. Additionally, the rewards can provide fun for the player in the form of anticipation before being awarded. However, the longer the expectation, the greater the reward should be.

Wang and Sun further categorized the reward systems in video games into eight different types [83]:

- **Score systems** - quantify a player's performance and provide them with feedback on their progress. Score systems can also rank players and create a sense of competition. Generally, scores do not affect gameplay but instead offer a form of glory.
- **Experience points** - represent a player's accumulated time or effort within the game. Players typically earn experience points (XP) by completing tasks or progressing through levels. When reaching pre-defined thresholds of XP, their characters traditionally level up. In contrast to scores, this often directly impacts the gameplay in the shape of new skills or increased attributes. Furthermore, whereas a score is normally player-bound, XP is usually tied to a specific avatar.
- **Virtual items** - enhance the gameplay experience and can be used by the player or their avatar. They can be a reward for exploring the game world or maintaining player interest during less exciting moments. The items can provide players with a sense of accomplishment and social comparison value, and usually have no meaningful effect on the gameplay.
- **Resources** - necessary for the player to progress through the game and are usually obtained through exploration, fighting, or quests. Unlike items, resources affect practical gameplay. For example, players can typically upgrade their avatars' abilities or unlock new areas within the game.
- **Achievements** - earned by completing specific tasks or challenges within the game and can be displayed to other players. Achievements can provide players with a sense of accomplishment and can be used to compare their progress with others. In addition, they can encourage different play styles and game exploration beyond what the player would otherwise do.
- **Feedback** - instant rewards that can come in various forms, such as in-game messages, animations, sound cues, etc. They do not affect gameplay or social aspects but invoke an immediate reward for the user. For instance, a satisfying animation can trigger when the player times a punch with high precision in a fighting game, giving them a sense of accomplishment.
- **Plot animations and pictures** - used to enhance the game's storytelling aspect and give players a sense of immersion. They can provide context for the game's storyline and encourage players to advance it.
- **Game content** - such as new levels or quests, can be unlocked over time to keep players engaged and provide them with new challenges. This type of reward stimulates the player's curiosity by making them wonder what could be lying ahead, and provides fun through anticipation. Unlockable game content can also help pace the game fluently instead of overwhelming the player by having everything unlocked from the start.

The different systems vary in their practical use. Experience points, unlockable game content, and resources usually directly affect the gameplay, whereas scores, virtual items, achievements, and plot animations and pictures have little direct impact on the game. However, these types of rewards can be beneficial for invoking feelings in the player. The systems can maintain a state of

flow in the player by establishing sub-goals through unlockable sections, providing instant feedback rewards such as visual pop-ups, maintaining a balanced challenge through achievements or scores, etc.

The authors also identified four types of characteristics for a reward: social effect, suitability for collection and review, gameplay effect, and time required to unlock. The social value of a reward depends on how easily it allows for social comparison or interaction. To illustrate, a rare cosmetic avatar item in an online game can show off a player's status to others. Furthermore, it can create feelings of likeness and community in the other players who possess the same items. Superficial rewards like these are particularly popular with the socializer player type. Social value can also relate to whether the reward encourages social interaction, e.g., with a reward requiring player cooperation to unlock. Achiever and killer player types are generally more concerned with the gameplay effect of their items, desiring rewards for their concrete skills. In addition, players generally want to collect their rewards and review them later, whether to reminisce or display their achievements to other players. Finally, the time required to earn the reward should scale with the value of the given prize. The tolerance of how forgiving this correlation should be varies from player to player. In particular, hardcore players will have higher patience than casuals.

7.6 Malone's Theory of Enjoyment

A commonly cited taxonomy for intrinsic motivation is Tom Malone's theory of enjoyment [42]. In it, he describes three key components that he believes make a game fun: *challenge*, *fantasy*, and *curiosity*.

7.6.1 Challenge

Challenge is necessary to invoke interest in the player, and to achieve a proper challenge, Malone argues there must exist a goal with an uncertain outcome. If the player knows from the start that they will win regardless of their actions, there is little challenge present. This uncertain outcome provides excitement and can be realized by having variable difficulty levels, goals on different levels (e.g., meta goals), hiding information from the player, and utilizing randomness. The objectives provided by the game should also strive to invoke the player's interest. For instance, using a skill should be the means to achieve a goal, not the goal itself, as this is generally not as interesting. Additionally, the game should provide feedback to guide the player toward fulfilling a goal. Designers should make this feedback constructive and not hurt the player's self-esteem, as it may lead to frustration and eventual quitting of the game.

7.6.2 Fantasy

The game should offer the player some fantasy that correlates with the player's emotional needs. Though fantasy is usually associated with something impossible, it could also be a realistic situation, such as a flight simulation. Malone differentiates between *extrinsic* and *intrinsic* fantasy. In an extrinsic fantasy, there is no correlation between it and the actions performed by the player. The player's skills will affect the fantasy, but not vice versa. On the other hand, in an intrinsic fantasy, the relationship between the actions and the fantasy is bidirectional; one affects the other. The two types of relations can be seen in Figure 7.3. Malone regards intrinsic fantasies as generally more desirable, as players can utilize analogies they are already familiar with in the real world to overcome new challenges in the game. One arguable advantage of an extrinsic fantasy is that it is easier to change without modifying the rest of the game. Thus, one could have several fantasies for the same mechanics, appealing to a wider audience.

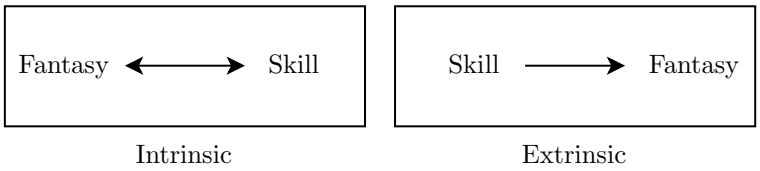

Figure 7.3: Intrinsic versus Extrinsic Fantasy.

7.6.3 Curiosity

Finally, curiosity encompasses the player's "*motivation to learn, independent of any goal-seeking or fantasy-fullfilment*" [42]. To promote curiosity in a game, one can withhold just enough information from the player to make them seek out more. Levels should strive to be optimally complex, meaning neither so complicated that they become incomprehensible nor so simple they become trivial. Furthermore, it is helpful to distinguish between *sensory* and *cognitive* curiosity. Sensory curiosity concerns the sensory stimuli of an environment. One can use audio or imagery for decorative purposes, to enhance the game's fantasy, as a reward (typically in direct feedback), or to represent information more effectively. Meanwhile, cognitive curiosity entails the player's desire to gain new knowledge. Malone argues that games should present just enough information to the player so that their knowledge feels incomplete, but not overwhelmingly so. Then, they will be inclined to seek out completeness of this knowledge. However, to ensure the player retains motivation and does not become lost, the feedback should guide them in the right direction.

7.7 Summary

This chapter has introduced several concepts crucial to the design of games. Firstly, flow theory in the form of GameFlow and Dual Flow. Both derive concepts from the original flow theory but adapt them to games and exergames. Next, the chapter introduced theories of player segmentation in the form of types, particularly emphasizing Bartle's four types: the killer, achiever, socializer, and explorer. Following this, the chapter explored the engagement loop and how socializing can help keep players retained in a game for longer. Rewards were also investigated as a form of player motivation. Finally, the chapter introduced Malone's key components for a fun game: challenge, fantasy, and curiosity. In the development of ideas for the feature concept, all of these design tools are important to keep in mind to ensure its success.

The ensuing chapter introduces augmented reality technology and design principles to consider when using it.

8 Augmented Reality

Augmented reality (AR) can be defined as "*systems in which computer-generated information is superimposed on top of the real world*" [32]. However, there is a fine granularity between whether something is the superimposition of computer-generated information on top of the real world, or the other way around, making terms such as augmented reality and virtual reality hard to separate. To distinguish between these different types of superimposition, Milgram et al. introduce the Reality-Virtuality continuum (see Figure 8.1) [43]. They argue that instead of seeing virtual- and augmented reality as two direct opposites, viewing them on opposite ends of a continuum is more practical. On the leftmost end of the spectrum are the environments consisting purely of real-world objects, whereas the other end is fully virtual. AR can be found on the left side, meaning it consists mostly of the real world with some virtual objects added onto it.

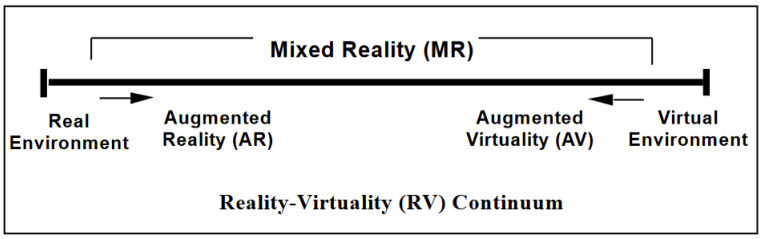

Figure 8.1: Reality-Virtuality Continuum [43].

Milgram et al. distinguish between two distinct types of AR: See-through AR and Monitor-based AR [43]. See-through displays allow the user to see through it while augmenting itself with virtual objects. Examples of these are, for instance, the Aryzon headset or the Microsoft Hololens. Generally, these displays are more difficult to develop successfully, as they face challenges with calibration and delay. The Monitor-based displays, however, are easier to create as they overlay the virtual objects onto digital video. One of the most prominent examples of this type of display is mobile AR, where the applications utilize a phone's camera to overlay effects on top of the camera feed. Examples include Snapchat lenses or AR games such as Pokémon GO. Figure 8.2 shows an example of each AR type. Apple's recent announcement of the Vision Pro headset illustrates a display that somewhat threads the line between the two types [47]. The user wears a headset with a monitor-based display. However, there is also a screen on the outside of the headset showing the user's eyes, imitating a see-through display.

Figure 8.2: Example of See-through AR (left) and Monitor-based AR (right).

8.1 AR Technologies

A wide range of libraries and frameworks exist for creating mobile AR applications. One notable example is Apple's ARKit, which contains tools to make the development of AR applications easier on Apple devices [33]. However, this solution is exclusive to the Apple ecosystem. For cross-platform support, a more commonly used framework is Google's ARCore [15]. This platform also provides motion tracking, environmental understanding, and light estimation but has Software Development Kits (SDKs) for Android, iOS, Unity Engine, Unreal Engine, and Web development. ARFoundation, the ARCore Unity Engine SDK, allows the developer to create games with AR features which can then be ported to a wide range of devices, such as Android and iOS. Another alternative for developing mobile AR applications in Unity is Niantic Lightship [49]. This solution is platform-agnostic, meaning it does not require any platform-specific code. However, underneath, Niantic's SDK also relies on ARCore or ARKit.

8.2 Design Principles

Google has released several design guidelines to consider when working with AR [26]. Because AR can technically be used anywhere, they claim a good practice is to tell the user which types of spaces the application is intended for and to plan for different kinds of environments. The expected environment size will vary with the intended game, and thus one should clearly communicate it. Since most applications before AR have been limited to two dimensions, one should encourage the user to move around the scene and to exploit all three dimensions. This is particularly applicable to games where the aim is to make the player exert energy. However, one should remind the player to observe their surroundings and never encourage them to walk backward to ensure their safety. In some applications, the AR features are only active at certain times. Clear transitions, like a fade-in, should be added to make these changes into AR mode as apparent as possible. Finally, Google encourages the possibility of using both landscape and portrait modes. However, if it is not possible, one should carefully consider which way is most optimal.

8.3 Summary

This chapter defined augmented reality as "*systems in which computer-generated information is superimposed on top of the real world*" [32]. It is a category of computer programs along the reality-virtuality continuum where most of the content is real. See-through AR, a type of AR where the user can see through an augmented display, was distinguished from Monitor-based AR, where digital objects are overlaid onto digital video. Furthermore, this chapter identified some of the most common AR frameworks today, such as ARKit and ARCore. Finally, some general design guidelines from Google were brought up. It is essential to keep these in mind if we extend BitPet with more AR functionality. One notable inconsistency between the suggested design principles and BitPet is the possibility of using both landscape and portrait modes. At the time of writing, BitPet only supports landscape and is designed to be played this way. This allows the designers to take advantage of the horizontal layout without considering how it should translate vertically. However, it also means that players are encouraged to walk around with their phones held sideways, which is not as natural.

The next chapter will define exergames and present some of their effects on mental health. Additionally, it will introduce different technologies relevant for exergames.

9 Exergames

This chapter introduces the term *exergame* and looks at such games' potential physical and mental effects on players. Finally, it showcases some of the relevant technology utilized in exergames.

9.1 Defining Exergames

When exploring literature focused on the subject of exergames, one can find many different definitions of the term. Sinclair et al., for instance, define exergaming as "*the merger of video games with exercise equipment*", whereas Wikipedia defines it as "*video games that are also a form of exercise*" [66] [90]. Moreover, there are many articles describing games that fall under these definitions but use other terms instead, especially articles by health-related scientists [52]. One example of this is Peng et al., who prefer the term *Active Video Games* and define it as "*commercial off-the-shelf video games that incorporate physical activity into gameplay by requiring players' body movements to interact with the game system*" [56]. Oh and Yang performed a literature review on the different terms and definitions used and proposed new definitions, which will be utilized for this project [52]. They define exergame as:

> "*a video game that promotes (either via using or requiring) player's physical movements*

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

Furthermore, their definition of exergaming is:

"*an experimental activity where playing exergames, video games, or computer-based is used to promote physical activity that is more than sedentary activities and also includes strength, balance, and flexibility activities*"

We will use these two definitions when referring to exergames and exergaming in this project.

9.2 Player Engagement in Exergames

Chan et al. reviewed motivational strategies in exergames and identified competition, cooperation, and gamification as particularly important [11]. However, they noted a lack of research on the effect of the social experience. Another study reiterated the knowledge gap two years later [12]. Other studies have shown that the enthusiasm for playing games developed for exergame research drops off after a couple of weeks [36]. Zhao et al. investigated how feature updates and gamification affected player retention in a custom-made wearable-based exergame [101]. They periodically released content updates throughout 70 days and observed the player patterns. A steady decline in player activity was observed, even with gamification elements. However, providing updates had an observable reserve effect on this decline.

9.3 Effect of Exergames on Physical Health

In general, the observed effects of exergames on physical health vary based on multiple factors, including game genre, demographics, and timespan. A study on games using Sony's EyeToy reported increased energy expenditure among pre-adolescents and adolescents between 129% and 400% [41]. Regular play also increased physical activity in sports and exercise [48]. Warburton et al. showed that male college students had higher exercise attendance if they were to play the exergame GameBike as opposed to traditional exercise [84]. An evaluation of the strength-based exergame Exermon showed that 40% of the participants reported exercising more during the evaluation period, with 90% reporting that they were motivated to play before each session [82]. The evaluation period was, however, only two weeks, making the long-term effects of exercise unknown.

9.4 Effect of Exergames on Mental Health

Whereas there have been many studies conducted on the physiological effects of exergames, there are far fewer on their psychological ones. As noted in the recommendations for mental well-being, regular physical exercise contributes to a better general psychological state. Thus, it is seemingly not far-fetched to assume exergames also positively affect mental health. Lee et al. reviewed articles published between 2011 and 2015 that at least partly focused on the psychological effects of exergames [38]. A majority of the articles reviewed observed a positive association between energy expenditure and desirable psychological effects. Interestingly, exergames that had group or competition modes showed a significantly positive psychological impact. The authors consider social interaction as a major design element for exergames, as people generally have a higher exercise adherence when they are in a group setting. To further illustrate the lack of research on exergames' psychological effects, Li et al. found that 9 out of 1099 articles on exergames were relevant to the games' effect on depression [39]. However, within the small selection, they found a positive effect on alleviating depression.

Andrade et al. present a review and meta-analysis to analyze the psychological effects of exergames on overweight or obese children and adolescents [2]. The review concluded that playing exergames

produces a small, beneficial psychological effect, measured primarily by the presence of depression, low self-esteem, or low self-efficacy. Competitive games had more beneficial effects on self-efficacy than cooperative games.

9.5 Exergame Technologies and Controllers

There exists a wide range of sensors and devices designed to track a user's physical movements, and many of these have been successfully incorporated into exergames. One popular method to track movement is computer vision. Figure 9.1 shows some examples of such trackers for games: the EyeToy, Xbox Kinect, and PlayStation Camera. All these sensors use cameras to recognize human movement. In addition, the Kinect has infrared depth sensors to be less affected by environmental lighting. Another device type, popularized by the Nintendo Wii, is the motion controller. This type of controller has accelerometers to sense motion, allowing users to perform various gestures. The gestures typically resemble real-life movements like swinging a tennis racket. Some successful examples include the Wii remote, PlayStation Move controllers, and the Nintendo Switch JoyCons and can be seen in Figure 9.2. Nearly all modern smartphones have location and motion sensors. These sensors have been used in exergames to, e.g., track the player's real-world location and movement. The phone's accelerometer senses orientation and enables the natural change between portrait and landscape modes. However, it can also be utilized to track the user's steps, which can then be incorporated into exergames. For instance, a game could require a certain amount of steps to be counted during a day to unlock a reward.

Finally, certain exergames have custom controllers made specifically for them. This can offer a greater connection between the activity performed by the player and the corresponding actions in the game. Furthermore, it allows the game designers to tailor movements according to the game's needs, instead of being restricted by the controllers offered by the game console. Examples of such controllers like the Dance Dance Revolution (DDR) dance pad, the Exerbike, and the Ring Fit Adventure (RFA) ring and strap can be seen in Figure 9.3. However, a drawback of this method is the lack of versatility and potential lock-in of the controller. If players want to buy such an exergame, they would also have to buy a controller that is locked to that specific game or game franchise. For instance, buying the RFA ring is a necessity for playing the game, but it currently can not be used in a meaningful matter in any other game.

Figure 9.1: Examples of motion tracking cameras. From left to right: EyeToy, Kinect, Playstation Camera.

Figure 9.2: Examples of motion controllers. From left to right: Wiimote, PlayStation Move controllers, JoyCons.

Figure 9.3: Examples of custom controllers. From left to right: RFA ring and strap, DDR pad, Exerbike.

9.6 Summary

This chapter covered the many existing definitions for exergames and chose Oh and Yang's definition for this project: "*a video game that promotes (either via using or requiring) a player's physical movements (exertion) that are generally more than sedentary and include strength, balance, and flexibility activities*" [52]. Exergames use various technologies to make physical movement part of the game input, such as GPS, accelerometers, and computer vision. They can also be custom made to allow specific movements, at the cost of less versatility.

Several shorter term studies show physical benefits akin to normal exercise when playing exergames. However, motivation can drop after playing for several weeks, which means the benefits would potentially diminish. In general, there is lacking research on the effects of exergames on mental health. However, the studies that exist generally report small positive effects on alleviating depression. As Lee et al. found, social interaction and group exercise are key elements to achieving desirable psychological effects in players. This stresses the importance of the social aspect of BitPet and shows that group functionality could be an interesting feature to test for our prototype. The following chapter will introduce and explore exergames which use some of the aforementioned exergame technologies. It will also outline research on their effects on players' physical health.

10 Existing Exergames

This chapter provides various examples of successful exergames and elaborates on their characteristics. In addition, it presents some related studies that evaluate their effectiveness.

10.1 Wii Sports

Wii Sports is the fourth most sold video game of all time, and the best-selling exergame ever released [93]. Nintendo released the game in 2006, and it came along with the Wii console when purchased. Intended as a showcase for the capabilities of the Wii remote, it uses different gestures to control characters in various sports settings. These settings include baseball, bowling, golf, tennis (see Figure 10.1), and boxing. The motions mimic the movement of each respective sport, although at a more simplified level. However, even though the movements imitate those of actual sports, a study by Graves et al. concluded that the energy expenditure of playing Wii Sports was not high enough to contribute to children's daily recommended exercise levels [29]. Still, it was significantly higher than playing traditional sedentary games. Exner et al. showed that the energy expenditure of playing Wii Sports was comparable with walking 5 km/h, resulting in higher calorie expenditure than normal computer activity [19]. Furthermore, a different study on players playing Wii Active reported that overweight and obese players experienced weight loss over seven months [68]. Finally, Willems and Bond concluded that the boxing activity could be a viable part of a structured exercise program for young adults because it had similar effects to rapid treadmill walking [95].

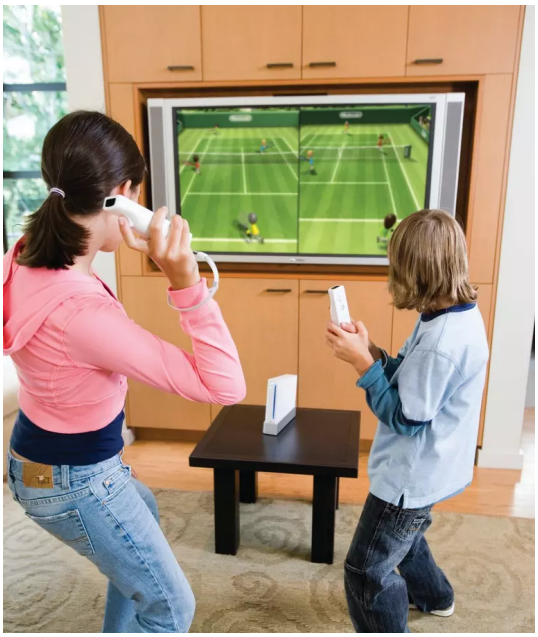

Figure 10.1: Two Children Playing the Tennis Mode in Wii Sports.

10.2 Pokémon GO

Pokémon GO is a location-based mobile AR game released in 2016 by Nintendo and developed by Niantic. It is arguably one of the most successful exergames of all time, grossing over $6 billion and amassing over 600 million downloads by 2022 [63]. The player takes on the role of a Pokémon trainer with the goal of catching all Pokémon, various fantastical creatures. Players can search for and capture Pokémon of different rarities by walking around in the real world. These can, in turn, be trained and used to fight other Pokémon. To catch them, the player must use Poké Balls, which can be purchased for real-world currency or collected at PokéStops scattered around

Figure 10.2: Example of the Player's Map in Pokémon GO.

the map (see Figure 10.2). The game heavily relies on the phone's GPS sensor to move the player around. An AR feature also utilizes the mobile camera to display the Pokémon in the player's physical surroundings. However, this feature is not mandatory and can be disabled.

Wang presented a thorough literature review on the health effects of Pokémon GO [80]. It showed that players recorded more steps than before playing the game and at a generally higher level than non-players. This was reflected in a different study showing an increase in distance walked, but with the note that this effect was only short-term. Most studies in the literature review corroborated the trend of short-term activity increase, showing an immediate increase in activity when playing but with an eventual decrease. The temporary increase lasted between three weeks and nine months, with no lasting effects after stopping playing. Several studies also found that players made new friends while playing the game. Pokémon GO was noted as one of few games that managed to increase activity levels among players who were not already active. This was reiterated in Wang and Skjervold's paper on the health and social impacts of playing Pokémon GO on various player groups [81]. Through a survey on over 2000 players they found that the game managed to motivate player groups who are otherwise hard to encourage to be socially and physically active. Players were also significantly more active both socially and physically after playing the game. Lee et al. also conducted a literature review on Pokémon GO focusing on physical activity and psychological outcomes [37]. They found a significant difference in the physical activity level of players and non-players. Active players of Pokémon GO were found to have significantly more daily steps and a higher number of days spent in moderate physical activity. Furthermore, they concluded that the game could improve players' social interactions and moods.

10.3 Ring-Fit Adventure

Ring-Fit Adventure (RFA) is an exergame released for the Nintendo Switch in 2019. As of June 30, 2022, it is the 10^{th} most sold game and the best-selling exergame on the console [50]. It utilizes the motion- and infrared sensors of the console's Joy-Cons, which are attached to the specialized ring and thigh strap shown in Figure 9.3. Using this sensor information, the game registers if the player is pushing, pulling, or rotating the ring. It also captures the movement of their leg. There are various game modes, such as adventure, quickplay, rhythm, etc. The core gameplay consists of running to move your character and performing multiple muscle-strengthening exercises to beat enemies. This ensures variety both in gameplay and the muscles trained. Figure 10.3 shows an example of such gameplay, where the player must defeat enemies by performing the movements

Figure 10.3: Ring-Fit Adventure gameplay.

displayed in the left-hand corner. RFA has 30 different fitness levels and attempts to specify its difficulty based on the information and feedback from the player. In adventure mode, the game follows a story through a level-based structure. One study with 80 participants found that those using the adventure mode for 30 minutes, three days a week for four weeks, reduced their 1600-meter running time by around 20 seconds [96]. Furthermore, the study concluded that RFA could sustain or improve players' fitness levels. Another study found that patients with chronic lower back pain experienced reduced pain after exercising once a week for eight weeks with RFA [60].

10.4 Strava

Strava is an activity-tracking and social media application for smartphones. Its user base constitutes the largest sports community in the world with over 100 million users [71]. Users of Strava can track their workout sessions in the app and record various metrics. The app integrates with a wide range of wearable sports devices, but it is also possible to only use the phone's built-in sensors. Importantly, Strava is more than a fitness recording app. It allows users to share their workouts to their social network and give and receive kudos to one another. This is one of several gamification elements employed in the app, along with achievements, leaderboards, competition, teams, etc. The app facilitates many types of challenges, both team-based and individual ones. For instance, the app challenges you to beat your previous records on certain distances. There are also monthly challenges, like running a certain accumulated length over the month. One such example can be found in Figure 10.5. Users can also join a club and compete against other participating clubs. The app incentivizes users to push themselves further and improve their fitness through these gamification elements. When analyzing the activity patterns of five Dutch Strava running clubs, Franken et al. found that receiving kudos increased their activity level [21]. However, the athletes would also become negatively affected by their friends who ran less frequently than them, possibly because they showed that it was acceptable to run less frequently. As Stragier et al. note, it appears that users of applications like Strava initially use them for their tracking abilities and not its social network, but that the social elements help users stay active [70].

10.5 Pikmin Bloom

Pikmin Bloom is another AR exergame developed by Niantic that leverages a Nintendo intellectual property. The game is more recent than Pokémon GO, released in October 2021. In Pikmin Bloom, the player has to find and care for plantlike creatures called Pikmin. This is achieved by walking around in the real world, where players can discover new Pikmins. Additionally, they can plant Pikmin seeds that will eventually bloom into Pikmin after walking a set amount of steps. Depending on where the player picked up the seed, the appearance of the Pikmin may change. The player must care for their Pikmin by giving them attention and feeding them. One can also find food by walking outside, further encouraging physical activity. Pikmin Bloom also works as a form of a diary. The routes walked by the player each day are stored and can be viewed at a later time. At the end of the day, the player is encouraged to describe how they felt and add photos. The game incorporates social aspects directly and indirectly through postcards and community flowers. By planting flowers in the same area, players can work together to create larger flowers, yielding resources in return. There is also a friend system, where players can send postcards with photos to their friends. They can also send collectible cards with their Pikmin on them. An illustration of some of the game's features can be seen in Figure 10.4. Furthermore, the game has various weekly challenges that can be completed together with up to four other friends. Here, each person's steps will contribute to the group's overall progress. Currently, more research on the potential physical benefits of Pikmin Bloom is needed, which is likely in part due to its recent release date.

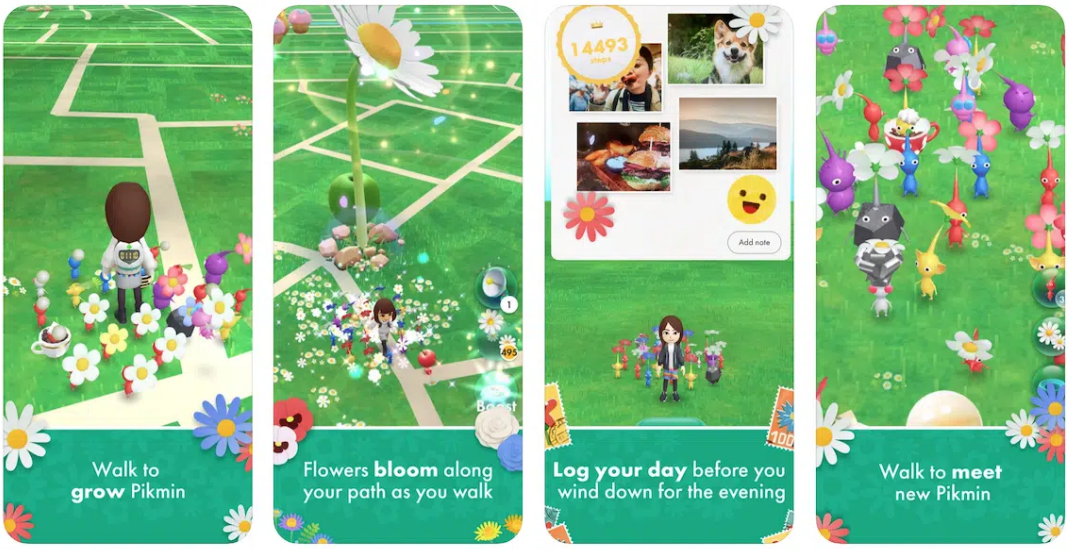

Figure 10.4: Feature Showcase for Pikmin Bloom.

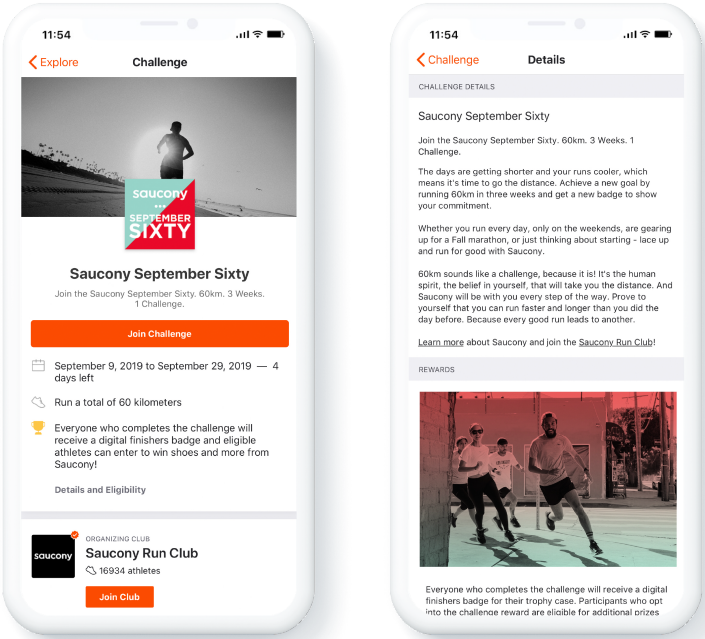

Figure 10.5: Example of a Running Challenge in Strava.

