PETBUDDY: AUGMENTED REALITY EXERGAME TO INCREASE PHYSICAL ACTIVITY

By

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Abstract

The prevalence of sedentary lifestyles in this technology-driven world is a significant public health concern, as it is linked to chronic diseases and diminished well-being. The rise in sedentary behaviour poses a major health challenge, necessitating innovative solutions to promote physical activity and overall health. While some technologies contribute to the problem, others offer solutions. Exergames, which combine exercise with gaming elements, create engaging and enjoyable PA experiences. However, research shows that if these games aren't fun and engaging, people may lose interest. Therefore, developing a fun and engaging exergame is crucial for maintaining sustained participation in PA. This thesis explores the potential of advanced technology to counteract sedentary trends by promoting PA through fun, engaging and immersive experiences. The study focuses on the development and evaluation of "PetBuddy," a mobile application designed to encourage regular walking and increase overall PA. The app integrates game experiences like AR, emotional engagement, and idle game design, along with gamification elements such as leaderboards, shop, points, and user profiles, employing persuasive strategies. A user study with 65 participants over 10 days assessed the app's effectiveness, while interviews with 17 participants provided deeper insights. The study used both quantitative and qualitative methods, including surveys and interviews, to evaluate the app's design and impact. The results revealed a significant increase in PA among participants, with many achieving the WHO's recommended weekly PA level of 600 METs. The intervention proved effective across all age and gender groups, with younger individuals and females showing particularly strong gains. The AR features and competitive elements, such as leaderboards, were found to be highly motivating for users. These game experience and elements kept users engaged and encouraged them to continue using the app, thus sustaining increased PA levels. Participants reported finding the app enjoyable and user-friendly, highlighting the importance of enjoyable and interactive elements. These findings highlight the potential of combining game experiences and gamification elements to promote healthier lifestyles by making PA more enjoyable and engaging. Overall, these findings highlight the positive impact of the exergame in increasing PA levels, promoting overall well-being.

List of Abbreviations

AR	Augmented reality
AWS	Amazon web services
GPAQ	Global physical activity questionnaire
HCI	Human-Computer Interaction
IMI	Intrinsic Motivation Inventory
MET	Metabolic equivalent task
PA	Physical activity
PT	Persuasive technology
PTs	Persuasive technologies
PSD	Persuasive system design
SUS	System usability scale
UCD	User-centred design
UI	User interface
UEQ	User experience questionnaire
WHO	World health organization

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Chapter 1: Introduction

In recent years, sedentary lifestyle has become a major health concern across the world [1], [2]. This is especially true with the rise of technology and the increasing use of computers and other devices that encourage people to remain in a sedentary position for extended period [3]. Low participation in PA is thought to be influenced by multiple factors. Environmental factors include air pollution, a shortage of parks or pedestrian walkways, and a lack of sports or leisure facilities [4]. Additionally, activities such as television viewing and video watching are correlated with a more sedentary lifestyle [5]. However, not all the forms of technology encourage sedentary behaviours. For example, there is a new generation of technologies such as smart watches, accelerometers, pedometers, and activity bracelets that monitor people's activity levels and encourage people to engage in PA [6].

An inactive lifestyle, that is predominantly sedentary without adequate exercise, has been described as one of the serious public health problems of the 21st century [2]. Research shows that physical inactivity is one of the leading risk factors for global mortality [7], [8]. Encouraging young people to adopt a healthy lifestyle and develop PA habits can help to prevent chronic conditions including coronary heart disease, stroke, type 2 diabetes, cancer, and musculoskeletal disorders [9]. To maintain good health and decrease mortality rates, it is important to make a conscious effort to keep physically active and reduce sedentary behaviour. New forms of technology can support these efforts by providing tools and incentives to help people monitor and increase their PA levels.

The primary focus of this research is to investigate the power of technology for encouraging PA. In this thesis a mobile intervention was developed using the game experience and gamification elements using persuasive strategies to promote PA through walking. This approach enhances the experience by incorporating game experience such as AR technology and gamification elements. Enhancing the experience is important because many individuals do not find PA intrinsically motivating. By making the process more engaging and enjoyable, the aim is to boost user motivation and adherence to regular

PA. Gamification and AR can help transform ordinary exercise routines into immersive and fun experiences, making it easier for people to incorporate PA into their daily lives and sustain a healthy lifestyle.

1.1 Problem Statement

One out of every three adults worldwide, aged 15 years and older, fails to achieve enough exercise, which can harm their health [2]. Not only that, but many people also spend a great deal of time sitting down, which is called sedentary behaviour [10]. For example, Americans spend about 55% of their awake time (around 7.7 hours a day) sitting, while Europeans spend about 40% of their free time (about 2.7 hours a day) watching TV [1]. Similarly, a significant portion of Canadian adults face a heightened risk of poor health outcomes, as the majority (82.5%) do not meet the physical activity guidelines and spend much of their day being sedentary (9.6 hours) [11]. We know that not getting enough exercise, or being physically inactive, is bad for health. In fact, it's the fourth leading cause of death worldwide, contributing to about 6% of all deaths [3]. Sedentary behaviour refers to any time spent sitting or reclining with minimal PA, such as not walking around [5]. Living a sedentary life can raise your chances of dying from any cause and increase your risk of heart problems, diabetes, high blood pressure, and certain cancers (like breast, colon, colorectal, endometrial, and ovarian cancers) [2].

PA encompasses any movement of the body that uses energy, such as walking, lifting, exercising, playing, traveling, biking, dancing, gardening, and doing household chores [6]. It is really important for keeping people healthy and happy [9]. Insufficient exercise can result in increased health issues and, in severe cases, mortality [7], [8]. On the other hand, being active helps lower the risk of diseases like heart disease, diabetes, and cancer [12]. The more exercise you do, the lower the risk. Regular PA also brings many health benefits and promotes longer life [13]. Therefore, emphasizing the significance of consistent PA is crucial for promoting overall health and wellness. Consequently, comprehending and advocating for methods to boost participation in PA within today's society have significant implications for public health and well-being. The WHO has set the standard guideline for adults, recommending a minimum of 150 minutes of moderate-intensity aerobic exercise

per week or 600 MET minutes [6]. Engaging in activities such as walking, cycling, brisk walking, and swimming can assist individuals in meeting their PA goals [12].

Today, children and adolescents spend most of their free time engaging in sedentary activities such as watching TV for hours, continuously surfing the Internet on computers, or playing video games without interruption [14]. Research suggests that people are attracted to interactive video and computer games because they can satisfy basic psychological needs [15]. Given their tendency to prefer interactive computer games, there is a genre of games that are purposefully designed to encourage PA to play. Such games are commonly referred to as active video games (also known as, exergames) that require players to interact with the game which requires some physical effort[16]. Exergames are interactive digital games that encourage participation in PA [17] and have been shown to be particularly effective for people who may be reluctant to engage in the more traditional forms of exercise [18]. Exergames have the potential to reduce sedentary behaviours and engage youth in physical activities. Consequently, exergames have been increasingly utilized in recent years as a method to promote PA among children and adolescents. Previous research indicates that while exergames can initially spark interest in exercise [14], this interest tends to decline if they are not enjoyable and engaging [19][20]. Therefore, it is important to develop an exergame that is both fun and engaging, as these factors are crucial for motivating and sustaining continued participation in PA [9],[21],[22]. It has been acknowledged that exergames can offer enjoyable experiences, with this enjoyment being a key factor in motivating individuals to participate in and continue playing the games [14].

1.2 Solution

Exergaming has been shown as an innovative and effective tool for promoting PA across various populations [23]. However, previous research has shown that interest in exergames can wane if they are not engaging and enjoyable [19][20]. By leveraging innovative approaches with persuasive technology, there is potential to design interventions that effectively encourage individuals to increase PA levels while making it fun and engaging experience.

To contribute to research in exergames and persuasive technology for promoting PA, this work presents the design, development, and evaluation of a mobile exergame intervention aimed at increasing PA. This study aims to develop an effective intervention to motivate individuals and enhance their PA levels through enjoyable features. To achieve this, we created a mobile intervention called "PetBuddy," which harness the persuasive capabilities of game experience along with gamification elements. PetBuddy incorporates three key game experiences—AR, emotional connect, and idle game design to promote healthy behavioural changes and support a more active lifestyle through an immersive and engaging approach to PA.

Recent years have witnessed the integration of advanced technologies into exergames. One of these technologies is AR, which is used to encourage PA by integrating virtual components into the player's environment [24]. AR is a type of user interface technology that combines real-world views captured by a camera with computer-generated elements, like notes, graphics, animations, and 3D models [26]. AR technology transforms exergames into interactive experiences. Smartphones have become powerful enough to run AR technology smoothly, leading to a rise in the number of mobile AR applications that do not require additional hardware [25]. AR applications give users the chance to see the real world with added digital elements, making it more exciting and interactive [26]. Combining experience like AR with game elements make exergames more enjoyable and engaging way of staying active and healthy. We integrated additional game experiences such as emotional engagement and idle game design to enhance game engagement. Emotions are crucial for motivation, as they stimulate, and guide behaviours necessary to achieve the desired goals [27]. Likewise, idle games have become increasingly popular due to factors like accessibility and their alignment with modern preferences for multitasking and efficient time management [28].

The PetBuddy encompasses four gamification elements, each with specific functionalities aimed at promoting PA which are implemented through the Persuasive Systems Design (PSD) model [29]. This method has been identified as effective in fostering healthy behavioural changes by increasing engagement [30]. Consequently, incorporating

gamification into interventions for promoting PA is expected to enhance their overall effectiveness.

To evaluate the effectiveness of the solution, this study was conducted in two phases:

Phase 1: A system usability study was performed after the beta version of the app was developed. Participants from Dalhousie University, who were knowledgeable about HCI, provided feedback that was used to refine the final version of the application for the main study.

Phase 2: The main study, approved by the Dalhousie Research Ethics Board (see Appendix A), involved recruiting participants from Canada. They were instructed to use the app for 10 days, and pre- and post-study surveys were administered to assess the app's impact.

1.3 Contribution

The study presented in this thesis makes significant contributions to the field of Human-Computer Interaction (HCI) and game user research. It offers a thorough overview of existing studies, provides valuable insights for researchers and individuals interested in this area. This thesis addresses three research questions and provides answers to the following:

RQ1: How effective is the PetBuddy app in motivating physical activity?
RQ2: How effective are the game experience in the app in motivating physical activity?
RQ3: How effective are the persuasive strategies implemented in the app for healthy behavioural change toward physical activity?

To answer these three-research question, we designed, developed, and evaluated a mobile intervention called PetBuddy. The measurements and findings of this study offer valuable insights for future research, enabling researchers to adapt and enhance approaches for similar apps. Moreover, industry partners can utilize these findings to develop exergames that aligns with evidence-based strategies and interventions. This thesis contributes significantly to the field by introducing innovative methodologies for designing exergame apps, promoting increased PA, and supporting the development of healthy behavioural changes.

1.4 Research Overview

The remainder of this thesis is organized as follows:

- In chapter 2, we review background research in the field of sedentary behaviour, physical activity, mobile and AR technology, emotion and idle game design, walking, and persuasive strategies to build persuasive interventions that formed the foundations for this research.
- In chapter 3, first, we define concrete objectives that we aim to fulfil through our research. Then, we explain the development of our intervention in detail.
- In chapter 4, we provide an outline of the study design to capture the effectiveness of our intervention.
- In chapter 5, we present the results from the analysis conducted after study.
- In chapter 6, we discuss our findings in relation to existing research, reflect upon our research objectives, and share our design recommendations. Then, we identify the limitations of our work and offer directions for future research.
- In chapter 7, we summarized the main findings of the research and offer some closing remarks.

Chapter 2: Related Works

In today's world, the intersection of health, PA, and technology is gaining significant attention. However, the widespread rise in sedentary behaviour poses a major health challenge, linked to various chronic diseases and diminished well-being [31]. Nevertheless, technology emerges as a promising tool in tackling this issue. While certain technological activities contribute to sedentary lifestyles, innovative interventions have the potential to promote PA and overall health.

This chapter reviews existing studies on promoting PA, forming the foundation for the research and providing insights into current practices. It begins by examining research on health and PA, including initiatives designed to foster healthier behaviours and increase PA levels. The chapter explores various technologies, including mobile technologies and exergames, that motivate and enhance PA. The benefits of walking for PA and its overall health impacts are also discussed. Additionally, the chapter investigates how AR technology can make PA more enjoyable. In addition, the chapter delves into the concept of emotional engagement and its role in motivating individuals. The principles of idle game design are also considered, recognizing its potential to keep people engaged in promoting PA.

Moreover, we examine research on integrating persuasive strategies into PA interventions, aiming to understand how these can encourage people to stay active. By combining and carefully examining these various aspects of related research, we obtain valuable insights from the current literature. Drawing upon this comprehension, we have developed a thesis that not only builds upon existing studies but also integrates cutting-edge technologies to enhance the effectiveness and allure of our proposed intervention.

2.1 Health and Physical Activity

Physical activity can be defined as any bodily movement produced by skeletal muscles that results in energy expenditure [32]. PA is not only about sports, but also includes everyday activities such as walking, running, swimming, dancing, playing ball games, doing gymnastics, martial arts, and many other types of activities [33]. Previous research on living a healthy life by Piercy et al. [34] strongly supports the positive effects of regular

PA and highlights the dangers of being inactive or sedentary. Engaging in a single bout of moderate-to-vigorous PA can lead to enhanced sleep quality, decreased anxiety symptoms, improved cognitive function, lowered blood pressure, and increased insulin sensitivity on the same day as the activity. Furthermore, with consistent participation in moderate-to-vigorous PA, these benefits tend to amplify, and additional advantages may also emerge.

In 2020, WHO released new guidelines on PA and sedentary behaviour, developed following WHO protocols and reviewed by Bull et al. [35], an expert Guideline Development Group. These guidelines cover various age groups, including children, adolescents, adults, and older adults, and include specific recommendations for pregnant and postpartum women, as well as individuals with chronic conditions or disabilities. For adults, it is recommended to engage in 150–300 minutes of moderate-intensity or 75–150 minutes of vigorous-intensity PA per week, or a combination of both. Muscle-strengthening activities are recommended for all age groups. Additionally, reducing sedentary behaviour is advised across all age groups, although a specific threshold for sedentary behaviour was not quantified due to insufficient evidence. These guidelines emphasize that engaging in some PA is better than none, and more PA yields better health outcomes.

While Epidemiological studies often categorize physical activities based on energy expenditure, but public health recommendations should focus on promoting specific activities rather than simply energy expenditure [36]. Walking is a prime example because it is popular, affordable, and carries a low risk of injury. Allen et al. [37] highlighted the protective benefits of walking against heart attacks and coronary events, particularly among older adults. Aldenaini et al. [38] suggested that brisk walking is associated with reduced risks of heart disease and type II diabetes, and it contributes to improved overall fitness and decreased mortality rates. Moreover, walking is well-suited for older individuals, offering functional improvements and potential quality of life enhancements, with minimal risk of injury [39]. Proper et al [40], suggested that incorporating daily physical activities, such as parking farther away and walking to your destination, or choosing stairs over the elevator, can lead to small but significant increases in PA. These

minor adjustments that can be easily integrated into people's daily living and have the potential to contribute to overall improvements in health through increased PA.

Researchers have studied the advantages of staying physically active for a healthy life. For instance, regular PA can lower the risk of conditions like hypertension, heart disease, obesity, diabetes, and certain cancers [41]. Individuals who engage in consistent PA can significantly lower their risk of mortality, irrespective of the cause, and active individuals typically extend their life expectancy by approximately two years compared to their sedentary counterparts [42]. Additionally, regular PA yields various other benefits, including enhanced self-esteem, improved fitness levels and appearance, as well as increased self-confidence. It is crucial to emphasize that physical fitness encompasses more than just being well or being sick; rather, it constitutes a fundamental aspect of a fulfilling life.

2.2 Technology and Physical Activity

Lack of PA is a major global health issue, linked to higher risks of chronic diseases and negative impacts on both physical and mental well-being [43]. Technology-based interventions have surfaced as a possible solution to encourage PA and enhance mental health results [31]. Emerging technology presents a dual role in sedentary behaviour, contributing to both the problem and the solution.

Researchers conducted a study to assess the efficacy of technology-based interventions in increasing PA levels and improving mental health outcomes in both healthy and clinical populations. A meta-analysis found that interventions using mobile phones, the internet, and wearable devices were effective in promoting PA and reducing sedentary behaviour [44][45]. Study reported that technology-based PA interventions helped participants achieve their health and fitness goals, monitor their progress, and stay motivated to reach their fitness targets. Additionally, the convenience and accessibility of these interventions provided an easy way to incorporate PA into daily routines.

Gupta et al. [46], developed a web application called FitViz to aid arthritis patients in managing PA, with input from both physiotherapists and patients. Key requirements

included allowing clinicians to review activity data, extracting activity bouts and non-sedentary hours, and enabling patients to view their activity details. The system architecture involves clinicians setting personalized plans, Fitbit collecting activity data, and FitViz visualizing this data for patients. Evaluation via a pilot study with Rheumatoid Arthritis (RA) and knee Osteoarthritis (OA) patients showed increased awareness of activity behaviour, facilitated goal setting with clinicians, and strategies to increase PA. FitViz demonstrated the potential of technology to support PA management for arthritis patients through tailored goal setting, awareness support, and flexibility in goal achievement.

A systematic review and meta-analysis by Kirk et al [47], examined the efficacy of wearable technology in promoting PA behaviour change among adults suffering from chronic cardiometabolic diseases. The study synthesizes findings from various research articles to assess the impact of wearable devices, such as fitness trackers, on increasing PA levels and improving health outcomes. The meta-analysis reveals significant positive effects of wearable technology interventions on increasing PA duration and intensity, suggesting their potential as effective tools for promoting active lifestyles and managing chronic conditions. The study emphasizes how wearable technology can help people with chronic heart and metabolic conditions change their behaviours to be more active. It shows that these devices could be crucial for improving health and suggests there are many ways to explore their use in future research and healthcare.

Buchele and Chen [48] investigated the impact of a 4-week technology-enhanced PA intervention on fifth-grade students' real-time daily PA and aerobic fitness levels. The participants were assigned to one of three groups: an intervention group engaging in daily PA engaging the brain with Fitbit Challenge (PAEB-C), another intervention group wearing Fitbits only (Fitbit-O) daily, and a comparison group. Real-time PA data were collected via Fitbit, and aerobic fitness was pre- and post-tested. Results showed that PAEB-C students had significantly higher levels of activity and lower sedentary time compared to the Fitbit-O group. Both Fitbit groups demonstrated greater increases in aerobic fitness scores compared to the comparison group over time. Additionally, boys were found to be more physically active and fit than girls. The study concluded that

technology-enhanced PA intervention was effective in improving real-time PA and aerobic fitness levels among fifth-grade students.

In summary, studies presented in this section underscore the potential of technology to both exacerbate and alleviate sedentary behaviour, highlighting the importance of tailored interventions and support structures in promoting health and PA.

2.3 Mobile Technology and Physical Activity

Mobile apps have been studied for their potential to improve people's health and can be seen as a cost-effective and scalable solution. Using mobile apps to encourage exercise alongside healthy eating could boost health learning and potentially lower rates of non-communicable diseases, or at least help monitor and manage these illnesses [49]. A research study Pradal-Cano et al [49], reviewed several randomized clinical trials to see if using apps could help people exercise more. The results show that these app-based interventions are well liked and can help people reach moderate or intense levels of PA. Allen et al. [37] discovered that approximately 25% of participants considered the smartphone app the most beneficial aspect of the program, while all participants believed that using a tracking device would enhance their motivation to exercise. Furthermore, giving personalized exercise plans and advice through mobile technology has been proven to help people stick to their exercise routines and improve their overall health by focusing on what each person needs and prefers [49].

Another systematic review by Aldenaini et al. [38], examined studies that focus on various forms of mobile phone-based persuasive technology, encompassing those designed for smartphones and traditional cell phones, with the aim of addressing both sedentary behaviour and PA. Findings suggest that mobile phone-based PTs effectively promote PA and reduce sedentary behaviour, with 79% of the reviewed studies reporting successful or partially successful outcomes. Moreover, integrating mobile phone-based PT with activity trackers and sensors emerges as the most effective approach, yielding successful outcomes in 83% of studies in this category. The second most effective approach involves solely using mobile phone-based PT, with or without embedded sensors, achieving a success rate

of 80%. Additionally, incorporating mobile phones with gaming ranks third in effectiveness, with 87% of studies reporting favourable outcomes.

These findings highlight the suitability of mobile phones for deploying persuasive tools, owing to their widespread usage and tracking capabilities. The review identifies the top 10 most effective strategies for mobile phone-based PT, including tracking/self-monitoring, personalization, goal setting, reminders, social support strategies, praise and reduction, social competition, suggestion, social comparison, and tunnelling and social cooperation. Furthermore, most studies targeted behaviour change related to increasing PA, reducing sedentary lifestyle, or both, while others addressed motivation, awareness, and attitudes.

Elnagger et al. [39] examined patients' perspectives on mHealth interventions designed to boost PA maintenance post-completion of a Cardiac Rehabilitation (CR) program. Participants in this study found Fitbit devices user-friendly and beneficial for tracking their daily activity and progress. Additionally, they utilized mobile phone apps to monitor their PA, which aided in sustaining and enhancing their physical fitness. The study highlights the favourable reception of mHealth technologies in promoting PA among older adults post-CR. Participants expressed expectations for utilizing mHealth technology to track various health metrics, monitor personal progress, and engage in personalized communication with research staff. These findings lay promising groundwork for a community-based PA program post-CR, augmented by secure mHealth technology to offer personalized feedback and social support.

A comprehensive review done by Muntaner, Vidal-Conti and Palou [50], was undertaken to consolidate and refresh the current body of literature concerning interventions employing mobile devices to promote PA. Given the concerning levels of physical inactivity worldwide, especially in rapidly expanding urban settings, mobile devices have become indispensable instruments for PA initiatives. With diverse technical functionalities like voice response, text messaging, and Internet connectivity, smartphones are increasingly prevalent, notably in Spain, where smartphone adoption rates reach 55% of the populace. Mobile apps hold considerable promise in advancing public health by furnishing real-time feedback, facilitating goal setting, and offering seamless access to

information. In essence, mobile devices represent cost-effective tools that have gained widespread adoption, emerging as pivotal resources for disease prevention and interventions aimed at influencing health behaviours.