10.6 Summary

This chapter showed examples of existing successful exergames and some of their features. They illustrate the wide range of the genre. Some, like Wii Sports and Ring-Fit Adventure, are console-restricted games, whereas Pokémon GO, Strava, and Pikmin Bloom only require a smartphone. For BitPet, the features of Pokémon GO, Strava, and Pikmin Bloom will be particularly important for our concept development, as they utilize the same platform and technology. Strava also represents an "exergame" where the social aspect is essential, which is desirable to achieve in BitPet as well. Furthermore, Pikmin Bloom resembles BitPet in that players must care for their "pets". The next chapter will present another type of video game relevant for BitPet, social games.

11 Social Games

Social games, as we define it, include all games that encourage physical or virtual social activity. This includes traditional multiplayer games as well as primarily single-player games with some social aspects.

11.1 Features

Paavilainen et al. present a review of social features in primarily single-player games with social features [55]. The premise for the games in the study is that they build upon pre-existing friend networks from social media. However, only a small minority of the features Paavilainen et al. identified would require social media integration. What identifies these games is the lack of real-time communication, interaction, and team-forming that fully multiplayer games such as Massively Multiplayer Online games (MMOs) have.

The study identified some features as especially effective at forming a sense of community, social identity, and social support. The review concluded that the ability to visit friends' game spaces

and the ability to receive information about friends' actions in the game world created a common ground for the players. Posting to friends' Facebook walls from the game and ranking or other scorekeeping functionality created a social identity for the players. Some game functionality enabled social support, such as the ability to request items from friends, sending daily items that are free for the player sending, and the ability to interact simultaneously with friends in the same game space.

The final conclusion was that game designers should focus on communication, interaction and team forming, with the added note that less is more when it comes to social features.

A full overview of social features identified by Paavilainen et al. can be found in Table 17 in Appendix B.

11.2 Effects of Social Games on Mental Health

The effects of playing social games on mental health is a complex topic without one clear answer. Perry et al. found that playing video games with friends, whether they were real-life friends, online friends, or both, had a positive effect on social capital [57]. Granic et al. performed a literary review on the benefits of playing video games in general, both social and not [28]. Their literature review concludes that playing social video games such as World of Warcraft and Farmville helps players learn social skills and prosocial behavior. According to the APA Dictionary of Psychology, social skills range from regulating one's feelings to friendship-making skills [5].

The literature reviewed by Granic et al. also quite confidently concludes that playing video games, in general, is very effective at generating positive feelings in children and adolescents. They also point out that adaptive regulation strategies such as acceptance, problem-solving, and reappraisal, which are rewarded in gaming, are linked to less negative affect, more social support, and lower levels of depressive symptoms. Shawcroft et al. managed to show that playing games in person with friends provides a protective context against depressive symptoms for those not already experiencing them [64]. Players already struggling with depressive symptoms did not experience as much of a benefit, however. Research specifically related to the mental health effect of playing the exergame Pokémon GO is covered in Section 10.2.

On the other hand, Wei et al. found that those with many hours a week spent on online games had more severe depressive, social phobic, and internet addiction symptoms [85]. Long online gaming hours were shown to be a predictor of depression.

11.3 Summary

As has been discussed previously, diverse social networks and high levels of emotional support are highly correlated with depression prevention. Perry et al. and Granic et al.'s findings on social capital, social skills, and social support can be related positively to the previously discussed findings on recommendations for better mental health, with the conclusion that playing video games, particularly social video games, can contribute positively to one's mental health. Designing games in accordance with Paavilainen et al., focusing on communication, interaction, and team forming, and encouraging playing games in person with friends, should play into these identified factors and therefore be beneficial to the players' mental health. However, one should conversely be cautious about designing games that encourage long hours of playing without in-person physical contact. The next chapter provides examples and discussion of some social games.

12 Existing Social Games

This chapter presents some games with social features that have been particularly influential and relevant for BitPet.

12.1 Team Fortress 2

Team Fortress 2 (TF2) is a free-to-play (F2P) multiplayer class- and team-based first-person shooter developed and released in 2007 by Valve Corporation [94]. The game has various modes that the player can choose from, though the majority focus on playing with others in a team. Players can communicate through in-game voice and text chats, as well as various avatar emotes and voice lines. They can also customize their avatars with bountiful cosmetic items like hats and weapon decals. TF2 was originally a paid game but switched to a F2P model in 2011, which caused the active player count to quadruple [69]. This was achievable due to a gradual introduction of unlockable and purchasable cosmetic items through updates. Notably, the 2009 Sniper versus Spy update introduced decorative items, and the following 2010 Mann-Conomy update introduced player trading (see Figure 12.1), objects of various rarities, and micro-transactions [86] [87]. Since then, the virtual economy of TF2 has become increasingly complex and has spawned many community sites dedicated to trading, such as *backpack.tf*, *scrap.tf*, and *bazaar.tf*. Later, Valve also introduced an official trading platform through the Steam Market. In 2011 alone, it was estimated that the economy was valued at $50 million [25]. The game's financial model was highly influential, and Valve's following online titles, Dota 2 and Counter-Strike: Global Offensive, adopted similar solutions. However, TF2 also fostered an online community in other ways, such as with community-created items with the Steam Workshop, which allows players to create maps, cosmetics, weapons, etc. These items also have a chance of being added to the official game. Additionally, players can host private servers with their own modified versions of the game, allowing for new game modes and communities. This can appeal to players who would not necessarily enjoy the regular modes.

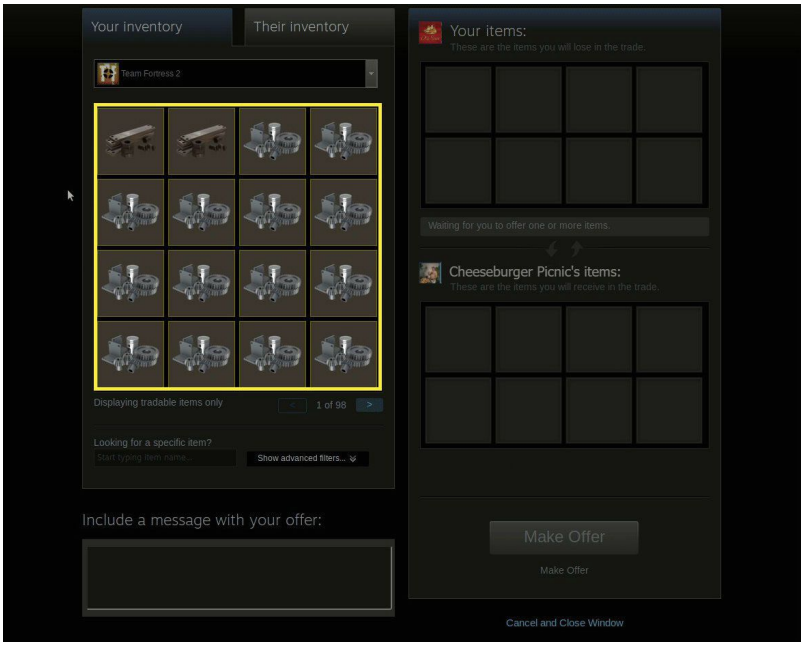

Figure 12.1: The Interface for Trading Items in Steam, Such as TF2 Items.

Figure 12.2: Social Events in Fortnite. Left: Short Nite Film Festival. Right: Travis Scott's Virtual Concert.

12.2 Fortnite

Fortnite is a F2P multiplayer third-person shooter released by Epic Games in 2017, available on PC, major video game consoles, and mobile phones [91]. It is one of the most successful games of recent years, with over 400 million registered users and several million concurrent players at any time [24]. Its most popular game mode is Battle Royale, where up to 100 players are dropped into a map and compete to be the last survivor. However, the game is much more than a competitive shooter. It contains many social features, such as clans, leaderboards, chats, friend lists, etc. A recent addition to the suite of social features is Party Worlds, which allows friends to have a place to socialize virtually. As Epic Games write, "*It's a space where you can go, relax, have a good time, and play some mini-games*" [75]. Party Worlds differ from a similar feature called Hubs in that their purpose is to be social destinations instead of showcases. Fortnite has also hosted several social events, including concerts and film screenings. Celebrities like Travis Scott and Ariana Grande have performed set lists within the game, garnering over 27 million event participants [27]. The game has also hosted film festivals where players can gather in groups and watch movies together [76]. Figure 12.2 shows two screenshots from these events. Additionally, the game is constantly evolving, following a chapter-based structure. Updates to the game map, features, and abilities are added and, later on, removed, ensuring that the game is constantly evolving.

12.3 Clash of Clans

Clash of Clans is a Real-Time Strategy (RTS) mobile game developed by Supercell and released in 2012 [88]. The game is based around player factions in the form of clans. Players can join a clan consisting of up to 50 people. Here, they can support each other by donating resources and chatting amongst themselves in a dedicated clan chat. The leaders of each clan can start wars, which last two days, against others (see Figure 12.3), and the winners receive a significant amount of loot. The resources can then be spent to upgrade player bases and armies. Players can signal their wish to participate in wars or not, but the leader determines which clan members will fight. The leaders also have control over the memberships of their clan, which leads to different clan archetypes. Some strive to be the strongest and most competitive and thus require all their members to participate in the game actively. Others can be far more casual, for instance, clans created by a group of friends for fun.

Figure 12.3: Overview of a Clan War in Clash of Clans.

12.4 Codename Neon and Tonehenge

Codename Neon and Codename Tonehenge are tech demos developed by Niantic and demonstrated in 2018 [34]. Codename Neon is an AR adaption of laser tag, a popular activity where players shoot at each other with infrared laser emitters. Like the real-world equivalent, players physically meet to play together. The players use their mobile phones as the interaction device in the demonstration. A live camera feed from the phone is augmented with a Heads-Up Display (HUD) around each player in the session, and the players must aim and shoot at each other using their phones. Codename Tonehenge is also a multiplayer AR game but focuses instead on collaboration. In the short demonstration, players must work together to solve puzzles. In addition, they can interact with and manipulate various objects in the AR world together.

12.5 Summary

This chapter has demonstrated some of the various shapes social games can take and how their features encourage socializing. TF2's trading and community-building innovations have inspired many games, including Valve's own. The game demonstrates how important cosmetic items can be for players and how trading can become a prominent social aspect of a game. Allowing player-created items to be incorporated into the game also encourages players to actively participate in the game's development. However, trading is not without concern, as it can also lead to exploitation and scamming. Thus, one should be careful with where and how one can trade and the game's monetization model. Fortnite's events show how a game that has mainly been a multiplayer shooter can extend it to a platform to socialize with friends. Clash of Clans demonstrates how clans can create a feeling of community and make players cooperate. Though Codename Neon and Tonehenge are short tech demonstrations, they showcase how to use AR to create exciting in-person games using only a mobile phone. As technology improves, this becomes an increasingly exciting prospect, and a similar concept could be done in AR with BitPet.

With both exergames and social games introduced, the following chapter will focus on BitPet. It will give a feature and technical overview of the game.

13 BitPet

BitPet is a mobile AR exergame where you care for, interact with, and fight with different virtual pets. After the game underwent a feasibility study at the School of Entrepreneurship at the Norwegian University of Science and Technology (NTNU), it started development in 2020 and is currently in open beta [8]. One of the game's primary goals is to increase players' physical and social activity levels. The game is being developed in parallel with this thesis by a team consisting of six developers and designers.

13.1 Gameplay

Players tend to one or more pets that need regular walks, food, and play to level up and become stronger. The pets reside in the player's home island, which can be decorated with flora found in the game. The players can own one of each pet type, of which there are currently 17. Each pet has different base stats and can be bought for in-game currency. There are currently two types of currency: coins and diamonds. Players can also unlock and buy various decorative items for their pets. If the pets are not adequately cared for, their status bars will deplete, and they will ultimately die. This incentivizes players to regularly return to the game. However, pets can be revived and will return to life after a given time period.

The game encourages physical activity by motivating players to move around in the real world. A virtual map is overlaid the real-world maps of players, and they can physically walk around to move their pet avatars. This allows them to collect food, encounter other animals, and gather coins. Players can also mark territories as they walk around to gain pet points and increase the number of points they receive by chaining the territories. These pet points can, in turn, be used to strengthen pets. While in the vicinity of other animals, players can battle them in AR battles, such as fights or coin races. If they beat the opponent animal, they unlock them as purchasable pets. A lure feature also allows the players to attract nearby animals that would otherwise be out of range. However, this ability is limited and can only be used every other hour.

Figures 13.1 and 13.2 show two essential gameplay scenarios from BitPet, using the map and partaking in AR battles.

Figure 13.1: Example of the Map View in BitPet.

Figure 13.2: Example of an AR Battle in BitPet.

13.2 Technology

This section provides a brief overview of the current frontend and backend architecture of BitPet.

13.2.1 Frontend

BitPet is developed in the Unity game engine, a prevalent, customizable engine that supports most game genres. The engine's architecture resembles the Entity-Component-System architectural pattern but with specific differences. The central abstraction in Unity is the GameObject, an empty object with a transform to which developers can add various components to create visuals, behaviors, audio, etc. Scripts written in the C# programming language declare the game's behavior.

The software architecture of BitPet's frontend is reminiscent of StrangeIoC, an Inversion-of-Control framework developed for Unity and C# (see Figure 13.3) [74]. Similarly to StrangeIoC, BitPet uses a Model-View-Controller-Service (MVCS) architecture with the Mediator and Command patterns. In an MVCS architecture, the classes are divided into Models, Views, Controllers, and Services. Model classes contain the logic and state of the application in defined data structures. Views use this information to display visual information to the user and react to their input. Controllers update the state of models, views, or services. Finally, the Service classes load and store information from *external* sources. In BitPet, the controllers are realized through the Command pattern. In this pattern, commands ensure operations between classes. This avoids the practice of calling classes directly. When a command executes, some application logic occurs. Separating the execution logic from the calling class improves the application's separation-of-concern aspect. Another separation comes through the use of Mediator classes. Some Views in the application will have corresponding Mediators. Instead of directly binding the Views to Models or Services, each View exposes an Application Programming Interface (API), which the corresponding Mediator will utilize to modify the View.

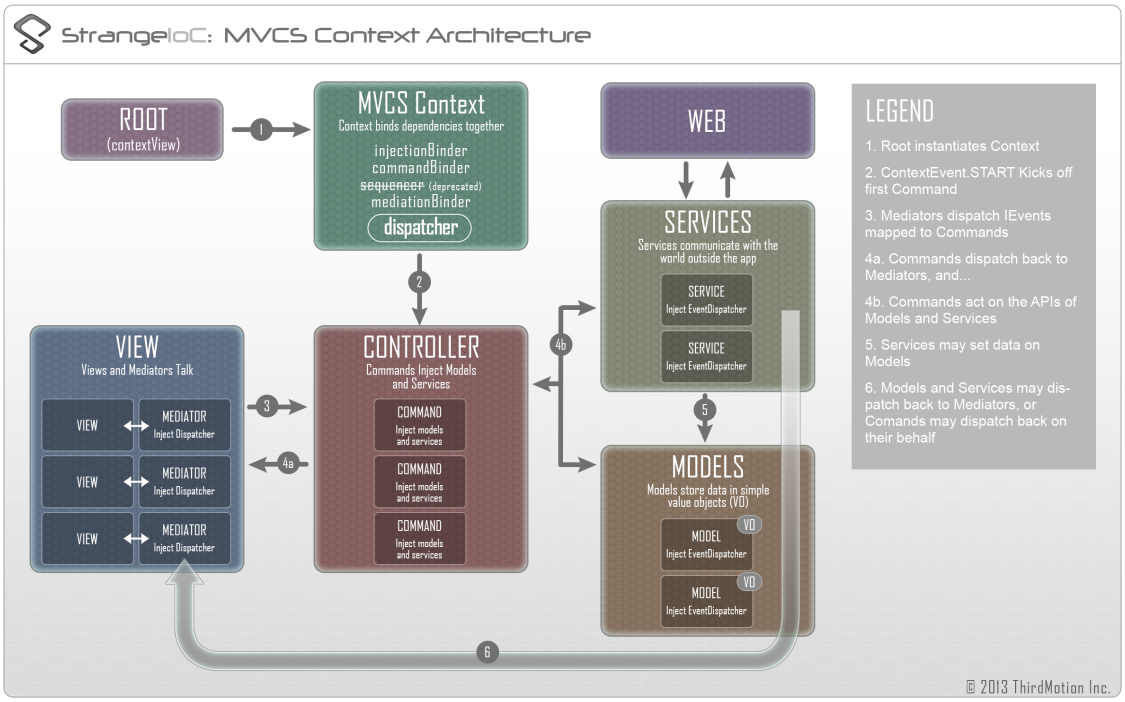

Figure 13.3: The Overall Architecture of the StrangeIoC Framework [74]. Note that BitPet Does Not Implement All of This.

Like StrangeIoc, BitPet uses the dependency injection pattern to decouple objects from one another. When using dependency injection, objects receive objects or functions that they depend on [89]. Instead of creating the necessary objects, the classes receive them from an injector. This enhances the loose coupling of the program. To implement this pattern, the developers use the *Extenject* library, an actively maintained version of *Zenject* [6] [44]. The library also supports communication between classes through a signal bus. To avoid classes directly calling each other, they instead fire signals which are sent and delivered through a central bus, again reducing their direct dependencies.

13.2.2 Backend

The BitPet client utilizes a REST API written in Ruby on Rails. The server is connected to a PostgreSQL database to store game data. It implements a REST API based on a modified Model-View-Controller (MVC) pattern. The application's admin panel is implemented fully in the MVC pattern but for the frontend application's purposes, the backend application is a JSON API.

The PostgreSQL database tables are modified by the Rails application through its Object-Relational Mapper (ORM), Active Record. The structure of the tables is written in migrations, in Ruby, and then applied to the database. The default content of the database is specified in seeds in the source code. In addition to the PostgreSQL database, some values are stored in a Redis in-memory key-value database to serve frequently called endpoints more efficiently. Cron jobs handle client-independent actions such as routinely decrementing pet stats like hunger and happiness. User authentication is done with Firebase Authentication.

13.3 Summary

This chapter gave an overview of BitPet, a mobile AR exergame based around virtual pets. It gave a brief historical and functional outline of BitPet, followed by a technical summary of the game. BitPet is implemented in Unity and implements the MVCS architectural pattern and the Mediator

and Command design pattern. The architecture resembles the one of StrangeIoC but is not a direct implementation, exemplified by using Extenject to achieve dependency injection instead. The app communicates with a Ruby on Rails server that uses a PostgreSQL database. Familiarity with the functionality of BitPet is crucial to suggest new concepts for the app. Furthermore, one should be intimately familiar with the technical solution if one is to extend it with additional features.

This chapter concludes the prestudy part. With the aforementioned topics in mind, the next part will present the proposed concepts for BitPet and determine a final feature concept to be implemented.

Part III

Concept

This part concerns the new feature concept for BitPet. As with Part II, it is based on the TDT4501 project report [17]. The part will introduce some proposed ideas for a new feature concept, informed and inspired by the prestudy. It will then present the feature to be implemented.

14 Feature Ideas

This chapter presents some of the feature concepts we have considered for BitPet. Most of the features focus on the social aspects of the game, as we have found through personal playtesting that there is more potential here. Furthermore, the previous part discussed many studies that highlighted the benefits of social features in games.

14.1 Planned Trips

One issue we experienced when playing BitPet was a need for more passive rewards for walking. As of the current implementation, one must actively play the game while walking around to receive the most rewards. This can be distracting from the surrounding environment. Furthermore, during colder seasons, it becomes increasingly difficult to use a phone outdoors due to cold temperatures. However, keeping the player engaged with the game is desirable even as the seasons change. This is, naturally, a more significant problem for countries with major changes in climate during different seasons. Nevertheless, if one could reward the player for walking without them having to actively keep the game open, it would potentially incentivize them to stay active. Games such as Pikmin Bloom achieve this through features like seeds.

There are already some features implemented to support passive walking rewards. Namely, there is a daily gem reward for walking a certain number of steps each day. Furthermore, the game allows the player to turn the display dark and still be able to collect items, reducing the phone's battery load and susceptibility to accidental touches. However, we believe that further facilitation is needed.

A new potential feature to support passive playing is planned trips. This feature would allow the player to sketch out a walking trip ahead of time and reward them when finishing said trip with a semi-randomly chosen reward. Thus, the game could track the player's position even with the phone locked and check if they did indeed finish the trip. Similarly to Pikmin Bloom, it would keep track of the player's movements during the day. One could require a small entry sum or minimum trip length and limit the number of daily trips to avoid abuse. The reward could be calculated based on the trip length and a randomized value so that the prize would excite the player. This lack of predictability could encourage them to make trip planning a regular activity to receive the best rewards. Such a feature would likely be most rewarding for players that fit the achiever and killer types, that prefer rewards with gameplay effects [83].

14.2 Friend System

A friend system is a foundation for many other potential socializing features in BitPet, of which there are currently very few. The prestudy showed that socializing is an important part of GameFlow, can encourage continued play, and can lead to positive psychological effects [38] [73] [70] [22]. Many modern games have some version of a friend system, whether within the game itself or using its platform (such as the Steam community). Thus, one of our proposed concepts is a similar system within BitPet. As each user already has a username, one could create a search function where users could add each other based on these. To expand on this, within the game, one could have a friend list where the user could see their online and offline friends and friend invitations. Additionally, one could implement a chat to communicate within the app and plan a walking trip together. The current leaderboard could also be expanded so that users could compare themselves with their other friends, building on the principles of upward identification and downward contrast. Furthermore, one could create an activity feed similar to Strava's, where you have a board with updates on what your friends have achieved, for instance, if their pet reaches a certain level. This could increase the feeling of playing alongside others and encourage players to reach new milestones so their friends are notified. As noted by Schoenau-Fog et al., achievements and unlockables typically encourage engagement, and if absent may cause disengagement in the players [61]. Furthermore, Paavilainen et al. noted how updates from friends' actions caused a common ground for all players [55]. Finally, Esteves et al. suggested notifying players of achievements from

similar players, which in this case is the player's friends [18]. All this suggests that a friend system combined with an activity feed would be beneficial to the game.

14.3 Different Rarity Items

BitPet already has a selection of cosmetic items that players can equip their pets with. As noted in the chapter on rewards, such virtual items can particularly appeal to socializers [83]. They are very suitable for review and collection, as the player will see them whenever they interact with their pet. However, as it currently stands, the rarity of each item is not conveyed to the player. Hence, we propose a tiered rarity system for the cosmetic items in BitPet. Taking inspiration from other games, one could create different levels of rarity, each with its name and graphical design. More common items would be more generic and provide less sensory stimuli than those of higher rarity, thus invoking a desire in the player to collect the rarer items. Taking inspiration from cosmetics like the unusual hats in Team Fortress 2 (TF2), rarer items could have various particle effects to increase their desirability. Players could want to collect certain cosmetics to show off their status to others, e.g., while doing augmented reality (AR) co-play or defending an area with their pet.

14.4 Seasonal Events

As noted in the player engagement in exergames section, continuous updates can help keep players engaged in a game [101]. Several games achieve this through seasonal events like Fortnite's concerts and film festivals. Having the events limited to a specific time could increase players' playtime during the event periods, as they cannot enjoy the provided features whenever they like. Seasonal events also help keep the game feeling exciting. Furthermore, since the event is only available for a limited time, there is more room for experimentation since new features would not necessarily have to be incorporated permanently. This feature concept is thus for BitPet to host seasonal events throughout the year. Such events could incorporate cosmetic items only unlockable for specific periods. Once unlocked, however, players can use them whenever. For instance, BitPet could release Halloween-themed clothes for pets in October. Furthermore, limited-time pets could spawn on the map during these events, such as reindeer during a Christmas seasonal event. If the players want to unlock these items, they must log in and play during that period. For the scope of this research project, only one seasonal event would be created and tested.

14.5 Trading Systems

Another way to encourage player interaction is a virtual items trading system. BitPet already has different types of currency that the player can purchase pets, cosmetic items, food, and other resources with. However, this interaction is only between the player and the game. Allowing players to trade items with each other could foster a stronger community and increase social interaction. The feature could require players to locate other nearby players to exchange with. Or, one could allow them to trade with each other based on a player tag and add a trading chat to discuss amongst themselves, similar to games like TF2. To keep the focus on social interaction, one should avoid a central marketplace where the players do not have to interact. The trading system idea could be enhanced in combination with the different rarity items and seasonal items concepts, as cosmetic items would assumedly have different values based on their popularity and rarity.

14.6 Visiting Friends' Bases

As suggested previously, this idea requires at least a basic implementation of a friend system. BitPet's current implementation allows users to interact and explore with pets in their home base. Additionally, they can customize their base with various decorations, primarily in the form of different flora. Our suggested extension is the ability to visit other players' bases. This could be used similarly to the party worlds in Fortnite as a place to hang out, or similar to viewing other

bases in Clash of Clans. Players could choose which pet they want to travel with and walk around the friend's base similarly to their home base. With players able to inspect each other's bases, the suitability for review and the social effect of the home base decoration rewards would likely increase, as players could show off to their friends. Hence, one should also consider incorporating more ways of customizing the base. Furthermore, players could take inspiration from each other's bases and become increasingly motivated to walk outside to collect more decorations. To encourage the use of this feature, it would be beneficial to give the players reasons to visit their friends' bases regularly. A possibility here is that players provide a weekly gift to their friends by visiting them.

14.7 Factions

As previously stated, belonging to a community is essential for player retention in online games [18] [22] [78]. To facilitate this feeling of belonging, we suggest a system where players can create, join and contribute to a faction. The factions could have names and logos and compete with other factions. For instance, one player's advancements in the game could simultaneously contribute to their and the faction's statistics. Examples of statistics could be how many times a player has successfully beaten another pet, defended an area with a pet, how many steps they have taken in one day, etc. To increase competitiveness, one could have faction leaderboards within the game. There are already leaderboards in the current release of BitPet, but they are player-specific. One could also have weekly and monthly faction challenges with rewards to motivate the player to contribute to the faction's progression. Like in Strava, teams could compete for the most steps taken during a week or month. Then all players in the top three factions could receive in-game rewards accordingly. Finally, factions could have dedicated chats for their members to increase players' feelings of belonging. As mentioned in Section 11.1, Paavilainen et al. explicitly mentioned such features (team forming and communication) as being particularly effective in creating a sense of community, social identity, and social support [55].

14.8 Trips with Friends

Another proposed concept is the ability to take walks with your friends in person. This feature encourages physical instead of virtual social interaction. When two players are near each other, they could receive a notification asking if they want to walk together. One could require that these players are already friends so that players will not receive unnecessary notifications. Or, instead of a notification, players would have to click on their friends and request them to go on a walk, which would only be possible when close enough to each other. Both players could receive special rewards, so these trips are preferable to walking alone. For instance, the game could boost the number of items spawned, experience points (XP) gained, or give unique rewards only achievable through this mode. A proposed idea is that after completing a walk together, you would have the chance to receive a unique cosmetic item. The longer the hike, the higher the odds of receiving a rare reward. Leaving a random aspect to the prize could encourage players to take several walks to increase their chances and turn it into a habit. Such a reward would stimulate the curiosity aspect of Malone's theory and also have social value [42]. To ensure integrity, players would have to stay within a certain radius of one another for the duration of the walk.

14.9 Summary

This chapter presented the various feature concepts we propose to incorporate into BitPet. The first proposition is a way to plan trips ahead of time and be rewarded when completing them. Next, a friend system where users can add each other and see updates in a feed. Taking inspiration from TF2, we propose an item rarity system and a trading system. Another proposed concept is seasonal events akin to e.g. Fortnite. Clash of Clans inspired two other potential features, visiting friends' islands and a feature for creating and joining player factions. The final concept is the ability to walk together in-game with friends and receive extra rewards. The following chapter will provide a ranking and discussion of the concepts and a final feature concept to implement.

15 Concept Discussion

This chapter details how we chose which concept to prototype and test. First, a ranking of the ideas is outlined. Then, a small discussion ensues before the final concept presentation.

15.1 Feature Concepts Rated

To choose a final idea based on the presented concepts, we formulated several criteria for each to be rated on a scale from 1 (lowest) to 5 (highest) . We chose the criteria based on what we wished to achieve with a new concept and how feasible we deemed it. The criteria were: *technical feasibility*, *social benefit*, *physical benefit*, *authors' motivation*, and *effect on retention*. *Technical feasibility* encompasses how feasible we believed it would be to implement the feature given the development time. *Social and physical benefits* regards how much of a positive impact we believed the feature would have on the social and physical activity of the player. *Authors' motivation* is our motivation for developing and testing the feature. Finally, *effect on retention* is how much we thought the feature would affect the player's continued play. We included this dimension due to the importance of keeping players returning for regular exercise, a challenge particularly prominent for exergames [36]. We gave each feature a score through discussion and reviewing the features against each other. It is important to note that these evaluations are our biased thoughts and estimations and might not reflect actual difficulty or effects.

Table 1: Feature Concepts Rated.

Feature	**Feasibility**	**Social Benefit**	**Physical Benefit**	**Authors' motivation**	**Effect on Retention**	**Sum**
Planned Trips	1	1	5	1	2	*10*
Friend System	4	5	2	5	3	*19*
Rarity System	5	2	3	3	3	*16*
Seasonal Events	4	3	3	5	4	*19*
Trading Systems	4	4	2	3	3	*16*
Visiting Bases	1	3	1	2	3	*10*
Factions	3	4	2	2	3	*14*
Trips with Friends	1	5	5	1	2	*14*

15.2 Chosen Idea

As evident from Table 1, there are features we believed would be of great value to the game but deemed too infeasible for us to implement. For instance, allowing for trips with friends would require extensive backend programming combined with frontend changes to constantly update each player's position in relation to each other, since communication is mostly through Hypertext Transfer Protocol (HTTP) calls, a request-response based protocol [20]. Planned trips also pose a challenge in creating a satisfying user interface for planning a trip and logic for tracking the player and ensuring they follow the given path. Allowing the player to visit other bases is not necessarily as complicated. Due to the loosely coupled architecture, one could change the player's game views with a friend's. However, we believed the feature would not be worthwhile unless we also added quite an extensive incentive for players to visit these bases, leading to a high workload. The low

feasibility also caused motivation for the features to be lower. Thus, we eliminated planned trips, visiting bases, and trips with friends as our final concept.

The remaining features are all quite feasible in comparison. Factions received the lowest score because it required a relatively comprehensive implementation to succeed. For example, allowing a player to join a faction without any interaction or other incentive would likely not result in a good feature. We still believe factions could complement the game socially, but it would require more effort than the short development period allowed. The other ideas all appeared achievable, and even combining some seemed doable. The rarity system, for instance, is partly implemented, as items have assigned drop rate values already.

The two concepts with the best score were the friend system and seasonal events. Both these features would contribute significantly to social and physical activity in the game. However, we hypothesized that a friend system would benefit BitPet's current state more. This is partly because the friend system enables several other proposed concepts, making them easier to develop later. For instance, implementing a trading system would be easier if players had friends they could trade with. On the other hand, seasonal events do not enable the other concepts to the same degree. In fact, with each seasonal event, the developers would have to add new content that would only be available for a limited time, leading to less capacity to focus on other permanent features. Thus, we decided to create a friend system in BitPet.

15.3 Summary

This chapter presented scores for each proposed concept based on perceived feasibility, social benefit, physical benefit, authors' motivation, and effect on retention. The friend system and seasonal events features performed best based on these criteria. Because a friend system would likely require less maintenance and be a stronger foundation for future features, we chose it as our final concept, thus concluding Part III. The next part will present the realization of this feature in BitPet.

Part IV

Development

This part concerns the design and implementation of the proposed friend system feature from the previous chapter. It primarily details the *Design and Creation* strategy outlined in Chapter 4. The part will not go into length about code details but rather give an overarching view of the process and solution.

16 Development Methodology

The distribution of work followed the lines of our pre-existing competencies. One of us covered user interface (UI) and frontend development, while the other covered database design and backend development. This separation of concerns allowed freedom of choice for code conventions, pull requests, etc., as each developer was wholly responsible for a different code base. Furthermore, the separation of concerns allowed development to be parallelized. Project status and progress were tracked on two Kanban boards; one for the backend and one for the frontend. They both had the sections *Not started*, *In progress*, *In review*, *Done*, and *On hold*. Drafts were designed for the UI and database before the actual development started, but we were flexible about changing the designs or implementation when necessary. The goal for the development phase was to create an MVP (Minimum Viable Product) for the friend system that users could test on iOS and Android devices. Bitbucket was used for version control, as the BitPet team already uses it for backend and frontend code repositories. Thus, modifying the existing solution was as simple as creating new branches on the above repositories and working from there. It should be noted that the branches were based on a beta version of BitPet, and were thus more prone to software bugs. A shared Postman workspace storing various values, methods, and endpoints was created to make testing the endpoints easier. Since frontend and backend were not always synchronized in features, Mockbin was sometimes used to mock specific endpoints temporarily. The development methodology was generally characterized by a significant degree of freedom. The BitPet team never interfered in the development but offered a supporting role when issues arose. Communication with them was entirely done via Skype, chat, or video.

17 User Interface and User Experience

Although Part III concluded on a friend system as the feature concept and proposed various functionality, the feature needed refinement before development could start. Since a friend system would consist entirely of UI elements, no new 3D game objects or animations were necessary for the implementation. Thus, mockups were created on paper, and later in Figma, before the friend system was implemented in Unity. Such prototyping allowed more rapid experimentation with different layout possibilities than if one were to program everything immediately in the game engine. Furthermore, as the friend system was a completely new addition to the game rather than an extension of an existing feature, we did not want to integrate it into any existing UI panel. Instead, a new panel was created containing all friends functionality. It could then be split into different views based on the usage context. With inspiration from other friend systems, the panel ended up with three different tabs: *friends*, *feed*, and *profile*. The following sections describe each of these.

17.1 Friends Tab

The friends tab is the entry point of the friend panel. Figure 17.1 shows the final mockup of this tab. It displays the users' other friends in a list. Each friend item shows their total pet points, username, and a delete button to remove the friendship. Additionally, there is a button to chat with the users. There is also an 'Add Friend' button that the user can click to add new users. Both users must add each other this way for the friendship to appear. Incoming friend requests will appear at the top. The current user can view their friends' profiles by clicking on usernames.

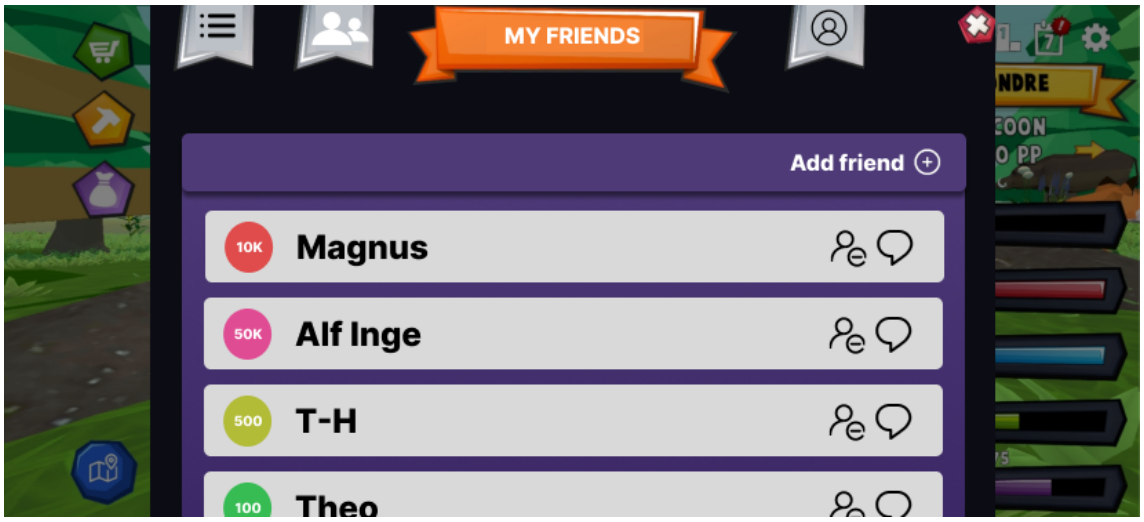

Figure 17.1: Final Figma Mockup of the Friend List.

17.2 Activity Feed

The feed consists of activity updates from the user's friends, where each new achievement leads to a post in the feed. Achievement criteria were based on a balance between difficulty to achieve and how frequently posts should appear. Ideally, the players should see new posts whenever they log in, but not so many that the feed would become bloated. After brainstorming what achievements would be interesting, the following were chosen:

- Total steps walked in a day.
- Total Player versus Environment (PvE) battles won.
- Total pet points earned.
- Pet reached a new level.
- New pets unlocked.
- New pet accessories unlocked.

To enhance the user experience, a reaction button and a date stamp were added to each post to indicate when the user made the achievement. Reactions ensure that users can easily express their emotions toward their friends' accomplishments, while dates let them keep track of the timeline of their progress. Inspiration was initially taken from applications such as Facebook Messenger and Slack, where users can choose between various emojis to express their reactions [67] [10]. However, because of limited development time, the approach used by apps like Strava and Duolingo proved more feasible, where users can only react with a single emoji [16]. Finally, a comment section was added to each feed entry to allow different expressions beyond reactions, where users could congratulate each other more personally.

Figure 17.2 shows the final mockup of the friend feed. It includes several posts for an imagined scenario.

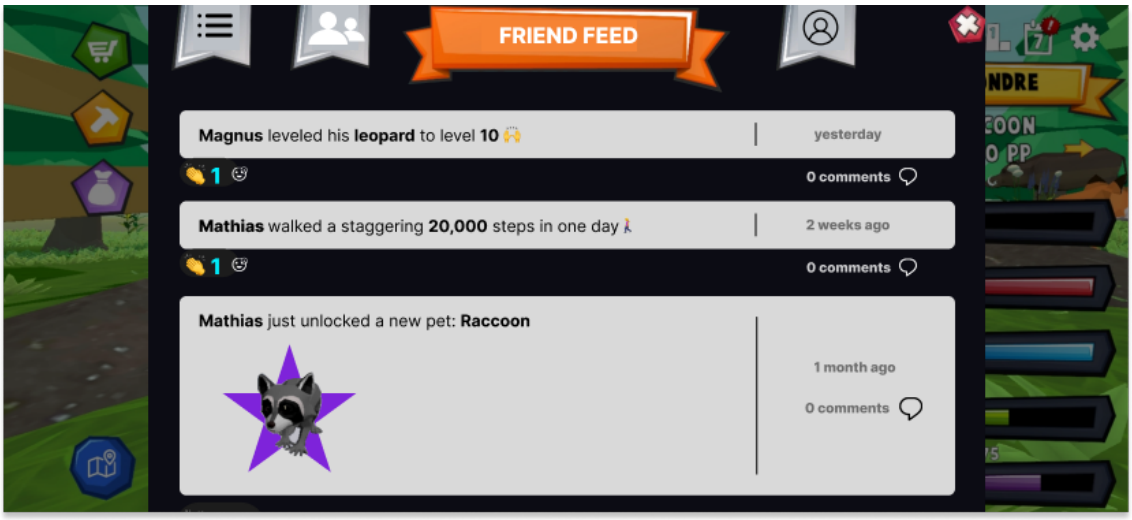

Figure 17.2: Final Figma Mockup of the Friend Feed.

17.3 User Profile

The user profile shows the progression of a user. The dedicated tab allows the currently logged-in user to see their profile, whereas clicking a friend profile in the friend list shows a similar view but for a friend instead. A chat button will also appear if the user views a friend's profile. Figure 17.3 shows an example of visiting a friend's profile. An associated title is displayed along with the user's total pet points. When reaching new thresholds of pet points, the title will also change to be more grandiose. The profile shows the user's currently unlocked pets and cosmetics, which allows them to compare themselves with others and see their progression.

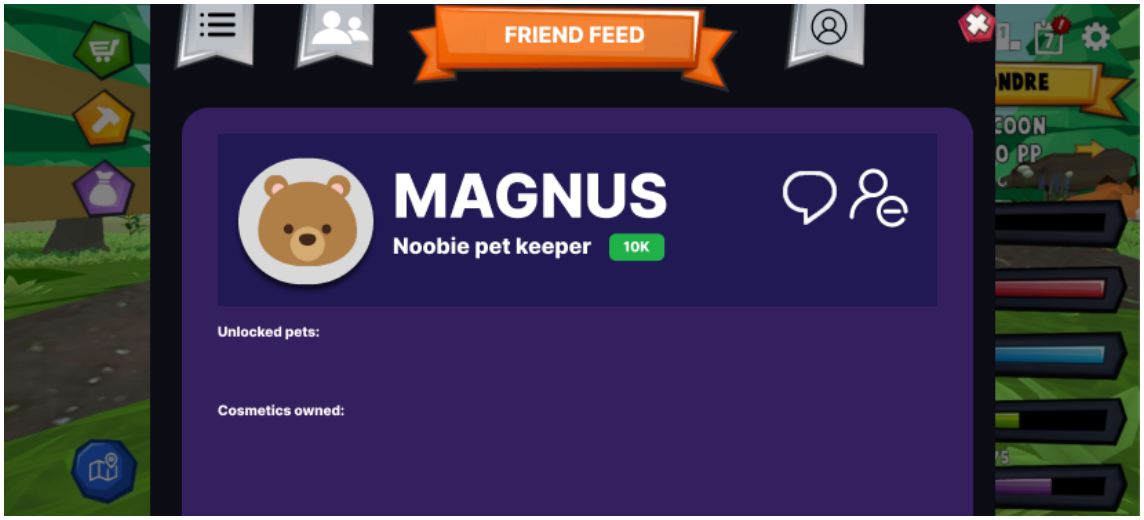

Figure 17.3: Final Figma Mockup of the User Profile.

17.4 Summary

This chapter described the design process of the UI and the final mockups created before implementing the feature in code. Since no 3D elements were necessary, Figma was an apt tool for rapid prototyping. The final mockups included a dedicated friends panel consisting of three tabs: friends, feed, and user profile. The following chapter details the backend implementation of this functionality.

18 Backend

This chapter describes how the backend code was modified and deployed to serve the feature concept. First, it outlines the deployment and hosting. Then it describes the relevant database changes. Finally, it presents special cases related to the Application Programming Interface (API).

18.1 Deployment

For the prototype to work on phones, the backend had to be accessible over Hypertext Transfer Protocol (HTTP) from anywhere, not just locally. Because the Rails code was modified for the experiment, the existing production server for BitPet could not be utilized, meaning a new hosting service was necessary. Due to a lack of dedicated hardware and the ease of modern cloud hosting, the choice of service landed on an Amazon Web Services (AWS) virtual machine (VM). BitPet's existing development server runs on Elastic BeanStalk (EBS), a service from AWS intended to simplify the deployment of servers on virtual machines. Replicating this seemed to be the most straightforward approach for the project. However, uploading the source code for the backend proved troublesome. Because EBS offers limited customizability and control, the choice instead landed on an Elastic Cloud Compute service (EC2), a service for virtual machines with direct Secure Shell (SSH) access that EBS runs on top of. Thus, all dependencies could be installed, and commands run directly from a Linux terminal. Rails does not offer a built-in solution for hosting an application server, so a Phusion Passenger was set up in standalone mode. The reverse proxy service NGINX was also initially used, but it had to be removed after issues with reachability. Furthermore, standalone mode offers the most effortless setup while remaining suitable for our prototyping purposes. BitPet also uses Firebase to handle user signup and authentication. Therefore, a separate Firebase project was set up and connected to the server to avoid conflicts with the production data.

Figure 18.1 illustrates the deployment setup. The two main entities are the backend and frontend, each consisting of smaller modules. The frontend in this scenario is a smartphone with a production build of Unity running on it. It communicates with the backend using HTTP. The backend is split in two, the EC2 VM and Firebase. They also communicate over HTTP. Inside the VM are the different programs running on the computer, along with the two databases previously described.

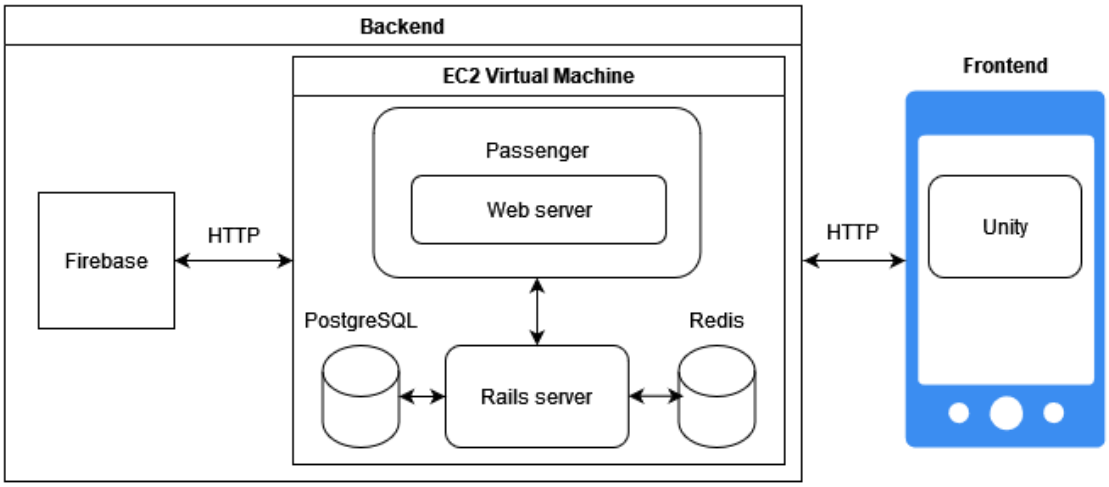

Figure 18.1: Deployment Overview.

18.2 Database

The friend system required significant additions to the database. When referring to timestamps in this section, that is a reference to Postgres' automatically generated fields *created_at* and *up-*

dated_at. All changes to the database were done through a total of 13 migrations in Ruby on Rails' ActiveRecord Object-Relational Mapper (ORM). Figure 18.2 is an Entity-Relationship (ER) diagram showing the additions made to the database. The entities with *<other attributes>* existed before development started; they are only there because some of our additions have relations to them.

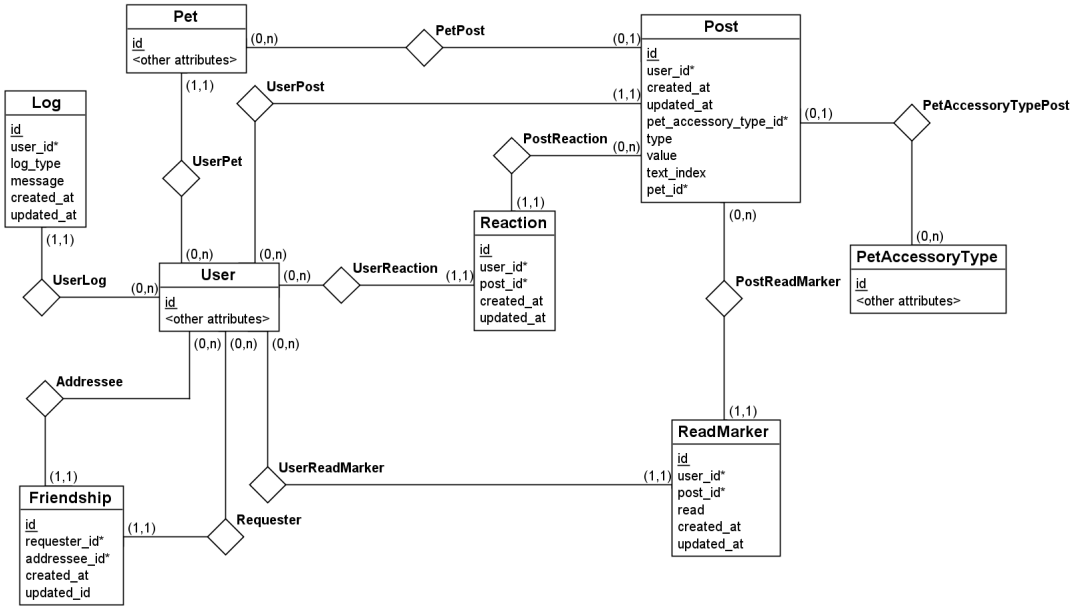

Figure 18.2: Database Additions.

18.2.1 Post

The multiple different kinds of posts in the friend feed are all represented by the same database entity. The *type* attribute denotes what kind any given post is. *type* is a keyword in Ruby on Rails to use when using the Single Table Inheritance (STI) technique. It is just interpreted as a regular NOT NULL character varying field by Postgres, but Rails will map each post to a different Ruby model based on the *type* string.

Post has the not nullable attributes *id*, *user_id*, *type*, timestamps, and *text_index* and the nullable attributes *pet_accessory_type_id*, *value*, and *pet_id*. The nullable quality of the final three attributes allows STI in Rails to validate the appropriate presence and absence of attributes for a given post type.

18.2.2 Friendship

Several different approaches to structuring the friendship between two users were considered. In the implementation, friendships are not stored explicitly in the database. Instead, they are defined as a relationship between two users who both have taken on the roles of requester and addressee. In the *Friendship* entity, the requester is a user expressing their desire to become friends with the addressee. This may occur either when sending a friend request or when accepting one. If two users have expressed this desire to each other, they are interpreted as friends.

Another alternative was a single *Friendship* entity for a given friendship. This solution would

simplify some querying, but it would have required constraints to avoid duplicate friendships and proved especially troublesome in handling friend requests.

18.2.3 Log, Reaction, ReadMarker

The last three changes to the database are the additions of the *Log*, *Reaction*, and *ReadMarker* entities. These are simple entities with relations to users and posts to track in-game actions, post reactions, and markers for whether a user has read a post.

18.3 API

All new entities in the database have a corresponding model and a controller to access it. Among other things, the models contain methods, definitions of relations, validations, and automated actions. As many of the models are very simple, with controllers mainly containing standard create, read, update, delete (CRUD) operations, we consider this code too trivial to describe in depth. However, below are the special cases and considerations that were necessary.

18.3.1 Posts

As mentioned in section 18.2, the *Post* entity maps to models according to the STI technique. One *Post* model exists with common validations and methods for all posts, such as the presence of required fields. For each type of post, there exists a different model which inherits from the *Post* model: *NewPetPost*, *NewPetAccessoryPost*, *PveWonPost*, *LevelUpPost* and *PetPointsPost*. These models have unique validations, such as the presence or absence of specific fields. In the case of *NewPetPost* and *NewPetAccessoryPost*, there are also unique implementations of certain methods relating to the pet and pet accessory relevant to a given post.

The post creation happens automatically as the user plays the game and not on explicit request by the user. Various controllers call the method which ultimately adds the post to the database, depending on the user's action and the post that corresponds to this action.

There are some scalability concerns with fetching a user's friends' posts. As a user adds more friends, the load on the system will increase, primarily due to *fan-out*, meaning that one request for posts depends on multiple other requests to different tables [35]. As the system stands, a join between *Friendship*, *User*, and *Post* is required to fetch posts for a user's activity feed. Kleppmann describes how Twitter maintains a cache for each user's timeline, which would translate to the activity feed in the BitPet friend system. This approach is unnecessary at BitPet's current scale and for an MVP. Still, it would be something to keep in mind for a system that may experience load orders greater than expected for the early stages of BitPet.

18.3.2 Read Markers

ReadMarker is a simple model representing whether a given user has read a post. However, deciding when to create a new *ReadMarker* object provided an interesting case. Creating one read marker for every post for every user would make the database bloated with unnecessary data. In this solution, a user has read markers created for every post created by their friends. When a new post is created, a *create_read_mark* method automatically triggers to create that post's read marker for every user who has declared their wish to be friends with the post's creator. When querying for unread posts to enable the notification marker in the UI, only posts from friends return, not those who have not accepted their friend request yet.

18.3.3 Validations

Some additional validations have been necessary to prevent undesired behavior. Users can not add themselves as friends and a given user can only add another user as a friend once. In other words, only one row in the Friendship table can exist in which the same two users occupy the same requester/addressee roles, even if the primary key differs. Therefore, the pair of the *requester_id* and *addressee_id* share some properties with a hypothetical composite primary key. A similar uniqueness constraint is put on the *post_id* and *user_id* pairs in *Reaction* and *ReadMarker*.

18.4 Summary

This chapter has detailed the project's backend development. The server was deployed on an AWS EC2 service with SSH communication. Several new tables had to be added to the database to support the feature concept, and they all have a corresponding model in the Ruby on Rails code: *Post*, *Friendship*, *Log*, *Reaction* and *ReadMarker*. The following chapter details the frontend changes made to the application.

19 Frontend

This chapter describes the changes made to the Unity project and its code. It includes considerations for the UI elements, established architectural and design patterns, and a particular challenge with incremental deserialization. Afterward, specific encountered issues and unimplemented features are presented.

19.1 UI Elements

Since the friend system is only accessible via the pet lobby, mainly one of the many scenes in the game had to be modified. Because several UI elements were already present in the scene, adding a friends icon to the main Heads-Up Display (HUD) was easy. Beyond this, the remaining UI had to be laid out from scratch while creating new pop-up panels. Thankfully, the existing game already contained many assets that fit the feature concept's needs, so it was seldom necessary to design new sprites. Developing a mobile game entails that one must support a vast amount of different screen sizes. Thus, as many dynamic layout options as possible were used through Unity elements, such as horizontal and vertical layout groups, relational positioning, etc. One notable exception concerns the text body of a feed post. Because the full text comprises five game objects with a text component, and it is unclear ahead of runtime if it will be active and how long each text segment will be, using traditional layout groups does not work. Thus, a custom solution had to be made, which calculates each text element's preferred width and the total layout's width based on each game object's preferred width.

The figures 19.1-19.5 show the final UI elements of the friend system in-game. Figure 19.1 is a screenshot of the game lobby where players care for their pets and home base. The HUD has an added friends button in the top right corner that the player can press to open up the friend system. Upon pressing the button, they go to Figure 19.2, where their friends are listed. Each purple rectangle represents a different friend and shows their accumulated pet points and username. Players can add new friends and remove existing ones from this tab. If they press on an existing friend, they go to Figure 19.3. Here, the player cannot interact much but can see their friends' unlocked pets, cosmetics, and pet points. A similar view will show if the player presses the profile tab, except the view will be for their user profile instead. Pressing the feed tab in the top left corner creates a view similar to Figure 19.4. In the feed, different achievements from friends are shown in chronological order. Under each feed entry, there is a button that the player can click on to react to the post. Players can see all the reactions by clicking the smile icon, which opens a window similar to Figure 19.5.

The style differs from the Figma mockups, mainly due to using the existing sprites in Unity. Some features are also missing, which is explained further in Section 19.5.

Figure 19.1: Lobby HUD With Friends Icon.

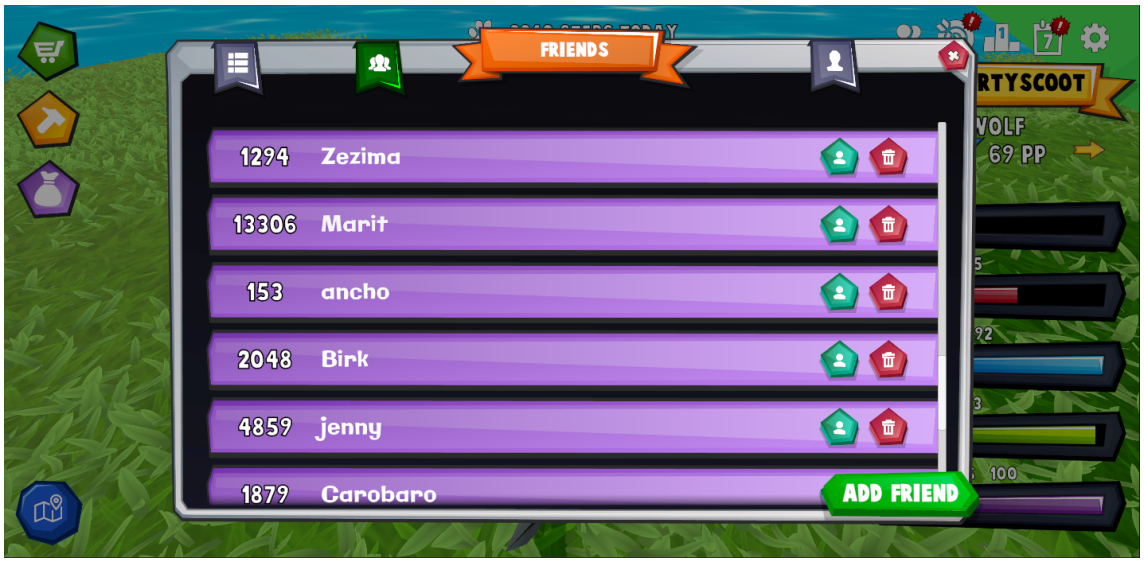

Figure 19.2: Friends Tab.

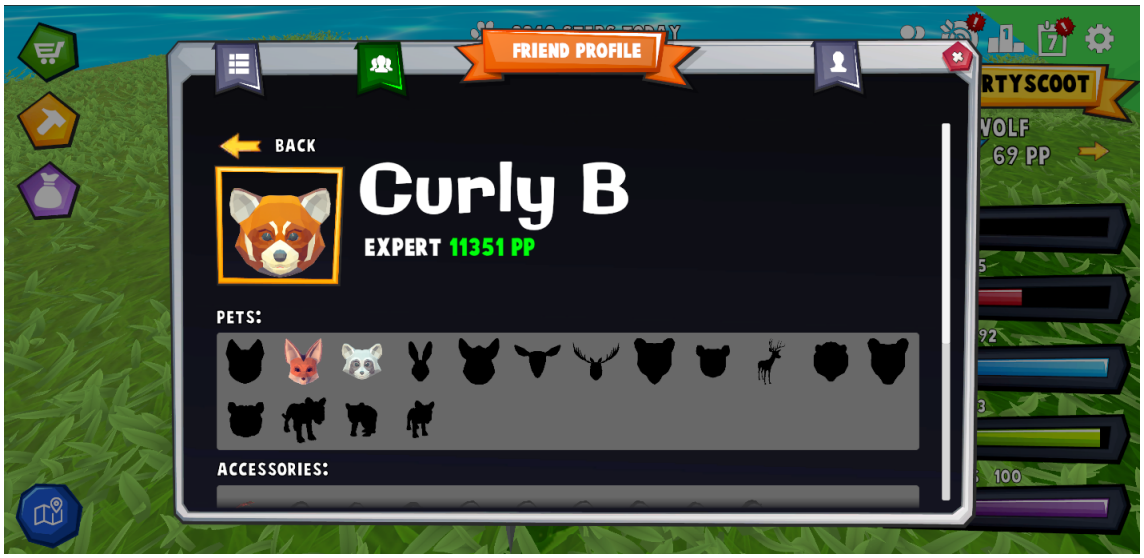

Figure 19.3: Friend Profile.

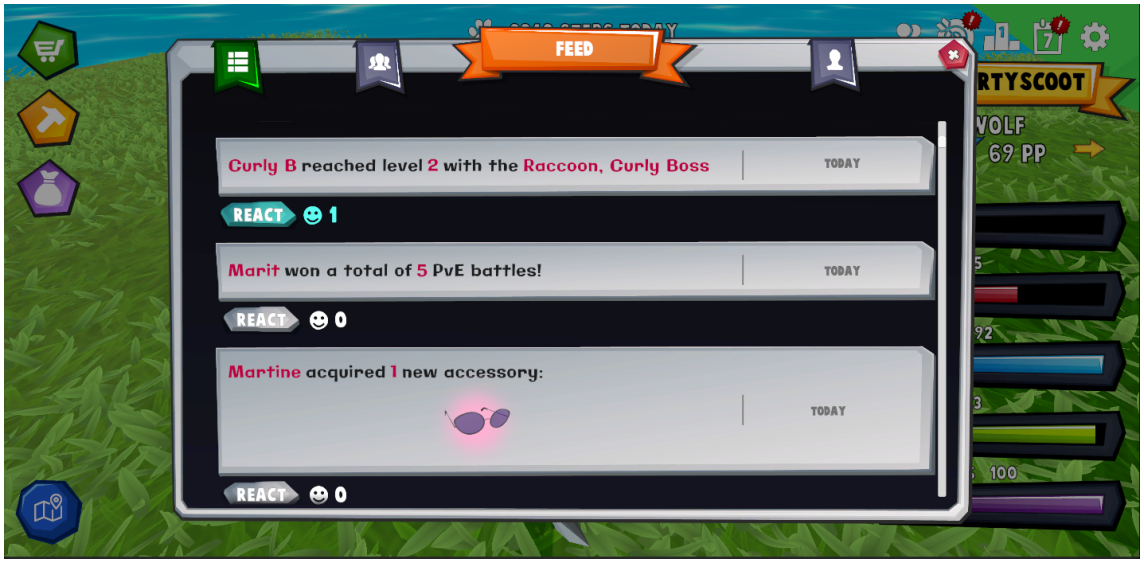

Figure 19.4: Feed Tab.