Overall, mobile devices represent indispensable resources for public health initiatives, offering diverse functionalities to influence health behaviours and address the global challenge of physical inactivity.

2.4 Exergames for motivating Physical Activity

Exergames are interactive digital games that encourage participation in PA [51] and be particularly effective for people who may be reluctant to engage in the more traditional forms of exercise [18]. Exergames are also referred to as active video games [51], motion-based games [52], exercise games [53], exertion games [54], fitness games [55]. Research suggests that exergames are considered enjoyable and entertaining ways to encourage people to be more physically active and promote better health [56], [57][58][59][60]. The primary aim of games utilizing kinetic interfaces is to incentivize individuals to engage in PA. The premise is that by merging the enjoyment of video games with PA, individuals will be more inclined to participate in exercise. While traditional sedentary video games and computer games exacerbate physical inactivity, recent innovative technologies like mobile applications (e.g. Zombies Run![1]), wearable health devices (e.g. Fitbit), and active video games (DDR or BoxVR) can be leveraged to promote PA and health [8].

Berkovsky et al. [61], devised a game called "PLAY, MATE!", to incentivize players to engage in PA while gaming. It entails adjusting the game to reward specific features with virtual incentives, informing players of the opportunity to earn these rewards through real-world activity, and offering an interface that captures and converts PA into rewards. Using the accelerometer and GPS on mobile devices, the game monitors activities like jumping and running/walking, allowing players to accrue points for casual physical exertion, which can then be used to acquire in-game items. The objective is to seamlessly integrate PA into gameplay without compromising the overall enjoyment of the gaming experience. In a

[1] https://zrx.app/

trial with 135 young players, researchers found that activity levels increased while the enjoyment of playing remained high. This suggests that games designed to encourage PA could change how people play games and help them live healthier lives.

A study by Yim and Graham [54], investigated the growing popularity of physically engaging games and their potential to inspire individuals to engage in exercise. This study explores the potential of physically engaging games to motivate exercise among non-exercisers by addressing issues like weak exercise identity and low self-efficacy. It introduces "Life is a Village" (LIAV), a multiplayer exercise game where players control avatars using a recumbent bicycle and wireless controller in a virtual world. The game's realistic physics simulate increased speed with harder pedalling and more challenging uphill climbs, designed for stability and comfort suitable for overweight or inexperienced individuals. LIAV includes cooperative gameplay, allowing players with varying fitness levels to participate together by completing quests and avoiding snowball attacks. The study highlights LIAV as a model for integrating these principles into game design, with plans for future development focusing on creating a persistent multiplayer environment and incorporating biometric feedback for enhanced gameplay control.

Many games have been designed to promote PA in various ways to motivate people to stay physically active. For example, “FitQuest” is a mobile game played while running in the real world [62]. It uses GPS technology to update the player's location in the game world based on their real-world location. The game features eight mini-games with a farmyard theme, incorporating running or walking mechanics and tasks such as collecting objects, evading characters, and racing against time. For instance, in "Collect the Coins," players must gather yellow coins within a specified time while avoiding a wolf character. Successful collection is indicated by phone vibration. Points are awarded based on individual performance improvement rather than comparison to benchmarks or other players. While typically fostering social interaction, FitQuest currently lacks multiplayer mini games involving simultaneous participation of multiple players.

“Woody” is an Android smartphone game designed to increase outdoor activity and teach children about trees and nature in urban areas [63]. It combines PA through location-based

interactions with educational information about trees. In this game, participants must venture outdoors to locate actual trees and utilize their smartphones to engage with them, ensuring the survival of the game's character, a timber worm. Initial assessment findings indicate that children derived enjoyment from the gameplay experience and augmented their outdoor PA levels.

“BunnyBolt” is a maps-driven exercise game for youth. It disguises in-app exercises with a youth-friendly storyline, making it engaging and beneficial for all ages [64]. In “Nourish Your Tree!” the persuasive exergame encourages PA by using a tree metaphor to link a player's PA level (measured by step counts) to the health of a virtual tree [65]. The game utilizes a tree metaphor that correlates a player's PA level, measured by step count, with the health of a virtual tree. Consequently, as the player engages in physical activities like walking or running, the tree thrives. Conversely, if the player's PA decreases, the tree begins to deteriorate. To enhance player motivation and ensure an enjoyable experience, the game incorporates several persuasive strategies rooted in the Persuasive Systems Design (PSD) framework.

Collectively, these games aim to make PA more enjoyable and accessible while promoting a healthy lifestyle. Research in this area focuses on understanding the motivational factors behind exercise-oriented games and designing interventions that effectively motivate individuals to adopt active lifestyles. These initiatives illustrate the potential of exergames to transform gaming interactions and contribute to the promotion of healthier lifestyles by making PA engaging and accessible.

2.5 Walking as Physical Activity

Walking stands as one of the most universally embraced forms of exercise globally. It offers numerous health benefits without the need for expensive equipment or specialized skills [66]. Whether you opt for a tranquil stroll amidst nature, a brisk walk-through bustling city street, a session on the treadmill, or a few laps around your workplace, walking presents a readily accessible means to maintain PA. Some individuals might perceive walking as less impactful compared to more strenuous workouts. However, a comprehensive cohort study involving both runners and walkers revealed that over a six-

year period, when expending the same amount of energy, engaging in moderate-intensity walking provided comparable benefits to high-intensity running. These benefits included reducing the risk of conditions such as high blood pressure, high cholesterol, and diabetes [67]. The WHO has set the standard guideline for adults, recommending a minimum of 150 minutes of moderate-intensity aerobic exercise per week or 600 metabolic equivalent task (MET) minutes [35].

In England, McIlroy, Useche, and Gonzalez-Marin [68] explored the viability of introducing and assessing an intervention where advocates for walking to work are enlisted and trained to motivate colleagues who presently do not walk or cycle to work to increase their walking during the daily commute. The research centres on baseline data to investigate the correlation between commuting mode and objectively measured PA among adults. The findings indicate that walking to work was linked to generally elevated levels of PA in young and middle-aged adults. These findings offer initial evidence supporting the necessity for interventions aimed at promoting active commuting, particularly walking, among adults.

Walking rates have globally decreased due to advancements in transportation and the prevalence of elevators and escalators. A study was aimed to highlight the physical and mental health benefits of walking [69]. Using a descriptive approach, Mohammed et al. [69] revealed that walking reduces body fat, improves heart health, lowers the risk of heart attack and stroke, lowers high blood pressure, reduces diabetes risk, and alleviates stress and depression. Additionally, walking helps maintain a healthy weight, regulates blood pressure and cholesterol, strengthens bones, and improves digestion. Moreover, it alleviates symptoms of depression and anxiety, enhances sleep quality, and improves cognitive performance. These findings underscore the importance of walking for individual well-being and suggest potential cost reductions in treating associated health conditions.

A study examined the effectiveness of interventions promoting group walking to increase PA in adults and explored potential factors influencing this effectiveness [70]. The meta-analysis of 19 studies involving 4,572 participants indicated that group walking

interventions significantly increased PA levels. The review also identified characteristics of these interventions associated with larger behaviour changes, offering insights for improving efficacy. Recommendations include investing resources in group walking interventions due to their potential to target more individuals and considering interventions that address self-efficacy and outcome expectations for long-term behaviour maintenance. Additionally, interventions targeting both genders and older adults were found to be more effective, suggesting the need for tailored approaches to attract men and capitalize on the benefits for older populations. Interestingly, interventions delivered by lay people were as effective as those by professionals, indicating the potential for training lay individuals to effectively administer such interventions.

Cardiovascular diseases and cancers are significant contributors to global mortality, responsible for millions of deaths annually. Moderate-intensity PA has been established as a means to reduce the risk of these diseases, with the NHS recommending at least 150 minutes per week [71]. A systematic review and meta-analysis conducted by Garcia et al [72] found that even 75 minutes per week of moderate activity significantly reduced the risk of early death by 23%, cardiovascular disease by 17%, and cancer by 7%. The study suggests that incorporating moderate activity into daily routines, such as walking or cycling, can yield substantial health benefits, with the potential to prevent a significant number of premature deaths and disease cases globally.

Han and Kim [73] indicated that the varying levels of intensity in leisure walking can influence the mental health of older adults. A study aimed to examine the association between leisure walking intensity levels and the mental health and health perceptions of older adults. Employing a purposive sampling method, data from 4,737 adults aged 65 and above were extracted from the 2017 California Health and Interview Survey. Analysis of the data revealed that older adults who engaged in moderate and vigorous leisure walking reported higher health perceptions compared to those involved in light leisure walking. Furthermore, participants in moderate leisure walking reported better mental health than those engaged in light leisure walking. These findings suggest that engaging in moderate and/or vigorous leisure walking may enhance the mental health and health perceptions of older adults.

The studies presented in this section highlight the significant impact of walking as a form of PA on various aspects of health. Studies emphasize the importance of moderate to vigorous intensity walking in reducing the risk of cardiovascular diseases, cancer, and early mortality. Recommendations suggest that even small amounts of weekly walking, such as 75 minutes, can yield substantial health benefits, including improved mental health and perceptions of well-being. Overall, incorporating walking into one's daily routine can contribute to better health outcomes and overall quality of life.

2.6 Augmented Reality and Physical Activity

The decline in global PA levels can be attributed to the proliferation of digital technology. Accessible internet connectivity on mobile devices has led to a gradual shift from active pursuits to increased screen time [74]. Rather than advocating for a reduction in technology usage, innovative approaches aim to leverage it effectively to encourage PA and active lifestyles [8]. Recent years have witnessed the emergence of AR technology, where virtual 3D objects are seamlessly integrated into real-time 3D environments [75]. Presently, AR finds applications primarily in health-related fields, such as managing gait issues in older adults or within medical and surgical practices [26]. This technology holds promise for promoting and engaging healthy adults in PA through gamification. Recently, smartphones have become powerful enough to run AR technology smoothly, leading to a rise in the number of mobile AR applications that do not require additional hardware [54]. AR applications give users the chance to see the real world with added digital elements, making it more exciting and interactive [26].

Philippe et al. [75] investigated the use of AR in exergaming for aerobic training among healthy young adults. In a within-subject design, 18 participants engaged in dodgeball sessions, including a traditional format and an AR exergame version. Participants engaged in sessions comprising a 10-minute warm-up followed by 36 minutes of playing HADO, an AR dodgeball game. HADO involves two teams of three players using virtual energy balls to score points by hitting opponents. Players wear an AR headset and a connected bracelet to perform actions like throwing and reloading. Physical loads and intensities were measured using accelerometers, RPE, and heart sensors, while enjoyment was assessed using a short version of the PA enjoyment scale questionnaire. Results indicated that both

conditions provided appropriate aerobic training, although physical load and intensity were slightly higher in the traditional format. Nevertheless, participants reported high levels of enjoyment in both conditions, with slightly greater enjoyment in the traditional format. Overall, the findings suggest that AR exergaming can effectively achieve aerobic training and enjoyment among healthy young adults, comparable to traditional PA gameplay.

Another study by Lee and Huh introduced [76] an approach to counteract negative perceptions of gaming while enhancing psychological and mental well-being. While games are often associated with reduced PA and psychological withdrawal, exercise games offer a solution by combining gaming enjoyment with physical sensations. The study aimed to treat game-addicted adolescents using exercise games with AR technology. Twenty students participated in offline exercise protocols or played an experimental AR game called AR Earthman with HoloLens2 AR devices. Measurement tools included surveys, NIRSIT for game addiction, mood state, and motion recognition, as well as monitoring heart rate and motor awareness. The study designed an exercise protocol that incorporated low- to medium-intensity aerobic movements. Results showed no significant difference in exercise effectiveness between offline and AR exercise, indicating the efficacy of AR-based exercise in treating game addiction. Participants reported increased mental pleasure and satisfaction with AR exercise, suggesting it as a more beneficial method for teenagers compared to offline exercise. Additionally, applying the AR exercise protocol showed potential for treating psychological and mental effects associated with game over-immersion.

Farič et al. [77] investigated people's motivation and experience using a narrative-based AR exergame app called Zombies, Run! (ZR) for PA. ZR immerses users in a post-apocalyptic world where they collect supplies and build a base while running. Participants from various countries, primarily the USA and UK, aged 16-53, predominantly used ZR for running, cycling, or walking. Five main themes emerged: reasons for starting and staying with ZR, preferred features, perceived effects of ZR, and pros and cons of the app. Participants were drawn to ZR's gamification and narrative appeal, enjoying the immersive storyline and characters, which motivated longer sessions and sustained engagement. The

study highlights how AR narrative-based apps, like ZR, can effectively engage users with exercise by altering their perception of PA through storytelling, potentially encouraging adherence to health-related behaviours or habit-forming activities.

Nair et al. [78] developed "Endure", a fitness application that merges gaming elements, placing users as first-person players in a horror-themed game using AR technology. Users can engage with this chapter-by-chapter application both indoors and outdoors. The game challenges users to increase their distance covered while limiting the time needed to complete each level. AR game objects, like chicken legs, motivate users to maintain their virtual character's survival by accelerating their pace to match the countdown timer. The application features multiple functionalities working together to create a gaming environment. Each chapter increases in difficulty in terms of distance, with a corresponding countdown timer set based on average walking speed. Users can collect AR chicken legs to buy extra time during the challenge, and once used, they must speed up to keep pace if no more chicken legs are available. Overall, "Endure" aims to encourage users to stay active by offering a fun virtual environment.

"The Journey" developed by Odenigbo et al. [79], is an AR smartphone app designed to promote PA among young adults by allowing them to explore touristic sites and acquire virtual assets. Users can tour any location of interest from their home or outdoors using their smartphones. The app tracks users' step count to help them navigate locations, and users develop an empty piece of virtual land by unlocking assets through meeting activity goals and completing tours. The app encourages users to exercise by walking while virtually touring locations, setting daily activity goals based on their PA level or WHO recommendations. Additionally, the app features a leaderboard to foster competition among users. Evaluation findings suggest that "The Journey" has the potential to motivate individuals to improve their PA both indoors and outdoors.

Westlin and Laine [80] developed a AR driven game called “Calory Battle” where players embark on a quest to locate and neutralize virtual calory bombs that exist in the real world. To interact with the virtual bombs, the players utilize a special “Multitool”, which is also integrated into the game using AR technology. The combination of virtual calory bombs

and the AR-powered Multitool makes the gameplay exciting and interactive, promoting PA and fostering learning in an engaging way. The combination of AR with fitness elements makes exergame an enjoyable way to stay active and healthy while having fun on your mobile device.

In general, AR technology is being increasingly employed in health-related field to encourage PA through immersive and enjoyable experiences. Despite global declines in PA influenced by digital technology, integrating AR into exergaming and health interventions shows promise in promoting active lifestyles effectively. Continued advancements and the growing accessibility of AR applications on smartphones create innovative avenues to merge virtual elements with real-world activities, thereby enhancing both physical and mental well-being.

2.7 Emotion as Motivation

Emotions play a pivotal role as factors in motivation, as they evoke states, forces, and energies that initiate and direct work-related behaviours [27]. Consequently, a motivational dynamic arises not solely from needs but also from emotions, intentions, goals, and the strategies employed to attain them, spanning mental, emotional, and physical realms. Emotions are integral to the motivation process, influencing action in several ways [81]. They serve as motivational states, directing behaviour based on needs. Anticipated emotional outcomes can act as incentives. Additionally, emotions aid self-regulation by indicating progress towards goals. Overall, emotions play a crucial role in determining behaviour through their functions within the motivation process.

There is a growing trend in game development for entertainment to prioritize creating affective gameplay experiences [82]. Games typically evoke a range of emotions, both positive and negative, which motivate players to adapt and improve. For example, failure in games often prompts players to learn through repetition, facilitated by rapid feedback loops. Engagement in games is closely linked with motivation, though terminology varies, with some considering it as a form of need fulfilment.

Berkling et al. [83] conducted a study to introduce the design of a 3D running game with educational content aimed at teaching German capitalization to children. The game presents sentence of increasing difficulty, with decapitalized words that players must correctly capitalize. An emotional avatar and speed factor are integrated into the game design to motivate children to play longer and improve their performance. The study involved 20 children playing the game with the avatar and 16 playing without, with qualitative feedback collected via an online survey and performance profiles were analysed. Results indicated an increased engagement and performance with the emotional avatar. The game features a chicken character named "Henry" that players control to pick answers in an endless run. Sam, the emotional avatar, provides feedback through expressions such as happiness and sadness. The paper discusses the game's design elements and their effects on player motivation and performance, noting that players expressed a desire to avoid causing sadness to the avatar. Overall, both versions of the game were well-received by participants, with more concern expressed regarding mistakes in the version with the emotional avatar.

Emotions are fundamental drivers of motivation, shaping work-related behaviours through their influence on needs, intentions, and goal-directed strategies across mental, emotional, and physical domains. The gaming industry increasingly prioritizes creating affective gameplay experiences, recognizing the profound impact of emotions on player engagement and learning.

2.8 Idle Game Design

An idle game, also referred to as an incremental game, constitutes a genre characterized by its primary strategy element: allowing the game to run autonomously with minimal or no player intervention [84]. Idle games frequently permit, and sometimes incentivize, player engagement. The objective usually remains boundless: amassing points through idling or active interaction to acquire diverse upgrades, consequently yielding even higher points, resulting in a continually escalating total. Typically, the objective in idle games is limitless, allowing players to engage for mere minutes while continuously advancing. Idle games represent a relatively recent addition to the video game landscape, with the genre's inception dating back to the early 2000s. Idle Games have surged in popularity, driven by

several factors such as their accessibility and their ability to satisfy the contemporary inclination towards multitasking and efficient time utilization [28].

A study by Alharthi et al. [85] was conducted to provide a comprehensively examination of idle games, analysing their characteristics and feature. By scrutinizing 66 idle games alongside 10 non-idle games, the research explores various aspects such as gameplay mechanics, rewards, and interactivity. It elucidates how idle games encourage players to engage less actively while still progressing, challenging traditional gameplay assumptions. Additionally, the study discusses design implications, including strategies for cognitive offloading and considerations for ludic efficiency. The distinctive attributes of idle games offer an opportunity to encourage sustained engagement and cultivate specific behaviours over the long term. They have the capacity to reshape perspectives on the significance of activities within gameplay, the structure of play itself, and the resources required for play, encompassing both human factors like sustained attention and environmental considerations such as power consumption.

Sadprasid et al. [86] investigated the potential of idle games as persuasive tools for promoting consistent engagement in therapeutic exercises, focusing specifically on deep breathing practices. Introducing "Breath Persuade," an idle game designed to incentivize deep breathing through gradual progress and incremental rewards, the researchers conducted a four-week study to examine the effectiveness of the game and found that idle games' effectiveness in maintaining deep breathing adherence compared to traditional breathing guides. These findings underscore the stealthy persuasiveness of idle games, immersing players in gameplay prioritizing gradual progress over health-related goals, reshaping attitudes toward deep breathing and making it more appealing and sustainable. Careful consideration is needed in selecting target behaviours compatible with the idle game model, while crafting specific engagement patterns through pushing and pulling mechanisms offers flexibility in tailoring engagement to diverse contexts. Incorporating context-aware triggers and relevant rewards is crucial for sustaining long-term engagement, posing challenges for designers in aligning rewards with evolving player preferences. Overall, idle games hold promise as subtle yet effective tools for behavioural change, warranting further exploration and refinement in therapeutic game design.

Villareale et al. [87] conducted a study to investigate the potential of idle games as a promising avenue for exergames and other games aimed at behavioural change. Through a survey of 11 popular idle games, the study identified the core gameplay loop and design patterns that support it, offering insights into extending these mechanics to social exergames to enhance player adherence. The proposed approach focuses on incorporating PA into the gameplay cycle, improving long-term engagement, and mitigating the snowball effect in social exergames. By addressing key design considerations such as integrating PA, enhancing adherence through timed actions and highlighting state changes, and implementing player-driven auto-play to mitigate the impact of inactivity, the paper lays the groundwork for future exploration and innovation in this space. The application of these patterns to multiplayer social exergames holds promise for fostering lifestyle integration and motivating player return, addressing common challenges in exergame design.

In general, idle games have emerged as a significant genre in the gaming landscape, characterized by their autonomous gameplay and limitless objectives. A comprehensive examination of idle games, along with subsequent studies, reveals their potential as persuasive tools for promoting consistent engagement in therapeutic exercises and behavioural change.

2.9 Persuasive Strategies

Persuasive strategies serve as methods utilized in the design of PTs to encourage favourable behaviours or attitudes [88]. Among these strategies, socially-oriented ones like competition, comparison, and cooperation are extensively utilized in both persuasive and gamified systems, as well as other online support systems [88]. These strategies harness the influence of social dynamics, making them effective in driving behaviour change.

Rita Orji [88] conducted a research to investigate the efficacy of socially oriented persuasive strategies in encouraging favourable health behaviours, uncovering both typical advantages and drawbacks inherent in these approaches. In this study, participants were recruited through Amazon's Mechanical Turk (AMT). A total of 1768 responses were

analysed, after filtering out incomplete and incorrect responses. All participants were at least 15 years old at the time of data collection and were proficient in English. While competition, comparison, and cooperation strategies leverage social influence to drive behaviour change, they vary in their operationalization and implementation.

Designers must address privacy concerns by incorporating mechanisms for user anonymity and data protection, ensuring the acceptance and adoption of PTs. Additionally, careful consideration is needed to prevent counterproductive effects, such as demotivation or negative social influence, which may arise from competitive or comparative contexts. Building trust among users through measures to deter cheating and promote transparency is crucial for the success of persuasive interventions. Moreover, empowering users to engage in self-competition and comparison can mitigate tensions and privacy risks associated with external competition, fostering intrinsic motivation and personal achievement. Encouraging cooperative efforts and facilitating multiple winners in PT designs can further enhance motivation and support among participants. Finally, maintaining fairness in comparison and competition by avoiding mismatches and utilizing realistic behaviour metrics ensures accurate evaluation and prevents discouragement. By addressing these considerations, designers can optimize the effectiveness of socially oriented PT in promoting positive health behaviours through PTs.