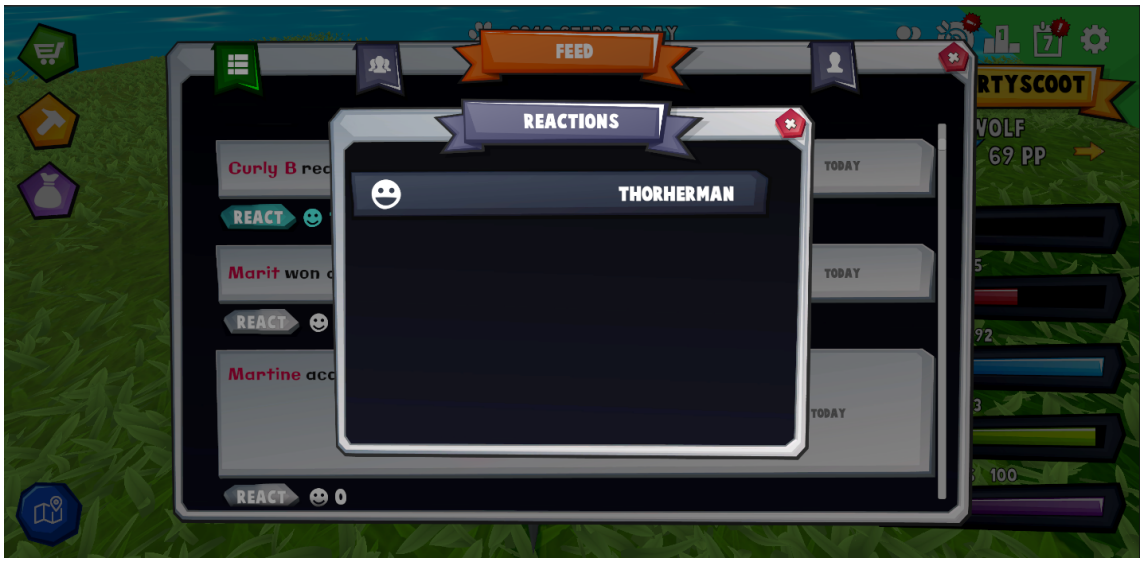

Figure 19.5: Reactions to a Feed Item.

19.2 Established Patterns

In general, the C# code for the concept follows the conventions already employed by the BitPet team. The panels and elements use some variant of a *View* interface. They are instantiated by factories and modified by commands. The views can send signals that can be intercepted by a connected mediator, invoking an appropriate command and calling on other view methods. An example of this is *FriendsView*, which is the base of the main friend panel. Non-singleton views are not instantiated with mediators but rather invoke commands directly. This is in part because the existing solution only utilizes singleton mediators. *FriendsModel* is a singleton class that stores all data related to friends and feed entries. Finally, a separate partial class called *ServerServiceFriends* handles all outgoing calls to the API related to friends and the feed. These are only some of the many classes added to the project, but highlight some of the most important ones.

Using the already established patterns makes extending and basing new solutions on the existing code easier. However, a disadvantage, particularly for prototyping, is that one needs to write more boilerplate code than when focusing plainly on functionality. Some commands only use a few lines of Unity-specific code but are still isolated in separate classes, surrounded by far more lines of boilerplate, and may again call on other similar objects to preserve the patterns.

19.3 Incremental Deserialization

One of the notable employed solutions in the frontend is the deserialization of posts in the feed. When retrieving all posts from the backend, the return value is a single JSON response with an array of different objects. The *type* field of each object determines its content. Thus, one cannot fully deserialize the response before checking the *type* for each post, as different posts have different fields. Hence, in the *GetFeedCommand*, it first deserializes the array of posts into objects with a *type* and *data* field of the types string and object, respectively. Then it performs a switch case on the *type* to determine the class into which it should deserialize. Finally, the objects can all be cast as a common *FeedEntryData* class for further processing.

19.4 Encountered Issues

Extending complicated software like BitPet leads to certain complications that do not exist when starting from an empty project. Specifically, several bugs affecting gameplay were already present

before our modifications. This may be because the frontend and backend branches were created on different dates, and thus the changes may not have been correctly aligned. For instance, certain assets had incorrect names, which caused animals like polar bears to disappear. Furthermore, the tutorial at the beginning of the game would freeze in several stages, and players would have to restart the game to proceed. Other issues included functionality present in the production version of the game that was undesirable in our testing prototype. The problems included playing the game without creating a profile, logging in with providers like Facebook and Google, and checking for new app versions on launch. These all had to be disabled.

Another encountered issue during development was creating a build for iOS devices. As both authors use phones with the Android operating system, testing the feature concept on iPhones was impossible before the evaluation period. Furthermore, creating a build for iPhones requires using a Mac product, which neither of us owns [77]. Thankfully, the other developers of BitPet resolved this, as they could create a build and deploy it on Apple TestFlight.

19.5 Unimplemented Features

While most concepts and designs from the Figma prototype exist in the game's final version, certain features were ultimately excluded. Specifically, the chat functionality between users and comments on posts were two notable examples. These features could foster greater user engagement and elicit more diverse responses to achievements. However, their implementation would have required extensive modifications to the user interface, frontend code, backend code, and database schemas. In particular, integrating the chat feature would have been especially demanding due to the need to use a non-HTTP protocol for real-time communication. Ultimately, due to time constraints imposed by user testing, other features were prioritized.

19.6 Summary

This chapter detailed the changes in the frontend. The UI elements resembled the Figma prototypes but were adapted to use the existing Unity assets. Chats and comments were also dropped in the final prototype due to time constraints. The added code used the same patterns employed by the BitPet team, making it easier to extend in the future. Since the content of feed posts depended on their type, incremental deserialization was also implemented. Some bugs and errors existed before prototype development commenced, causing specific unforeseen issues. Some functionality was also disabled, such as signing up with alternatives other than email and password.

This chapter concludes the development part of this project. The following part presents the experiment and data generation associated with the finished prototype.

Part V

Experiment and Data Generation

This part details the evaluation of the friend system feature concept. It covers the preparation for and execution of an experiment and the collection of data from the experiment's participants through questionnaires, interviews, and game data analysis.

20 Experiment

This chapter describes the preparation for and execution of testing the feature concept. Afterward, some problems encountered before and during the trial are detailed.

20.1 Preparation and Recruitment

The experiment could not commence without approval from the Norwegian Centre for Research Data (NSD), described in further detail under Section 22.1. Recruitment of test subjects started after approval from NSD when the development stage was in its final stages. Although one ideally would test the prototype on its target audience, recruiting from this demographic, i.e., children and teenagers, was challenging. The challenge was partly due to stricter requirements when performing user testing on minors and partly because this demographic is very poorly represented in our social networks. Furthermore, the experiment had no funding or rewards to entice people to play the game outside their own interests. This made finding external test subjects difficult, and thus convenience sampling was utilized. All the recruited test subjects were from our immediate social circles.

One day before the start of the experiment, participants received an introductory email with a consent form, information regarding the length and procedure of the trial, a pre-test questionnaire, an instruction sheet, access to a build of the game, and a unique and private ID which is described further under Section 22.1.

Since BitPet is a feature-rich game and the goal was to evaluate a specific part of it, the test participants needed to perform particular tasks within the game. The instruction sheet, therefore, included a guide with an overview of the friend system user interface (UI) and mandatory tasks. In addition, they were provided with other voluntary actions to give them goals beyond what was strictly necessary. This way, all test subjects would hopefully provide relevant insights and not play the game without trying the friend system.

The instructions included mandatory goals to ensure that the data provided enough useful information. The thresholds for the different goals were somewhat arbitrary but with the intention that the participants would have an understanding of the game. The pet points criterion was later reduced, as explained further in Appendix C.

The criteria were as follows:

- Create a user profile and log in with it
- Finish the tutorial
- Add the following users as friends:
  - Magnus
  - ThorHerman
  - AlfInge
- Check out the friend feed after having successfully added some friends
- Beat another pet
- Purchase a new pet in the store
- Walk more than 5,000 steps with one of your pets in one day
- Earn 4,000 pet points

The instruction sheet also included some voluntary goals for the test subjects to pursue if they completed all the necessary goals

- Add other test participants as friends
- Purchase a new pet accessory
- Level up one of your pets to level 5
- Beat 10 pets in battle
- Finish the testing period with more pet points than Magnus and ThorHerman

A complete overview of the instruction sheet exists in Appendix D.

20.2 Testing Procedure

The experiment was conducted over ten days, from Wednesday, April 26 to Saturday, May 6, with 31 participants. They received access to a modified build of BitPet containing the final prototype. Android testers downloaded the application through a distributed Android Package (APK) file, while iOS testers could download it via TestFlight. Due to previously mentioned issues with building for iOS devices, the TestFlight version was available on Thursday 27th, giving the Android users a head start. Optimally, the prototype needed to be free of bugs that would break the game, as updating the game after installation would be a hassle for the participants. To ensure that the testers would fulfill the necessary goals, a reminder email was sent out on May 2.

Upon completion of the testing period, all testers received a second questionnaire. After some rudimentary analysis of the questionnaires and game data, some testers were then invited to interviews.

20.3 Weather during Testing

As the game encourages spending time outside, we considered it relevant to record the weather data. Yr.no provides meteorological data for all Norwegian cities, including Trondheim, where most of the testing was to occur. Table 2 shows Yr.no's recorded weather for each day of the testing period, with temperature and precipitation values [99] [100]. The precipitation is measured at 07:00 each day. Note that temperature data was unavailable for May 6 after 21:00, which may skew the average temperature or exclude the actual maximum or minimum temperature for that day only.

Table 2: Trondheim Weather During Testing.

Date	Minimum Temperature	Maximum Temperature	Average Temperature	Precipitation
2023-04-26	-2.0°C	4.2°C	0.9°C	7.9 mm
2023-04-27	0.5°C	2.3°C	1.4°C	4.4 mm
2023-04-28	0.6°C	7.1°C	2.0°C	9.8 mm
2023-04-29	-3.6°C	4.4°C	0.3°C	0.0 mm
2023-04-30	-0.2°C	3.6°C	1.0°C	9.6 mm
2023-05-01	0.4°C	5.3°C	2.0°C	14.2 mm
2023-05-02	0.3°C	7.0°C	3.2°C	2.3 mm
2023-05-03	-0.3°C	4.6°C	1.9°C	4.1 mm
2023-05-04	-2.7°C	5.6°C	1.8°C	2.8 mm
2023-05-05	-3.3°C	9.8°C	3.7°C	0.0 mm
2023-05-06	-1.3°C*	10.7°C*	5.6°C*	0.0 mm

20.4 Encountered Problems

Despite testing during the development stage, it was inevitable that BitPet, a complex application, would encounter bugs and issues. These problems arose due to pre-existing errors and modifications made to the application. Certain outdated phones could not install the application or its Android augmented reality (AR) dependency, ARCore, preventing test subjects from performing pet battles and making it impossible to progress correctly.

Most problems encountered during the testing phase did not completely ruin the game. However, they still affected the possibilities for the participants' progression. For example, all pets could be purchased and used, but they did not all spawn on the map for the player to beat. Additionally, pet stats such as hunger and happiness would decrease in minuscule increments, making it significantly easier to look after pets and less critical to gather food. Finally, the lure functionality to bring animals closer to oneself was broken in the prototype's version and could be used repeatedly without cooldown. The broken lure meant that participants did not have to walk to the locations of the animals physically but could always attract them to their area instead.

Some problems were fixed during the testing period because they existed exclusively on the server. *PveWonPost* had the wrong name in the fight controller, meaning the post generation for Player versus Environment battles (PvEs) won milestones did not work until this was fixed two days after the testing period began. Text indexing for posts was also not working correctly during this period, meaning all posts were rendered with the same wording in the first two days. The triggers for *LevelUpPost* and *PetPointsPost* were not always called. The logic for triggering these posts was kept in the controllers to keep complete control over the post creation. For *LevelUpPost*, it became apparent early in the testing period that pets were leveling up through different endpoints than expected. The logic was therefore moved to the model level. *PetPointsPost* had the same issue, but it was discovered too late in the testing period to be fixed. In retrospect, this logic should have all been in the model layer; it would, however, have required greater inspection and knowledge of the possible events that might have triggered it. One final issue was that the users' *pet_points* and *earned_pet_points* diverged in the database while playing. Which of these values was used for posts and user profiles was inconsistent, and was not fixed until seven days into the testing period. None of these issues were breaking for the testers, but their presence meant that

not all features were entirely tested for the full ten days.

20.5 Summary

This chapter described the experiment process. Participants were recruited from our close circles and given instructions along with questionnaires. The experiment lasted ten days, with iOS users starting one day later than Android users. The lowest average temperature during the test period was 0.9 degrees Celsius, while the highest was 3.7. Some technical difficulties occurred during the test, such as phones not supporting AR, pet stats diminishing too slowly, and lure being broken. Some were fixed while the experiment was ongoing, while others were not easily addressable. The next chapter details the methods used to generate quantitative and qualitative data from the experiment.

21 Data Generation Methods

This chapter describes the different ways data was generated during the experiment. Additionally, it describes how the data was analyzed.

21.1 Pre-Test Questionnaire

The pre-test questionnaire aimed to record information about the testers relevant to answering the research questions (RQs). It was divided into eight sections, each covering pertinent information to extract from our test subjects. The questions were in four formats: multiple choice, multiple answers (MCMA); multiple choice, single answer (MCSA); text; and Likert scale.

For the experiment to comply with privacy concerns, the test subjects had to consent to their participation and storage of their data (see Table 3). A short notice also supplemented the questions informing the test subjects that the questions referred to the information they received in the questionnaire email. The questionnaire's response alternatives are simplified in this chapter but can be found in full in Appendix E.

Table 3: Questions Regarding Consent.

Question	**Format**	**Alternatives**
I have received and understood the research project "BitPet" and I have been able to ask questions. I consent to the following (can select multiple):	MCMA	• Participating in questionnaires and user testing • Participating in interviews
I consent to results from this questionnaire being stored and used until the project ends.	MCSA	• Yes • No
I consent to my BitPet-username being shared with other participants of this project	MCSA	• Yes • No

As seen in Table 4, participants were asked what operating system they tested BitPet on. This question proved unnecessary, as they simultaneously received information for iOS and Android.

Table 4: Question Regarding Testing Platform.

Question	**Format**	**Alternatives**
Which platform will you be testing BitPet on?	MCSA	• Android • iOS

Table 5 shows the basic demographic questions. Each subject had to input their ID, as described in Section 22.1. They were also asked about age and gender to allow for comparison with existing scientific material and to uncover trends based on these two variables.

Table 5: Questions Regarding Demography (Pre-Test).

Question	**Format**	**Alternatives**
Enter the userID that was provided with the mail	Text	Open
What is your gender?	MCSA	• Woman • Man • Other • Prefer not to say
What is your age?	MCSA	Range from Under 18 to 45-54

The subjects also answered questions about their video game habits, as evident in Table 6.

Table 6: Questions Regarding Video Game Experience.

Question	**Format**	**Alternatives**
How often do you play video games alone?	MCSA	Range from Never to Daily
How often do you play video games with friends?	MCSA	Range from Never to Daily
What types of platforms do you play video games on?	MCMA	• None • PC • Game consoles (PlayStation, Xbox, Nintendo etc.) • Phone (Android, iOS, etc.) • Other (please specify)

A question about the participant's phone screen time recorded the tester's phone usage habits (see Table 7).

Table 7: Question Regarding Phone Usage.

Question	**Format**	**Alternatives**
What was your average phone screen time last week? Give an estimate if your phone does not have access to that information	MCSA	Range from 0-1 hours to 6+ hours

Testers also answered questions about their walking habits (see Table 8).

Table 8: Questions Regarding Physical Activity.

Question	**Format**	**Alternatives**
How often do you go for walks in your spare time?	MCSA	Range from Never to Daily
When you go for walks, do you prefer walking alone or with others?	MCSA	• Alone • With others

The testers were presented with a series of assertions (see Table 9) about their social life, to which they had to respond with how much they felt the claim fit them. They had three possible answers for each assertion: disagree, neutral, and agree.

Table 9: Questions Regarding Socialization.

Question	**Format**	**Alternatives**
I am comfortable in the presence of people I know	Likert	Range from Disagree to Agree
I am comfortable in the presence of people I don't know	Likert	Range from Disagree to Agree
I prefer being social over being alone	Likert	Range from Disagree to Agree
I wish to meet new people	Likert	Range from Disagree to Agree
I like to keep up with my friends' activities on social media	Likert	Range from Disagree to Agree
I regularly interact with my friends online	Likert	Range from Disagree to Agree

The last question in the questionnaire (see Table 10) recorded any feedback the testers may have had.

Table 10: Question Regarding Other Feedback (Pre-Test).

Question	**Format**	**Alternatives**
Do you want to add additional feedback to this survey? If so, please leave it below	Text	Open

21.2 Post-Test Questionnaire

Test subjects received the post-test questionnaire the day after the testing period ended. It aimed to record their experience playing BitPet and using the friend system. It was divided into five sections covering a different category of information we wanted to extract from our test subjects. The questions were in four formats: multiple choice, multiple answers (MCMA); multiple choice, single answer (MCSA); text; and Likert scale.

As with the pre-test questionnaire, the users had to input their unique ID. They also had to supply their phone model number for potential error seeking (see Table 11). The questionnaire response alternatives are simplified when presented in this chapter but can be found in full in Appendix F.

Table 11: Questions Regarding Demography (Post-Test).

Question	**Format**	**Alternatives**
Please enter your UserID that was provided with the mail	Text	Open
What device did you test the application on? Specify phone model	Text	Open

The test subjects were queried about their general playing habits and how these habits affected their physical and social activity, as shown in Table 12.

Table 12: Questions Regarding Usage.

Question	**Format**	**Alternatives**
How often did you play BitPet throughout the test period?	MCSA	Range from Never to Several times a day
When did you play BitPet?	MCMA	• While walking to a destination • While indoors • While taking a walk in my free-time • Other
I went on more walks than normal while testing BitPet	Likert	Range from Fully Disagree to Fully Agree
I went on walks with the sole purpose of playing BitPet	MCSA	• Yes • No
Was there anything hindering you from achieving the required goals?	Text	Open
Did you play BitPet with friends in-person?	Text	Open

Regarding the friend system, the test subjects were asked some questions and a series of assertions to which they were to provide their level of agreement, as shown in Table 13.

Table 13: Questions Regarding Friend System.

Question	**Format**	**Alternatives**
Did you try out the friend system while playing BitPet?	Text	• Yes • No
Please specify why	Text	Open
Did you add other players in BitPet? Beyond Magnus and ThorHerman	Text	Open
I regularly checked the friend activity feed	Likert	Range from Fully Disagree to Fully Agree
It was easy to navigate the friend system user interface	Likert	Range from Fully Disagree to Fully Agree
The friend system made me want to regularly return to BitPet	Likert	Range from Fully Disagree to Fully Agree

There was an appropriate amount of activity in the friend feed	Likert	Range from Fully Disagree to Fully Agree
I felt motivated by the fact that some of my in-game actions were shared in my friends' feeds	Likert	Range from Fully Disagree to Fully Agree
The level of activity made me want to play more	Likert	Range from Fully Disagree to Fully Agree
I regularly checked my friends' profiles	Likert	Range from Fully Disagree to Fully Agree
Being able to compare myself to friends made me want to play more	Likert	Range from Fully Disagree to Fully Agree
I frequently checked out who had reacted to my post	Likert	Range from Fully Disagree to Fully Agree
I frequently reacted to my friends' posts	Likert	Range from Fully Disagree to Fully Agree
I was motivated by seeing who had reacted to my post	Likert	Range from Fully Disagree to Fully Agree
I deliberately avoided playing BitPet when it was raining or snowing	Likert	Range from Fully Disagree to Fully Agree. Also includes Not Applicable
Do you have any improvement suggestions or other feedback regarding the friend system?	Text	Open

The test subjects were asked about experiences with bugs or errors while testing (see Table 14), as it could help uncover faulty data or explain questions about the game data that may have arisen.

Table 14: Questions Regarding Errors.

Question	**Format**	**Alternatives**
Did you encounter any errors or bugs while testing the game? If so, please elaborate below.	Text	Open
Did any of these errors or bugs prohibit you from completing the testing requirements?	Text	Open

Finally, the test subjects could provide not explicitly requested feedback, as seen in Table 15.

Table 15: Question regarding Other Feedback (Post-Test).

Question	**Format**	**Alternatives**
Do you want to add additional feedback? If so, please leave it below	Text	Open

21.3 Game Data

Logging was utilized to collect quantitative data on the usage of the application and the friend system in particular. Logs were sent through application programming interface (API) calls from the frontend to the backend when participants pressed certain elements. These interactions included opening the friends-UI and switching tabs there. Recording logins was also deemed useful. The four log types were the following:

- Login
- Open friend system
- Click feed tab
- Click profile tab
  - Contains flag for whether the profile check is for a friend or the user itself

The application posted a new log every time the test subject loaded the lobby scene. However, in retrospect, this was a mistake as the application sent a new login entry every time the participant switched to, e.g., the map or store and back. Thus, participants could send many login logs within one session of play. Still, it somewhat indicated total app usage. Other quantitative data was already being stored in the database as part of the gameplay and was retrievable through queries. For example, by querying the database, one could determine the number of reactions each participant had given to a post or the number of pet points they had accumulated.

21.4 Interviews

In the week following the culmination of the testing period, after the post-test questionnaire answers had been collected, five test subjects were summoned for interviews: subjects 8, 13, 20, 27, and 28. They had previously consented to be interviewed. The interviewees were chosen primarily based on their game data; test subjects were picked based on who had played enough to reach a certain understanding threshold of the game but who had different player profiles. We strived to recruit interviewees with varying gameplay profiles.

Five interviews were held over two days. The interviews took about 30 minutes each and were held eight to nine days after the final day of testing. As interviewers, we followed an interview guide to lead us through the main questions the interviews had to cover. Audio from the interview was recorded with the interviewees' permission and transcribed using a combination of Whisper from OpenAI and manual transcription after the fact [53].

The interviews were held in a semi-structured manner. This structure allowed for the interviews to cover all the necessary topics but also allowed the interviewees to express their individual opinions and experiences [51]. We expected that the answers could vary a lot, making it important to hold an interview that could veer off script to let the subjects elaborate on points they brought up. The fact that the interview audio was recorded presented some challenges; the interviewees could be nervous about being recorded, inhibiting them when responding, and it would not allow us to review body language, eye contact, or other non-verbal communication. The fact that all test subjects, including the interviewees, were recruited from our networks is also a point of consideration. Being interviewed by friends may change the interviewees' behavior. While it may make the interviewees more comfortable in the interview setting, it can also inhibit their ability to answer completely honestly. Thus, the interview context was made as equal for all interviewees as possible.

All interviews were held in private rooms. As interviewers, we were seated on one side of a table while the interviewee was placed directly across. We took on the same roles each time: one introduced the context and practical details of the interview, while the other led the discussion. Both of us asked follow-up questions when we felt it appropriate.

Each interview started according to the interview guide with some points of practical information:

- Thank you for participating in this interview.
- The purpose of the interview is to elaborate on the questions from the post-test and our analysis of your game data and to reach an understanding of your experience with the game.
- We would like to stress that we are looking for your completely honest opinion.
- The details of this interview will be deleted upon project end and will not be traceable back to you. If you wish to withdraw your consent and have your data removed at any point during the project, please inform us with the email given to you in the first information email.
- If it is alright with you, we would like to record the interview. The recording will be deleted afterward.
- The interview should take no longer than 30 minutes.

The interview would then take on a more fluid form. Questions were asked according to a pre-defined pool of questions. We made sure to cover each question, although the order could vary from interview to interview. Depending on the interviewees' answers, we were sometimes prompted to ask follow-up questions not covered by the pre-made interview guide.

- Do you feel that you have an understanding of the game and its mechanics now?
  - What is still unclear?
- What motivated you to keep playing the game?
- How did you interact with the friend system?
- Is there anything you would change/add to the friend system?
  - UI
  - How do you think this addition/change would have affected the way people play the game?
- Did you feel that the updates in the activity feed were relevant?
  - Are there any other types of updates you think should be added?
- Are there any other features you felt were missing in the current implementation of BitPet?
- Are there any features in the game that you disliked?

Some questions were asked differently depending on the interviewees' answers to the questionnaires.

- *If the subject had experienced any bugs*
  - Did the bugs significantly alter your game experience?
- *If the subject had added friends*
  - Would you have played the game less/differently if you had not been playing with your friends?
- *If the subject had not added friends*
  - Would you have played the game more/differently if you had been playing with your friends?
- *If the subject plays games (other than BitPet) with friends*
  - Do you prefer playing with friends in-person or over the internet?

  - How do you usually use friend systems in the games you play?

- *If the subject plays games (other than BitPet), but does not usually play with friends*
  - Why do you usually play games alone?

- *If the subject plays games (other than BitPet)*
  - What games do you usually play in your spare time?

21.5 Data Analysis

After generating all the data above, it had to be processed and analyzed. This was achieved with two different tools, Microsoft Excel and Python. Generally, Excel was used to filter questionnaire answers, compute average values, and create various graphs in Part VI. More complex data processing was achieved with Python, using a selection of third-party packages. *Psycopg2* enabled SQL queries via Python, which, coupled with a local copy of the primary database, allowed us to analyze the game data. The participants' game data could then be correlated with their corresponding questionnaire answers using the *pandas* package, which among other things, simplifies comma-separated-value (CSV) file processing. Finally, the *matplotlib* package allowed data plotting along date axes.

21.6 Summary

Several data generation methods were utilized to evaluate the game concept. The questionnaires were distributed before and after the testing period, data concerning the test subjects' in-game actions and behavior were stored, and interviews were conducted with a subset of the test subjects. The data were analyzed in Microsoft Excel and Python by filtering questionnaire answers, computing relevant values, and drawing graphs. The next chapter will outline how the integrity of the data was potentially affected.

22 Experiment and Data Generation Integrity

This chapter describes how the integrity of the experiment data might have been affected.

22.1 Ethics and Privacy Concerns

The introductory email mentioned in Section 20.1 contained a request and consent form approved by NSD. No data from a test subject would be used without their explicit approval by signature. The form contained general information about the project, the people responsible, and specific information about the treatment of the test subjects' data and their rights as test subjects. The full form can be found in Appendix G.

Strong precautions and a strict data treatment regime ensured proper treatment of the test subjects' data, preserving their privacy. When registering for the experiment, names and email addresses were stored securely in Microsoft SharePoint cloud storage behind two-factor authentication. Nowhere else was this data stored; each test subject instead had an ID that identified them throughout the test project. The mapping between the IDs and any identifiable information was exclusively stored in the Microsoft SharePoint cloud storage, rendering the game data, questionnaire, responses, and interview data unable to be tracked back to the test subjects upon deletion of the names and email addresses.

The interview audios were similarly stored in Microsoft SharePoint cloud storage and deleted after the completion of the project, per the terms agreed with the interviewees at the beginning of each interview.

22.2 Reliability and Validity

Multiple psychological phenomena might affect the data generation of an experiment and thereby threaten the validity of the research. This section covers some that are particularly relevant to this project and the methods of data generation used.

22.2.1 Hawthorne Effect

The Hawthorne effect is a psychological phenomenon that describes how participants in a research project might have their behavior affected by the knowledge that they are participating in said research project [4]. Therefore, this effect might be observed in any data generation where the research subject knows they are part of a study, such as observation, interviews, questionnaires, and documents. These data generation methods were used in this project, making the data susceptible to the Hawthorne effect.

22.2.2 Rosenthal Effect

When researchers communicate with research subjects, their expectations about the project's findings might unwittingly influence the behavior of the research subjects. This effect is called the Rosenthal effect or experimenter expectancy effect and is an effect that can easily affect projects like this one [3]. As research conductors, we have communicated with the test subjects during interviews and other official communication, but also outside of a research context, as most of the test subjects, in this case, were our acquaintances. In both these modes of communication, it is possible that we, as researchers, have inadvertently affected the test subjects' behavior.

22.2.3 Courtesy Bias

Courtesy bias refers to the tendency of research participants to avoid reporting their unhappiness or displeasure when testing a service or a product [1]. There is good reason to assume that this bias might affect the research participants in this project, as they were testing a product. The effect might be especially potent as the test subjects were mostly acquaintances of the research conductors. The interviewees were familiarized with potential bias at the beginning of each interview and urged to respond honestly. However, it may have affected the interviews or the other modes of data generation.

22.3 Summary

A strict data treatment procedure was followed to protect the test subjects' personal information and stay in line with demands from NSD. The nature of the experiment exposed it to challenges relating to the its validity, as experimenter effects or response biases such as the Hawthorne effect, the Rosenthal effect, or courtesy bias might have affected the results from the interviews, questionnaires, and documents gathered through data generation. The next part presents the results from the data generation.

Part VI

Results

This part presents the results accumulated throughout and after the test period. They have been collected using questionnaires, interviews, and game data.

Some graphs and results have been left out of this part due to less relevance and can instead be found in Appendix C.

23 Demographics

This chapter presents the demographics of the respondents to the questionnaires. Both basic and behavioral demographic results are included. All results in this chapter originate from the pre-test questionnaire and the interviews.

23.1 Selection

In total, 31 participants participated in the experiment. However, the final results showed that eleven participants either barely or did not play the game past the initial tutorial, as evident by their total pet points and battles. Two of these participants never logged in to the application. Thus, their data has been discarded and left out of the proceeding results (unless otherwise specified), leaving 20 participants.