Fogg [89] conducted a research to address the absence of a well-defined process for designing persuasive technology, aiming to establish guidelines for creating digital experiences that effectively influence people. This research resulted in the development of an eight-step process tailored for early-stage design of persuasive technologies. The process involves sequential execution of steps with occasional parallel actions or revisions. The primary focus lies on selecting a simple behaviour to target (Step 1), followed by identifying a receptive audience (Step 2) and understanding the barriers preventing the target behaviour (Step 3). Subsequently, the appropriate technology channel is chosen (Step 4), considering the behaviour, audience, and barriers identified earlier. Steps 5 through 7 involve finding relevant examples, imitating successful strategies, and conducting rapid tests to prototype and refine interventions. The final step (Step 8) entails expanding successful interventions systematically, possibly by scaling up the behaviour,

reaching new audiences, or broadening the scope of distribution. This structured approach provides a framework for designing persuasive technologies while allowing flexibility to adapt to various project requirements and circumstances.

A comparative systematic review by Ndulue and Orji [90] examined the trends in research on persuasive strategies used in persuasive games and their effectiveness in achieving their intended goals. The analysis involved 130 persuasive games. The review found that the reward strategy, which involves rewarding players for achieving milestones, was the most prevalent persuasive strategy in persuasive game research. In the domain of PA, reward was particularly prominent, with an occurrence rate of 85%. Additionally, self-monitoring was prevalent in 76% of the games, followed by rehearsal in 56%. Interestingly, third-party endorsements were notably absent, representing a missed opportunity to utilize influential endorsements for promoting behaviour change.

Persuasive strategies are techniques that can be used in persuasive technologies design (such as AR exergame aimed at promoting PA) to promote desirable behaviours [33]. Research shows that persuasive strategies (such as self-monitoring, reminders, rewards, praise, cooperation, competition, and social comparison) have been used effectively to influence users to be more physically active [41], [42]. In the papers reviewed, competition emerged as the most popular strategy. The presence of multiple strategies demonstrates the multidimensional nature of persuasive strategies applied in location-based AR exergaming.

Based on the literature reviewed in this section, persuasive strategies are instrumental in designing Persuasive Technologies (PTs) aimed at fostering favourable behaviours or attitudes. Additionally, the development of a structured eight-step process for designing persuasive technologies provides a framework for creating digital experiences that influence people effectively. Overall, these findings contribute to the understanding of persuasive strategies' role in designing technologies to facilitate positive behaviour change, particularly in promoting PA.

2.10 Summary

Research consistently provides evidence for the advantages of consistent PA, such as enhanced sleep quality, decreased anxiety, improved cognitive abilities, and lowered risks of health issues like hypertension, heart disease, and obesity. Moreover, technology-driven interventions like mobile applications and exergames have demonstrated their effectiveness in encouraging PA and enhancing mental well-being.

To our current knowledge, while walking is widely acknowledged as both enjoyable and potentially beneficial for increasing PA, the integration of walking interventions utilizing innovative technologies like AR, emotive avatars, and idle game design has yet to be explored. Many interventions described in existing literature have been tailored to specific target demographics. However, recognizing the significance of PA for maintaining a healthy lifestyle across diverse populations, there is a need to develop interventions accessible to a wider audience. Therefore, our research endeavours to meet this by developing an AR mobile application aimed at promoting PA through walking. Furthermore, we hypothesize that our intervention will positively impact individuals, encouraging increased PA and fostering a more comprehensive approach to overall well-being.

In summary, this study aims to assess the effectiveness of integrating enjoyable activities into PA interventions by utilizing advanced technologies such as AR. The objective is to create an AR mobile application that promotes PA among a broader audience.

Chapter 3: System Design

Based on the existing literature reviewed and presented in Chapter 2 of this thesis, the present study aims to enhance PA by utilizing AR technology to develop an AR-based intervention. This intervention is designed to assist users in sustaining their PA levels through walking. This chapter provides a detailed description of the intervention design and outlines our research questions.

3.1 Framework and Technology used

For this research, we developed a mobile app aimed at promoting PA and integrating AR [91] features. Building such an app requires careful consideration of both frontend and backend technologies. We selected Flutter as the framework for frontend development, due to its cross-platform capabilities. Flutter is an open-source UI software development kit developed by Google [92]. It allows developers to create cross-platform applications from a single codebase, supporting web, Fuchsia, Android, iOS, Linux, macOS, and Windows. Our focus was on developing a mobile app for Android devices. Flutter's flexible set of tools and quick updates using hot reload were key in creating a smooth and engaging user interface that works well on various types of Android devices.

To track step counts accurately in the app, we added the pedometer Flutter package [93]. This tool connects directly with the device's built-in sensors, like the accelerometer, to record live movement data from users. To create engaging AR experiences, we used the ARCore Flutter package [94]. ARCore, Google's platform for AR on Android, provides a range of tools and APIs to integrate advanced AR features smoothly into apps. These experiences include features like interactive 3D models that respond to user interactions and adapt to real-world surroundings, creating compelling and interactive virtual elements within the app.

We developed the intervention's backend with REST APIs [95] in Java, abstracting resource-intensive tasks to ensure optimal performance. MySQL was chosen as the database management system, storing data such as user login details, profiles, step count records, and points. The MySQL database was hosted on an AWS EC2 instance [96],

providing a scalable and reliable environment. The database schema was optimized for performance, ensuring efficient data storage and retrieval.

Developing this mobile app to promote PA and integrate AR features involved a comprehensive and well-planned approach to both frontend and backend technologies development. By utilizing these tools, a robust mobile app customized for Android devices was created, providing users with a smooth and captivating experience that encourages PA.

3.2 User-Centred Design Approach

This paper details the implementation of an iterative user-centred methodology in the design and development of the PetBuddy app. User-centred design (UCD) entails an iterative design process wherein designers prioritize the users and their requirements at every stage [97]. Within UCD, design teams engage users continuously throughout the design journey, employing diverse research and design methodologies, with the aim of crafting products that are exceptionally usable and accessible to them. The progression of this design process, commencing from the initial conceptualization to the conclusive design employed in the study evaluation, is depicted in Figure 3.1. Subsequent subsections provide an elaborate description of each stage within this process.

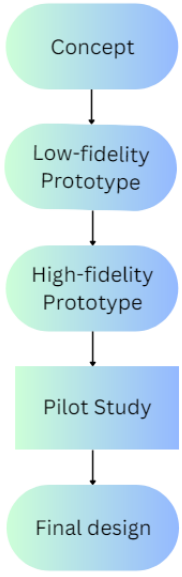


Figure 3.1: Iterative design stages followed for the design and development of the PetBuddy app

3.2.1 Low-Fidelity Prototype

We created initial concept sketches using Balsamiq Wireframes [98]. Balsamiq Wireframes is a rapid, low-fidelity UI wireframing tool that reproduce the experience of sketching on a notepad or whiteboard, in a digital format. Its primary emphasis lies in concentrating on the framework and content, avoiding discussions about colours and details that should come later in the process. These prototypes were evaluated for the fundamental design layout, including screens, buttons, icons, and overall UI design of the app. Feedback on the low-fidelity prototype was gathered from friends and colleagues, who suggested some colour schemes for the app, changing the button layout for better screen flow, and renaming the app from "Pet World" to "PetBuddy." Figure 3.2 shows the low-fidelity prototype developed using Balsamiq Wireframe.

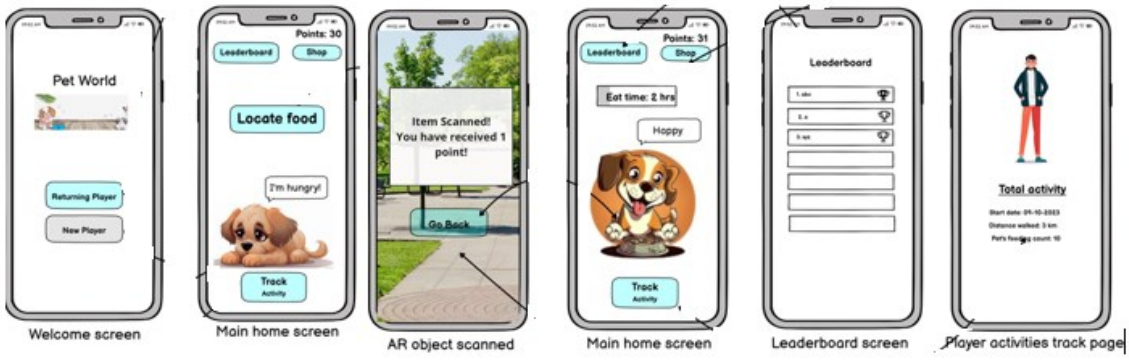


Figure 3.2: Low-fidelity prototype developed using Balsamiq Wireframes

3.2.2 High-Fidelity Prototype

Following our initial stages using Balsamiq Wireframes, we transitioned to refining our ideas using Figma to create a high-fidelity interactive prototype. Figma simplifies the process of exploring the functionality of app and seamlessly transitioning from conceptualization to the final product [99]. This allowed us to gain a clearer understanding of our colour theme implementation, screen layout, button design and flow of transition between screens. By utilizing Figma's capabilities, we further developed the screens by going deeper into colour schemes, explore various palettes, and assess their impact on the overall design aesthetic. Simultaneously, the screens were designed to optimize user experience and strategically placed buttons for smooth navigation. This step was crucial in refining our visual representation, ensuring coherence and resonance with our target audience. Positive feedback on the concept was received from several colleagues, prompting us to proceed with the development of a functional prototype. Figure 3.3 shows the high-fidelity prototype on Figma.

Figure 3.3: High-fidelity prototype on Figma

3.2.3 Final Prototype

We created a functional version of the application. To gather feedback, we conducted a pilot study (which will be discussed in detail in Section 4.1.1) before the official user study. Generally, the study gathered positive reviews. However, suggestions for enhancements were noted, including:

1. Altering the Dog avatar due to ambiguity in conveying emotions.
2. Displaying points on the leader board.
3. Offering options to return to the homepage if users decide not to proceed with the walk.
4. Optimizing AR object loading times.
5. Uniformly scale button displays across different screens within the app.

3.2.4 Final design

The final version of the design was informed by feedback gathered during the pilot study. As a result of the pilot evaluation feedback, several adjustments were implemented, including:

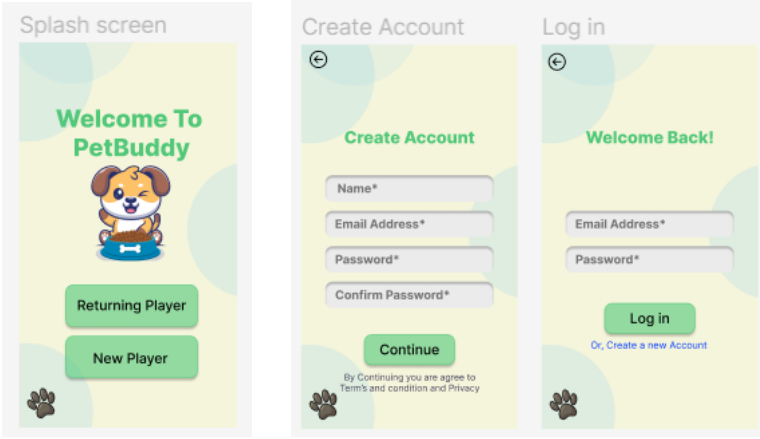
1. **Altering the Dog Avatar:** Users expressed confusion in interpreting the emotions conveyed by the dog avatar, unsure whether it appeared sad or happy. To address this, we redesigned the dog avatar to enhance emotional clarity, ensuring that users can easily understand the dog's mood and respond accordingly.
2. **Displaying Points on the Leaderboard:** In response to user feedback, we decided to incorporate a feature to show points on the leaderboard. This addition would provide users with a clearer understanding of their progress and achievements within the app's community, fostering engagement and motivation.
3. **Offering Options to Return to the Homepage:** Users requested the ability to return to the homepage if they decided not to continue with their walk. To accommodate this, we intended to implement an intuitive navigation feature that allows users to easily navigate back to the homepage from any screen within the app, enhancing user convenience and experience.
4. **Optimizing AR Object Loading Times:** Feedback highlighted concerns regarding the loading times of AR objects within the app. To address these issues, we compressed the texture of the 3D model to optimize the loading process of AR objects to minimize delays and enhance overall performance. These optimizations aimed to provide users with a smoother and more seamless experience while using the application.

5. **Consistent Button Proportions:** Ensure that button proportions remain consistent across different screen sizes to maintain a cohesive user interface. This consistency enhances usability and familiarity, allowing users to easily navigate and interact with buttons regardless of the device they are using.

3.3 PetBuddy App Design Overview

The central focus of this intervention is to actively involve users through a range of features, thereby motivating them to engage in physical activities. To achieve these objectives, the PetBuddy app was developed with a specific emphasis on delivering an enjoyable and interactive AR experience while also promoting PA. Given the research nature of the app, strict measures were enforced to safeguard the integrity and privacy of user data. Data collected was de-identified and coded to remove personal information. Throughout analysis and result preparation, data remained anonymized. During the initial app launch, users were required to provide their email addresses upon sign-up, facilitating comprehensive data analysis and monitoring throughout the 10-day study period.

In the app, Figure 3.4 (a) displays the initial splash screen, while Figure 3.4 (b) illustrates the user-friendly create account and login interface. These interfaces were carefully designed to ensure accessibility and user engagement for participants involved in the research intervention. Subsequent sections will explore the essential design components integrated into the AR-driven intervention, providing insight into the functionality and impact of the app on promoting PA through walking.



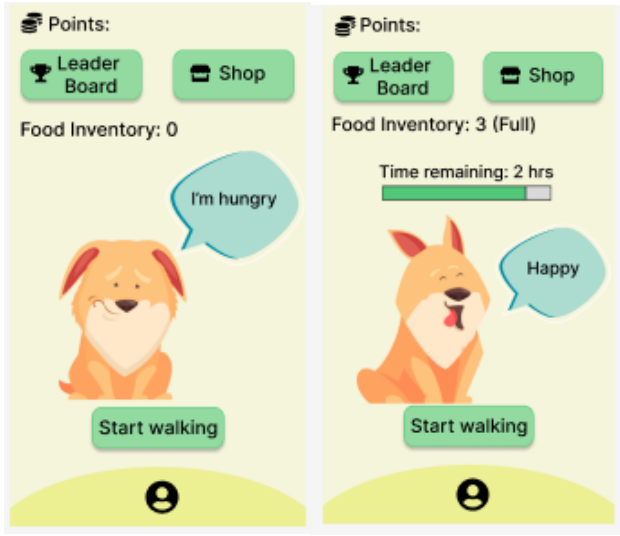
(a) Splash screen (b) Create account and Log in screen

Figure 3.4: User Interface Screens

3.3.1 Avatar

Upon successful authentication, users are directed to the application's primary interface, the home screen, which serves as a focal point of user interaction. At the core of this interface lies a captivating element—a dog avatar, integrated into the mobile application. The avatar is a character which is a part of the mobile application [100]. This avatar expresses two emotions: sadness and happiness.

When users start using the application, they will notice that the dog avatar appears sad indicating that the dog is hungry and needs food, as shown in Figure 3.5 (a). To change the dog's mood to a happier state, users can start walking and collect food items for the dog. Once the food item is collected, dog avatar can start eating food and it will display a happy expression, as illustrated in Figure 3.5 (b). The dog eats food over a 2.5-hour period, signifying progress and allowing users to take short breaks from the app. This incorporates idle game design, letting players enjoy the game passively as the dog eats, rewarding them gradually. During this time, players can take a break and attend to other tasks, while the dog is eating food. After the dog finishes eating, players can return to collect their points. It provides players with time to reflect between games, which is crucial for maintaining long-term behaviour change [101].



(a) Sad dog (b) Happy Dog

Figure 3.5 (a) and (b) illustrating dog emotion

3.3.2 Step count

To make the dog avatar happy, users are encouraged to start walking. As users embark on their walking journey, they will have the opportunity to gather food items once they have completed a total of 500 steps. To effectively monitor and record these steps, our approach involved leveraging the pedometer feature integrated within the Flutter library. This feature serves as a reliable mechanism for continuous step counting and closely monitors the walking activity of users through the utilization of the pedometer sensor embedded within Android devices.

The Flutter package "pedometer" [93] stands out as an asset within the Flutter framework, crafted for step counting functionalities within mobile applications. This plugin efficiently taps into the capabilities of the pedometer sensor found in Android devices, ensuring the tracking of users' steps as they engage in PA with no need for external sensors.

Upon reaching the milestone of completing 500 steps, users are then granted the opportunity to collect the food item, a rewarding experience that enhances the happiness of the players. This mechanism not only encourages PA but also elicits a sense of accomplishment and satisfaction among users as they progress towards achieving their goals within the application. Figure 3.6 shows the step count screen where the user

completed 300 steps as they are walking and eventually reaching their goal of 500 steps enabling them to collect the reward to feed the dog avatar.

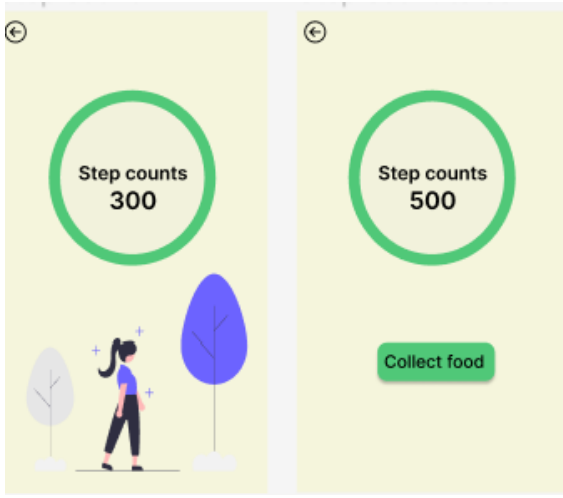


Figure 3.6 Step count screen and post-500 steps food collection screen

To prevent users from becoming overly fatigued from continuous walking and to facilitate breaks and reflections while using the app which is essential for sustained behaviour change, the app limits participants to collecting the food box a maximum of three times before disabling the "start walking" button. Completing 500 steps takes approximately 10-15 minutes; my friends and I tested this, and it took us 10-15 minutes to walk 500 steps. Excessive walking can have several adverse health effects. Research shows that prolonged walking without sufficient rest may lead to overtraining syndrome, characterized by fatigue, decreased performance, persistent muscle soreness, and an increased risk of injuries [102]. After the dog finishes eating the first food box, which takes 2.5 hours, the number of available food boxes decreases from three to one. Participants can then resume walking to collect the remaining food boxes one at a time.

3.3.3 Augmented Reality

Once a user achieves the goal of walking 500 steps, they can collect a food box. This food box can be obtained through an AR experience, where users view a 3D model of the food box within their real-world environment. Users will see the food box through the AR experience, as depicted in Figure 3.7.

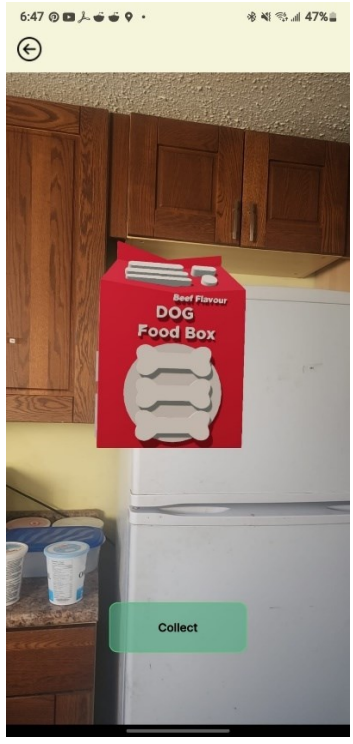


Figure 3.7: The AR experience screen showing the food box when the user achieves the goal of walking 500 steps

To incorporate AR functionality into the application, we utilized the AR flutter plugin [94] available in the AR library. This plugin facilitates the integration of AR features into the application and supports ARCore for Android devices. Figure 3.8 provides an overview of the software architecture of the AR Flutter plugin, highlighting its two main components: a unified, cross-platform API for interacting with the plugin within applications, and platform-specific implementations for Android that handle logic specific to each platform [103]. The exposed section of the framework includes widgets that can be seamlessly integrated into a client app's widget tree to enhance the user interface, as well as AR managers responsible for managing all AR-related functionalities and logic, serving as the control mechanisms of the plugin. Communication with platform-specific implementations occurs solely through the plugin's API.

Within this architecture, Flutter's platform channel and platform view system can be conceptualized as implementations of the adapter pattern. For instance, the AR View utilizes platform view adapters to expose functionalities of the underlying AR Activity on Android to external components. Various low-level implementations are consolidated into

a user-friendly and platform-agnostic API, ensuring ease of use and compatibility across different platforms. Similarly, the AR managers abstract interactions with platform-specific features such as tracking or rendering into a unified interface by leveraging platform channel functionality as an adapter between the Flutter API and the Swift or Kotlin code segments of the plugin. Subsequent sections delve deeper into the specific components comprising the AR Flutter plugin.

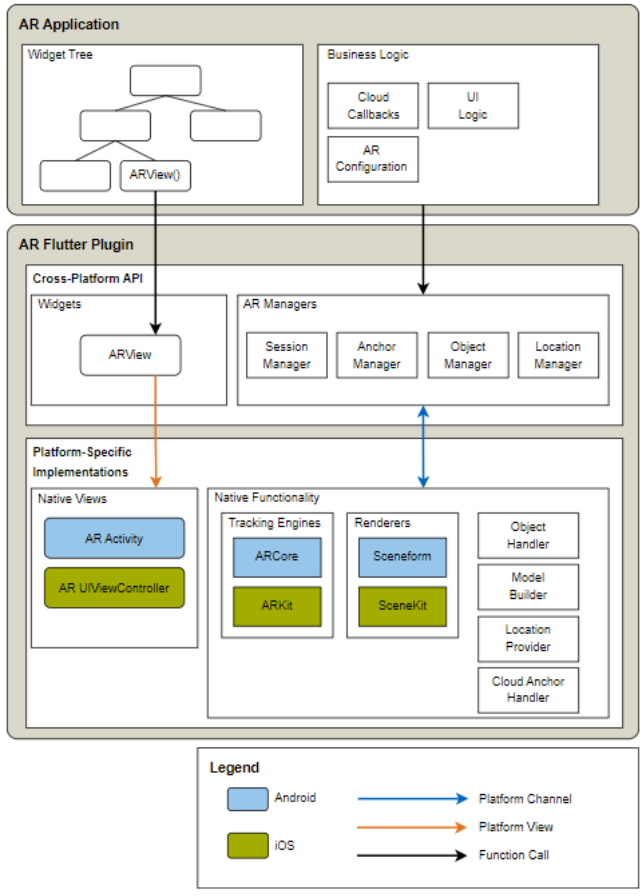


Figure 3.8: Software architecture of the AR Flutter plugin

The AR flutter plugin operates by overlaying digital elements onto the user's view of the physical world, creating an immersive and interactive experience. It leverages ARCore technology to ensure compatibility with Android devices, allowing users to seamlessly interact with virtual objects in their surroundings. This integration of AR technology adds a layer of engagement and excitement to the application, enhancing the overall user

experience. Once users successfully collect the food box in the AR environment, they can feed it to the dog avatar, thereby making the dog happy.

3.3.4 Gameplay Reward and Recognition

Once the dog has consumed the food provided by users, they can earn points as a reward. Users receive 50 points for each food box they feed to the dog. These points can be used to purchase various in-app accessories for the dog. Currently, there are four accessories available for purchase: a bowl for 150 points, a toy for 500 points, clothes for 700 points, and a house for 1000 points.

Figure 3.9, shows, the shop screen, where users can browse and purchase accessories for their dog. The inclusion of this feature aims to enhance user engagement and provide additional incentives for interacting with the dog.

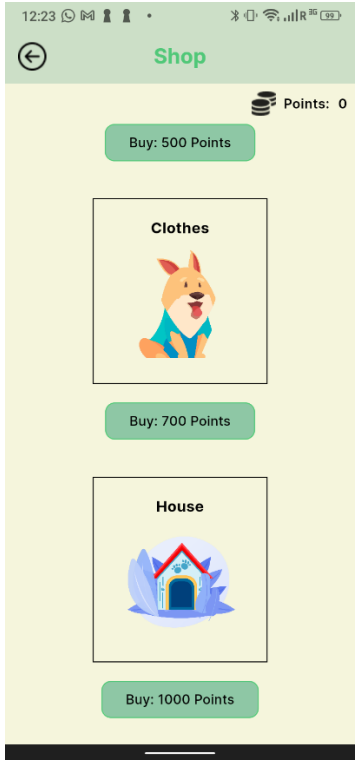


Figure 3.9: Screen displaying dog accessories available for purchase

The implementation of recognition within the leaderboard screen was focused on highlighting the achievements of the top 10 users who consistently demonstrated outstanding performance every day. By prominently showcasing these accomplishments, the platform

aimed to inspire and motivate other users to strive for similar levels of achievement. This approach was intended not only to recognize individual efforts but also to foster a sense of competition and community among participants. Ultimately, the goal was to encourage sustained participation and commitment to personal fitness goals, thereby creating a supportive and engaging environment for all users involved in the platform.

3.3.5 App Data log

The application systematically logs various user data points such as the user's start date, step count, points earned, and their current position in the leaderboard rankings. To ensure robust management and easy access, all these critical application data are securely stored on an AWS [96] server. This storage solution not only enhances the efficiency of data management but also ensures seamless accessibility for authorized personnel.

Furthermore, on the user's profile screen, these data sets are prominently displayed, facilitating users in monitoring and tracking their individual performance metrics over time. This comprehensive approach not only enhances user engagement but also provides valuable insights into user behaviours and interactions within the application.

3.3.6 Implementation of Persuasive Strategies

In our effort to encourage more PA, our intervention utilizes four persuasive strategies known for their effectiveness in promoting positive behaviour change. These strategies were carefully selected due to their success in persuasive systems. The following sections detail each strategy and how they are applied in our intervention. Based on the PSD model [29] we integrated the following four persuasive strategies:

1. **Competition:** Allows users to compete to perform the desired behaviour [29] was integrated into the leaderboard with the goal of encouraging users to increase their PA levels. By tapping into humans' inherent desire to compete, a system can effectively motivate users to adopt a desired attitude or behaviour. In our intervention, users earn points by walking and feeding the dog, with those accumulating higher points being featured on the leaderboard. This leaderboard is regularly updated to reflect users' progress in real-time. Overall, the intervention aimed to establish a fair and inclusive

recognition system, ensuring that all users of the application had the opportunity to be recognized for their efforts and achievements in enhancing their PA levels.

2. **Reward**: Offer virtual rewards to users for performing the target behaviour as described by the PSD model [29] has been thoughtfully incorporated into the system with the primary aim of expressing gratitude to individual users upon the successful completion of each walking session. This integration not only serves to acknowledge users' efforts but also aims to foster a sense of appreciation and motivation within the user community. To incentivize and encourage users to engage in more PA, a reward mechanism has been implemented as part of the intervention strategy. This mechanism offers users the opportunity to accumulate points as a form of recognition for their commitment to PA. These points are earned once the dog has finished consuming its food, thus reinforcing positive behaviour and serving as a tangible acknowledgment of users' dedication to their health and well-being.
3. **Self-monitoring:** Allows people to track their own behaviours, proving information on their progress [29], the current study endeavours to provide users with personalized performance histories, thereby facilitating the adaptation and sustained maintenance of their performance levels over time. By implementing a system that meticulously tracks individual performance or status, users are empowered to effectively monitor their progress and make necessary adjustments to achieve their goals. This personalized approach fosters a sense of accountability and empowerment, ultimately enhancing users' ability to maintain their desired performance levels consistently.
4. **Customization:** This persuasive strategy customization refers to the ability for users to tailor their experience according to their preferences and needs within the application's persuasive framework [29]. This entails offering users the flexibility to personalize various aspects of their interaction within the app to align with their individual motivations and goals. Users have the option to personalize the dog by selecting accessories from the in-app shop that best suit their preferences.

3.4 Research Questions

In this study, we developed an AR-driven intervention to promote PA through walking and formulated the following three questions to guid our research:

RQ1: How effective is the PetBuddy app in motivating physical activity?

RQ2: How effective are the game experience in the app in motivating physical activity?

RQ3: How effective are the persuasive strategies implemented in the app for healthy behavioural change toward physical activity?

Chapter 4: System Evaluation

To evaluate the effectiveness of the developed intervention for increasing PA, we conducted a user study that employed a mixed-methods (both quantitative and qualitative) approach [104]. The use of this approach allowed us to gain a well-rounded understanding of the intervention's impact on user's PA levels, engagement, and overall satisfaction. For the quantitative aspect, we gathered data through meticulously designed pre- and post-intervention questionnaires. These questionnaires were structured to capture a wide range of metrics relevant to our study objectives, providing us with numerical data that could be statistically analysed to assess changes pre and post app usage.

In addition to the quantitative data, we also sought to understand the experiences of the participants through qualitative methods. We also conducted optional interviews. These interviews allowed participants to share their personal insights and experiences in detail. The qualitative data collected from these interviews were invaluable, offering rich, contextual insights that complemented the numerical data from the questionnaires.

By integrating both quantitative and qualitative data, we were able to address the three research questions outlined in Section 3.5. In this chapter, we provide a detailed explanation of the study's methodology. We describe the design principles that guided our research, including the rationale behind choosing specific data collection methods and the processes employed throughout the study. This includes the development and administration of the questionnaires, the protocol for conducting interviews, and the analytical techniques used to interpret both quantitative and qualitative data. Through this detailed methodological explanation, we aim to provide a clear and thorough understanding of how the study was conducted, ensuring the transparency and reproducibility of our research.

4.1 Materials and Procedure

4.1.1 The Pilot Study

To assess the usability, interaction flow, labels, buttons, technical issues of PetBuddy, and to gather initial feedback for further refinement, a pilot study was conducted with six participant's Human-Computer Interaction (HCI) knowledge. Among the participants, four were male and three were female. During the pilot study, participants were given access to the PetBuddy app and instructed to use it for three days to explore its features and functionalities. After using the app, they completed the System Usability Scale (SUS) [105], a validated instrument for assessing software usability. The SUS questionnaire, tailored for the pilot study evaluation, aimed to gather quantitative data on the participants perceptions of app's usability. Additionally, they were asked to provide their overall feedback, including recommendations for improving the app based on their user experience.

Figure 4.1 shows the results of the SUS scores for each participant. The average SUS score obtained was 85.80 (*SD* = 5.84), indicating an "excellent" level of usability [106]. Based on the feedback collected from the open-ended question asking participants to provide recommendations for improving the app, in general, participants found the concept of PetBuddy appealing and motivating; for instance, one participant noted, *"The app's idea is appealing and should encourage us to be active."* [P3].

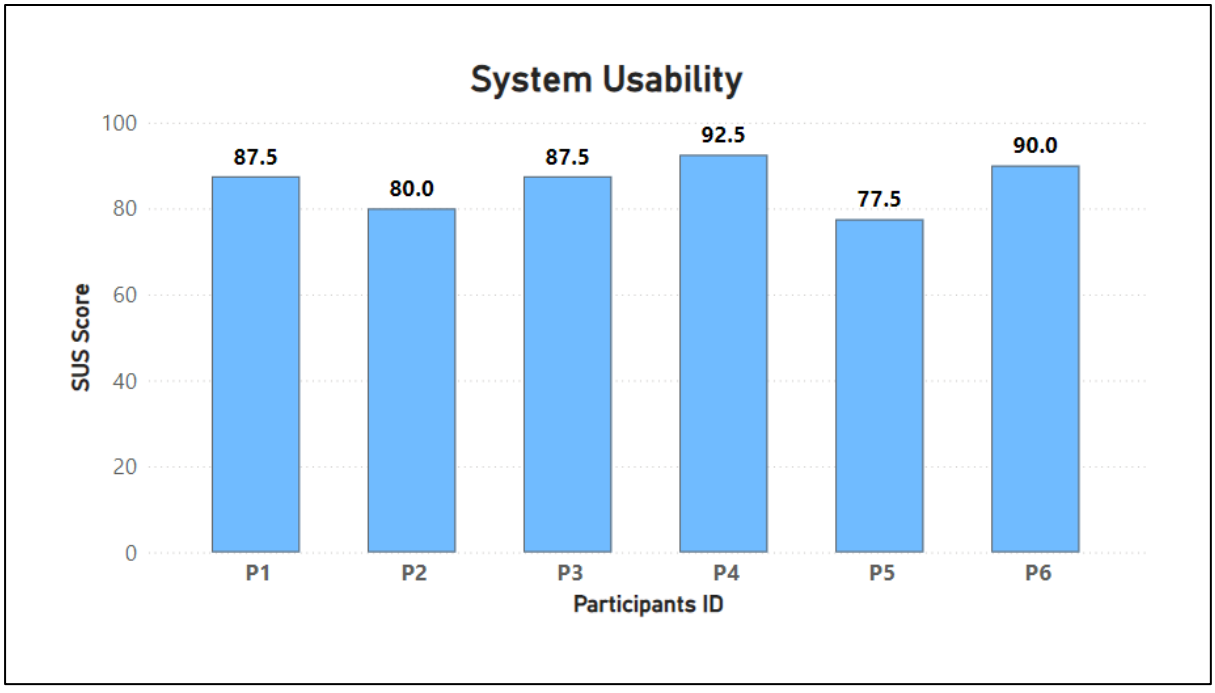


Figure 4.1: Pilot study SUS score. (M = 85.8, SD = 5.84)

Based on feedback from the pilot study, PetBuddy underwent several key improvements prior to the main study. First, the Dog avatar's emotional expressions were redesigned to ensure clearer communication of mood, addressing user concerns about ambiguity. Additionally, users suggested incorporating points for each participant on the leaderboard to better track their progress and enhance engagement within the app. To enhance user navigation convenience, a back button was added to easily return to the homepage from any screen was implemented. The loading times of AR objects was optimized by compressing 3D model textures. These improvements were designed to reduce wait times and enhance overall performance, providing PetBuddy users with a smoother experience with its AR features. Finally, all the buttons were uniformly scaled across all the app screens. These enhancements were implemented to boost usability and user satisfaction, setting the stage for PetBuddy's successful transition to the main study phase.

4.1.2 Main Study

The primary objective of this research is to evaluate the effectiveness of the PetBuddy app in promoting PA through walking. To achieve this goal, a comprehensive user study was

conducted, involving the recruitment of participants to engage with the intervention. The evaluation was conducted using a combination of quantitative and qualitative methods, focusing on data collected through use of questionnaires.

Prior to the commencement of the study, ethical clearance was obtained from the university ethics committee (REB: 2024-7064) to ensure adherence to required ethical standards. The recruitment process involved creating a detailed notice, which was disseminated through various channels, including social media platforms and email campaigns. Interested individuals were invited to participate by accessing a link provided through Dal Opinio, where they could submit their email addresses to indicate their willingness to participate and proceed with the pre-study questionnaire. The appendices section includes all relevant documents: the recruitment notice (Appendix A), the study consent form (Appendix B), the interview consent form (Appendix C), the recruitment notice for social media (Appendix D), the pre-study survey (Appendix F), the post-study survey (Appendix G), and the interview questions (Appendix H). These appendices serve as comprehensive references for the study's procedural documentation.

Figure 4.2 in this chapter provides a graphical representation of the step-by-step procedures involved in completing the study, offering a visual overview of the entire process from recruitment to data collection and analysis. The pre-study survey was designed to collect essential data on participants' demographic characteristics and current levels of PA. This baseline information was crucial for analysing the intervention's impact. At the end of the survey, participants were provided with a link to download the PetBuddy mobile app.

Participants were asked to use the app daily for a minimum of 10 minutes of walking each day over a 10-day period. During this time, the app recorded various data points, including the number of steps taken, points accumulated, and current leaderboard rankings. All data were securely transmitted to and stored on a remote server hosted by Amazon Web Services (AWS) [96], providing a scalable and reliable infrastructure for the study.

At the end of the 10-day intervention period, participants received an email invitation to complete a post-study questionnaire hosted on Dal Opinio. This survey was designed to

gather feedback on their experiences with the PetBuddy app. The questionnaire included inquiries about current PA levels and perceptions of the app's effectiveness, ease of use, and overall usability.

After completing the post-study survey, participants were offered the opportunity to participate in an optional interview to provide more in-depth feedback. This optional interview aimed to gather detailed qualitative insights into the intervention's effectiveness and user experience. Participants who expressed interest were subsequently contacted to schedule a convenient time. Prior to the interview, they received an electronic consent form, which they needed to acknowledge to formally agree to participate.

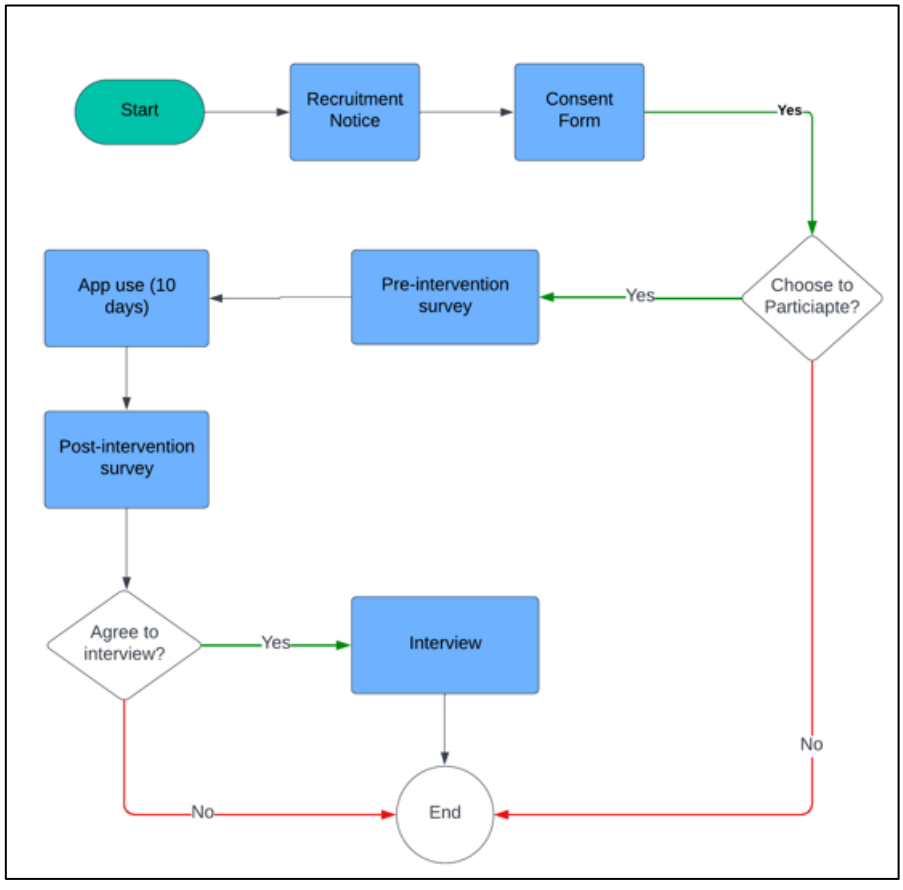


Figure 4.2: Flow chart showing the study procedure

4.2 Measures and Variables

The pre- and post-surveys in this study were designed to gather valuable feedback from participants regarding the intervention and to address the research questions outlined in

Section 3.5. Seven specific scales were utilized to assess various aspects of the intervention are as follows:

The Global Physical Activity Questionnaire (GPAQ) [107] was employed to measure participants' PA levels before and after the intervention. The Perceived Persuasiveness [108] scale was used to analyse participants' perceptions of the intervention's persuasiveness. The Simplicity [109] scale measured participants' perceptions of the intervention's simplicity and ease of use. The Usability [110] scale evaluated participants' perceptions of the intervention's overall usability. Additionally, the Intrinsic Motivation Inventory (IMI) [111] and the ARCS (Attention, Relevance, Confidence, Satisfaction) model [112] were used. The IMI scale assessed participants' intrinsic motivation and interest in the intervention, providing insights into how engaging and motivating the intervention was. The ARC scale evaluated participants' perceptions of the intervention's ability to capture their attention, its relevance to their needs, their confidence in using it.

The effectiveness of the intervention in promoting PA, as well as the answers to RQ1, were determined by analysing the variables GPAQ [3]. Additionally, Perceived Persuasiveness scale played a crucial role in addressing RQ2 and RQ3, as they allowed for an examination of participants' perceptions of the intervention's persuasiveness. Other scales helped to access the overall effectiveness of the app. As part of the survey, participants also provided information about their demographic characteristics, including age group, gender identity, last education obtained. These demographic details are essential for understanding the diverse participant pool and its potential impact on the intervention's outcomes. The specific details and descriptions of all the measures employed in this study will be provided below:

1. **Global Physical Activity Questionnaire:** To assess the current level of PA among the participants, we used the GPAQ [3], a validated instrument consisting of four relevant questions. One such question was, “In a typical week, on how many days do you do moderate-intensity sports, fitness, or recreational (leisure) activities?” This instrument was included in both the pre- and post-study surveys to determine participants' initial behavioural tendencies and attitudes towards PA before the intervention. Additionally, the same scale was employed to identify any behavioural changes that indicated increased

physical activity following the intervention. This data is important for addressing Research Question 1 (RQ1), which focuses on examining the impact of the intervention on participants' PA levels.

2. **Perceived Persuasiveness:** The Perceived Persuasiveness Scale [108] is used to measure the effectiveness of persuasive strategies in encouraging participants toward positive behaviour change. This 7-point scale includes four questions, such as "This feature would influence me to improve my physical activity," to evaluate the overall persuasiveness of the intervention. By analysing this scale, we addressed Research Questions 2 (RQ2) and 3 (RQ3). It is important to note that this scale was applied individually to each of the persuasive strategies implemented within the intervention, as outlined in section 3.6, and subsequently evaluated within the context of the four key features of the intervention.

3**. System Usability:** The SUS [110] was employed to evaluate multiple dimensions of the intervention's usability, including ease of use, complexity, learnability, integrity, and consistency. This scale, which comprises 10 questions adapted from Brooke [110], utilizes a 5-point rating system. Participants responded to statements such as "I think that I would like to use this system frequently," enabling us to derive a comprehensive usability score for the intervention. The SUS facilitated the assessment of key usability aspects inherent in our intervention design. By systematically measuring these aspects, we gained essential insights into the overall user. This detailed evaluation helped us understand how intuitive and user-friendly the intervention was, identifying areas for improvement and validating the design's effectiveness in meeting user needs.

4. **Simplicity**: To evaluate the perceived simplicity of our intervention among participants, we used the Smartphone Interface Simplicity Scale [109], which employs a 5-point rating system. This scale was critical for gaining insights into the ease of use and coherence of our intervention's design, especially given its mobile app nature. We adhered to the facets outlined by Choi and Lee [4], which include Information Design, Task Complexity and Visual Aesthetics. Information Design assessed the clarity and organization of the information presented in the app. Task Complexity evaluated the perceived difficulty of

completing tasks within the app. Visual Aesthetics examined the appeal and attractiveness of the app's interface.

5. **Intrinsic Motivation Inventory (IMI) modified:** To evaluate participants' intrinsic motivation and interest in our intervention, we employed the Intrinsic Motivation Inventory (IMI) scale [111], which uses a 5-point rating system. This scale is essential for understanding how engaging and motivating the intervention was for participants. Specifically, we focused on two sections of the IMI: interest/enjoyment and value/usefulness. The interest/enjoyment section assessed how enjoyable and engaging participants found the intervention, while the value/usefulness section evaluated the perceived usefulness and relevance of the intervention to the participants. These dimensions provided a comprehensive assessment of the participants' intrinsic motivation and engagement with the intervention. It offered valuable insights into how the intervention influenced participants' motivation and overall experience.