23.2 Age and Gender

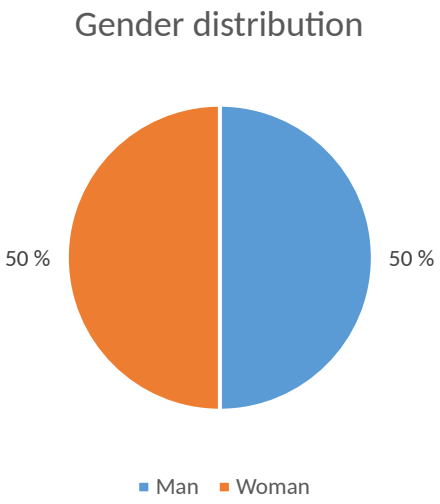

Figure 23.1: Gender Distribution.

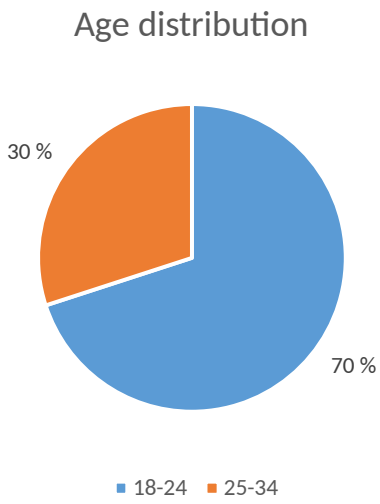

Figure 23.2: Age Distribution.

As Figure 23.1 shows, there was an even gender distribution among the participants. Figure 23.2 shows the age distribution, where a large majority were in the group 18-24 years old.

23.3 Phone OS and Usage

As evident from Figure 23.3, a majority (70%) of the participants were testing on the iOS operating system. The average screen usage for the week before the test period (see Figure 23.4) varied somewhat, but almost half of the participants averaged 4-5 hours daily.

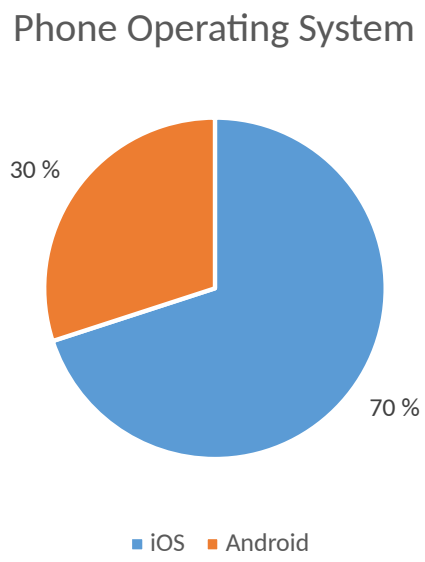

Figure 23.3: Phone OS Distribution.

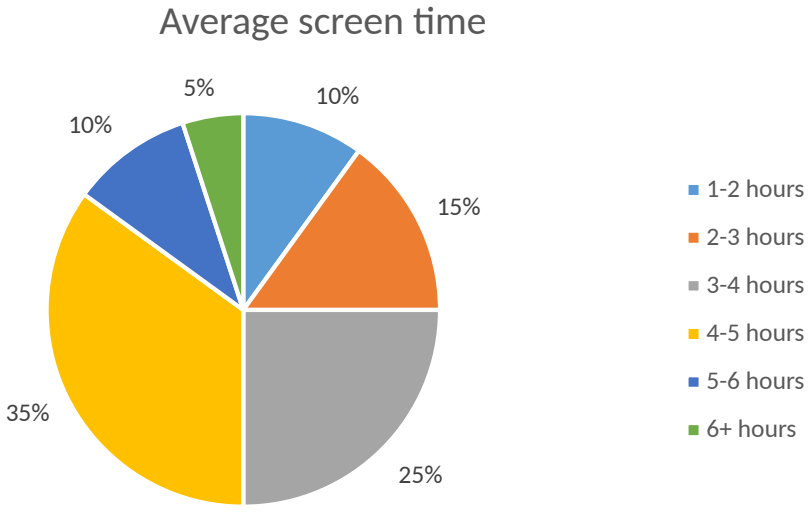

Figure 23.4: Average Screen Time.

23.4 Gaming Habits

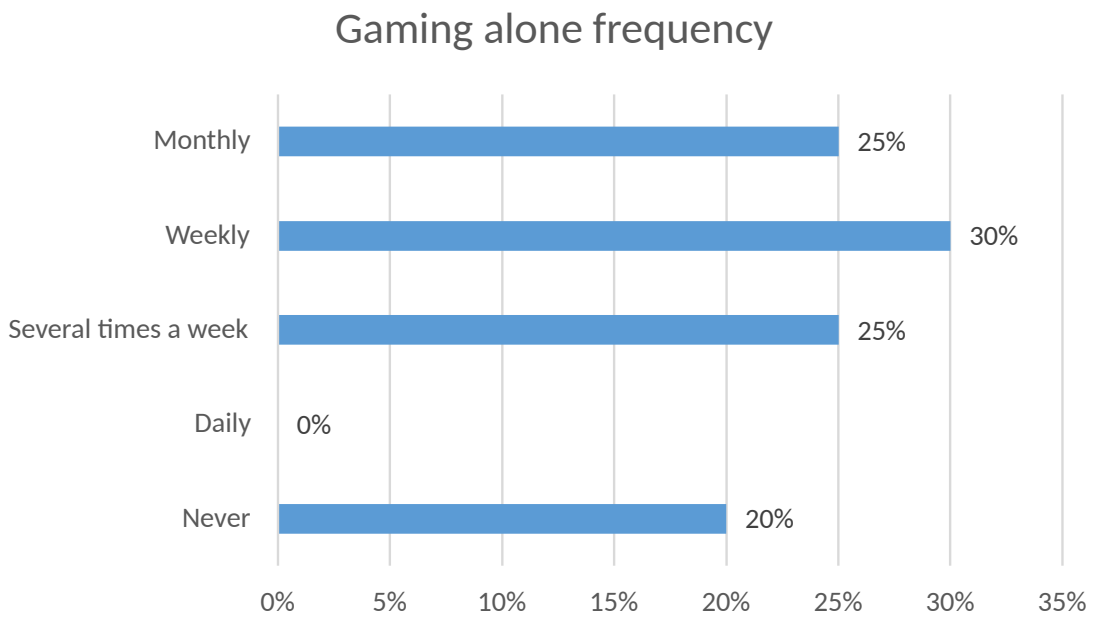

Figure 23.5: How Often Participants Played Games Alone.

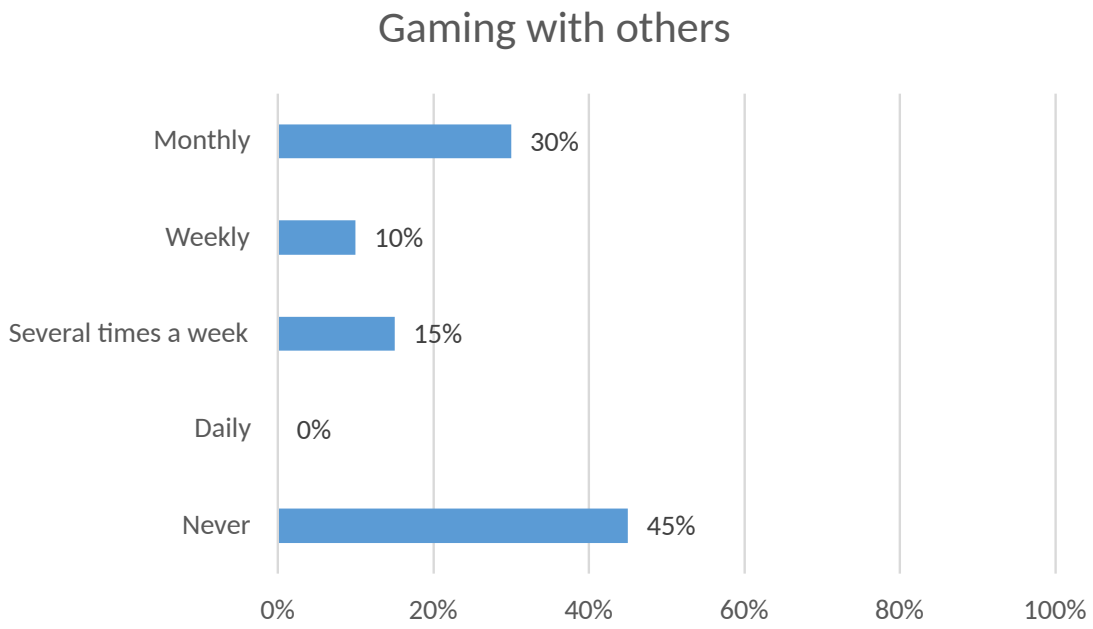

Figure 23.6: How Often Participants Played Games With Others.

Figures 23.5 and 23.6 present the participants' reported gaming habits. The graphs show that participants played games alone more frequently than with others. No test subjects reported playing games daily, and it was most common to play games weekly or monthly.

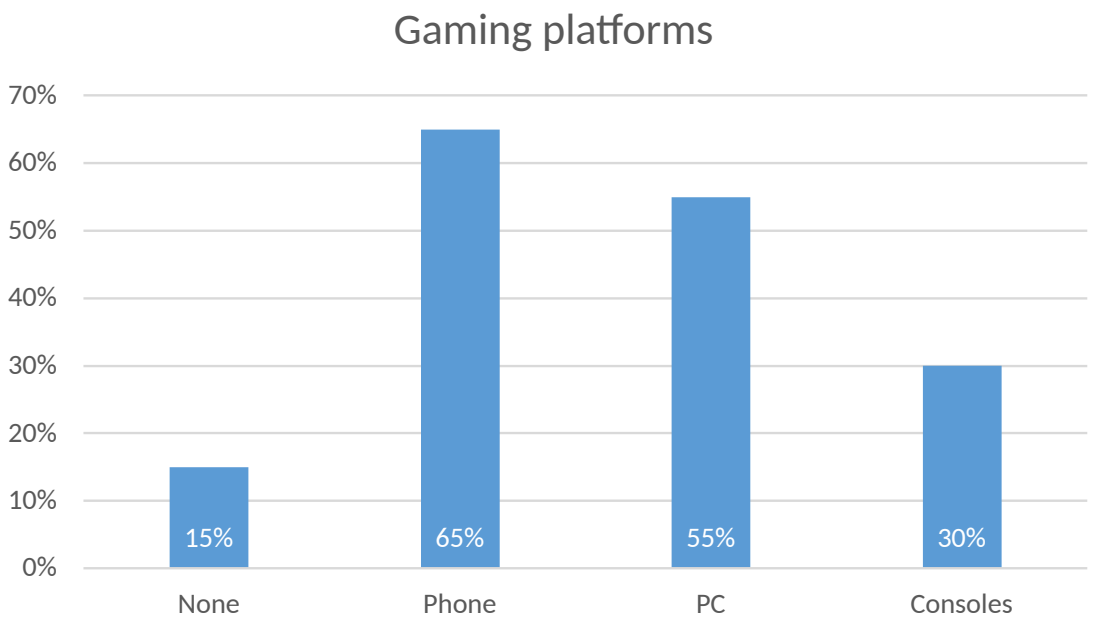

Figure 23.7: Gaming Platforms Used.

Figure 23.7 shows which platforms the participants usually played games on. Most test subjects played games on their phones and PCs. When asked what games they usually played, the interviewees responded with various games. However, one common denominator was that they all primarily played single-player mobile games. No one mentioned any online multiplayer games, but all but test subject 13 played local multiplayer games such as Mario Kart, Piko Park, or Minecraft through LAN.

23.5 Physical Activity

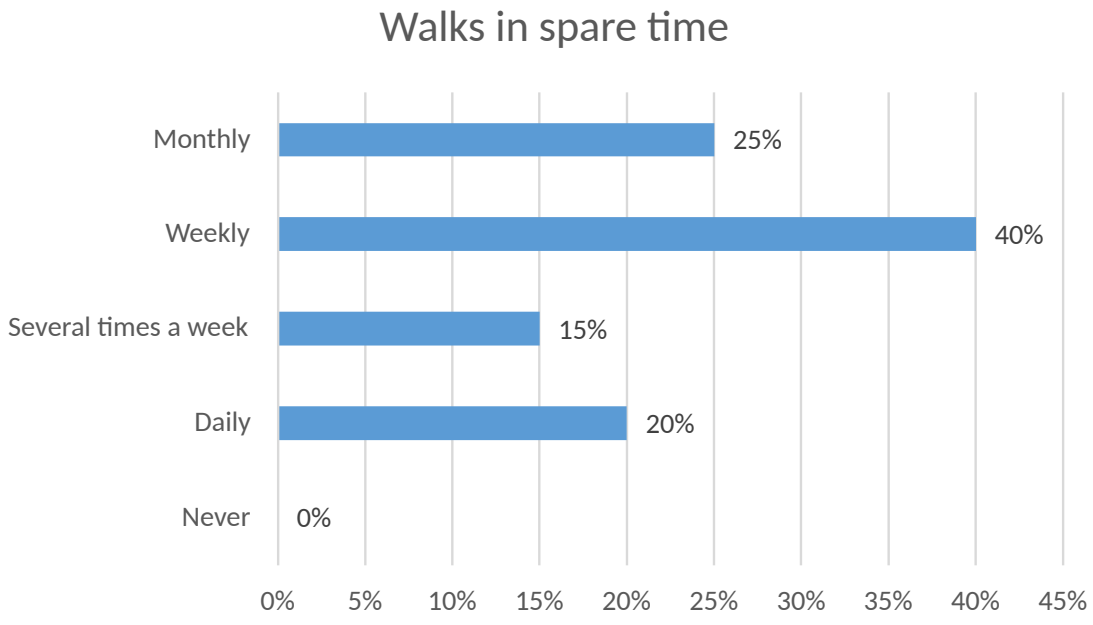

Figure 23.8: Frequency of Walking in Spare Time.

Figure 23.8 shows that all participants reported walking in their spare time, though with varying frequency. Fifteen respondents walked weekly or more often, while the remaining five did it at least monthly.

23.6 Social Interaction

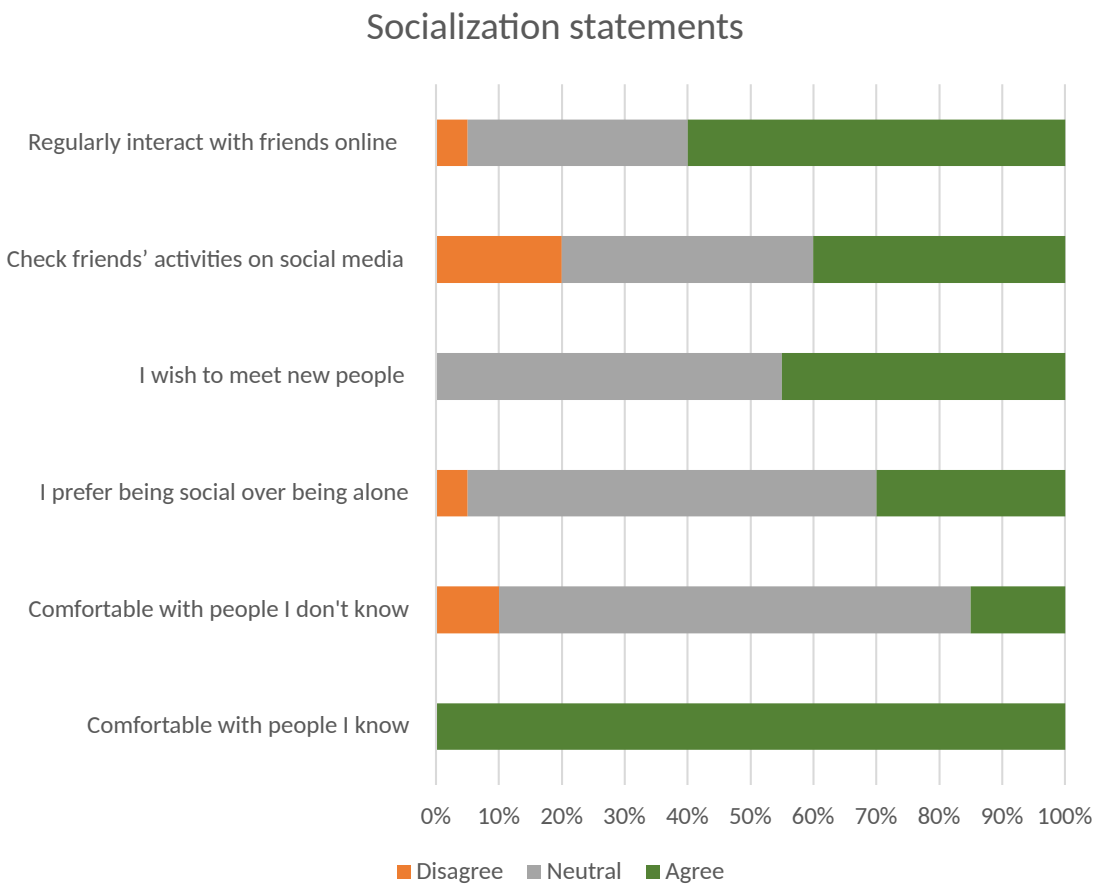

Figure 23.9: Results From Socialization Statements.

Figure 23.9 shows the responses to the social behavior questions from the first questionnaire. All participants agreed to being comfortable in the presence of people they already knew, and most were neutral about being comfortable in the presence of unknown people. Most respondents were either neutral or agreed with preferring socialization and meeting new people, and over half also agreed to regularly interacting with their friends online.

23.7 Summary

This chapter illustrated the demographic results of the experiment. Ten males and ten females participated, all within the age range of 18-34. Most participants had an iOS device and played games weekly or less frequently, alone and with others. The primary gaming platforms were phones, followed by PC. All test subjects walked in their spare time, though with varying frequency. Finally, the participants trended more toward social behavior. The next chapter presents how they interacted with the application.

24 General Usage

This chapter presents results about the general usage of the BitPet application, not constrained to the friend system.

24.1 Questionnaires

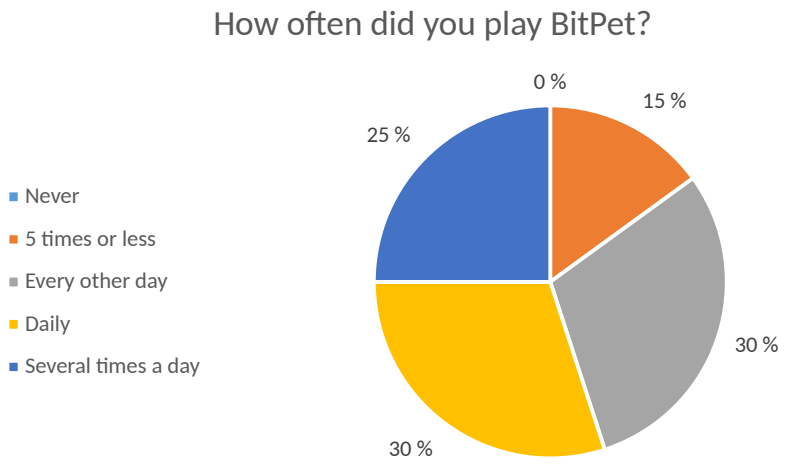

Figure 24.1: Play Frequency Among the Participants.

Figure 24.1 shows that over half of the respondents reported playing BitPet daily or several times daily. Since participants that did not play the game were struck from the data set, no one reported never playing BitPet.

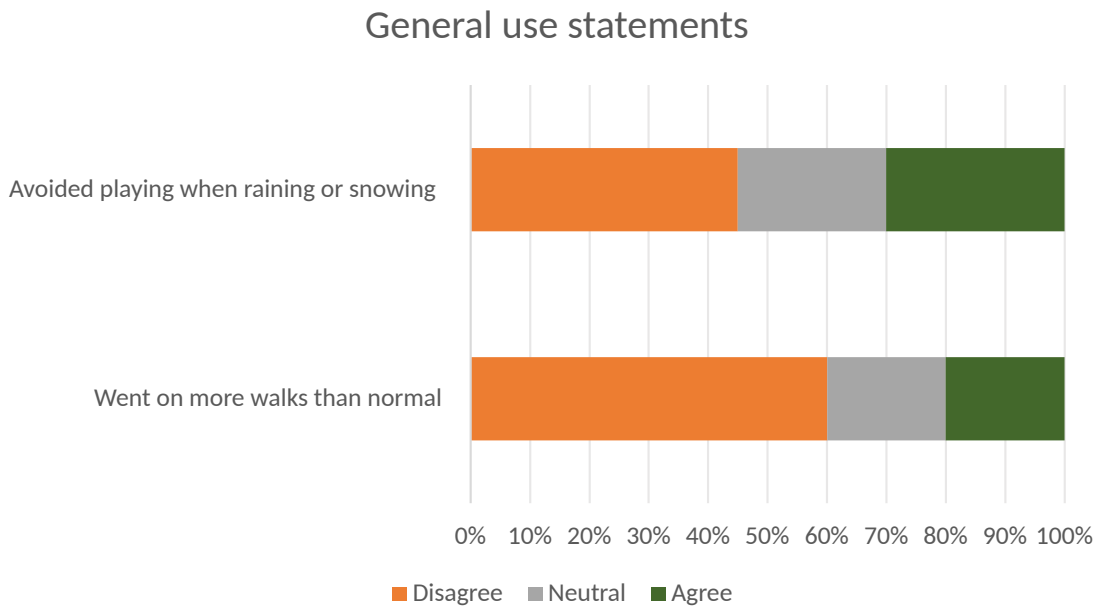

Figure 24.2: Answers to Statements on General Usage of the Application.

Participants disagreed on whether they avoided playing BitPet due to bad weather conditions.

Figure 24.2 depicts that most test subjects disagreed or were neutral when asked if they went on more walks than usual, though 20% somewhat agreed.

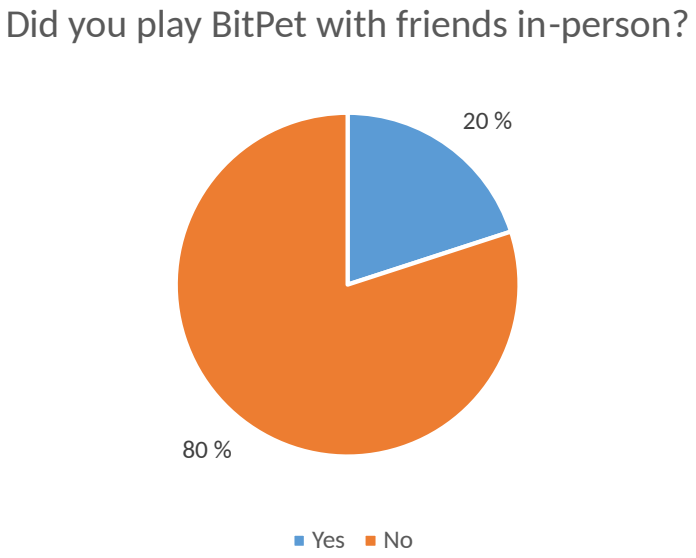

Figure 24.3: Playing Bitpet With Other Friends In-Person.

Most players did not play with other friends in person, as shown in Figure 24.3, though four participants (20%) did.

Figure 24.4 shows the answers to the statements regarding when players played BitPet. The most common scenario was when walking to a destination, though many players played indoors.

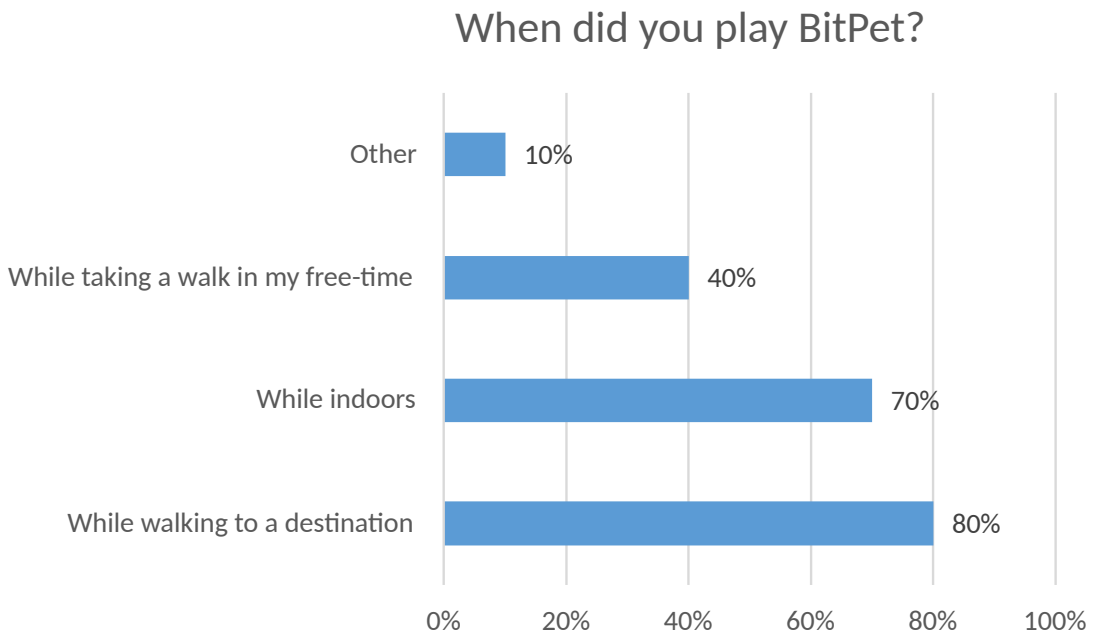

Figure 24.4: At What Occasions Participants Played the Game.

24.1.1 Quotes

The post-test questionnaire also had optional open-ended questions that allowed test subjects to add additional information on their experiences. A selection of them follows:

> "*Fun and interactive game! And good graphics*"

> "*I think the game would have been easier to play if it was not in landscape. You have to play with two hands which makes it difficult to play if you are walking your dog or holding something.*"

> "*it wasn't straightforward how to earn (so many) pet points in the beginning. It helped when I learned that you achieve a greater amount of points each time you mark a new territory in a coherent chain of territories.*"

> "*I got demotivated so you should have made some incentive to finish the goals:(*"

> "*Did not quite understand the game*"

> "*The requirement to play with AR strongly deterred me from playing in public. The option to play without AR should be considered*"

24.2 Game Data

The following two graphs (see Figure 24.5 and Figure 24.6) are based on the data present in the database after the final testing day. They show the number of pet points each participant amassed and how many pet battles they attempted.

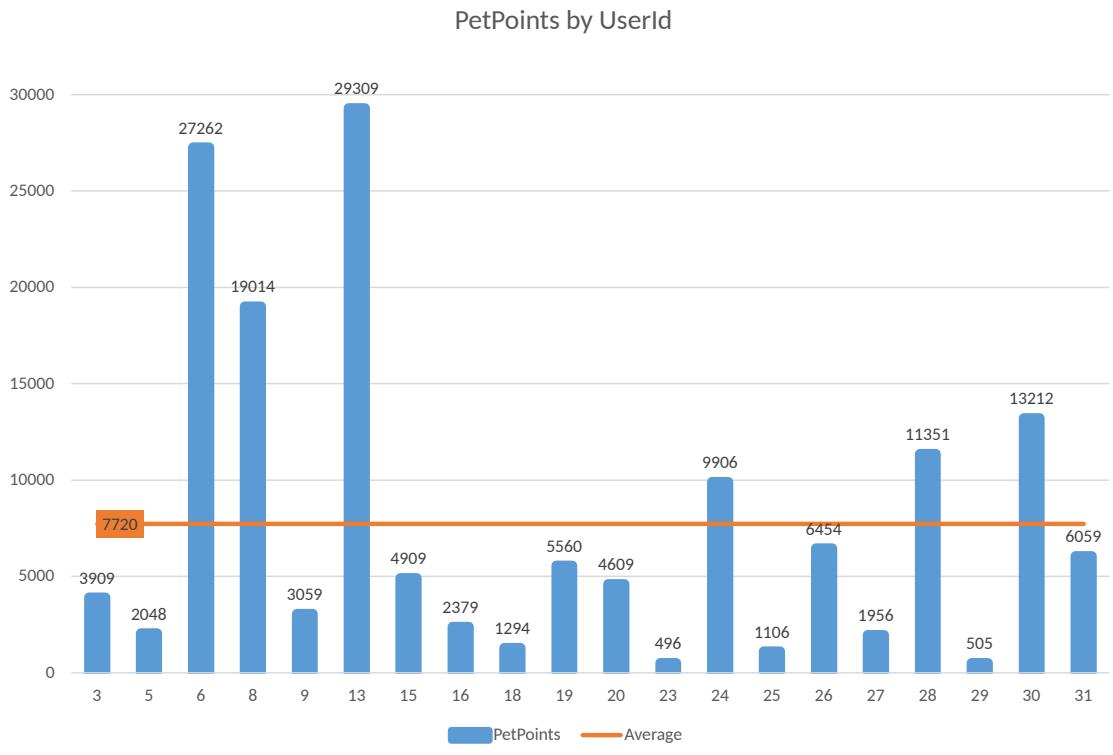

Figure 24.5: PetPoints for Each User.

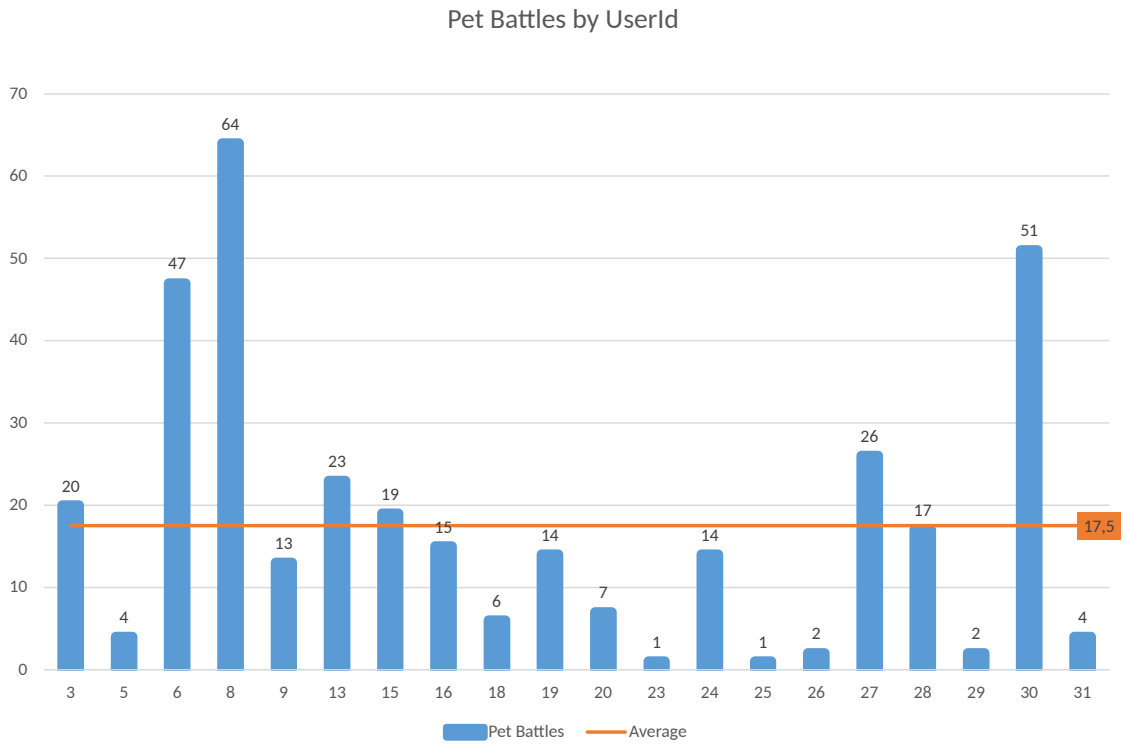

Figure 24.6: Number of Pet Battles for Each User.