6. **ARCS**: To evaluate participants' engagement and motivation in our intervention, we employed the ARCS (Attention, Relevance, Confidence, Satisfaction) model [112], which uses a 5-point rating system. This model is crucial for understanding how well the intervention captured participants' attention, its relevance to their needs, and their confidence in using it. The ARCS model covers various dimensions, including attention, relevance, confidence and satisfaction. These dimensions collectively provide a comprehensive assessment of the participants' engagement and motivation. It offered valuable insights into how the intervention influenced participants' engagement and perceived effectiveness.

In addition to the validated scales discussed in the previous section, participants' demographic information was collected and analysed to support all research inquiries. As a supplementary approach, optional interviews were conducted to gather further feedback on the intervention, with the intent of addressing all three research questions comprehensively. These interviews aimed to encourage participants to share honest and open feedback, exploring different aspects of the intervention and offering valuable insights into its overall effectiveness. For ease of reference, the interview questions,

demographic inquiries, and all other scales discussed in this section are included in the appendices section of this thesis.

4.3 Recruitment of Participants

The research adopted a recruitment strategy, beginning with the distribution of a recruitment notice that included a link directing prospective participants to Dal Opinio. This online platform facilitated the collection of participants' email addresses and questionnaire responses. The recruitment notice was shared across various channels which include university email lists and multiple social media platforms, to maximize reach and engagement. In addition to these broad outreach methods, snowball sampling techniques were employed, enabling enrolled participants to refer other potential participants to the study. This referral method helped expand the participant pool organically through personal networks.

A total of 65 participants was successfully recruited and completed the study. From this group, 17 individuals expressed a willingness to participate in further optional interviews. For the interview phase, an organized approach was taken. Interested participants received a personalized email invitation to schedule their interviews at a convenient time. Those who responded to this invitation and confirmed their availability were subsequently interviewed via online Teams [113] meetings.

Each interview session was carefully planned to last between 15 to 30 minutes and was conducted using the Microsoft Teams platform [113]. This choice of platform ensured that the interviews could be conducted seamlessly, regardless of participants' geographical locations. During the interviews, in the event participants consented to record their interviews, records were maintained to capture the participants' responses accurately. These records were essential for subsequent qualitative analysis and interpretation, providing valuable insights into participants' experiences and perceptions of the intervention.

This thorough and systematic recruitment and interview process ensured a diverse and representative sample, enriching the overall findings of the study. The combination of initial broad outreach, personal referrals through snowball sampling, and detailed

qualitative interviews allowed for a comprehensive evaluation of the PetBuddy app's effectiveness in promoting PA.

4.4 Data Analysis

The study employed an extensive data collection strategy, integrating both quantitative and qualitative sources, each subjected to distinct analytical methods. Quantitative data, obtained through questionnaires and application logs, was analysed statistically to derive meaningful conclusions. This process included generating graphs, charts, and tables to enhance the understanding of underlying patterns and trends. Statistical analysis for the quantitative data was conducted using SPSS software [114], while charts and graphs were created with Power BI [115]. SPSS, known for its robust data analysis capabilities, provided valuable insights into patterns, relationships, and trends within the datasets. Power BI, renowned for its user-friendly interface and powerful visualization features, enabled the creation of diverse and dynamic visualizations, further clarifying the statistical findings. The quantitative analysis involved various statistical tests, including t-tests, ANOVA, and post-hoc pairwise comparisons. Frequency histograms were also generated as needed to visualize data distribution shapes. These rigorous analytical methods allowed for a robust evaluation and interpretation of the quantitative data, yielding significant findings to address the research objectives.

The qualitative data analysis involved a rigorous thematic analysis of interview responses and open-ended questions, using Atlas.ti software for thematic analysis and coding [116]. This process included reviewing all transcribed interview data and systematically coding responses. These coded responses were then organized into distinct thematic categories. Initially, themes were generated to capture the richness and diversity of the data. Subsequently, a thorough examination of these initial themes led to the amalgamation of common themes to avoid redundancy and overlap. This iterative process continued until no further overlaps between themes were observed, ensuring comprehensive theme refinement. Thematic analysis of the qualitative data revealed deep insights into participants' perspectives, organized systematically using Atlas.ti. Initial coding allowed for capturing a wide range of themes, which were refined through an iterative process to ensure clarity. The software facilitated efficient and organized thematic analysis.

The integration of quantitative and qualitative analyses provided a holistic view of the research findings. In the next chapter, the significant findings from both analyses will be discussed, offering a comprehensive understanding of the study's outcomes.

Chapter 5: Results

In this section, we present the results of our analysis based on the data collected during our research study. 83 participants completed the pre-intervention survey, and out of which 69 participants filled out the post-intervention survey. After removing incomplete entries, and cleaning the data, a total of 65 participants were included in the quantitative analysis, providing us with a comprehensive dataset. This dataset includes responses from pre and post study questionnaires, optional interview responses from 17 participants, and data logs automatically recorded by the app. This chapter is divided into three subsections, namely the Participant Demographic, the Quantitative results subsection and the Qualitative results.

We conducted a reliability test, which demonstrated that all the scales used in the study exhibited good internal consistency [117]. The Cronbach's alpha (α) values for each scale were above the recommended threshold of 0.70, as shown in Table 5.1.

Table 5.1: The Cronbach's alpha (α) values for each scale

Scale		*Cronbach's Alpha (α)*
System Usability Scale (SUS)		.805
Simplicity Scale		.744
ARCS	Attention	.788
	Relevance	.873
	Confidence	.911
	Satisfaction	.767
Intrinsic Motivation Inventory (IMI) Modified	Interest/enjoyment	.769
	Value/Usefulness	.955
User Experience Scale (UEQ)	Pragmatic Quality	.880
	Hedonic Quality	.910
Perceived persuasive scale (Self-Monitoring)		.916
Perceived persuasive scale (Customization)		.939
Perceived persuasive scale (Reward)		.953
Perceived persuasive scale (Competition)		.944

5.1 Participants Demographics

In this section, we provide a detailed overview of the demographic characteristics of the participants in our study. Understanding these demographics is essential for interpreting the context and relevance of our findings. Table 5.1 summarizes the participant demographics.

The age distribution of our participants shows a significant representation of young adults, with 29 individuals (45%) falling within the 18-25 years age group. The largest age group, however, is 26-35 years, comprising 30 participants, which accounts for 46% of the total sample. In contrast, only 2 participants (3%) are aged 36-45 years, suggesting minimal representation from this age group. Additionally, there are 4 participants (6%) over the age of 46, indicating a small but notable presence of older adults in our study.

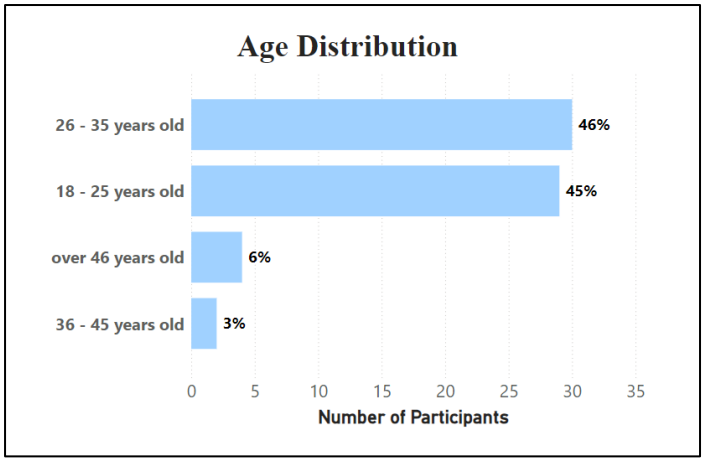
The gender distribution of our participants reveals a slightly higher representation of males, with 37 participants (57%). In comparison, there are 28 female participants, making up 43% of the sample. This gender distribution suggests that while both genders are significantly represented, there is a slight predominance of male participants in our study.

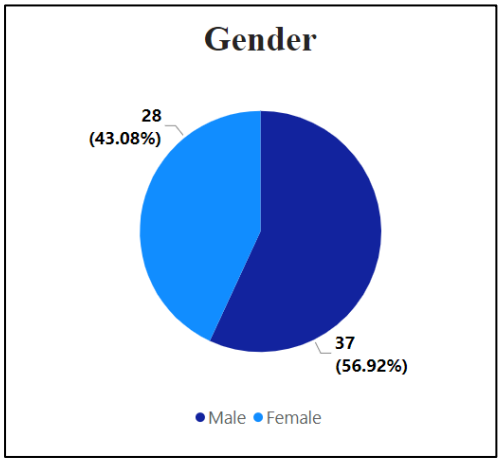
Regarding educational background, the participants exhibit a diverse range of academic qualifications. Six participants (9%) have completed high school or an equivalent level of education. Similarly, another 6 participants (9%) hold a college diploma. The majority of participants, however, possess a bachelor's degree, with 32 individuals (49%) falling into this category, indicating that nearly half of our participants have completed undergraduate education. Additionally, 20 participants (31%) have earned a master's degree, highlighting a substantial proportion with advanced academic qualifications. Only one participant (2%) has a doctoral degree, showing minimal representation from individuals with the highest level of academic achievement.

Overall, the demographic profile of our study participants highlights a diverse group in terms of age, gender, and educational background. Most participants are young to mid-career adults, with a strong representation of those holding bachelor's and master's degrees. This demographic information is crucial for contextualizing the results of our study and understanding the perspectives and experiences of our participants. Table 5.2 shows the demographic characteristics of the participants.

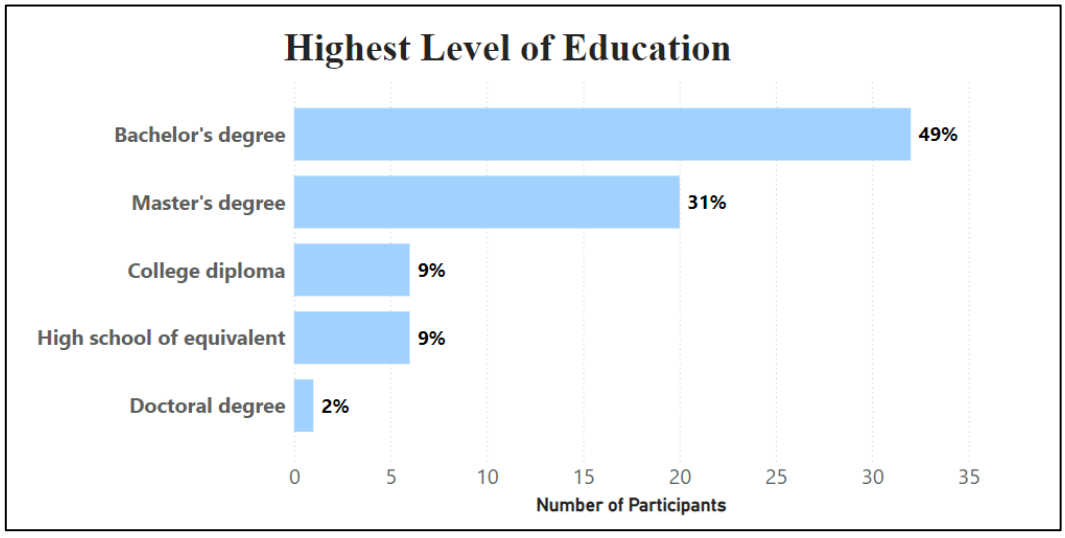
Table 5.2: Demographic characteristics of the study population

Demographic Characteristics		*N* (%)
Age Range	18 – 25 Years old	29 (45%)
	26 – 35 Years old	30 (46%)
	36 – 45 Years old	2 (3%)
	Over 46 Years old	4 (6%)
Gender	Male	27 (57%)
	Female	28 (43%)
Highest Level of Education	High school of equivalent	6 (9%)
	College Diploma	6 (9%)
	Bachelor's Degree	32 (49%)
	Master's Degree	20 (31%)
	Doctoral Degree	1 (2%)





(a) Age Distribution (b) Gender Distribution



(b) Education Level Distribution

Figure 5.1: (a), (b) and (c) illustrating an overview of the demographics of study

5.2 Quantitative Results

To thoroughly address the research questions outlined in Section 3.5, a comprehensive statistical analysis was conducted on the quantitative data gathered during the study. The detailed findings resulting from our quantitative data analysis are expounded upon in the subsequent sections. These sections will provide an in-depth exploration of the statistical results, offering an understanding of the patterns, relationships, and trends identified in the data.

5.2.1 Perceived Change in Physical Activity

The study employed the GPAQ [107] to measure changes in participants' PA levels. To evaluate the effectiveness of the intervention and address Research Question 1 (RQ1), participants' responses were analysed at both time points. In accordance with GPAQ guidelines [107], participants' responses were converted into actual MET values per week. The WHO recommends a minimum of 150 minutes of moderate to vigorous activity per week, which is approximately 600 METs. Initially, descriptive statistics for the pre- and post-intervention data were computed and are presented in Table 5.3

Table 5.3: Descriptive statistics of the PA data at pre- and post-study.

Scale	**Condition**	*M*	*SD*
GPAQ	Pre	528.62	238.7
	Post	692.92	210.01

The results shown in Table 5.3 indicate that the overall initial GPAQ PA score ($M = 528.62$, $SD = 238.70$) did not meet the WHO's recommended baseline of 600 MET. However, the overall post-intervention PA score ($M = 692.92$, $SD = 210.01$) exceeded this threshold. A paired sample t-test was conducted to assess the effectiveness of an intervention designed to increase PA levels among participants.

The paired sample t-test indicates a highly significant increase in PA levels post-intervention, $t(64) = -5.933$, $p < .001$, mean difference of 164.3 (post-pre). The correlation between pre-intervention and post-intervention PA was 0.511, which was statistically significant ($p < 0.001$), indicating a moderate positive relationship between the two measurements.

The effect size, measured using Cohen's *d*, was 0.74, with a 95% confidence interval ranging from -1.008 to -0.459. This suggests a medium to large effect, indicating a substantial practical significance of the intervention. This indicates that the intervention had a meaningful impact on increasing PA levels among the participants.

This observed result is further supported by the data illustrated in Figure 5.2, revealing a statistically significant 13% rise in the post-intervention PA score compared to the baseline score ($p < 0.001$), as demonstrated in Figure 5.2.

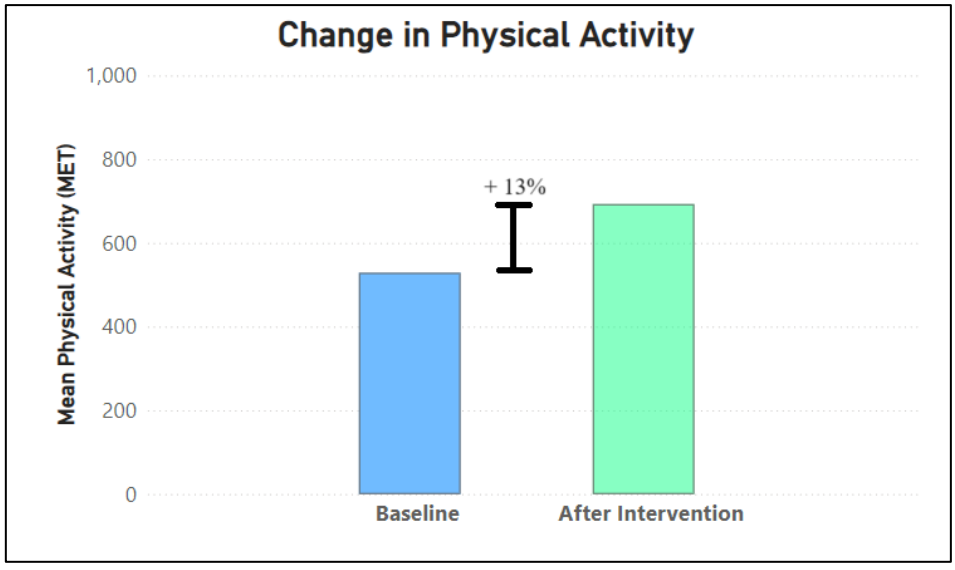


Figure 5.2: Bar chart showing the percentage difference in mean of PA at baseline and after the study.

Figure 5.3 shows the observed trend of PA level escalation measured in MET, with a dotted line indicating the 600 MET benchmark for comparison. The findings illustrate that individuals categorized with low PA initially had MET scores below 600 at baseline, but these scores significantly increased to above 600 post-interventions ($p < 0.001$). Interestingly, participants classified with high PA, who initially reported frequent PA engagement, also increased their PA scores post-intervention. Additionally, Figure 5.4 demonstrates a consistent increase in PA levels for both low and high categories of participants. These results strongly indicate the effectiveness of the intervention in improving participants' PA level.

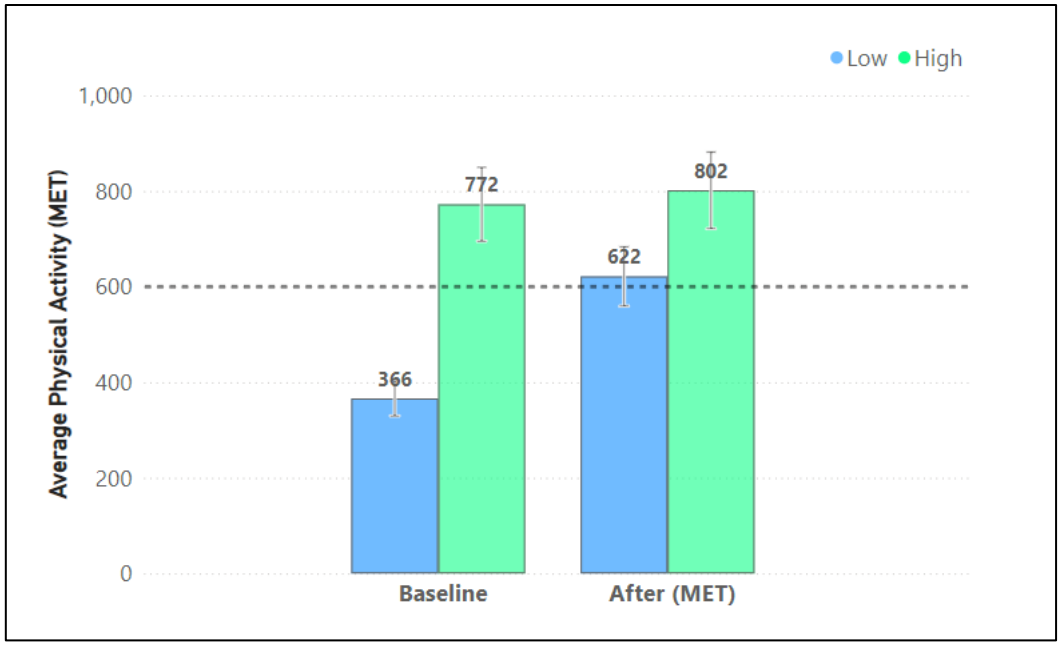


Figure 5.3: Bar chart illustrating pattern of increase in PA level at baseline and after the study

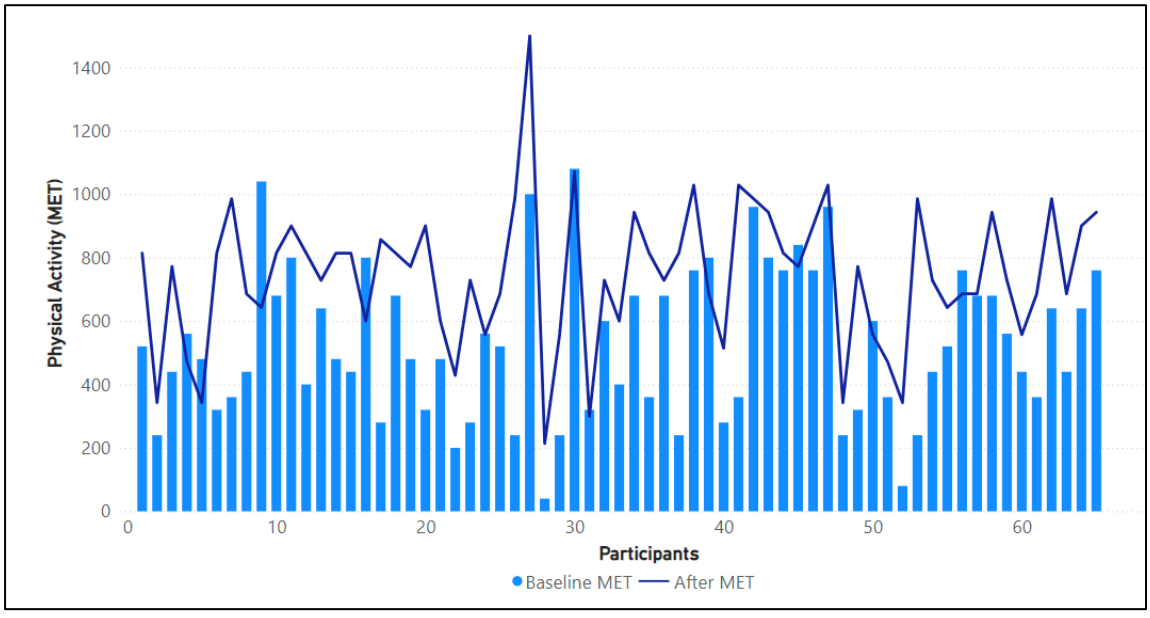


Figure 5.4: Chart illustrating Participant increase in PA at baseline and after the study.

5.2.2 PA with Respect to Age Groups and Genders

Our intervention was designed to foster PA among individuals, regardless of their age or gender. Consequently, we evaluated its effectiveness across various age groups and genders. For age categorization, participants were divided into four groups: (1) 18-25 years

old, (2) 26-35 years old, and (3) 36 - 45 years old, and (d) 46 years and above. Likewise, participants indicated their gender belonging to two categories: female and male. Consequently, we structured the data analysis according to these documented gender classifications. The results of our data analysis regarding PA data concerning age groups and gender categories are shown in Table 5.5 and Table 5.6, correspondingly. These tables encompass descriptive statistics enabling a thorough comprehension of the intervention's influence across diverse age groups and genders.