The following graph (see Figure 24.7) was produced by querying the game data on date-unique login logs. It shows how many test subjects logged in for each day of the test period.

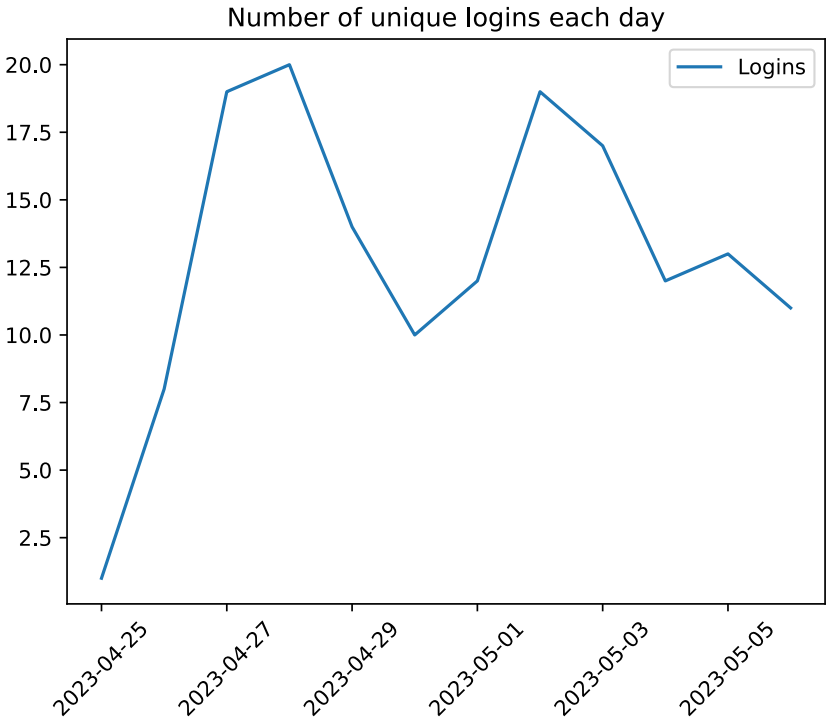

Figure 24.7: Unique Logins per Day of the Test Period.

24.3 Interviews

This section details the most relevant interview findings related to the general usage of the application.

24.3.1 Gameplay Experience

Test subjects 8 and 20 reported walking more than usual during their interviews. Subject 8 talked about how they stopped taking the bus to their university campus and instead took the 20-minute walk, even choosing a slightly longer and more scenic route because they were playing the game. Subject 20 mentioned that their walk to their university campus was very short but that they instead went on slightly more walks than usual during the testing period.

While the interviewees all reported understanding the game quite well by the end of the testing period, they all mentioned some aspects which they considered confusing or hard to understand. Subjects 8 and 20 had trouble understanding the tomato planting mechanics. They also mentioned difficulties in understanding the augmented reality (AR) minigame mechanics. Subject 28 was confused by the multiple different kinds of currency. Subjects 13 and 27 did not understand the purpose of pet points initially, if at all. Subjects 20 and 27 were confused about the mechanics of placing pets. Subject 13 mentioned how they were confused by a lack of explanations of the primary game concepts, while subject 20 wished the game would provide more feedback when doing something the wrong way, such as placing tomato seeds directly on the ground. Subject 27 spoke about how they had tested the application two years earlier, making their experience influenced by a different version with different features.

24.3.2 Motivation

Competition, improving pets, and curiosity were the three main motivations the interviewees mentioned. Subjects 8, 13, and 27 discussed how the game triggered their competitive instinct. Subject 13 said that *"[they] thought it was a little fun to kick other people from the territories they were holding; that it was a sort of hostility game."*, explaining that they were more attracted to the Player versus Player (PvP) functionality than Player versus Environment (PvE) because it was more fun to annoy other players than fight pets who did not belong to anyone.

Subjects 8 and 13 were motivated to gather pet points to climb the pet points leaderboard, while Subject 27 was inspired to fight other pets to climb the PvE leaderboard. Subject 8, in particular, explained how they had a pet point leaderboard competition with a different test subject they knew in real life. Subjects 20 and 28 explained how they were motivated by leveling up pets, and Subject 27 was motivated by finding more accessories for their pets. Subjects 13 and 28 mentioned a motivation for getting new pets, but for differing reasons; Subject 13 wanted new pets to hold new territories, while Subject 28 wanted them to satisfy their curiosity. They also mentioned the importance of connecting to the other players. At the same time, Subject 13 explained how they were more motivated to climb the leaderboard because they recognized competitors' names from friends they had in real life.

Subject 20 explicitly mentioned the agreement to participate in the test as a motivation for playing. However, they also specified that they played more than the minimum requirements because they thought the minigames were fun. Subject 28 similarly said that one of their motivations was that they thought testing master theses was fun.

Speaking in general terms, Subject 28 said they needed a social aspect for a game to be attractive unless the game had an incredibly intriguing story.

24.3.3 Points of Frustration

The interviewees pointed out some features they were frustrated by or wished differed. Subjects 8, 20, 27, and 28 all mentioned how they found some or all of the AR functionality uncomfortable or hard to use. As Subject 8 put it, *"You could not do it in a room with many people because it looks like you're filming the whole room."* This sentiment was echoed by Subject 27, who gestured as if they were taking a landscape photograph and said that *"[AR] was a pretty big dealbreaker, to be honest, considering you had to be out in public. Having to take out your phone and stand like this was something I was not comfortable with."* Subject 20 expressed the same sentiment but said they preferred doing it outdoors to indoors because the AR functionality was not fit for small rooms with many objects. Subject 28 noted that the coin minigame was particularly hard to use because of the AR functionality.

Subject 13 said they thought *"those plants were incredibly unnecessary."* They followed up by saying they thought the whole home base was messy and wanted to chop down some of the trees. Subject 20 expressed frustration with the home base, saying they had trouble orienting themselves.

24.4 Summary

This chapter outlined the experiment results related to the general usage of the game. About half of the players played at least once daily, and most played alone. Specific quotes from the post-test questionnaire indicated confusion regarding the game mechanics and frustrations with AR and landscape mode. The interviews reiterated some of these sentiments. The number of pet points gained and PvE battles performed varied significantly between players. This variation could correlate with the interview findings, where participants expressed different motivations for playing, such as competition, progression, and curiosity. The ensuing chapter shows results related to the usage of the friend system.

25 Friend System Usage

This chapter focuses on results related to the implemented feature, the friend system.

25.1 Questionnaires

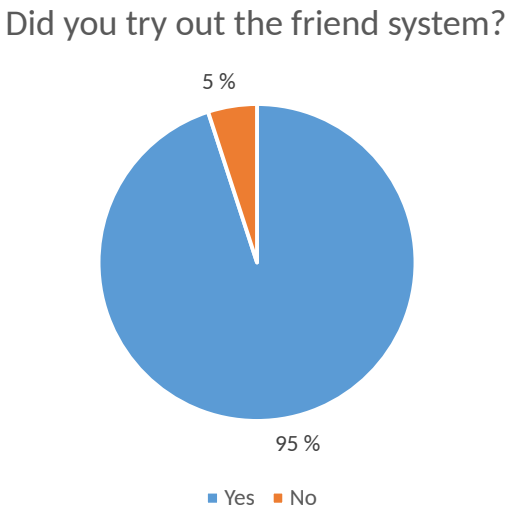

Figure 25.1: Percentage That Tried the Friend System.

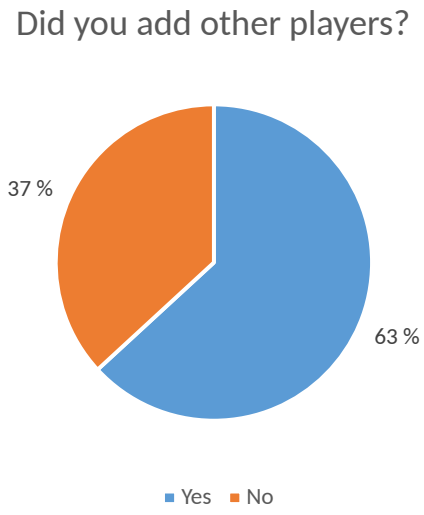

Figure 25.2: Percentage That Added Friends Beyond the Requirements.

Of the 20 participants that played past the tutorial, all but one reported trying out the friend system (see Figure 25.1). This meant that they did not reply to several of the ensuing questionnaire statements, as they were dependent on a *yes* from this question. However, the game data shows that the test subject did open the friend panel and added other users. Trying out the friend system was also specified as a requirement in the instruction sheet in Chapter 20. As evident in Figure 25.2, 63% said they added users beyond the requirements.

All test subjects who reported trying the friend system were presented with statements and the ability to signal how much they agreed with them, as seen in Figure 25.3. Most of the test subjects were negative to the statements about regularly checking the friend activity feed, regularly checking friends' profiles, frequently checking who had reacted to posts, and frequently reacting to friends' posts. However, one should note that the last statement had over 40% in agreement, making it more controversial than the other statements. The majority were positive to statements covering being motivated by comparing oneself to friends, by in-game actions being shared with friends, whether the amount of activity in the activity feed was appropriate, and whether the user interface was easy to navigate. The participants had neutral or mixed responses to all other statements, covering being motivated by seeing who had reacted to one's posts, whether the amount of activity feed posts led to playing more, and whether the friend system led to regularly returning.

25.1.1 Quotes

Some of the open-ended questions had answers focusing specifically on the friend system. These are the most relevant ones:

> "*The friend system was hard to find at first. I didn't know what and when something was posted to my feed. I wish a pop-up would show up when something was posted. It would be nice if I got a red dot or a notification to tell me if someone reacted to my post or if something new was added to the feed*"

> "*I think I could get lost in the feed if I had more friends because there was already a lot of activity. Therefore, it could perhaps be nice to group the achievements per friend in some way (more achievements listed in one post instead of one post per achievement), for instance, everything achieved in a given time frame or achievements of the same type*"

> "*Nice work, being able to "compete" with my friends was very motivating, especially when we all started at the same time for this testing period. The reactions were a nice touch to let them know that I was watching their progress, and to feel like I could impress them with mine. I didn't use the friend profile much, but I still think it is a nice addition because it was motivating to see the pets and accessories my friends had unlocked that were only shadows for me – it made it seem more possible to unlock them myself, and it was just in general fun to see the designs of the items that were only shadows for me.*"

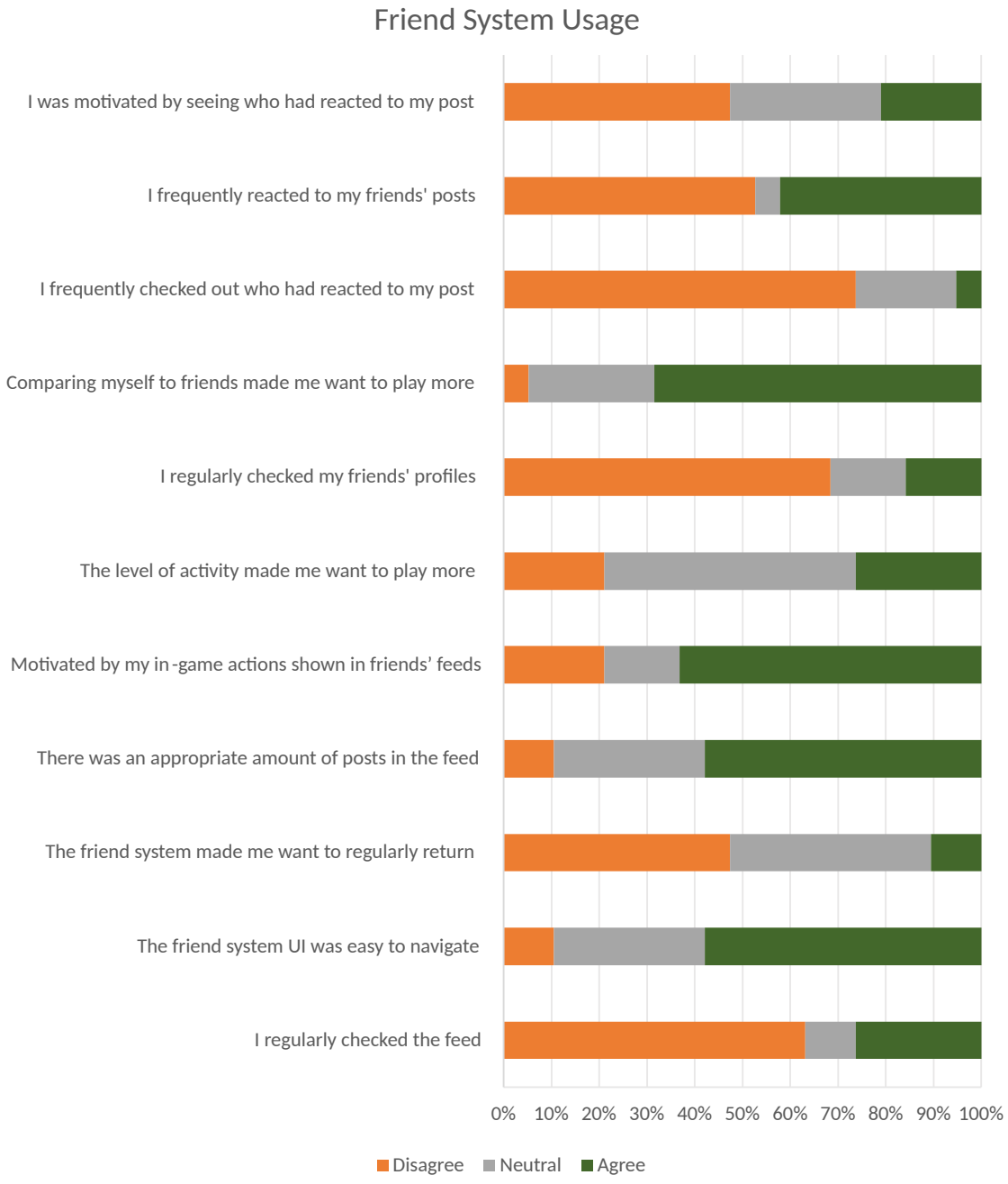

Figure 25.3: Answers to Statements about the Friend System

25.2 Game Data

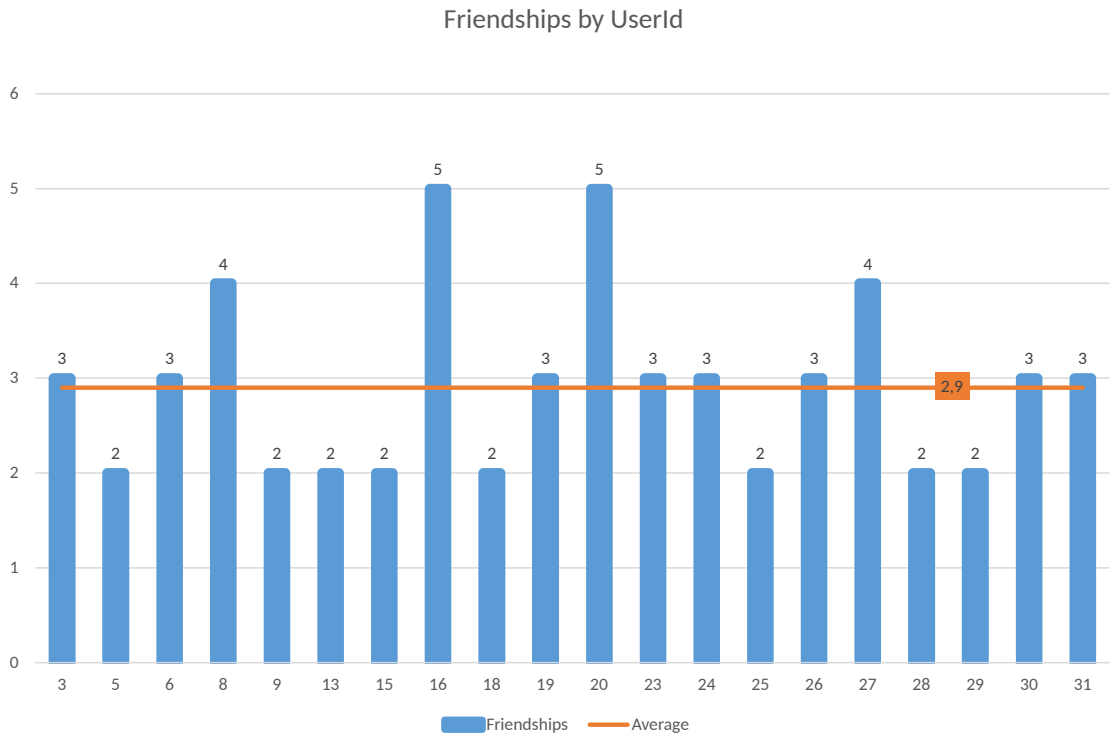

Figure 25.4: How Many Friends Each User Had.

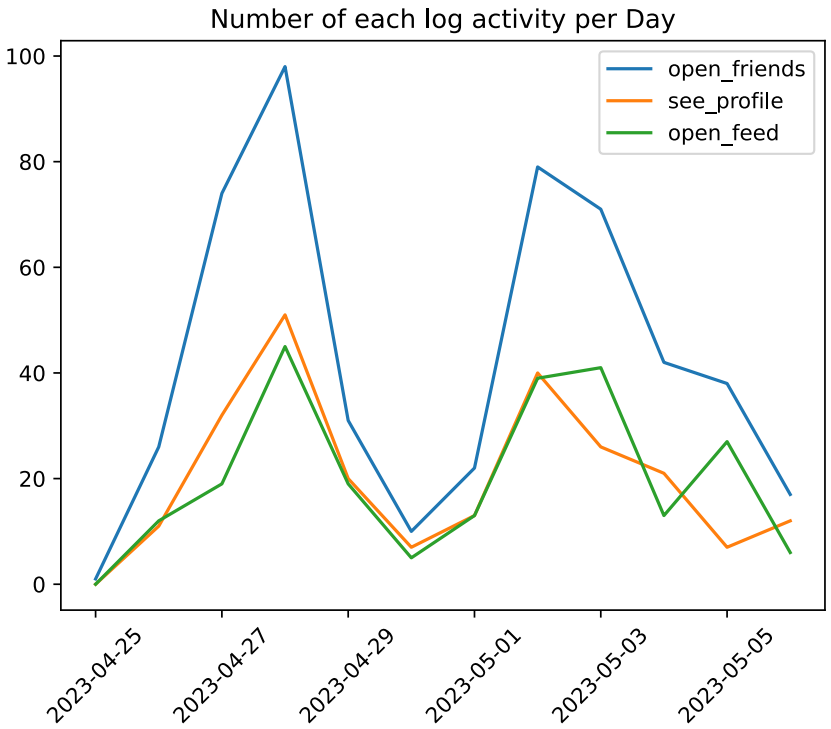

Figure 25.5: Number of Each Log Type Produced per Day.

Figure 25.4 shows the number of friends each test subject had. Nine test subjects had only two friends, the minimum requirement, while two participants had five. The average number of friends was close to three (2.9). Figure 25.5 displays the amount of each log type per day. There is a significant decline between Saturday, 29th of April, and Monday, 1st of May. Afterward, the activity resurges before finally reducing again near the end of the test period (Saturday, 6th of May).

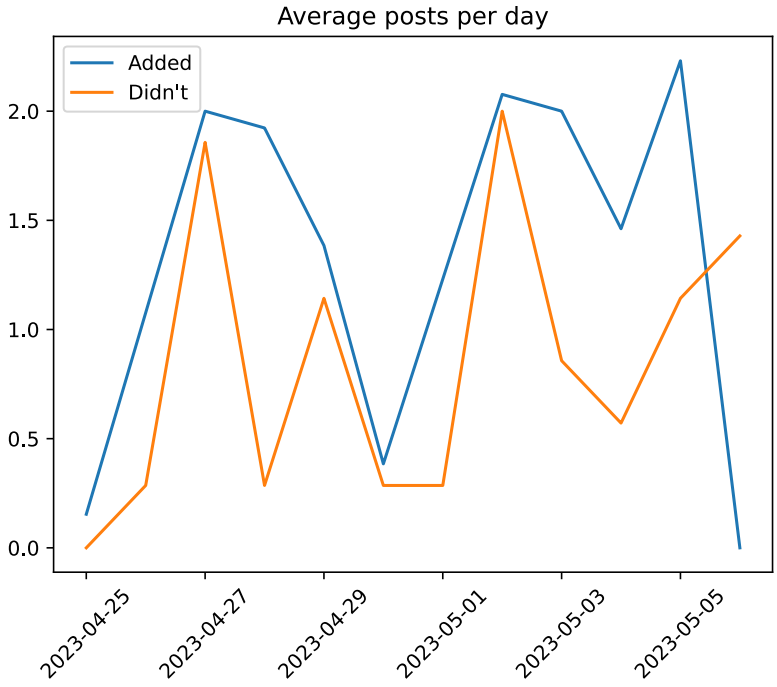

Figure 25.6: Normalized Average Posts per Day.

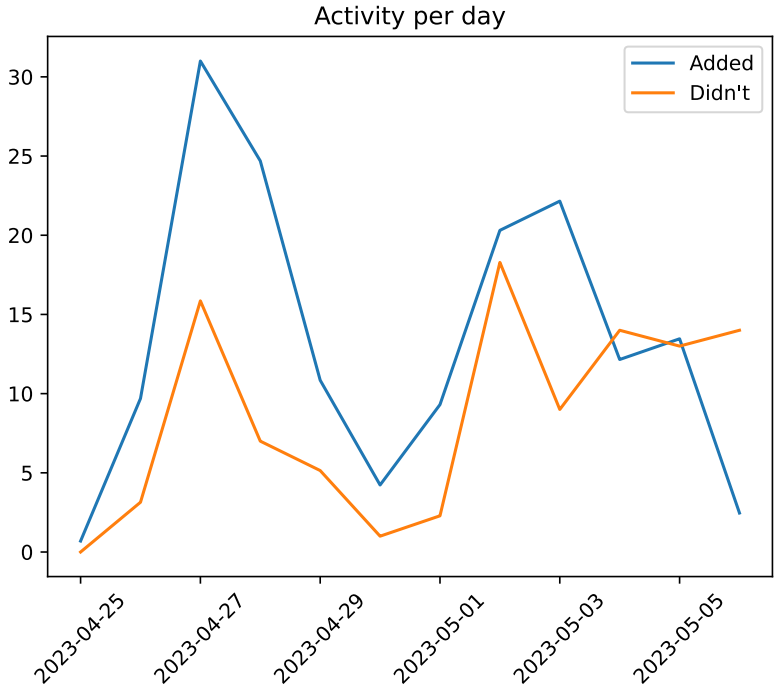

Figure 25.7: Normalized Activity Logs per Day.

Figure 25.6 compares the average number of posts generated each day for two groups: those who added more than the required friends and those who did not. Generally, there are more posts created each day by the former group. Figure 25.7 similarly compares the two groups by logs generated each day, here dubbed activity. Again, the participants who added more friends created more entries each day.

25.3 Interviews

The interviewees answered questions about their experience with the friend system. The questions covered how they interacted with the friend system, what changes or additions they would make to it, how relevant they perceived the activity feed posts to be, and how adding or not adding friends would have affected how much they played. The final question varied based on whether they had added friends or not.

25.3.1 Interaction with Friend System

When asked how they interacted with the friend system, the interviewees primarily responded with how they used the activity feed. Reported usage typically ranged from very rarely to every once in a while. Of those who had added real-life friends to the game, none reported actively playing together with them while physically together. However, subject 28 speculated that if they had been younger, they would have played more with their friends.

Subject 8 talked about how they reacted to posts and checked who had reacted to theirs. They thought seeing their friends' major achievements was cool, but it was less interesting when many of the posts were smaller achievements from the same player. Regarding the types of posts, subject 8 said that *"I thought they were relevant. I thought it was the most fun when people got new accessories. Then I was like, 'Oh, shit,' because I thought everyone else had cooler accessories than I had."*

Subject 13, on the other hand, said about the activity feed that *"I don't feel like I used it that much. It was only so-so interesting to see what glasses [interviewer] had."* However, when commenting on the posts in the activity feed in general, they said that *"As far as I remember, they were fine. Not too much, not too little, either. I don't know. I was only friends with [interviewers], so it would probably have been more if one were friends with more. [...] I don't know how much it actually gave me, but it wasn't annoying either."* Neither did they report checking out the user profiles more than a couple of times, explaining that they did not find their content too interesting.

Test subject 20 initially had trouble understanding the friend system and took a while to explore the different features. They explained that *"I discovered the last day that you could react to people's achievements, so then I just went du-du-du-du-du [gestures as if they were reacting to a lot of posts]. I think it was a bit about me, in a way, not exploring the app so much in the beginning."* When asked about the relevance of the activity feed posts, they said it was fine. However, they interpreted the feed more like a list of achievements than a social media wall, meaning they did not need to check it constantly. Along with subject 28, they also felt limited when adding new people because they could not recognize real-life friends from the usernames they saw on the leaderboards.

Subject 27 described their interactions with the friend system like this: *"I didn't use it that much. Or, I added some of the other test subjects I knew that I saw. But I used the leaderboards more, really, than that friend feed. It was more fun to see yourself beating your friends than seeing what they buy or achieve."* When asked about the activity feed posts' relevance, subject 27 answered: *"I experienced it as not so relevant, in my opinion. I have to admit that I forgot about it a little. I didn't quite feel like it was that important to see what others were up to."* Like subject 13, subject 27 did not use the profile pages too much. Despite being interested in collecting as many accessories as possible, they said they preferred using the shop to see which were available rather than checking out which silhouettes were blacked out on their profile page.

Test subject 28, on the other hand, checked out the friend list and activity feed a few times.

They explained that they wanted to compare pet points, react to some posts, and see what was happening to their friends' pets. In the activity feed, they were clear about preferring updates showcasing in-game development, such as new pets or pets leveling up, to someone *"planting ten tomatoes."* However, they were concerned about the number of posts one could get if one had many friends.

Multiple participants reported confusion about the in-game notification they received when there was a new post in their activity feeds. Test subject 8 reported that *"I just saw that it said there was something new, but then I didn't see what was new."* and *"I went in and saw that there weren't any friend requests or anything, but I realized after a while that you were supposed to go to the feed."*. Subject 20 said about the activity feed that *"You had to click that little icon and then scroll between those four icons. It was a little hidden."* However, subject 28 thought the friend system UI was clear and good.

25.3.2 Ideas for Improvements to the Friend System

The interviewed test subjects had several ideas for improvement to the friend system. For the activity feed, subject 8 suggested adding more reactions. Other subjects' suggestions echoed the concern subject 28 raised about receiving too many posts. Subject 28's solution was to prioritize posts from friends you interact more with. Subject 8 suggested only sharing an activity with your friends when explicitly accepting a prompt to share, giving the player the option to pick what is interesting enough to share and what is not. Subject 27 suggested limiting the posts to only special occasions akin to finding a shiny Pokémon in a Pokémon game.

Test subject 20's suggested solution to their and subject 8's confusion about not knowing what they were receiving activity feed notifications for was to make the friend button in the primary user interface (UI) lead directly to the activity feed instead of the friend list. Subject 20 also suggested making activity in the activity feed more visible, for example, by adding pop-ups within the app whenever a new action happens. However, in terms of features, they were pretty content.

Multiple test subjects suggested new types of posts to the activity feed. Test subject 28 suggested getting updates from other people's bases in the activity feed, subject 20 wanted posts for reaching specific steps walked milestones, and subject 27 suggested making it possible to share a pet with its current accessories — its *"drip"*, as subject 27 described it. Subject 28 also suggested making real-life friends easier to find by adding an integration to Facebook, a comment section to the activity feed, and a private chat. Subject 27 suggested adding the ability to see your friends' activity in the map view and an indicator to show who is online at a given moment.

25.4 Summary

This chapter covered the test subjects' experiences with and usage of the friend system. The questionnaire, interviews, and game data showed that the subjects used different parts of the friend system to varying degrees. All participants tried the friend system, but only 63% added friends beyond what was required, with the average number of friendships being 2.9. Participants with more friends generated more posts and activity logs than those who did not. Generally, a majority of subjects were negative to frequently using the system. As the quotes show, some subjects needed clarification on the interface and found the feed overwhelming. The interviews also indicated a mixed reaction to the friend system. However, most participants also reported being motivated by comparison to others. This motivation also emerged in interviews, with several subjects mentioning the leaderboard as a significant motivator.

The next chapter presents other results that are relevant to the project.

26 Additional Results

This chapter concerns results beyond demographics, general, and friend system usage that are still of interest to the project.

26.1 Technical Issues

The questionnaire asked the test subjects if they experienced any bugs or errors while testing the game. A selection of the answers can be found below:

"*The app crashed occasionally*"

"*The game just crashed sometimes, but was alright when I restarted it*"

"*when giving the game access to the camera, it crashed*"

These issues were echoed by test subject 20 in the interviews. They explained that it did not happen to them when performing specific tasks but at seemingly random moments while playing the game. Subject 8 talked about their issues with the app sometimes freezing while playing, but it was easily solved by restarting the application. Not one interviewed test subject mentioned any bugs breaking their game experience, but there were some major annoyances.