The analysis of PA levels before and after the intervention indicates a substantial improvement across various age groups and genders. Table 5.4 and 5.5 shows the descriptive statistics of the PA data in MET with respect to age group and Gender for pre and post condition. These results suggest that the intervention was effective in enhancing PA levels universally, with younger individuals and females showing particularly notable gains. This underscores the intervention's positive impact on promoting PA across different demographics. Figure 5.5 and 5.6 depicts Line chart showing the main effect of PA across age groups and gender respectively, with a dotted line indicating the 600 MET benchmark for comparison.

Table 5.4: Descriptive statistics of the PA data in MET with respect to age groups.

	Condition			
	Pre		**Post**	
Age Group	*M*	*SD*	*M*	*SD*
18 – 25 Years	590.34	277.88	722.76	250.69
26 – 35 Years	460	185.47	678.66	158.43
36 – 45 Years	560	395.98	600	169.71
Over 46	580	147.87	640	267.33

Table 5.5: Descriptive statistics of the PA data in MET with respect to genders

	Condition			
	Pre		**Post**	
Gender	*M*	*SD*	*M*	*SD*

Male	574.05	224.94	707.03	173.09
Female	468.57	247.02	675.71	250.71

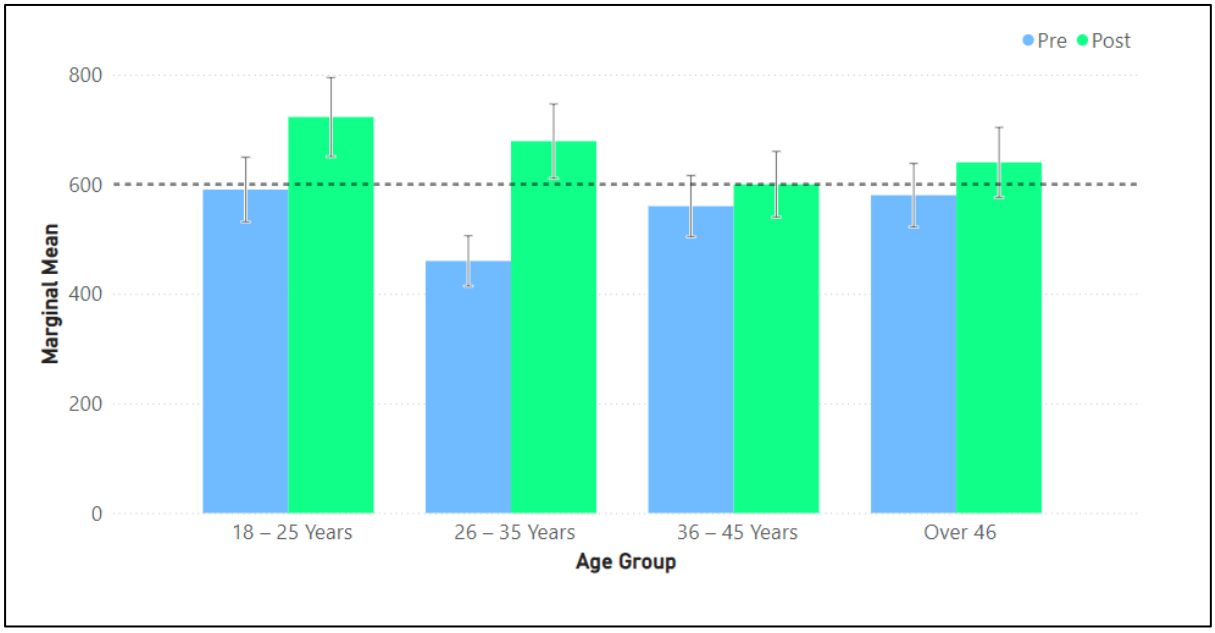


Figure 5.5: Line chart showing the main effect of PA across age groups.

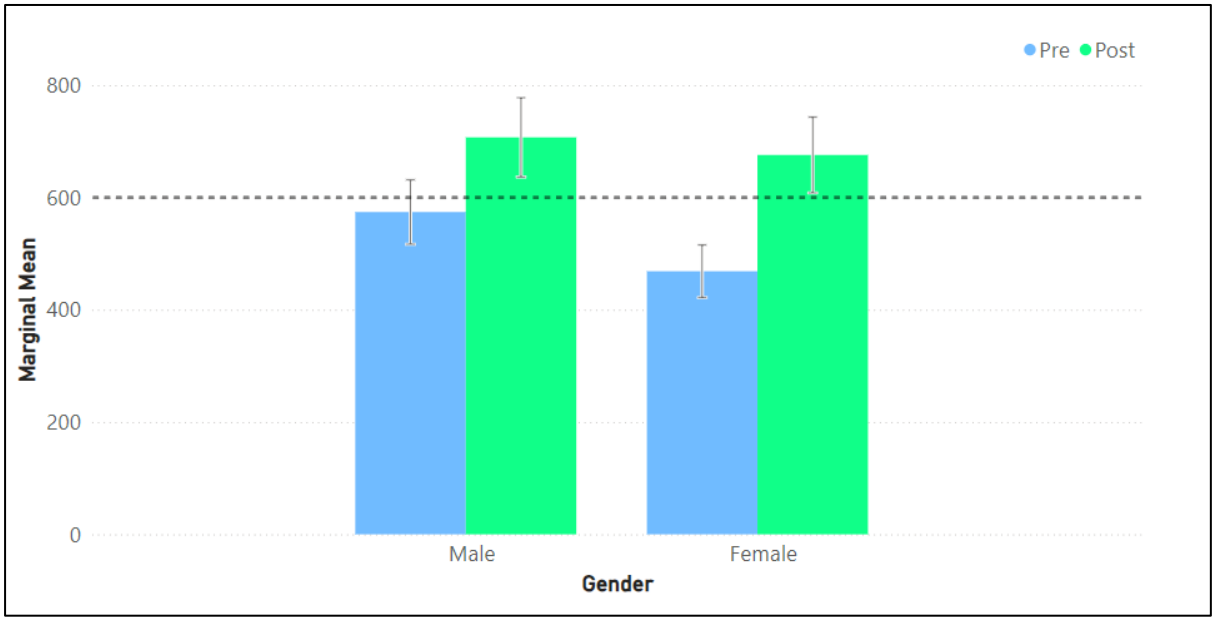


Figure 5.6: Line chart showing the main effect of PA across genders.

5.2.3 Recorded Physical Activity during Study

As detailed in Section 3.3.5 of the study, participants' daily walk duration was monitored using app logs throughout the entire study. At the end of the study, the aggregated walk duration data was extracted from these logs. To account for the natural variability in participants' walk durations, we classified them into two distinct groups: "low" and "high." This categorization was based on the median total walk minutes recorded for each participant, which was calculated to be 85 minutes. The rationale behind utilizing the median as a measure was that it provided a stable representation of the data, facilitating the categorization of participants into low and high. The median provides a better measure of central tendency when dealing with skewed data distributions. Participants with walk durations below 85 minutes were placed in the "low" group, while those exceeding this threshold were placed in the "high" group. Figure 5.7 illustrates the outcome of this categorization process. Specifically, 30 participants, with an average walk duration of 112 minutes, were classified into the "high" group, whereas 35 participants, with an average walk duration of 50 minutes, were categorized into the "low" group.

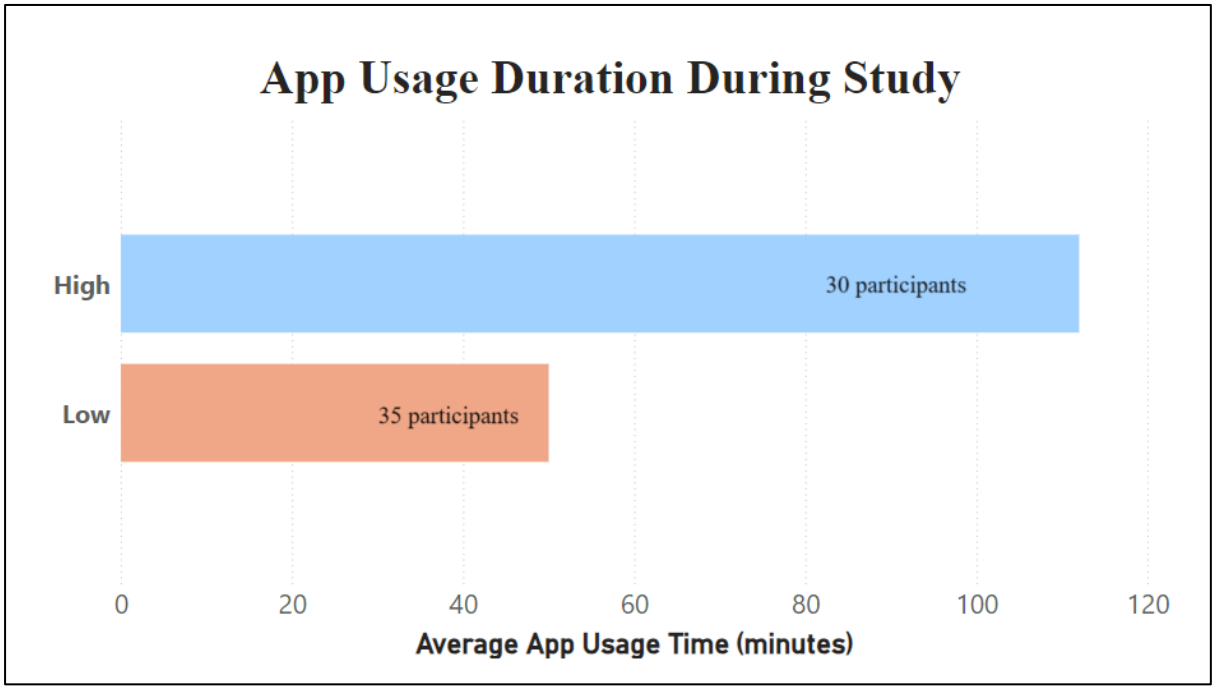


Figure 5.7: Bar chart showing the walk duration during study where participants' performance was categorized into high and low.

Additionally, we examined whether our intervention influenced participants' engagement in walking during the study period. To do this, we extracted each participant's weekly walking activity before the study and compared it to their weekly walking activity after the intervention using a paired sample t-test. The results show a significant increase in walking activity from pre- to post-intervention, $t(64) = -5.58$, $p < .001$. The results indicate a significant increase in participants' walking activity from pre-intervention to post-intervention. Figure 5.8 shows the walking activity comparison of each participant before and after the study. The length of the bar and line on y-axis in Figure 5.8 indicates the number of days a participant walked in a week.

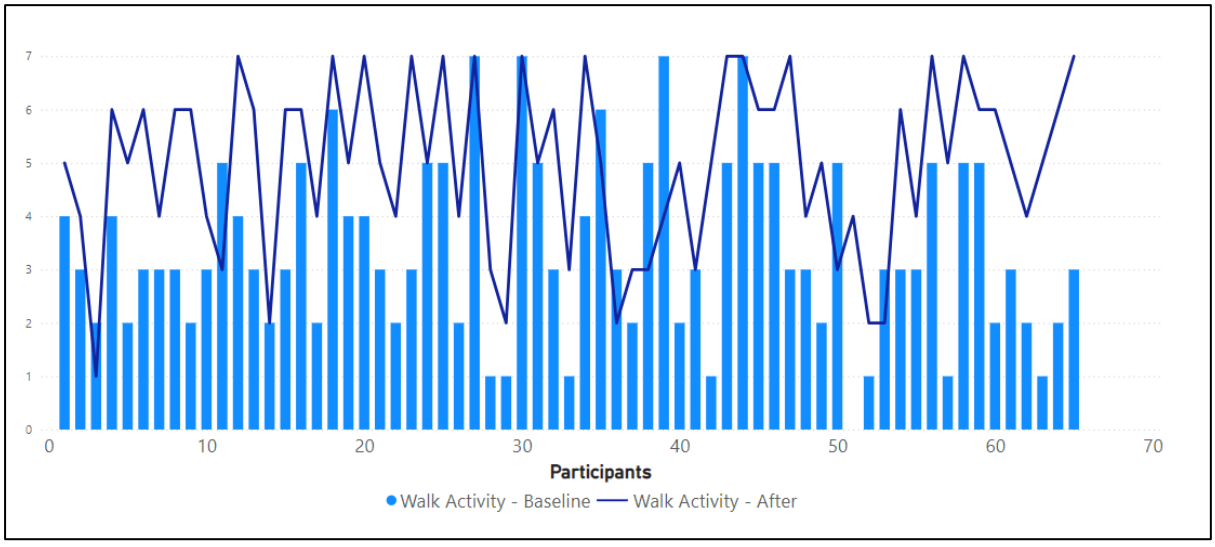


Figure 5.8: Weekly Walk activity of each participant before and after the study.

To assess the correlation between the walking data reported by participants from the survey and the app log, we employed intraclass correlation coefficients (ICC). The ICC values demonstrate a substantial correlation between the data collected via the survey and the app log. Specifically, the results indicate a high degree of reliability between the two data sources, with single measures showing an ICC of 0.743 ($p < .001$) and average measures showing an ICC of 0.853 ($p < .001$). The high ICC values indicate that both the app log and survey data effectively capture similar levels of physical activity, supporting the reliability of these methods for measuring MET. According to Koo & Li (2016) [118], these ICC scores, particularly the average measure, suggest substantial agreement, further

affirming the consistency of the data collected through both approaches. Figure 5.9 shows the correlation between the app log and survey data.

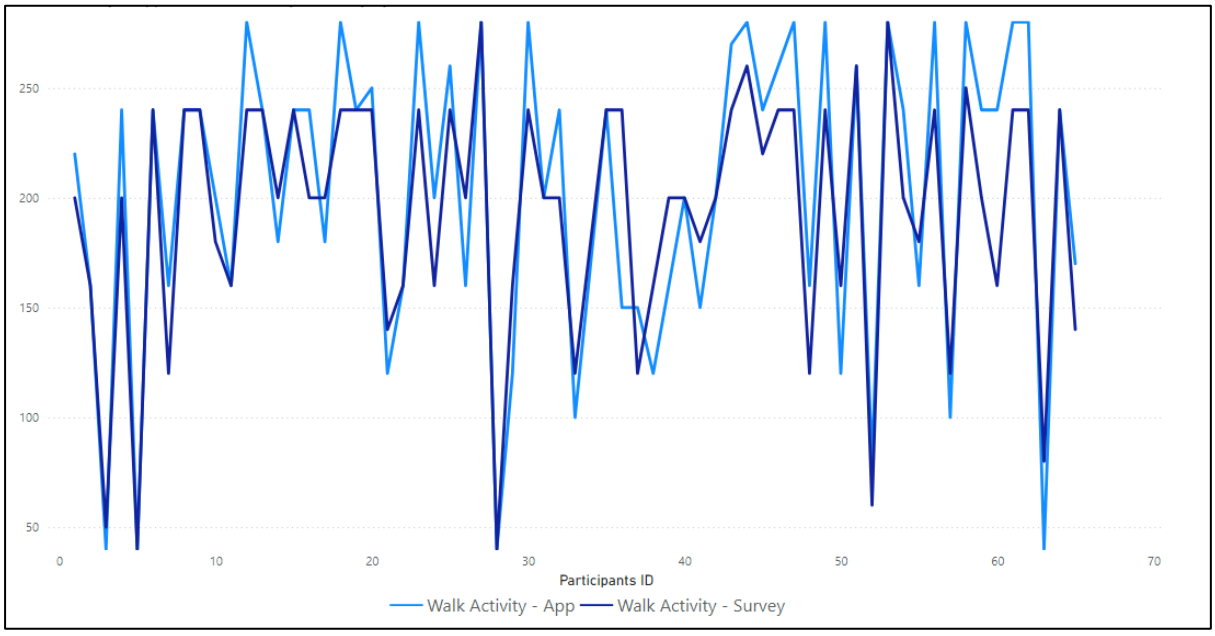


Figure 5. 9: Weekly Walk activity Correlation between App log and Survey data

5.2.4 Perceived Persuasiveness of Gamification Element

To evaluate the perceived persuasiveness of the gamification elements—Profile (Self-Monitoring), Shop (Customization), Points (Reward), and Leaderboard (Competition)—we utilized the perceived persuasiveness scale with a neutral midpoint value of 4. The one-sample t-test results revealed that all four elements were perceived as significantly persuasive, with mean scores exceeding the neutral value as shown in table 5.6.

Table 5.6: Descriptive statistics and one sample t-test of the perceived persuasiveness of the intervention.

		Descriptive Statistics		**One sample t-test**		
Gamification Elements	**Persuasive strategies**	*M*	*SD*	*t*	*df*	*p*
Shop	Customization	5.21	1.3	7.56	64	<.001
Profile	Self-Monitoring	5.57	1.07	11.80	64	<.001
Points	Reward	5.76	1.11	12.73	64	<.001
Leaderboard	Competition	6.21	1.01	17.63	64	<.001

The Profile element, which represents the Self-Monitoring strategy, achieved a mean score of 5.57 (*SD* = 1.07). The one-sample t-test showed a significant deviation from the neutral value, $t(64) = 11.80$, $p < .001$, indicating that participants found this feature to be significantly persuasive. This suggests that enabling users to monitor their own progress effectively enhances the perceived persuasiveness of the intervention.

The Shop element, associated with Customization, had a mean score of 5.21 (*SD* = 1.30). The t-test result ($t(64) = 7.56$, $p < .001$) confirmed its significant positive perception. Although persuasive, the Shop element was rated lower than Profile, suggesting that while customization is valued, it may not be as compelling as self-monitoring features.

The Points element, which embodies the Reward strategy, received a mean score of 5.76 (*SD* = 1.11). The significant t-test result $t(64) = 12.73$, $p < .001$ highlighted its high perceived persuasiveness, indicating that rewarding users is an effective persuasive strategy. Participants responded very positively to this feature, reflecting the motivational power of rewards.

The Leaderboard element, representing the Competition strategy, had the highest mean score of 6.21 (*SD* = 1.01). The t-test result $t(64) = 17.63$, $p < .001$ demonstrated a strong positive perception, making it the most persuasive feature among the four as shown in figure 5.10. This indicates that competitive elements strongly enhance the perceived persuasiveness of the intervention, likely due to the engaging and motivating nature of competition. Competition can stimulate users' desire to outperform others, leading to increased effort and engagement with the intervention.

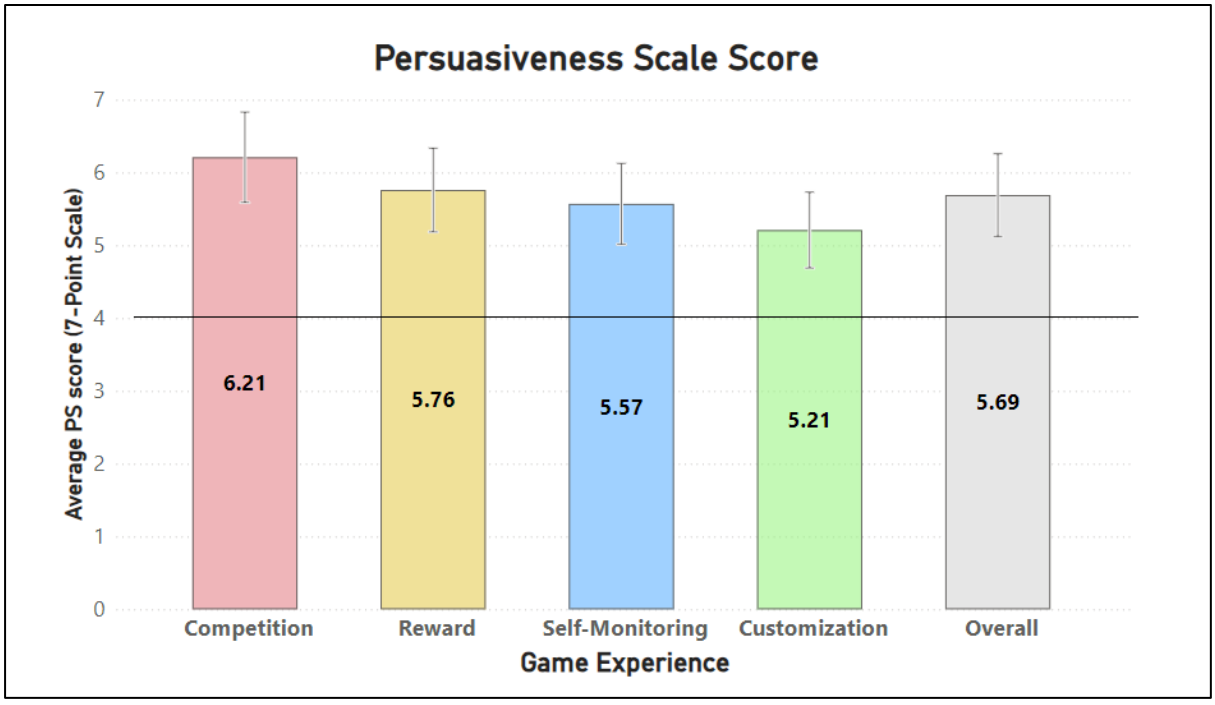


Figure 5.10: A bar chart showing the persuasive score of each feature and the overall persuasiveness

5.2.5 Differences in the Perceived Effectiveness of the Gamification Element

To further understand the differences in perceived persuasiveness between the gamification elements, a Repeated Measures Analysis of Variance (RM-ANOVA) was conducted after validating ANOVA assumptions. The analysis aimed to compare the effectiveness of different gamification features: self-monitoring, customization, reward, and competition.

First, Mauchly's Test of Sphericity indicated that the assumption of sphericity had been violated ($\chi^2(2) = 35.656$, $p < .001$). Consequently, the Greenhouse-Geisser correction was used to adjust the degrees of freedom for the RM-ANOVA. The results revealed a significant main effect of the gamification feature on perceived persuasiveness ($F(3, 69) = 35.656$, $p < .001$, $\eta^2 = .741$), indicating that there are significant differences in perceived persuasiveness among the gamification elements.

To discern the extent of significant differences among the features, post-hoc pairwise comparisons with Bonferroni correction were employed. The pairwise comparisons

yielded several insights. Table 5.7 shows pairwise comparison results of the perceived persuasiveness of the intervention. Self-monitoring was perceived as significantly more persuasive than customization (Mean Difference = 0.354, $p = 0.009$). However, there was no significant difference in perceived persuasiveness between self-monitoring and reward (Mean Difference = -0.188, $p = 0.058$). Conversely, self-monitoring was perceived as significantly less persuasive than competition (Mean Difference = -0.638, $p < .001$).