Subject 28 experienced that their progression was heavily hindered by the fact that more advanced pets did not spawn on the map. Subject 8 also commented on the same issue. Subject 13, on the other hand, had trouble with marking not always working, breaking chains, and thereby limiting the pet point return. They also explained that they used the lure extensively, exploiting the fact that it had no cooldown. Subject 27 mainly complained about the UI being slow to update, such as the leaderboard showing outdated stats or the shop not showing recently unlocked accessories.

26.2 Suggested Features

The questionnaire responses had several suggestions to improve the gameplay experience. One respondent expressed their frustration with the orientation of the phone, saying that "*I think I would have enjoyed it more if I could only play against pets in landscape but any other part of the game were in normal horizontal*". This sentiment was further reiterated in an interview with subject 27. Another respondent suggested that the different types of posts in the feed be color-coded, so it would be easier to distinguish at a glance. Finally, a test subject desired an overview of outgoing friend invitations, as the prototype only showed incoming ones.

The interviewees suggested more features that did not directly concern the friend system. Test subject 8 suggested adding more incentives to walk, for example, by giving bonus points if you were to walk alongside someone else and adding coin bonuses at certain steps walked milestones. They also suggested adding more customizability to home bases and making it possible to visit other people's bases, like in MovieStarPlanet [45]. While subject 13 expressed limited desire for such a feature, they did say they expected it to be possible and were surprised when it was not.

The interviewed test subjects presented many new ideas to increase players' engagement. Subject 28 suggested adding more minigames without specifying anything in particular. Subject 13 suggested adding a gifting or trading system to use, for example, in the case that you have an accessory that someone else wants. They also suggested, along with subjects 20 and 28, the possibility of fighting your friends' pets. To keep leaderboard competition interesting with many players, subject 13 also suggested limiting the leaderboard to friends or adding a league system where you compete with players with similar stats.

Several interviewees had suggestions for new quality-of-life features. Subjects 13, 20, 27, and 28 all requested more instructions: Subject 13 wanted more explanations of basic concepts; subject 20 wanted more feedback when doing something unintended, for example, trying to plant tomatoes on the grass; and subjects 27 and 28 wanted more explanations of the different currencies and how to earn them. Subject 20 also suggested making the phone vibrate when leaving a marked area to remind the player to place a new mark to start or maintain a chain. While subject 8 did not suggest this feature, they did echo the frustration of forgetting to mark while walking. Subject 13 suggested being notified of changes to the leaderboard if you are competing with someone else for leaderboard spots, for example, if you have been bypassed by someone else. In an attempt to solve the AR issues presented in Subsection 24.3.3, subject 8 said they would have preferred it if one could play the minigames in a 3D world instead of using AR.

26.3 External Factors

Several factors that affected participants' playtime and interaction with the game were mentioned. Since the testing was done during the exam period at the Norwegian University of Science and Technology (NTNU) and almost all participants were students there, a lack of time was mentioned by many as an important reason for not playing enough. Another participant was on vacation during the exact week of the test period and thus did not focus on the game. One participant also mentioned becoming sick during the test period and was unable to walk outside the last few days. Finally, several Android testers could not install the required dependency, ARCore, and thus were unable to perform any pet battles.

Both test subjects 8 and 20 commented on the effect of the weather on their playing experience. Subject 8 said *"I was outside quite a lot even if it rained"*, but said of playing in the rain that it did not work very well and that they avoided battles and stuck to building marking chains. Subject 20 spoke more generally about the weather, commenting that *"I was generally quite affected by the cold."*

26.4 Summary

This final chapter of Part VI presented other results that were of interest to the experiment. Firstly, it detailed some of the technical issues experienced by the test participants. Many test subjects experienced bugs and errors in some fashion, though no one claimed they were critically affected. Participants also suggested a plethora of features beyond the friend system, including portrait mode support, home base customizability, a trading system, etc. Finally, some participants struggled with playing the game due to factors such as an exam period, vacation, and lack of support for their phones. Part VII will discuss the results presented in this part in light of the research questions formulated in Part I.

Part VII

Discussion

This part discusses our findings concerning each research question formulated in Chapter 3. In addition, it discusses the validity of the results presented in the preceding part. The discussion will also be used as a basis for the conclusion and further work in Part VIII.

27 RQ1: Effective Exergames

This chapter discusses the first research question:

> *What factors contribute to the effectiveness of exergames?*

The following sections discuss different aspects of this question.

27.1 Physical Intensity

Exergames' unique aspect compared to other games is their incorporation of physical activity. As mentioned, they have been proposed as an alternative way to satisfy the activity recommendations set by health authorities [56]. This paper's prestudy (Part II) showed extensive research on such games and their effects on player fitness. Various research papers showed positive results for physical health — for instance, the studies conducted on Ring-Fit Adventure and Wii Sports boxing [19] [68] [96] [60]. However, although an exergame may be more effective at energy expenditure than traditional computer gaming, studies such as Graves et al. indicated these levels are not necessarily high enough to contribute to the daily recommendations [29]. Hence, one measure of an exergame's effectiveness could be how well the energy expenditure matches alternative exercise. However, this is not a simple measure as people of different fitness levels require different loads to stay in, or improve, their physical shape. **For an exergame to be effective regarding workout efficiency, it should therefore strike a balance between the player's fitness levels and the difficulty of the challenges it provides**. An exergame could provide challenges that expend remarkable amounts of energy, but it would not be very effective if the player could not perform them. The Dual Flow framework highlights this significant design challenge and suggests that an exergame must balance fitness with intensity to provide a flow state; it must achieve *effectiveness* [66].

Still, any activity level is arguably better than remaining sedentary in front of a digital screen, even if it is not high enough to contribute to the daily recommendation levels. The greatest beneficiaries of increasing activity levels are those with the lowest levels to begin with [31]. Thus, exergames could still be effective for these groups of people, even with suboptimal intensity. Especially if these players would never perform any other exercise otherwise. Furthermore, an exergame could be an introduction to further exercise for such people. For instance, as shown in the prestudy, Pokémon GO managed to increase the activity levels in its players, even those who were not already active [80]. However, this would not work if the game is not enjoyable, leading to another factor of an exergame's effectiveness.

27.2 Player Retention

An essential aspect of the notion of exergame effectiveness is player retention. As Chapter 10 notes, enthusiasm for such games developed for research usually declines after some weeks [101]. **No matter how effective an exergame is at providing a satisfactory workout in a single play session, it will not remain a viable alternative to exercise if the player quickly loses interest.** Commercial exergames may be more effective at addressing this challenge, as they are often more concerned with retaining a player base. However, even these games can still suffer from player decline over time.

To address the issue of player retention, one can utilize established game design principles. Like conventional video games, exergames can benefit from employing strategies that engage and captivate players long-term. Various models and theories have been proposed to enhance player engagement and combat the decline in enthusiasm. This paper has detailed Malone's theory of enjoyment, rewards, player types, game flow, and retention strategies. Malone's enjoyment theory suggests that **providing players with a sense of challenge, mastery, and autonomy can heighten their enjoyment and prolong their interest in the game** [42]. **Understanding**

player types and tailoring gameplay experiences to cater to different preferences and motivations can also enhance players' investment [7]. Admittedly, not all games appeal to all types of players; thus, an exergame will not effectively retain all players. Yet, incorporating mechanics that appeal to different players and allowing them to customize their experience will likely help mitigate this issue.

In addition to these theories, including rewards and progression systems within exergames can create a sense of achievement and incentivize continued play [83]. Offering meaningful and tangible rewards, such as unlocking new levels or character customization options, can provide a sense of progression and encourage players to persist with their exercise routines. Simply anticipating a reward can be gratifying and keep players returning to the game when experiencing less enjoyable sections. Furthermore, **implementing effective retention strategies, such as regular content updates, social features, and community engagement, can foster a sense of belonging and connection among players**, further enhancing their commitment to the game [18] [22] [78]. The research that has been presented has indicated that competition, cooperation, and gamification are especially important for exergame retention [11]. Studies on the effects of socialization are still somewhat lacking, but as seen with social games, it can be a powerful tool to keep players invested [12].

27.3 Summary

By applying game design principles and leveraging existing models and theories, exergame designers can create immersive and compelling experiences that deliver effective workouts and sustain player interest and retention over an extended period. Ultimately, **fitness level adaption with sufficiently high energy expenditure and game design principles that promote retention are essential factors to making an exergame *efficient*.** The next chapter discusses how BitPet can be improved to encourage physical and social activity.

28 RQ2: Encouraging Physical and Social Activity

The second research question was:

> *How can BitPet be improved to encourage physical and social activity?*

The following sections discuss different aspects of this question.

28.1 Potential for Change

This project aimed to enhance BitPet by introducing features that promote physical and social activity. Therefore, it was crucial to explore opportunities for improvement in these areas. BitPet is currently in an open beta phase, meaning it is still in the early stages of development. This allows for significant changes to be implemented, presenting numerous possibilities for improvement. In the prestudy (Part II) of this paper, various exergames and social games were examined, each offering unique features within their respective genres. BitPet has already drawn inspiration from Pokémon GO, incorporating features such as avatar leveling, augmented reality (AR) battles, and real-to-virtual world mapping. Further inspiration can be derived from other successful exergames like Strava and Pikmin Bloom.

28.2 Social Features

After evaluating the current state of BitPet, social features were identified as the primary area requiring improvement. BitPet's core gameplay mechanic revolves around walking, which is already supported by step missions, map rewards, and the need to gather food for pets. Thus, there were already several systems supporting physical activity. In comparison, the social aspect of the game appeared limited. While the leaderboard could be considered a social component, interaction with it was minimal. In addition, although a player versus player battle mode exists, it necessitates encountering another BitPet player in-person.

The prestudy findings indicated that socializing and fostering a sense of community enhance player retention, engagement, and overall physical activity. Furthermore, socializing was a key component to achieve GameFlow and was seen as critical to ensure success in mobile multiplayer games [40] [73]. Lee et al. also found that social features were essential for achieving desirable psychological effects in players [38]. Therefore, it was proposed that **many of the improvements to BitPet should focus on encouraging increased social interaction within the game, as it would promote both social and physical activity. Furthermore, player retention has been identified as especially challenging for previous exergames, making it an important focus area** [36]. Suggestions were the inclusion of factions, visiting friend bases, joint trips, and trading systems. These features drew inspiration from successful social games like Clash of Clans and Team Fortress 2. Additionally, we recommended planned trips and seasonal events as potential enhancements. These features are not inherently social but could stimulate increased playtime and encourage more physical activity.

The interview subjects also identified the potential for social features in BitPet, as they mentioned several such ideas when asked about how the game could be improved. We had already proposed some of these ideas, such as the ability to visit friends' bases, trade with others, and take trips with friends. However, new ideas were also presented, such as seeing other friends' activities on the map or the ability to challenge other players. Though the interview selection is quite minimal, it could strengthen the claim that there is a general desire for BitPet to introduce more social features in the future.

Ultimately, it could be asserted that the **most beneficial improvement would be introducing a friend system**. Although our feature refrained from encouraging in-person social activity, many such features would likely be better when combined with an existing friend system. The reasoning being that it would be easier to communicate and plan a meet-up, as well as interact together in

the game while meeting. Thus, **our feature would serve as a foundation for such future enhancements.**

28.3 Evaluating the Feature

After implementing this feature, it had to undergo a thorough evaluation to ensure that it genuinely enhanced social activity. Therefore, determining the appropriate evaluation methods was a sub-question of our research question. Ultimately, we adopted Oates' research model to define our strategies and data generation methods [51]. While the model may not be specifically tailored for evaluating game mechanics and provides a broader research framework, the techniques employed generally apply to most user testing scenarios. Furthermore, strategy and data triangulation strengthened the foundation upon which the discussions are based.

28.4 Summary

BitPet still has much potential for improvement as it is in the beta phase. Social mechanics are particularly promising since the possibilities for socializing in-game are currently quite limited. The friend system can facilitate more such features. The next chapter discusses RQ3 and how the feature should be implemented and integrated into the game.

29 RQ3: Implementation and Integration

The third research question was:

> *How should the proposed feature be implemented and integrated into the existing application?*

The following sections discuss different aspects of this process.

29.1 Prototyping

The concept underwent a user interface (UI) prototyping phase before the modification was made locally and subsequently deployed to the web. **Prototyping the UI in Figma first proved to be a worthwhile prioritization, as it allowed for rapid changes and experimentation.** However, if the feature had not been UI-centric but rather focused on, e.g., AR functionality, Figma would not have offered meaningful aid. In this case, immediately extending the existing codebase might have been preferable. Thus, how new features should be implemented depends on their nature; there is no universal approach.

In retrospect, the prototyping phase should have been extended further. When satisfied with the layout, the required code modifications were carried out immediately. Instead, **it would likely have been preferable to perform user testing already at this stage since changes required less effort.** As seen in the previous part, the UI received plenty of feedback from the participants with suggestions for improving it. One of the quotes highlighted that the system was hard to find and that understanding when other players' posts were posted was unintuitive.

Furthermore, several interviewees mentioned that the feed was elusive. The log data fortifies this statement, as the number of times test subjects opened the friend system was substantially higher than how many times they checked the feed. This might, admittedly, be due to a lack of interest in the feed. Regardless, if we had performed some minor user testing before starting the final experiment, frustrations with navigation could have been uncovered and mediated, potentially leading to increased usage.

There is, however, also a limitation to how helpful such early testing might have been, as the test subjects would not have an understanding of the game yet. For instance, it would have been difficult to evaluate the usefulness of different posts, how many posts should appear, or what features were missing, as the participants would not be familiar with the game's mechanics. However, activity feeds are prevalent in games and social media, and testers might still have feedback on what features they would expect. An example of this is the addition of more reactions, which was mentioned in the interviews. It would likely also have been helpful to see whether the participants could easily find and navigate around the interface.

29.2 Technical Implementation

Being a complex application, BitPet requires extensive knowledge about the code to be modified without introducing breaking changes. Therefore, before modifying the code in BitPet, both frontend and backend architecture and code were investigated in-depth. Prototyping generally has a short time span, and thus one would have to find a balance between inspecting existing- and writing new code. Much of this inspection was done as part of the prestudy and thus did not heavily affect the development time. It would not have been feasible to review the entire codebase, but, thankfully, the architectural patterns removed much of this need [74]. Furthermore, our situation was perhaps an unusual way to prototype new features for a game since we were external developers modifying someone else's codebase. In a professional environment, the in-house development team would likely carry out the prototyping and thus already be familiar with the existing code. Either way, **reviewing the technical solution before implementing new features proved essential, but it was important to know when to move on.**

Since BitPet is a pre-existing, publicly available game, creating a separate environment for prototype testing was necessary. This way, code modifications would not interfere in any way with those of the BitPet team. However, this entailed separate deployment and app distribution, requiring a significant effort beyond implementing the new concept. If BitPet is to be extended in similar fashions in the future, it might be preferable to streamline this process so that less time is spent on replicating an existing setup and more on developing the feature itself. Yet, one could argue the difficulties with deployment stemmed from lackluster communication with the development team. Instead of spending significant time debugging and trying different deployment methods, **it would have been wiser to consult the developers more frequently.**

All in all, to successfully implement and integrate new changes to BitPet, one should study the patterns and code and communicate heavily with the development team.

29.3 Quality Assurance

As a minimum viable product, our friend system never sought to be perfect. Instead, it prioritized more features with acceptable quality. Still, a certain level of quality assurance must be carried out to ensure the concept is working as intended. While developing, the application was tested after changes were made. Usually, this testing was limited to the functionality that was actively being worked on. Unbeknownst to us, other parts of the application, such as the degradation of hunger, did not work properly. Performing a complete verification of the game each time a change was introduced was not a viable option. **However, in retrospect, more time should have been set aside between finishing the code and distributing the application.** This might have allowed for the discovery of some of the bugs discovered during the test period. Particularly the frontend would have benefited from this, as modifications after distribution required participants to reinstall the application. Modifying the backend with minor fixes was possible throughout.

Test subjects generally reported that bugs did not affect their gameplay in a meaningful way, but some issues could still have impacted their desire to play — namely, the problems with higher-tiered animals not spawning and pet stats degrading far too slowly. The former meant that **players did not experience the intended progression curve and were, thus, perhaps less inclined to play the game. This, in turn, means that they would interact less with the feature concept.** Furthermore, the latter meant that gathering food and frequently logging in to take care of pets was not necessary, again limiting how often players would play. If there was a larger time gap between the end of development and start of testing, this might have been discovered in time to fix it. However, there would have been a tradeoff, as either the test period would be shorter or there would be less development time.

Though the server was deployed and continuously tested during development, app building was only prioritized towards the end of the process. Importantly, the iOS app was only built directly before starting the experiment. This caused a delay for the iOS testers and, furthermore, did not grant us time to verify that the application worked properly for iPhones. Thankfully, the iOS version had no unique issues, but this was far from guaranteed. **Ideally, one would want both iOS and Android devices to test on during development, which means having a Mac is also necessary** [77].

29.4 Summary

Several lessons were learned during the development of the feature. Firstly, prototyping the UI prior to implementation is important, and one should also consider user testing at this early stage. Next, more time should be set aside for quality assurance before starting the final testing. Finally, when making mobile phone games for several platforms, one should test on all platforms to ensure correct functionality across operating systems. The next chapter discusses how player activity was affected by the friend system.

30 RQ4: Effect on Players

The fourth research question was:

> *How does the new feature affect player activity?*

The following sections discuss different aspects of this question.

30.1 Game Activity

It is easier to determine the extent of the friend system's effects on overall activity with comparison data, but participants' statements and activity logs can still provide insights. Ideally, one would perform A/B testing, where one group plays the game without the friend system and another one with [98]. However, due to a lack of time and test subjects, the discussion is based on player patterns and statements instead.

Over half of the test subjects disagreed somewhat or entirely with regularly checking the friend system (see Figure 25.3). Thus, one could argue that the new feature had little effect on them. Yet, the activity logs (see Figure 25.5) show that the system was used daily throughout testing. Furthermore, seven test subjects were neutral or agreed to checking it regularly, and even more agreed to reacting to posts frequently. **Hence, though the feature may not have critically affected the general gameplay, participants did check for updates from their social circle.**

A potentially promising finding was that test subjects who added more than two friends consistently generated more posts than those who did not (see Figure 25.6). This finding is bolstered by the same group also generating more logs per day (see Figure 25.7). Still, this correlation is perhaps more self-evident, as logs were related to the usage of the friend system. Posts were designed to cover different measures of activity within the game, and thus a higher overall post number would generally correlate with a higher activity level. **Therefore, one could argue that the friend system caused overall game activity to increase**. However, the direction of the correlation is somewhat dubious, as it might be that the test subjects who generally played more also added friends. Furthermore, the participant with the highest amount of pet points, subject 13, had only added the required friends, as shown in Chapter 25.

30.2 Social Activity

The final implementation of the friend system did not include as much social interactivity as intended due to time constraints. Therefore the level of total social activity might not have increased much with the addition of the friend system. For instance, the concept initially included a comment section and chat, allowing test subjects more ways to interact socially. However, the current implementation limited social interaction to adding friends and reacting to their posts. However, 40% did agree to frequently reacting to their friends' posts. It could be that playing the game caused players to socialize more as they would play it together. However, most participants did not play with friends in person (see Figure 24.3). This was perhaps unsurprising, as discussed in RQ3.

30.3 Physical Activity

Regarding physical activity, most test subjects did not increase their levels, though a few test subjects agreed to taking more walks. The majority disagreed with the statement, "*I went on more walks than normal while testing BitPet*" (see Figure 24.2). **In retrospect, we realize that the wording is unfortunate, as test subjects could have retained the number of walks but increased the distances.** Furthermore, the Likert scale does not suit the statement

particularly well, as there is no clear distinction between disagreeing and being neutral. Regardless, four participants agreed to walking more than usual, meaning there was an overall effect on the physical activity. Two of these were called in for interviews, where subject 8 said they would walk instead of taking the bus, and subject 20 said they increased the length of their trips. Whether this stemmed from the friend system or the game in general is challenging to determine, though subject 8 claimed to check in on the feed frequently. As further discussed in Chapter 33, the physical activity may also have been affected by bad weather and luring being broken.

30.4 Summary

Though many participants did not evaluate themselves as actively using the friend system, game logs show that most of them still checked it regularly. Those who had more friends also had a generally higher activity level, indicating that the system has an overall positive effect on game activity, which could, in turn, lead to higher physical activity. Social activity may have increased somewhat but less than desired due to missing socializing features such as chat and comment sections. The next chapter discusses what motivated participants to play the game and how their retention was affected.

31 RQ5: Effect on Motivation and Retention

The fifth research question was:

> *How does the new feature affect player motivation and retention?*

The following sections discuss different aspects of this question.

31.1 Motivation

Our research on player types in the pre-study made it clear that different players can be motivated by different features. It should therefore be no surprise that the test subjects were split on the friend system's effect on their motivation.

The questionnaire showed that **significant parts of the test subject group were, by their own assessment, motivated by the different friend system features.** 63% reported being motivated to some degree by having their in-game actions shared with their friends, with one participant commenting *"[...] being able to 'compete' with my friends was very motivating, especially when we all started at the same time for this testing period. The reactions were a nice touch to let them know that I was watching their progress and to feel like I could impress them with mine [...]"*.

No interviewee explicitly mentioned any of the new friend system features as particularly motivating factors, but some mentioned earning enjoyment from the features. One interviewee specified that they needed games they played to have a social aspect unless the game story was particularly intriguing. Neither the questionnaires nor the interviews provide any reason to think that the feature deterred people from playing.

Of the three (out of five) interviewees who reported being motivated by the game's competitive aspects, all added that they competed with their real-life friends. 68% of the questionnaire respondents similarly reported being motivated by being able to compare themselves to their friends. This is also in line with the research on player engagement in the pre-study, with Esteves et al. finding that features that allow for upward identification and downward contrast increase continuation intention in players [18]. While the explicitly competitive aspects, such as the leaderboards, were not new additions, **our results seem to quite definitively identify an increased focus on competitive features with friends to increase motivation.** This, again, aligns with Esteves et al.'s recommendation of adding a leaderboard to increase continuation desire. A suggestion from the interviews was to limit the leaderboards only to show one's friends, which could intensify this effect even further.

31.2 Retention

Long-term retention is hard to measure in a testing period of only ten days. The questionnaire did, however, query the test subjects about to which degree the friend system made them regularly return to BitPet. The response to this was quite negative, with only 11% agreeing to any degree. **While the results seem not to identify any strong positive effect from the feature, the basis is too thin to be conclusive.** It can, for example, not be ruled out that a friend system has a subconscious effect not identified by a questionnaire. Retention did not particularly drop off as time passed (see Figure 24.7), with the weekend/weekday separation accounted for, but attributing this to the friend system is premature. The length of the testing period was also insufficient in telling how this trend would have developed long-term. The results from the statement conflict somewhat with, e.g., the study from Stragier et al. which indicates that a social network would help retain players [70]. Furthermore, incorporating achievements and being able to show them to your friends were noted as important for keeping players invested [61] [83]. However, this might indicate that the system has room for improvements, as discussed further in the next chapter.

31.3 Summary

The results show that the friend system features had moderate effects on player motivation. Most test subjects were motivated by the activity feed and other features that enabled comparison. However, there was still a significant segment whose motivation was not affected by the new feature. Measuring player retention proved too hard to conclude with anything safely, but the few results that were produced did not identify any substantial effect of the new feature. The following chapter will cover the test subjects' general perception of the friend system features.

32 RQ6: Participant Perception

The sixth research question was:

> *How do the players perceive the new feature?*

The following sections discuss different aspects of this question.

32.1 General Feedback

In general, the perception of the friend system in BitPet was split. Some participants regarded the system positively, as evidenced, e.g. by one of the interviewees saying *"I thought [the posts] were relevant. I thought it was the most fun when people got new accessories. Then I was like, 'Oh, shit,' because I thought everyone else had cooler accessories than I had."* However, several interviewees responded with mild to moderate enthusiasm regarding the system and had interacted with it in limited regard. This might be because their player types did not align with the socializer or achiever archetype, but their reported gaming habits would indicate otherwise. The log activities graph indicates a balance in the perceived usefulness of the feed and user profiles.

32.2 Missing Features

Regarding the realization of the friend system, the results indicate it should have included more features and modified some existing ones. Certain elements were always intended to be present but fell short due to a lack of time. These included a chat, comments, improved notifications, and posts about reaching step walked milestones or updates from friends' home bases. The results showed that there was a general desire for all of these. For instance, one interview subject mentioned chatting with friends as a desired feature within the system. Both interviews and the questionnaire indicated that the current implementation of the notification was confusing and that it should be clearer why it appears. This confusion is another issue we were aware of but chose not to prioritize. One test subject also mentioned the possibility of a "steps walked" post, a feature that even existed in code. Unfortunately, it did not work correctly in time for the user testing. **In the end, the friend system should optimally have included the chat, comment section, clear notifications, and the steps walked post, but they, unfortunately, had to remain unimplemented due to time constraints.** If the system is developed further in the future, one should consider these ideas.

Interviews showed that the leaderboard was motivating for several subjects and that **a leaderboard for friends could be a significant motivator**. The questionnaires further strengthen this claim, as a participant mentioned that competing with friends was very motivating. The friends leaderboard was considered for an addition to the pre-existing leaderboard in Part III. One could argue that this is an unnecessary addition because the player base is not sufficiently large. However, if BitPet were to gain significant popularity, finding other friends on the leaderboard would be hard.

32.3 Other Additions

Several exciting additions arose during the interviews that were not considered earlier in the feature concept development. An interview subject mentioned the possibility of a Facebook integration to add friends more easily. During the testing period, there were few players in total, and thus one could see on the leaderboard which test subjects they already knew. However, if the usernames have no connection to their real-life names, particularly if the player pool grows, it would be hard to find out who is playing BitPet without asking your friends outside the application. BitPet does not necessarily need to integrate with Facebook, but finding real-life friends should be more straightforward.

Participants also suggested other improvements to the feed. These suggestions include the ability to choose what feats are posted, grouping them by friends, and increasing the thresholds. **Interviews indicated that people thought the current implementation of the feed was somewhat bloated.** Several subjects reported that too many events were posted, despite an overall low friend count (the highest number of friends any player had was five). Some questionnaire answers further reiterate this sentiment and may be why the feed was not as actively used. However, when looking at the statements regarding the friend system, most participants agreed that there were an appropriate amount of posts. Bloating had been accounted for by creating post thresholds, such as which levels and number of pet points should trigger a new post. Still, these limits should be further increased, especially if participants add many friends. One subject suggested grouping the achievements by friends, which could mitigate the problem somewhat.

32.4 Summary

In summary, the **feature should have balanced the feed more and incorporated more methods for social interaction, but this was not achievable with the given scope.** The next chapter discusses the validity of the results.

33 Results Validity

This chapter discusses the validity of the experiment and its results. It concerns the demographics of the testers, their relation to us, and other factors that might influence the experiment's outcome.

33.1 Target Audience

When analyzing the results data, it is crucial to consider the test subjects' demographics. In this particular study, **the participants were exclusively young adults, which could mean their motivations and reflections do not accurately represent the preferences and experiences of the game's intended target audience**. Our perception is that BitPet caters to a younger audience. Furthermore, most participants did not play other games more frequently than every week. BitPet requires almost daily interaction to maintain pet health, which could have been too demanding for these test subjects. Additionally, only 65% of the test subjects played mobile games. This could help explain why many users did not interact more with the game. However, one should not disregard the feedback as simply the players not being a suitable match with the game, as there are likely design flaws within the game, not to mention bugs. Either way, despite the representation limitation, it is still possible to draw general conclusions from the collected data. Furthermore, considering that a larger audience is desirable for the game's success, it becomes even more essential to account for a broader user base's diverse perspectives and preferences.

A particular aspect where opinions might differentiate between children and adults playing BitPet is the use of AR. Several participants reported that they did not particularly enjoy the AR battles and pointed out that using the phone's camera in public was uncomfortable. It seems probable that **children would feel less awkward using AR in public since they may not be as aware of the social stigma associated with it**. However, this is only a hypothesis and should be further investigated. Some of the AR feedback was unrelated to stigma and was instead related to awkwardness in the controls and surface detection. This frustration would likely not differ much between age groups.

33.2 Experimenter Effects and Response Biases

Test subjects 20 and 28 mentioned that **they were participating in a research project as a motivation for playing BitPet during experiment**. This motivation shows how the Hawthorne effect might affect a research project and how it has affected this study. It can also be considered an example of courtesy bias, as the game data was affected by the test subjects' wish to make us researchers happy and uphold our agreement when they registered to participate. This and other experimenter effects or response biases should be considered when assessing the interviews, questionnaires, and game data results, as the Hawthorne effect might have affected more test subjects than just subjects 20 and 28.

33.3 External Factors

While the questionnaire shows that the test subjects were split on rain and snow's effect on their playing experience (see Figure 24.2), **two test subjects were quite clear about the weather negatively affecting their playing experience**. The weather data from the testing period (see Table 2) shows that no day had an average temperature above 4.0°C in Trondheim, while several days also had enough precipitation to think that it could reasonably affect the way one would play the game. There is no clear pattern to be found when comparing the weather data to post, game log, or login data, but this is partly explainable by the fact that 70% of the test subjects reported playing the game at least partly indoors.

As the test subjects were from our immediate networks, they were primarily students. The fact that the testing took place in late April and early May may have caused exams or thesis deliveries

in May or June to interfere. One test subject reported playing the game on vacation, which might also have interfered with the testing.

33.4 Technical Issues

For the most part, no technical issues broke the game experience completely. Some had phones which would not support the application or the AR functionality, but the technical issues apart from this were non-breaking and relatively minor. However, the inability to encounter the more advanced pets on the map must be considered when evaluating the players' motivation to play. This would have become an especially sensitive issue had the testing taken place over a longer period, but **even after ten days, multiple test subjects should have encountered higher-tiered pets and therefore experienced a greater feeling of progression.**

33.5 Summary

Several factors have affected the results to some degree. Firstly, the demographics could have been more representative, as participants may have had other motivations and reservations than a younger audience. With most subjects being students, the ongoing exam period and impending thesis deliveries likely further interfered with overall usage. Poor weather, experimenter effects and response biases also affected how several interview subjects interacted with the game. Finally, technical errors caused the progression of test subjects not to be representative of the actual game.

The next part summarizes the project's findings and presents further work beyond the scope of this thesis.

Part VIII

Conclusion and Further Work

This part concludes the earlier findings, aligning them with the research goal introduced in the opening. Additionally, it offers recommendations for future efforts beyond the scope of this thesis.

34 Conclusion

The aim of the project was to develop a game concept that motivates players to socialize and be physically active. The developed game concept was conceived and implemented as an extension to the existing mobile augmented reality (AR) exergame BitPet.

Our findings indicate that effective exergames apply principles such as Malone's theory of enjoyment, player rewards, player types, game flow, and retention strategies to design engaging exergames that sustain player interest. Effective exergames should retain players over an extended period and balance the difficulty of the challenges they provide with the players' fitness levels **(RQ1)**.

BitPet aims to encourage social activity along with its exergame features. The game, at the start of this project, left a lot to be desired in this area, proving the need for features that promote social interaction in-game. Additionally, player retention has been identified as a particular challenge for exergames in general. Thus, we conceived multiple possible concepts for capability for social interaction and improving retention. Ultimately, we chose a friend system concept with the ability to add friends, see their profiles, and receive regular updates about their in-game actions through an activity feed. Several of the other concept ideas were dependent on the existence of a friend system, making the chosen concept an important basis for further development **(RQ2)**.

The concept was implemented using the application's existing architectural- and design patterns, minimizing barriers for the BitPet developers to continue development and expand on it. However, closer collaboration with the developers could have diminished some of the issues that arose during development and testing. It proved helpful to prototype in Figma and to study the code in-depth before implementation. Still, the concept and testing would have benefitted from early user interface testing and more robust quality assurance **(RQ3)**.

The testing and subsequent analysis showed the feature to have a positive but limited effect on players' physical and social activity. Some players showed an increase in physical activity but the increase in social activity was minimal. This reflects that the friend system itself was limited in its possibilities for social interaction. Most test subjects did not play physically with each other **(RQ4)**.

The increase in player motivation was shown to be moderate; the results from the experiment point to an increase in motivation in the majority of the players, but a significant segment of them did not experience this. The feature's effect on player retention proved hard to measure, but the produced results indicate that the effect is small, if present at all. However, the feature seems to show particularly great potential for further development that can increase both motivation and retention **(RQ5)**.

This potential aligns well with the test subjects' general perception of the feature. Several test subjects requested features that were originally included in the concept but dropped because of time limitations, such as chats and post comments. Furthermore, they requested even more social features beyond what we had conceived of. Additionally, several test subjects' found the feed somewhat bloated, which could be a reason for reduced interest in the feed **(RQ6)**.

The results from the experiment are inconclusive regarding the effect of the friend system because the effects on physical and social activity, motivation, and retention prove hard to measure. The feature did not garner large amounts of enthusiasm, and it was hard to evaluate due to the practical limitations of the experiment. The testing period was severely limited on time, and the group of test subjects faced challenges regarding sample size and demography. One must also consider how experimenter effects such as the Hawthorne effect, response biases, technical issues, or external factors such as weather or exams affected the end results. Despite the inconclusive effect of the friend system, the feature has shown itself to be a great basis for further development of features that may garner orders of magnitude more enthusiasm if implemented.

35 Further Work

This project has tested the feasibility of a simple friend system, but much work remains in improving it and testing its effects on players. The BitPet team intends to continue developing the feature and should thus consider its current potential and limitations. Since some feedback has gone beyond our concept, this chapter highlights future work regarding the friend system and BitPet as a whole.

35.1 Experiment

As mentioned previously, the experiment was limited by a short timeframe and non-representative demographics. To increase knowledge about the effects of the feature, one should perform testing through a more extensive experiment. Notably, the sample size should increase to draw more general conclusions. The quantitative data will also show clearer trends with more test subjects recruited. Furthermore, one can gather more meaningful data on player retention by extending the testing period from ten days to a month or longer. It would also be interesting to test this feature on other demographics, particularly other age groups, to see whether they interact differently. Finally, one should conduct a new experiment with A/B testing so the general effects of the game are distinguishable from those particular to the friend system [98].

35.2 Friend System and Social Features

Concerning future development of the feature, there are a vast amount of potential modifications. Initially planned functionality that was left out due to time constraints can be fully implemented, such as chats and comments. As mentioned in the discussion, these are also features that the interviewees requested. The BitPet team can also adjust the system per the feedback presented in this thesis. For instance, tweaking the thresholds for when posts occur, clarifying for players when new posts are triggered, seeing what players are online, etc. Part III also shows other features that could be complemented by a friend system and further enhance the social experience of the game. These include trading, visiting friends' bases, and trips with friends. Furthermore, a significant motivator for several test subjects was competition among friends. This indicates that further work on BitPet should include new methods of competing with friends, such as friend battles and a friend leaderboard.

35.3 BitPet as a Whole

Improvement suggestions go beyond the scope of the feature and to BitPet as a whole. The development team should consider incorporating these to please future players. Currently, BitPet has a limited pool of players; thus, this project could offer meaningful insights into the game's overall experience. The results showed that several participants were discouraged by the AR requirement. Though AR can offer meaningful and unique gameplay experiences, it is not an essential actuator for players' physical or social activity. Without AR, players would still have to be physically active when playing the game. Hence, the BitPet team should reflect on whether they want to adopt a mechanic similar to Pokémon GO, where players can choose if they want to use AR. Subjects also generally requested more information when playing the game and found certain parts confusing. Ensuring players understand the mechanics of the game should, therefore, also be of priority moving forward. Finally, other potential improvements include like more customizability to the home base and a leaderboard league system.

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Appendices

A GameFlow

Table 16: Game Flow Criteria [73].

Element	Criteria
Concentration Games should require concentration and the player should be able to concentrate on the game	• 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 shouldn't 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 Games should be sufficiently challenging and match the player's skill level	• challenges in games must match the players' skill levels • games should provide different levels of challenge for different players • games should quickly grab the players' attention and maintain their focus throughout the game • 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 Games must support player skill development and mastery	• 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 actions in the game	• 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 Games should provide the player with clear goals at appropriate times	• overriding goals should be clear and presented early • intermediate goals should be clear and presented at appropriate times

Feedback Players must receive appropriate feedback at appropriate times	• 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 experience deep but effortless involvement in the game	• 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 and create opportunities for 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

B Social Features

Table 17: Social Features [55].

Code	Social feature	Description
PRE1	Activity information	The game informs the player about friends' actions in the game world.
PRE2	Community challenge	Community tournaments and other organized events in the game, which are accessible for the player.
PRE3	Automatic friend bonus	Automatic gameplay bonus based on the number of friends playing the game.
PRE4	Friend requirements	The player cannot complete a gameplay task without requesting their friend to do an action.
PRE5	Off-game sociability	In-game links to off-game social spaces such as discussion forums, wikis and Facebook fan pages.
PRE6	Presence information	Player receives information about the presence of other players in the game.
PRE7	Scorekeeping	Ranking and scorekeeping information, where the player can compare their status against others.
PRE8	Social user-interface element	Graphical user-interface elements, which have a social reference such as player portraits, links, pop-up dialogues etc.
PRE9	Visit game space	The player can visit a friend's game space.
PRE10	Community progress indicator	An indicator representing community progress on a gameplay task.
PRE11	Relocate game space	Relocation of the player's own game space in the game world, to play in close proximity with friends.
COM1	Asynchronous communication	An ability to communicate with others via asynchronous means (e.g. in-game message system, discussion board, or sign posts in game space).
COM2	Facebook wall post to a friend	Sending a wall post to a friend's Facebook wall from the game.
COM3	Facebook wall post to own wall and the news feed	Posting a message from the game on a player's own Facebook wall and the news feed.
COM4	Facebook notification	In-game activity that is presented as a Facebook notification for other players
COM5	Invite request	Sending a request to a friend to join the game (also asking a friend to become a neighbor in some games).
COM6	Rematch/Replay	Requesting a rematch or replay from another player.
COM7	Request activity	Requesting an in-game gameplay action from a friend.
COM8	Request items	Requesting an item from a friend. Commonly known as a gift request.
COM9	Synchronous communication	An ability to communicate with others via synchronous means (e.g. chat).
INT1	Competitive action	Player vs. player gameplay action.

INT2	Facebook click post reward	Clicking a Facebook game post leads to an in-game reward.
INT3	Interaction reward	Interacting in a friend's game space leads to an in-game reward.
INT4	Receive items	Receiving items sent by friends. Commonly known as accepting gifts.
INT5	Remove friend	Removing a friend from in-game contacts/neighbors.
INT6	Send finite items	Sending an item to a friend. The sending player loses that item from her inventory.
INT7	Send in-app purchase items	Buying an item with premium currency in the game and sending the item to a friend.
INT8	Send infinite items	Sending an infinite item to a friend. Infinite items are free for the player and can be sent on a daily basis.
INT9	Synchronous interaction	Interacting simultaneously with a friend in the same game space.
INT10	Team formation	Forming a team or an alliance through in-game actions.

C Other Results

As mentioned in Part V, several criteria were defined and given to the participants to complete in order for their test to be valid. However, the questionnaires and interviews showed that several participants did not understand how to effectively gather pet points. Hence, the threshold for removal from the data set was instead defined at 400 pet points since this meant the test subject had at least played the game somewhat past the tutorial. However, one remaining test subject did not use the friend system and was thus discarded as well, leaving the final total of 20 participants.

Figure C.1 shows how many participants preferred to walk alone versus how many preferred to walk with others. Opinions were split, with the majority preferring to walk with others.

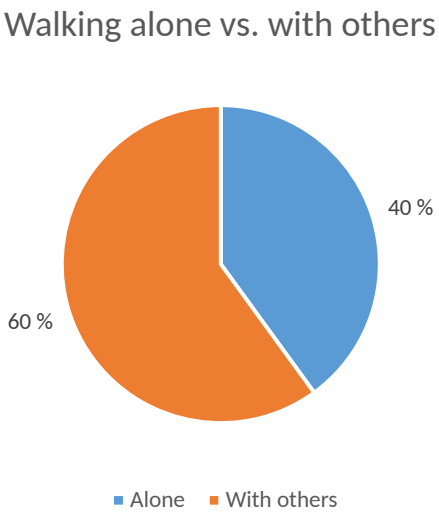


Figure C.1: Participants Preferring to Walk Alone versus With Others.

Figure C.2 depicts the ratio of participants that went on walks with the sole purpose of playing BitPet. Only one fifth of participants did so.

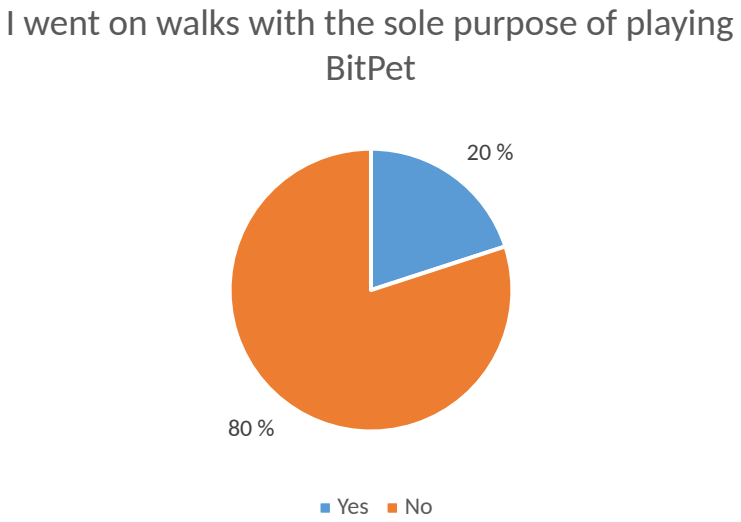


Figure C.2: Taking Walks Solely to Play BitPet.

D Instructions Sheet

BitPet

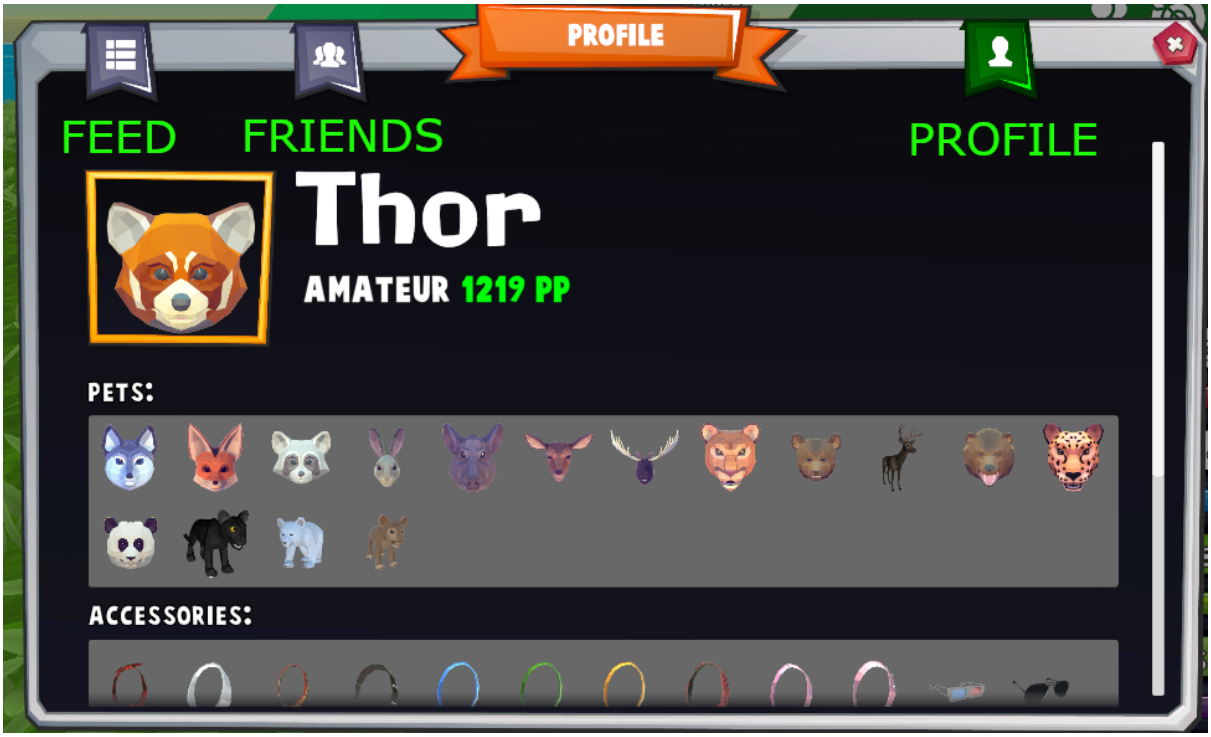
Thank you for taking the time to test our feature concept!

In order to test the application properly, we have defined a few goals for you to complete during this testing period. Some are required for the test to be valid, while most are goals which we hope you pursue and complete, but which are optional.

User Interface

To access the friend panel, you can press the following icon

The panel consists of three tabs: *Feed*, *Friends,* and *Profile*



Required goals

- Create a user profile and log in with it
    - Use the e-mail you received the instructions on
    - **Important:** Don't press "Play Now" when first opening the app. Go straight to creating an account with your email.
- Finish the tutorial
    - There is a known bug where the tutorial freezes at certain steps, simply restart the app once or twice when this occurs and it should resume.
- Add the following users as friends:
    - Magnus
    - ThorHerman
    - AlfInge
- Check out the friend feed after having successfully added some friends
    - *New entries will appear here as you and your friends progress*
- Beat another pet
    - *This will unlock it for purchase*
- Purchase a new pet in the store
- Walk more than 5,000 steps with one of your pets in one day
- Earn 4,000 pet points
    - *You can see your current pet points under your profile*
    - *You receive pet points naturally by playing the game*

Optional goals

- Add other test participants as friends
- Purchase a new pet accessory
    - *These will sometimes be unlocked for purchase after beating another pet in a challenge*
- Level up one of your pets to level 5
- Beat 10 pets in battle
- Finish the testing period with more pet points than Magnus and ThorHerman
    - *You can check the leaderboard to see your status*

E Pre-test Questionnaire

Questionnaire pre-test

This is a questionnaire that is to be answered before the test period of Bitpet.

* Required

Consent

Thank you for choosing to participate in this questionnaire. Question 2 is related to the information contained in the email with the link to this questionnaire as well as sent out when you registered interest in the project. You can at any time contact us at theggele@stud.ntnu.no in order to delete your data or withdraw from the project.

1. I have received and understood the research project “BitPet” and I have been able to ask questions. I consent to the following (can select multiple): *

- [ ] Participating in questionnaires and user testing
- [ ] Participating in interviews

2. I consent to results from this questionnaire being stored and used until the project ends. *

- ◯ Yes
- ◯ No

3. I consent to my BitPet-username being shared with other participants of this project *

- ◯ Yes
- ◯ No

Platform

4. Which platform will you be testing Bitpet on? *

- ◯ Android
- ◯ iOS

Demography

5. Enter the userID that was provided with the mail *

6. What is your gender? *

- Woman
- Man
- Other
- Prefer not to say

7. What is your age? *

- Under 18
- 18-24
- 25-34
- 35-44
- 45-54

Video Game Experience

8. How often do you play video games alone? *

- ◯ Daily
- ◯ Several times a week
- ◯ Weekly
- ◯ Monthly
- ◯ Never

9. How often do you play video games with friends? *

- ◯ Daily
- ◯ Several times a week
- ◯ Weekly
- ◯ Monthly
- ◯ Never

10. What types of platforms do you play video games on? *

- [ ] None
- [ ] PC
- [ ] Game consoles (PlayStation, Xbox, Nintendo etc.)
- [ ] Phone (Android, iOS, etc.)
- [ ] Other (please specify)

Phone Usage

11. What was your average phone screen time last week? Give an estimate if your phone does not have access to that information *

- ◯ 0-1 hours
- ◯ 1-2 hours
- ◯ 2-3 hours
- ◯ 3-4 hours
- ◯ 4-5 hours
- ◯ 5-6 hours
- ◯ 6+ hours

Physical Activity

12. How often do you go for walks in your spare time? *

- ◯ Daily
- ◯ Weekly
- ◯ Several times a week
- ◯ Monthly
- ◯ Never

13. When you go for walks, do you prefer walking alone or with others?

- ◯ Alone
- ◯ With others

Socialization

(Statements: 1=Disagree, 2=Neutral, 3=Agree)

14. I am comfortable in the presence of people I know *

1	2	3

15. I am comfortable in the presence of people I don't know *

1	2	3

16. I prefer being social over being alone *

1	2	3

17. I wish to meet new people *

1	2	3

18. I like to keep up with my friends' activities on social media *

1	2	3

19. I regularly interact with my friends online *

1	2	3

Other Feedback

20. Do you want to add additional feedback to this survey? If so, please leave it below

F Post-test Questionnaire

Questionnaire post-test

This is a questionnaire that is to be answered after the test period of BitPet

* Required

Consent

Thank you for participating in our survey, you can at any time contact us at theggele@stud.ntnu.no to delete your data or withdraw from the project

Demography

1. Please enter your UserID that was provided with the mail *

2. What device did you test the application on? *
   Specific phone model

Usage

3. How often did you play BitPet throughout the test period? *

- ◯ Several times a day
- ◯ Daily
- ◯ Every other day
- ◯ 5 times or less
- ◯ Never

4. When did you play BitPet? *

- ☐ While walking to a destination
- ☐ While indoors
- ☐ While talking a walk in my free-time
- ☐ Other

5. I went on more walks than normal while testing BitPet *

(1 = Fully disagree, 3 = Neutral, 5 = Fully agree)

1	2	3	4	5

6. I went on walks with the sole purpose of playing BitPet *

- ◯ Yes
- ◯ No

7. Was there anything hindering you from achieving the required goals? *

* Create a user profile and log in with it
* Finish the tutorial
* Add Magnus and ThorHerman as friends:
* Check out the friend feed after having successfully added some friends
* Beat another pet
* Purchase a new pet in the store
* Walk more than 5,000 steps with one of your pets in one day
* Earn 4,000 pet points

8. Did you play BitPet with friends in-person? *

Friend system

9. Did you try out the friend system while playing BitPet? *

- ◯ Yes
- ◯ No

10. Please specify why *

11. Did you add other players in BitPet? *

Beyond Magnus and ThorHerman

12. I regularly checked the friend activity feed *

(1 = Fully disagree, 3 = Neutral, 5 = Fully agree)

1	2	3	4	5

13. It was easy to navigate the friend system user interface *

(1 = Fully disagree, 3 = Neutral, 5 = Fully agree)

1	2	3	4	5

14. The friend system made me want to regularly return to BitPet *

(1 = Fully disagree, 3 = Neutral, 5 = Fully agree)

1	2	3	4	5

15. There was an appropriate amount of activity in the friend feed *

(1 = Fully disagree, 3 = Neutral, 5 = Fully agree)

1	2	3	4	5

16. I felt motivated by the fact that some of my in-game actions were shared in my friends' feeds *

(1 = Fully disagree, 3 = Neutral, 5 = Fully agree)

1	2	3	4	5

17. The level of activity made me want to play more *

(1 = Fully disagree, 3 = Neutral, 5 = Fully agree)

1	2	3	4	5

18. I regularly checked my friends' profiles *

(1 = Fully disagree, 3 = Neutral, 5 = Fully agree)

1	2	3	4	5

19. Being able to compare myself to friends made me want to play more *

(1 = Fully disagree, 3 = Neutral, 5 = Fully agree)

1	2	3	4	5

20. I frequently checked out who had reacted to my post *

(1 = Fully disagree, 3 = Neutral, 5 = Fully agree)

1	2	3	4	5

21. I frequently reacted to my friends' posts *

(1 = Fully disagree, 3 = Neutral, 5 = Fully agree)

1	2	3	4	5

22. I was motivated by seeing who had reacted to my post *

(1 = Fully disagree, 3 = Neutral, 5 = Fully agree)

1	2	3	4	5

23. I deliberately avoided playing Bitpet when it was raining or snowing *

(1 = Fully disagree, 3 = Neutral, 5 = Fully agree, 6 = Not applicable)

1	2	3	4	5	6

24. Do you have any improvement suggestions or other feedback regarding the friend system?

Errors

(Statements: 1=Disagree, 2=Neutral, 3=Agree)

25. Did you encounter any errors or bugs while testing the game? If so, please elaborate below.

26. Did any of these errors or bugs prohibit you from completing the testing requirements?

Other Feedback

27. Do you want to add additional feedback? If so, please leave it below

G Request and Consent Form

Would you like to participate in the research project *Implementing and Evaluating a Friend System in BitPet?*

This is a request for you to participate in a research project with the purpose of evaluating a friend system in an AR- and GPS-based game aimed at encouraging physical and social activity. This letter will provide information about the project goals and what participation will mean for you.

Purpose

This research is being conducted as part of a master's thesis at NTNU Trondheim, Faculty of Information Technology and Electrical Engineering, Department of Computer Science. The purpose of this project is researching how a friend system affects engagement and player retention in the AR- and GPS-based exergame BitPet. BitPet is a game in which you keep virtual pets and take them for walks. Training and accessorizing the pet can be done by moving in real life, with the app counting your steps as you go.

Who is responsible for the project?

The research is being conducted by master's students Thor-Herman van Eggelen and Magnus Hanesand. Professor Alf Inge Wang at the Department of Computer Science is the project's supervisor and ultimately responsible for the project.

Why have you been asked?

You have been asked to participate because you have participated in a forum we have considered relevant to the game in consideration, or because you are a part of the researchers' networks.

What will participation mean for you?

By participating in the project, you will be taking part in an experiment spanning 9 days. We will ask you to fill out a digital survey mapping your gaming and phone usage habits in the beginning of the project.

When the 9 days have passed, we will ask you to fill out a post-survey summarising your experiences. You may be summoned for an in-depth interview. It will be possible to withdraw from the pool from which we draw interviewees. You can do this by not consenting to being interviewed in the form on the last page. The interviews will be recorded, with the recordings being deleted upon the completion of the research project.

Your answers to the survey will be collected digitally. Game data will be stored in an encrypted cloud service, decoupled from any personal data. This data will be deleted upon the completion of the project, or whenever you request it.

Participation is voluntary

Participation in the experiment is voluntary. Your consent to participating can be withdrawn at any moment. All personal data will in that case be deleted.

How will we treat your personal information

Your personal data will only be used for the purpose described in this letter. Your data will be handled confidentially and in accordance with Norwegian privacy laws.

The access to your personal data will be exclusively available to the people described in the earlier section “Who is responsible for the project?”.

The following information is stored by the game client and servers:

- E-mail, username, date of registration
- Number of steps walked while the application is running
- Number of times the app has been opened
    - Other clicks inside of the app
- Operating system of the device
- Failed and successful transactions

Upon completion of the testing period, the game data will be exported and stored along with interview and survey data in Microsoft SharePoint cloud storage. The information will be encrypted and locked behind the NTNU organisation login. You can find further reading about Microsoft SharePoint’s treatment of your data here.

What happens to your personal information when the project is finished?

When the project is finished with an approving grade, all personal information will be deleted. Survey responses will be anonymised when interviewees have been chosen. The interviews will not be anonymised, only deleted upon completion of the project.

Your rights

For as long as your data makes you identifiable in our systems, you have the right to:

- Know what personal information we have stored and access to a copy of this
- Have your personal information corrected
- Have your personal information deleted
- Send a complaint to the Norwegian Data Protection Authority (Datatilsynet) about the handling of your personal information

What allows us to handle your personal information?

We handle your personal information based on your consent.

NSD - Norwegian Centre for Research Data has assessed that our treatment of your personal information is in accordance with Norwegian privacy laws.

How can I find out more?

If you have any questions or would like to exercise your rights as described under “Your rights”, please contact:

- The research conductors
    - Magnus Hanesand: magnhan@stud.ntnu.no
    - Thor-Herman van Eggelen: theggele@stud.ntnu.no
- Supervisor:
    - Alf Inge Wang: alf.inge.wang@ntnu.no
- The Data Protection Officer at NTNU

If you have any questions about the assessment NSD has made of the project, please contact:

- NSD - Norwegian Centre for Research Data by email (personverntjenester@nsd.no) or by phone (+47 55 58 21 17)

Regards

Alf Inge Wang (Supervisor)	Magnus Hanesand (Research conductor)	Thor-Herman van Eggelen (Research conductor)

Consent form

I have received and understood information about *Implementing and Evaluating a Friend System in BitPet*, and have been given the opportunity to ask questions. I consent to

- ☐ Participating in the digital survey
- ☐ Participating in the experiment evaluating the mobile application BitPet
- ☐ Participating in the random draw of interviewees and the subsequent interview

I consent to having my personal information handled until the project has been completed

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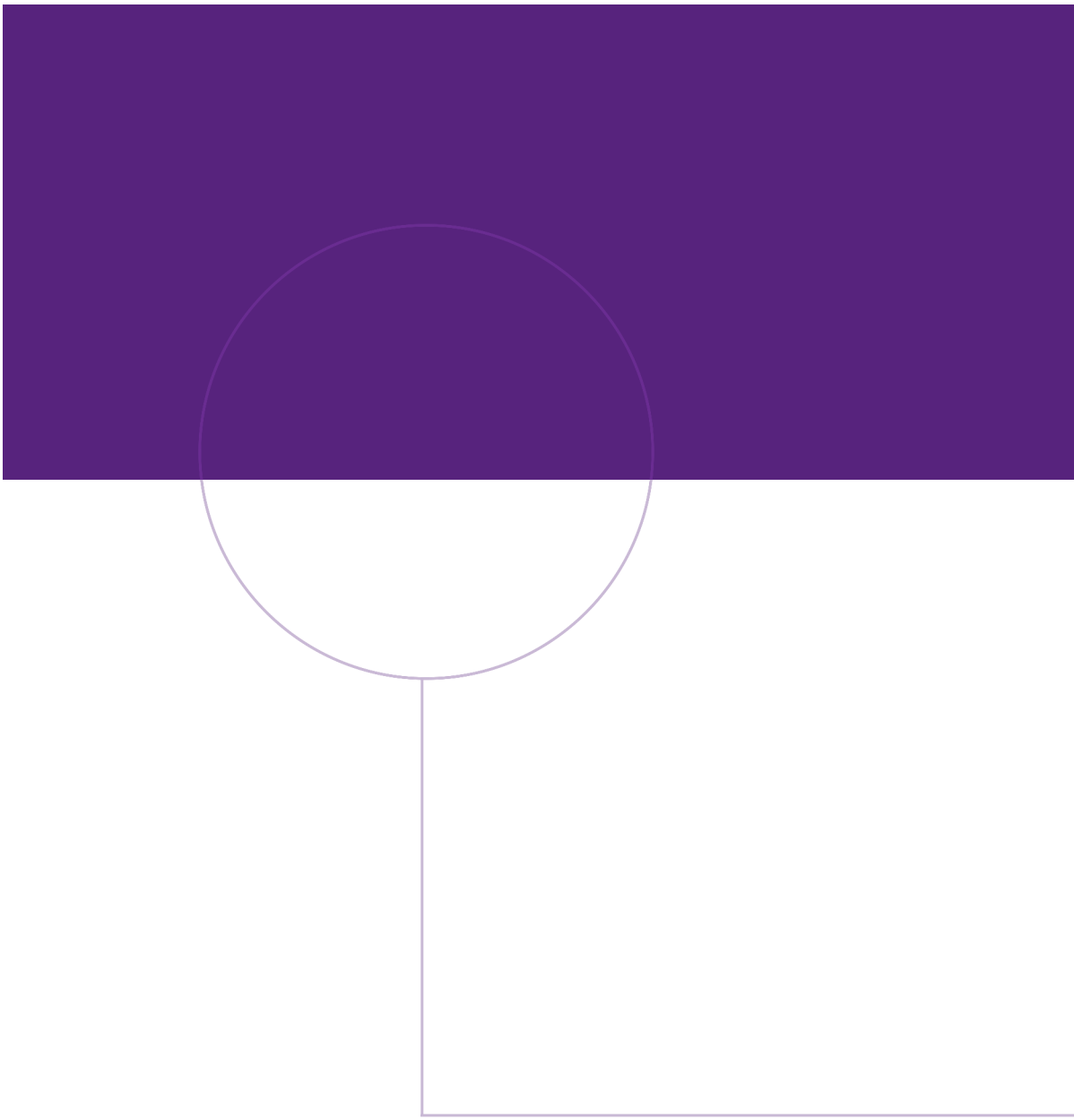
(Signed by the participant, date)



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