Further comparisons indicated that customization was perceived as significantly less persuasive than reward (Mean Difference = -0.542, $p < .001$) and significantly less persuasive than competition (Mean Difference = -0.992, $p < .001$). Additionally, reward was perceived as significantly less persuasive than competition (Mean Difference = -0.450, $p < .001$).

These results highlight that ***competition was perceived as the most persuasive gamification element***, overall followed by self-monitoring, reward, and customization. The findings suggest that incorporating competitive elements into gamified applications can significantly enhance their perceived persuasiveness, potentially leading to higher user engagement and motivation.

Table 5.7: Pairwise comparison results of the perceived persuasiveness of the intervention

Gamification Elements (I)	**Gamification Elements (J)**	Mean difference (I – J)	Std. Error	*p*
Profile	Shop	.354	.132	.009
	Points	-.188	.097	.058
	Leaderboard	-.638	.137	<.001
Shop	Profile	-.354	.132	.009
	Points	-.542	.153	<.001
	Leaderboard	-.992	.175	<.001
Points	Profile	.188	.097	.058
	Shop	.542	.153	<.001
	Leaderboard	-.450	.106	<.001
Leaderboard	Profile	.638	.137	<.001
	Shop	.992	.175	<.001
	Leaderboard	.450	.106	<.001

5.2.6 Perceived Persuasiveness of Game Experience

To evaluate the perceived persuasiveness of three different game experiences—AR, Emotion (Happy/Sad Dog Face), and Idle Game Design—we utilized the Perceived Persuasiveness scale with a neutral midpoint value of 4. The one-sample t-test results as shown in Table 5.8 revealed that all three game experiences were perceived as significantly persuasive, with mean scores exceeding the neutral value.

Table 5.8: Descriptive statistics and One Sample t-test of the perceived persuasiveness of the intervention.

	Descriptive Statistics		**One sample t-test**			
Game Experience	*M*	*SD*	*t*	*df*	*P*	*Cohen's d*
AR	5.82	1.07	13.75	64	<.001	1.71
Emotion	5.46	1.12	10.50	64	<.001	1.12
Idle game	4.92	1.34	5.67	64	<.001	1.34

The AR game experience had a mean score of 5.82 (SD = 1.07). The one-sample t-test indicated a significant deviation from the neutral value, $t(64) = 13.75$, $p < .001$), with a large effect size (*Cohen's d* = 1.71). This suggests that participants found the AR experience highly persuasive. The immersive and interactive nature of AR likely enhances engagement, making it a compelling persuasive tool.

The Emotion game experience, featuring Happy/Sad Dog Face, achieved a mean score of 5.46 (SD = 1.12). The t-test result $t(64) = 10.50$, $p < .001$) also indicated a significant positive perception, with a large effect size (*Cohen's d* = 1.12). Although not as highly rated as AR, the Emotion experience still had a strong persuasive impact, possibly due to its emotional engagement with users through expressive feedback.

The Idle Game experience received a mean score of 4.92 (SD = 1.34). The t-test result $t(64) = 5.67$, $p < .001$) confirmed its significant persuasiveness, with a moderate effect size (*Cohen's d* = 1.34). While rated lower than both AR and Emotion experiences, the Idle Game was still perceived as more persuasive than the neutral value, indicating its

effectiveness in engaging users, perhaps through its casual and ongoing interaction style. Figure 5.11 shows a bar chart of persuasiveness score of each game experience.

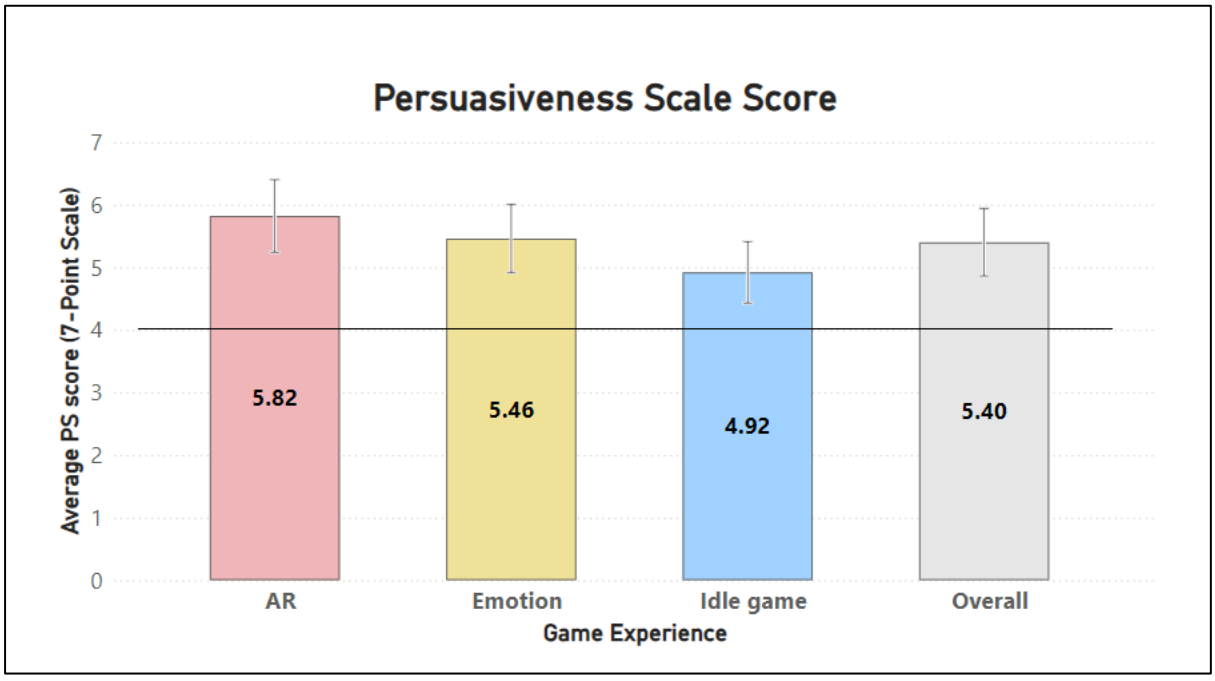


Figure 5.11: A bar chart showing the persuasive score of each Game Experience and the overall persuasiveness

5.2.5 Differences in the Perceived Effectiveness of the Game Experience

To further understand the differences in perceived persuasiveness between the gamification elements, a Repeated Measures Analysis of Variance (RM-ANOVA) was conducted. The within-subjects factors included three experiences: AR, Emotion, and Idle. The results from Mauchly's Test of Sphericity indicated that the assumption of sphericity had not been violated, $\chi 2(2) = 4.110$, $p = 0.128$.

The RM-ANOVA revealed significant differences in perceived persuasiveness across the three experiences. Post-hoc pairwise comparison was conducted to identify specific differences between each pair of experiences. Table 5.9 shows that the perceived persuasiveness of the AR experience was significantly higher than that of the Emotion experience and Idle game experience, with a mean difference of 0.362 and a standard error of 0.137 ($p = 0.010$and a mean difference of 0.881 and a standard error of 0.162 ($p < 0.001$), respectively.

Further comparisons indicated that the Emotion experience was also significantly more persuasive than the Idle experience, with a mean difference of 0.519 and a standard error of 0.134 ($p < 0.001$). These results underscore the distinct impact of each gamification element on persuasiveness, highlighting the potential effectiveness of AR and Emotion experiences in enhancing user engagement compared to a passive Idle game.

In conclusion, the RM-ANOVA and subsequent pairwise comparisons provide robust evidence of significant differences in perceived persuasiveness between the AR, Emotion, and Idle experiences. These results highlight that ***AR was perceived as the most persuasive gamification element***, followed by Emotion and Idle game.

Table 5.9: Pairwise comparison results of the perceived persuasiveness of the intervention.

Gamification Experience (I)	**Gamification Experience (J)**	*Mean difference (I – J)*	*Std. Error*	*P*
AR	Emotion	.362	.137	.010
	Idle game	.881	.162	<.001
Emotion	AR	-.362	.137	.010
	Idle game	.519	.134	<.001
Idle game	AR	-.881	.162	<.001
	Emotion	-.519	.134	<.001

5.2.6 Perceived Usability of the Intervention

Given that PetBuddy is introduced as an innovative intervention, assessing its usability is important. To achieve this, we utilized the System Usability Scale (SUS). The data collected from the SUS survey, which included scores, and item means, provided a comprehensive overview of the application's usability.

The average SUS score for PetBuddy was 75.12 ($SD = 15.06$) indicates that the overall usability of the PetBuddy app is considered "above average" [119]. The relatively low standard deviation further indicates that participants' ratings were consistently positive, reflecting a consensus on the usability of the application.

To determine whether this score significantly deviates from a neutral midpoint value, a one-sample t-test was conducted. The results revealed a $t(64) = 38.52$, $p < .001$. This indicates a highly significant deviation from the neutral midpoint, demonstrating that the usability of app is perceived very positively by the participants. Additionally, the effect

size, calculated using *Cohen's d* = 4.778, suggesting a very large effect and reinforcing the substantial usability of the system.

To visualize how ratings are distributed, we generated a 100% stacked bar chart. Figure 5.12 illustrates that most respondents chose "agree" or "strongly agree" for statements. These results indicate strong support for the intervention, with more than 75% of participants falling into this positive category. Such a favourable reaction reinforces the idea that the PetBuddy app demonstrates notable usability and learnability characteristics.

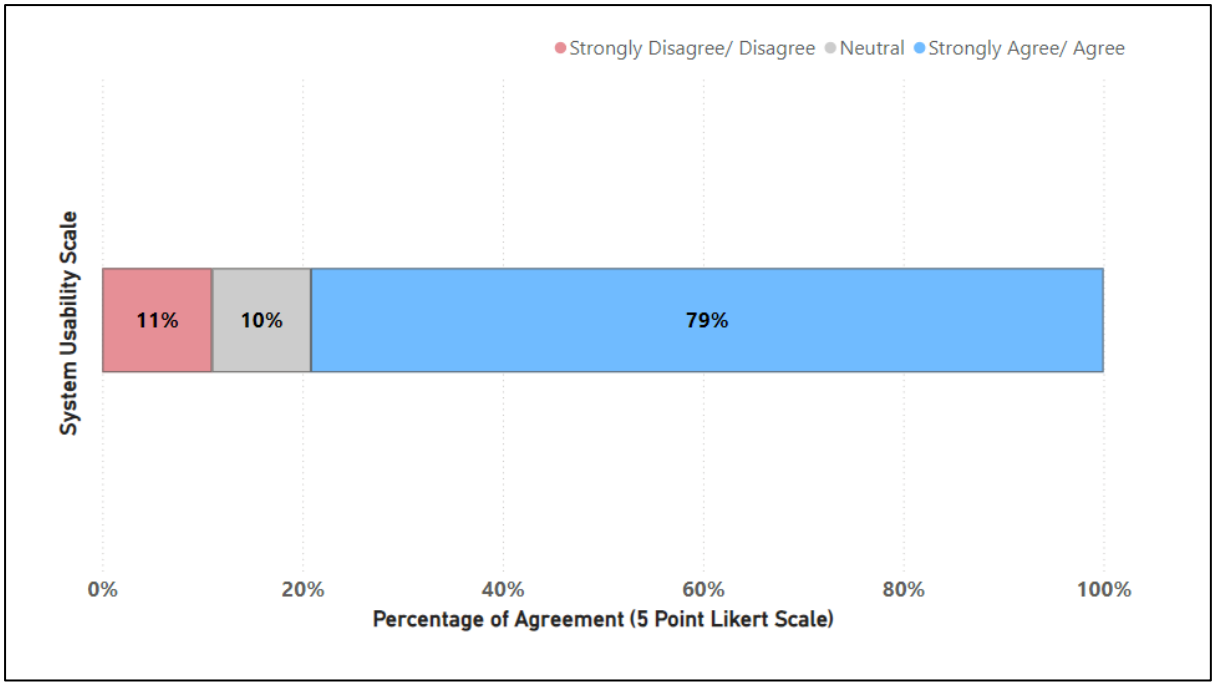


Figure 5.12: Bar chart illustrating the usability of the intervention

5.2.7 Perceived Simplicity of the Intervention

To gain insight into the overall simplicity of the intervention, we conducted a one-sample t-test, employing an optimistic neutral score of 3 on 5-point scale. This allowed us to determine whether the participants' simplicity scores were significantly higher or lower than the optimistic neutral score of 3. The results of the one-sample t-test as demonstrated in Table 5.10 shows that the simplicity scores were significantly higher than the neutral score of 3. The mean simplicity score was 3.94 (*SD* = 0.48), indicating a positive reception regarding the ease of use of the intervention. The t-value $t(64) = 15.81$, $p = <.001$ signifying a statistically significant difference. The effect size, as measured by *Cohen's d*

= 1.96, which suggests a very large effect. These findings highlight the high level of user-friendliness perceived by the participants and affirm the intervention's simplicity.

Table 5.10: One sample t-test of Simplicity

Scale	**Domain**	*M*	*SD*	*T*	*Df*	*p*	*Cohen's d*
Simplicity	Information Design	3.96	0.70	11.11	64	<.001	1.38
	Task Complexity	3.38	1.17	2.65	64	0.010	0.33
	Visual Aesthetic	4.29	0.64	16.22	64	<0.001	2.01

In summary, we incorporated simplicity scale questions derived from three distinct domain: Information Design, Task complexity and Visual Aesthetic. The graphical representation of the simplicity scale, shown in Figure 5.13, illustrates participants' perceptions of our intervention's simplicity, indicating positive responses in visual aesthetics (92%), information design (75%) and task complexity (59%). These results suggest that our intervention was user-friendly and straightforward in its application.

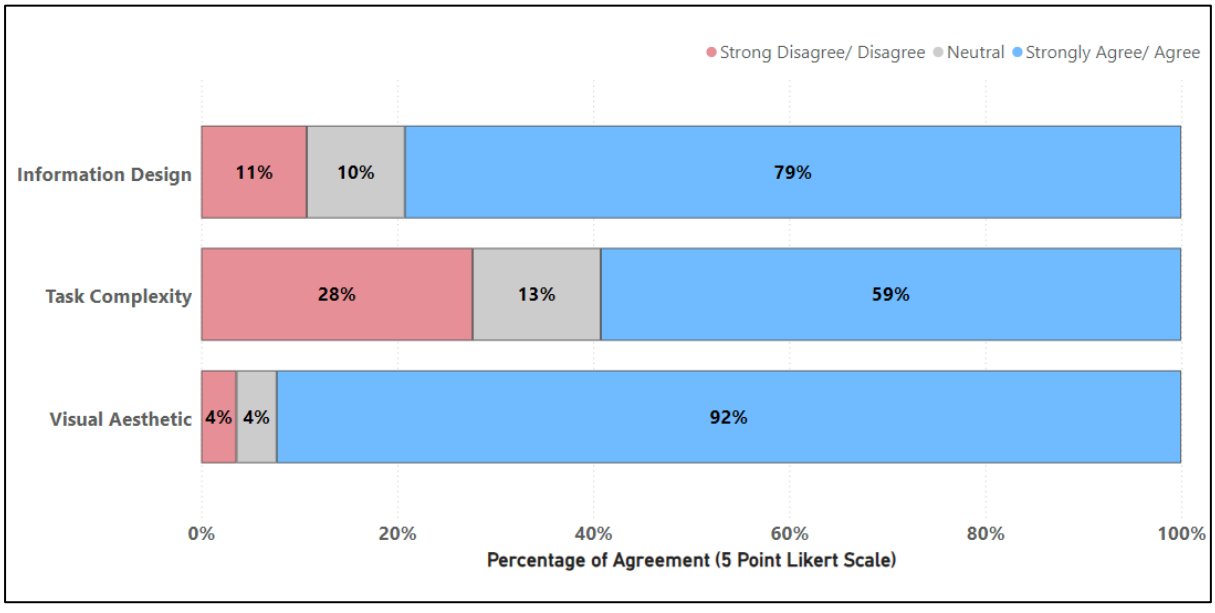


Figure 5.13: Bar chart illustrating the simplicity of the intervention.

5.2.8 User Experience and Intrinsic Motivation of the Intervention

To evaluate the user experience and intrinsic motivation of our intervention, we conducted comprehensive analyses using both the Short User Experience Questionnaire (UEQ) and a modified version of the Intrinsic Motivation Inventory (IMI). These analyses provided insights into various dimensions of user experience and intrinsic motivation among participants.

The Short UEQ analysis revealed positive feedback across both pragmatic and hedonic dimensions. The pragmatic quality, reflecting the practical aspects of usability, had a mean score of 2.14 (*SD* = 0.88). The confidence interval for this score ranged from 1.93 to 2.35, indicating a consistently positive evaluation of the intervention's usability. The hedonic quality, encompassing the emotional and aesthetic appeal, yielded a mean score of 1.90 (*SD* = 0.91) with a confidence interval ranging from 1.68 to 2.13. Both dimensions received an "Excellent" rating compared to benchmark data, positioning our intervention within the top 10% of similar products and indicating a high level of user satisfaction.

To assess intrinsic motivation, we employed a modified version of the IMI. The scale revealed a mean score of 4.34 (*SD* = 0.56) on a 5-point Likert scale. A one-sample t-test was shown in Table 5.11 determined that this score significantly deviated from a neutral midpoint of 3, with a $t(64) = 19.07$, $p < .001$. This indicates a significantly higher intrinsic motivation among participants. The effect size, measured by *Cohen's d* = 2.36, indicating a large effect size and suggesting that the intervention successfully enhanced participants' intrinsic motivation.

Table 5.11: One sample t-test of IMI scale

		Descriptive Statistics		**One sample t-test**			
Scale	**Domain**	*M*	*SD*	*T*	*df*	*p*	*Cohen's d*
IMI Modified	Value/ Usefulness	4.2	0.62	15.66	64	<.001	1.94
	Interest/ Enjoyment	4.47	0.59	19.79	64	0.01	2.45

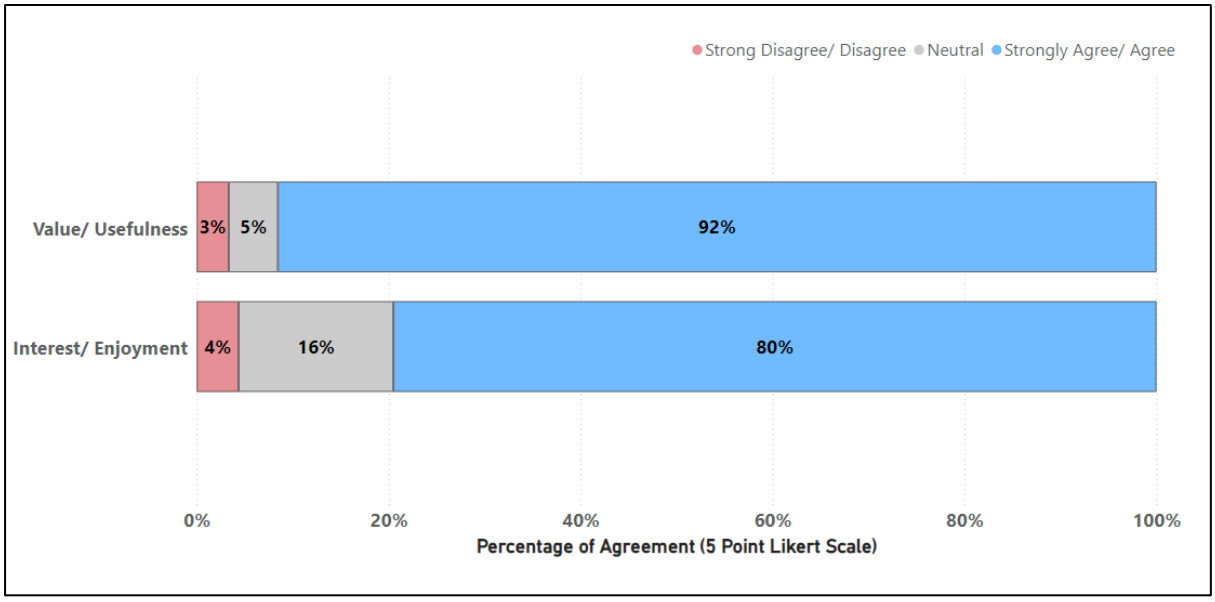


Figure 5.14: Bar chart illustrating the Value/Usefulness and Interest/Enjoyment of the intervention.

In summary, we incorporated modified IMI scale questions including two distinct domains: Value/Usefulness and Interest/Enjoyment. The graphical representation of the scale as shown in Figure 5.14, illustrates participants' perceptions of our intervention's, indicating positive responses in Value/Usefulness (92%) and Interest/Enjoyment (80%). These results underscore the efficacy of our approach in capturing participants' engagement and validating the perceived benefits and enjoyment derived from our intervention.

Overall, the results underscore the user-friendliness, appeal, and motivating nature of our intervention. The high scores in both pragmatic and hedonic qualities, along with the significant positive intrinsic motivation, reflect a well-rounded and successful implementation. Participants not only found the intervention easy to use and aesthetically pleasing but also felt intrinsically motivated, highlighting the intervention's value and effectiveness.

5.2.9 ARCS Model

The Attention, Relevance, Confidence, and Satisfaction (ARCS) scale was utilized to evaluate the participants' engagement and satisfaction levels. The descriptive statistics showed a mean score of 4.2 (SD = 0.59) from a sample of 65 participants. These statistics

indicate a generally positive assessment from the respondents regarding the dimensions measured by the ARCS scale.

To further explore whether the mean score significantly deviated from the neutral midpoint of 3, a one-sample t-test was performed. Results are shown in Table 5.12. The analysis yielded with a $t(64) = 15.60$, $p < .001$. This significant difference suggests that the participants' ratings on the ARCS scale were substantially higher than neutral, indicating a favourable perception of their experiences.

Moreover, the effect size, measured by *Cohen's d*, was calculated to be 2.03. This large effect size implies that the difference between the observed mean and the neutral midpoint is not only statistically significant but also practically meaningful. The large effect size indicates that the high ratings on the ARCS scale are robust and reflect a strong positive response from the participants. These findings highlight the substantial impact and perceived value of the experience.

Table 5.12: One sample t-test of ARCS

		Descriptive Statistics		**One sample t-test**			
Scale	**Domain**	*M*	*SD*	*t*	*Df*	*P*	*Cohen's d*
ARCS	Attention	4.12	0.62	14.63	64	<.001	1.81
	Relevance	4.17	0.61	15.37	64	0.010	1.91
	Confidence	4.28	0.68	15.14	64	<.001	1.88
	Satisfaction	4.19	0.77	12.39	64	<.001	1.54

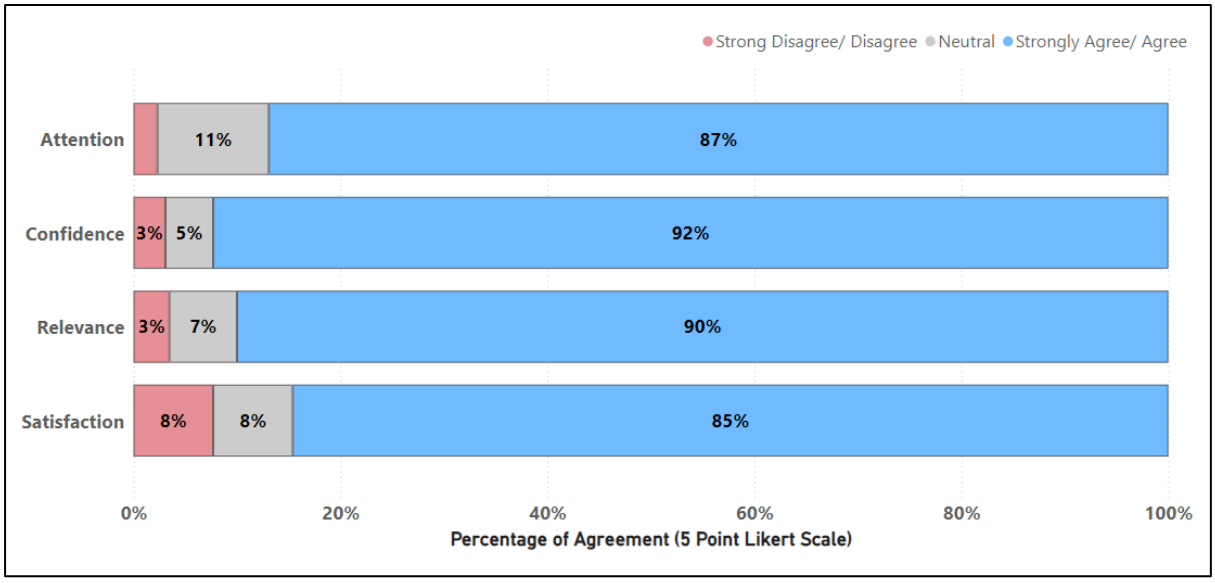


Figure 5.15: Bar chart illustrating the Attention, Relevance and confidence of the intervention.

In summary, we incorporated ARCS scale questions including four distinct domains: Attention, Relevance, Confidence and Satisfaction. The graphical representation of the scale as shown in Figure 5.15, illustrates participants' perceptions of our intervention's, indicating positive responses in Attention (87%), Relevance (90%), Confidence (92%) and Satisfaction (85%). These results underscore the effectiveness of our approach in capturing participants' engagement and validation of our intervention's impact.

5.3 Qualitative Results

We conducted interviews to gather additional feedback from 17 participants. Those interested in participating in an interview provided their email addresses at the end of the study. We then contacted them to schedule the interviews. Each interview included 12 semi-structured questions (see Appendix H) and lasted approximately 15 - 30 minutes. After the interviews, we analysed the participants' feedback to understand the overall reception of the system by identify recurring themes in their comments. After completing 17 interviews, we reached the point of saturation, where no new themes or insights emerged from the responses. This indicated that our data collection had achieved data saturation, and we decided to conclude the interview phase. We then proceeded to analyse all the collected feedback to derive meaningful and generalizable conclusions. A thematic

analysis of the interview responses was conducted using Atlas.ti, a qualitative data analysis software [120].

The following section presents a qualitative analysis of the participants' experiences with the PetBuddy app. The analysis is based on the responses from 17 participants and aims to identify key themes related to the app's usability, features, and overall impact on the users' PA and engagement. There were no specific criteria for participation in the interview, as all study participants were eligible. Consequently, we conducted a thematic analysis [121] using inductive approach. After setting the initial codes, revisiting them, and updating when required, our thematic analysis uncovered nine themes: (1) The design of the app is visually appealing, (2) The app is simple and easy to use, (3) Features that encouraged more walking (4)Setting goal increases enjoyment and facilitates positive attitude change towards physical activity, (5) Competition motivates players to walk more and earn more points, (6) The app enhance the engagement with AR by being fun and innovative approach to exercise, (7) Step tracking helps me to monitor progress, (8) I would recommend the app to others, (9)Additional features, activities and reward has the potential to enhance the overall game experience. The following subsections define and provide sample quotes to support each of these themes. Quotes are presented verbatim with minor spelling and grammatical corrections.

Theme 1: The design of the app is visually appealing

This theme describes the visual appeal of the PetBuddy app among participants. In general, participants perceived the app positively. Many participants commented on the visual design of the app, including its calming colour scheme received specific praise. Many participants also felt that the good visual elements contributed to a pleasant user experience, making the app visually appealing and enjoyable to use. A sample few comments supporting how participants thought the design was visually appealing are presented below.

> P5: *"The calming image of the dog and the colour scheme made the app very **pleasant** to use."*
>
> P17*: "I liked the concept. The design is **nice**."*

P38: "*The design of the app is **neat and appealing.**"*

P63*: "My experience with this app was undoubtedly **unique** as I have not encountered similar apps like PetBuddy. The design was also **eye catchy** and very useful for getting details to the user who are using the app for first time.**"***

This is a positive result because the design is the first aspect users notice when they start using the app. A well-designed interface can significantly enhance their initial impression and overall user experience.

Theme 2: The app is simple and easy to use

Ease of use was another theme that arise from the data. Several participants noted that the app was straightforward and user-friendly, making it accessible. This ease of use is essential for ensuring that users do not become frustrated or overwhelmed. For example, participants said:

P2: *"The app is really **easy** to use, and I didn't have any trouble figuring it out."*

P5*: "The app is **fairly simple** to use."*

P13*: "I appreciate how **intuitive** the app is. It made me want to use it more."*

P44: *"The app is pretty simple to use. Everything is easy to access from the homepage."*

The simplicity and user-friendliness of the PetBuddy app were key factors in shaping users' initial perceptions and encouraging continued use. Participants consistently highlighted the app's intuitive design and ease of navigation. This ease of use is critical for fostering a positive user experience and ensuring sustained engagement with the app.

Theme 3: Features that encouraged more walking

This theme describes the motivation for sustaining PA through walking. Participants reported that the app's features, such as the competition, reward system, step counter and dog played significant roles in encouraging them to incorporate more PA into their daily routines. One of the most direct impacts of the app was on participants' daily walking

habits. Several participants noted that they began walking more frequently and for longer durations after starting to use the app. For example, participants said:

> P1: *"I go for a **walk every single day** since downloading the app. After starting to use the app I am motivated to walk more."*
>
> P2: *"I've added an **additional 15–20-minute walk** to my schedule instead of taking the bus."*
>
> *P16: "My **step count has increased**. I've become fitter."*
>
> *P44: "The app motivates me to **walk more** which I was not used to do earlier."*
>
> *P63: "This app helped me to regain those hours of being inactive and utilize them to **being active and confident** about myself as well."*

The step counter helped participants to monitor their PA. This feature served as a constant reminder of their PA levels and motivated them to maintain or exceed their daily targets. The visibility of their progress through the profile section created a sense of accountability and encouraged continuous engagement with their goals. For example, one participant said, *"The step counter really helped me **track my progress and motivated me** to achieve my steps every day"* [P7] while other said, *"Before using the app, I never noticed my step count. But now, I am able to **keep track of my steps which motivates** me"* [P46]. Participant felt a sense of accomplishment as they watched their step counts rise, which in turn motivated them to keep pushing themselves further.

Leaderboard provided an additional layer of motivation by offering users a concrete incentive to stay active. The excitement of earning rewards and seeing their names on the leaderboard kept participants engaged and motivated to maintain their PA levels. The app's reward system, which included earning points for steps taken was another significant motivator. Participants appreciated the rewards that they could earn, which added an element of gamification to their activity routines.

> P7: *"The reward system, especially the **leaderboard**, really **motivated** me to keep walking and earn more points."*

P32: *"The **leaderboard** sparked a little bit of competitiveness in me, **motivating** me to walk more."*

The emotional connection with the dog also played an important role in motivating participants. The app created an engaging and interactive experience where users could care for the dog by staying active. This feature added a unique emotional dimension to the app, making PA more enjoyable and meaningful. Participants felt a sense of responsibility towards the dog avatar, which encouraged them to stay active to keep the dog happy. This emotional engagement made the app more than just a fitness tool; it became a source of joy and motivation in their daily lives. For example, some participants said:

*P2: "I try to walk more steps to keep my **dog happy**. It's a good feature."*

*P16: "Seeing the pet sad, **motivated** me to earn more points."*

*P61: "If the **pet was happy, I was happy**. It gave me a sense that at least I made a virtual pet happy by being active."*

In summary, the PetBuddy app effectively motivated participants to increase their PA through features such as the step counter, leaderboard, reward system and Emotional connect with dog. By integrating these elements, the app not only promoted PA but also made the experience enjoyable and engaging, leading to lasting changes in participants' exercise habits.

Theme 4: Setting goals increases enjoyment and facilitates positive attitude change towards physical activity

This theme describes factors influencing attitude change in PA. The PetBuddy app not only motivated participants to increase their PA but also facilitated a positive change in their attitudes toward PA. This section delves into the various factors that influenced this shift in attitude using the app. One of the primary factors that influenced participants' attitudes toward PA was the app's ability to facilitate to keep track of step count and achievement. The app facilitated positive changes in participants' attitudes towards PA by making them more goal-oriented and motivated to stay active.

P5: *"It became a challenge to myself to maintain my step count, and it **motivated** me to walk more."*

P22: *"I've become more **goal-oriented**, setting a certain number of steps to complete as a challenge to myself."*

P46: *"The app has made me more **motivated** to stay active and set goals for myself."*

The app not only influenced participants' exercise habits but also prompted broader lifestyle changes. P2's decision to walk instead of taking the bus is an example of how the app encouraged users to make more active choices in their daily lives.

P2: *"The app has made me **rethink my daily routines**, and I'm choosing to **walk more** instead of taking the bus."*

The psychological benefits of using the app, such as reduced stress and increased enjoyment of PA, also influenced participants' attitudes. One participant said, *"The **happy** image of the dog and the overall design of the app made exercising **less stressful and more enjoyable**."* [P5]

The app facilitated positive changes in participants' behaviour, which in turn influenced their attitudes toward PA. By fostering a sense of accomplishment and making walking sessions more pleasant, the app not only encouraged regular PA but also cultivated a more positive outlook towards maintaining an active lifestyle.

P32: *"I've started **walking more** and incorporating more exercise into my daily routine thanks to the app."*

Overall, the app had a significant impact on participants' attitudes toward PA. It has helped create a more positive and motivated approach to increase PA, encouraging users to adopt healthier habits and stay engaged in PA. Participants reported feeling more motivated and confident in their ability to maintain a consistent exercise regimen, highlighting the app's effectiveness in not only initiating but also sustaining positive health behaviours.

Theme 5: Competition motivates player to walk more and earn more points

The competitive elements of the PetBuddy app, especially its leaderboard feature, significantly influenced participants' motivation to maintain PA levels. This theme delves

into how these elements fostered healthy competition among users and enhanced their overall app experience. The leaderboard emerged as a standout feature, effectively instilling a sense of competition among participants. They valued being able to monitor their rankings and compare their progress with others, which spurred them to strive for better results. For example, participants said:

> P2: *"The **competition** aspect was one of the most perfect parts of the application. Seeing others' progress **motivated** me to work harder."*
>
> P7: *"The reward system, especially the **leaderboard**, really **motivated** me to keep walking and earn more points."*
>
> P16: *"I like the **friendly competition** between friends. It **motivates** me to stay active and make each other better in an active environment."*
>
> P32: *"The **leaderboard** sparked a little bit of competitiveness in me, **motivating** me to walk more."*
>
> *P38: "I really Liked the **leaderboard** as it **motivated** me to walk more."*
>
> *P53: "**Competition motivated** me take more steps in order to be on top of the leaderboard."*

With participants highlighting the leaderboard as the app's most attractive feature, it becomes evident that this competitive element was pivotal in driving user engagement. It not only motivated participants to increase their PA but also fostered an engaging environment where striving for the top spot became a shared goal.

To summarize, the competitive features of the PetBuddy app played a crucial role in motivating users to maintain an active lifestyle. By creating a healthy competitive environment, the app succeeded in enhancing user engagement and retention. These insights underscore the importance of balancing competitive elements in fitness apps to ensure they are stimulating rather than stressful. Incorporating such features effectively can significantly boost motivation and long-term user satisfaction in fitness applications.

Theme 6: The app enhances engagement with AR by being fun and innovative approach to exercise

The AR feature within the PetBuddy app was widely praised by participants for its innovative and engaging qualities, significantly enriching their overall experience. By seamlessly integrating AR technology, the app allowed users to merge virtual elements with their real-world surroundings, creating a uniquely interactive dimension. This capability not only made PA more enjoyable but also introduced a novel method for motivation. Participants appreciated the AR feature for its ability to transform their exercise routines into more immersive experiences. One participant noted that *"Firstly the concept is really good because there is a lack of good apps for improving PA. So, I think the idea was* ***very cool to have AR integrated****."* [P5]. This sentiment reflects the participants' positive initial impressions of the AR feature.

AR technology allows users to actively interact with virtual elements overlaid onto their real-world environment. This interaction turns exercise into a more engaging and dynamic activity, transforming mundane workouts into immersive experiences that feel more like a game or adventure. For instance, one participant enjoyed using AR, describing it as enjoyable "*As for the AR application, it was* ***something different, something new****. I haven't used it in other apps, so it was like a* ***fun*** *thing to utilize, especially for a fitness form of app."* [P17]. This acknowledgment of novelty and fun illustrates how the AR feature not only attracted users but also enhanced their motivation to engage in PA through its interactive and visually appealing elements.

PetBuddy introduces a playful element that transforms exercise into an enjoyable and rewarding experience. This gamification not only makes workouts more entertaining but also motivates users to achieve goals and earn rewards within the app. Participants further emphasized their enjoyment and motivation derived from the AR experience. For example:

> P5: *"My favourite feature was the AR experience; it was really* ***fun****."*
>
> P22: *"The app was* ***interesting and motivated*** *me to walk more. I like the AR experience."*

P30: *"I really liked the AR experience. It was **fun and something new** in terms of collecting food item through AR."*

P38*: "I really enjoyed the AR feature; it made the experience much more **fun and engaging**."*

P46: *"AR feature was **nice and fun**. Would love to see more AR objects."*

In summary, the AR feature of the PetBuddy app played a significant role in enhancing the user experience by adding a layer of fun and engagement. Participants valued the innovative approach and visual appeal of the AR elements, which made their PA routines more enjoyable. Overall, the AR feature contributed to the app's success in motivating participants to increase their PA and maintain a positive attitude toward exercise.

Theme 7: Step tracking helps me to monitor progress

The step count feature of the PetBuddy app was instrumental in helping participants keep track of their PA. This section explores how the step count feature influenced participants' exercise habits and overall experience with the app. The step count feature allowed them to monitor their progress throughout the day. This continuous monitoring helped users stay aware of their activity levels and encouraged them to meet their daily step goals. For example, participants said:

P1: *"Seeing my step count throughout the day helped me **stay on track and motivated me** to walk more."*

P30: *"Setting a specific step goal for the day gave me something to **aim** for, and it felt great to **achieve** it."*

The step count feature also increased participants' awareness of their PA levels. By providing a tangible measure of their daily activity, the app helped users become more mindful of their movement and encouraged them to incorporate more PA into their routines.

P61: *"I became more **aware** of how much I was moving each day, and it **motivated** me to walk more."*

The step count feature served as a constant reminder to stay active. Participants reported that seeing their step count motivated them to take more steps and stay active throughout the day.

> P7: *""The reward system, especially the leaderboard, really motivated me to **keep walking** and earn more points."*
>
> *P44: "Earlier I couldn't keep track of my step count, but now because of PetBuddy I am able to see how many steps I have taken and **how much I need to take more to reach my goal**."*

The step count feature acted as a form of positive reinforcement, encouraging participants to stay active and meet their goals. Seeing their step count increase throughout the day provided users with a sense of accomplishment and motivation. One participant said, *"Watching my step count go up was very satisfying and **motivated me to keep moving**."* [28]

The step count feature also influenced participants' daily routines by encouraging them to incorporate more PA into their schedules. One participant said, *"I've added an **additional 15 - 20 minute walk** to my schedule instead of taking the bus, thanks to the step counter."* [P2]. While the other noted, *"Now because of PetBuddy I **walk more** to reach my step count goal."* [P16].

This feature in apps can effectively motivate users to increase their PA. The step count in PetBuddy app played an important role in helping participants keep track of their PA. By making PA more visible and measurable, it empowers users to take proactive steps towards improving their overall well-being.

Theme 8: I would recommend the app to others

The participants' intention to share the PetBuddy app with others is a strong indicator of their satisfaction and the app's perceived value. This section explores the factors that influenced participants' willingness to recommend the app to friends, family, and colleagues. A positive user experience was a key factor influencing participants' intention to share the app. Participants who had a favourable experience with the app's features, design, and motivational elements were more likely to recommend it to others.

P1: *"I would definitely **recommend** this app to my friends. It's easy to use and has helped me stay active."*

Participants' perception of the app's effectiveness in promoting PA also influenced their intention to share it. Those who experienced increased motivation and PA levels due to the app were eager to share it with others.

P2: *"I've **already told my family about the app** because it's really helped me stay more active."*

The app's unique features, such as the AR was also a compelling reason for participants to share it. These innovative elements set PetBuddy apart from other fitness apps and provided users with a novel and enjoyable experience.

P5: *"The AR is a unique feature that I think my friends would enjoy. It's something different from other fitness apps."*

Friendly competition on the leaderboard, encouraged participants to share the app with their social circles. The leaderboard created a dynamic and engaging environment where users could see how their step counts compared to those of their friends and other app users. Users who saw their friends' making strides towards better fitness through the app were more likely to be inspired to join and participate themselves.

P38: *"The friendly competition between friends is something **I want to share with my social group**. It makes staying active more fun and engaging."*

Personal endorsements from satisfied users are powerful motivators for others to try the app. Participants' willingness to share their positive experiences and endorse the app to their friends and family highlights the app's perceived value and effectiveness.

P63: *"I've already **recommended** the app to a few friends because it's helped me stay active and it's fun to use."*

In summary, participants' intention to share the PetBuddy app with others was influenced by their positive user experiences, the app's effectiveness in promoting PA, its unique features, and ease of use. The willingness of participants to personally endorse the app highlights its perceived value and potential for widespread adoption.

Theme 9: Additional features, activities and rewards has the potential to enhance the overall game experience

The app could see significant improvements by integrating various scenarios and introducing levels for users to progress through. Many participants expressed a strong desire for the addition of levels. By reaching the highest levels, users could be rewarded with extra points. This addition would create a more engaging and game-like experience, motivating users to continue using the app to unlock new scenarios and achieve higher levels. One participant noted,

> P28: *"The reward system motivates the person to go for and collect more. I would love to see new scenarios and levels."*

Another popular recommendation among participants was the addition of more AR food items, which would make the app more visually appealing and interactive. By incorporating a wider variety of pets and giving users the option to select their preferred pet type was also suggested. The inclusion of various animal diversities in future updates can cater to a broader audience, making the app more personalized and engaging. As one participant mentioned,

> P46: *"Maybe a few more models can be added, like different types of pets and AR food objects, in future updates."*

Incorporating notifications is another suggestion that would enhance user engagement by reminding users to interact with the app. Notifications could alert users when their pet is hungry or when they haven't used the app in a while, ensuring consistent usage. One participant suggested,

> P32: *"Adding notification features, like if the pet is hungry alerting the user to come back and feed the pet, would be an additional but useful feature."*

Adding more in-game activities related to different physical exercises could also make the app more engaging. Implementing a more complex points system to reward various activities would encourage users to diversify their exercise routines. Additionally, expanding the shop market with more products and options would provide users with further incentives to earn points and stay active.

P53: *" Incorporating additional in-game activities will make the experience more engaging."*

P13: *"Currently shop have limited accessories, expanding the items would make it more fun."*

One of the recommendations was to enable users to send friend requests so they can connect, compete, check each other's progress, and engage in general conversations.

P38: *"If instead of that they can just send friend invites to somebody and are only able to see their workout progress that would have been a good add-on."*

In summary, enhancing the PetBuddy app by integrating scenarios and levels, expanding AR features, introducing notifications, adding more in-game activities, and improving the shop market can significantly improve user engagement and satisfaction. These recommendations, supported by participant feedback, highlight the potential for the app to become even more effective in promoting through a fun, competitive, and interactive experience.

The qualitative analysis reveals valuable insights into participants' experiences, emphasizing the importance of visual appeal and usability in user engagement. The straightforward and user-friendly interface was another key factor, ensuring accessibility and preventing frustration. Participants also appreciated friendly competition and leaderboard, which added an engaging and motivating aspect to the app. They found the AR experience fun and enjoyable. These findings underscore that positive initial impressions and ease of use are critical for user retention and engagement. Overall, the study provides valuable insights into how design elements and user-friendliness impact user satisfaction and engagement.

Chapter 6: Discussion

This study aimed to investigate the effectiveness of PetBuddy, an application designed to increase PA through walking. We conducted a 10-day study with 65 participants and analysed the data collected from both pre and post intervention. The findings from this analysis helped us answer the research questions outlined in Section 3.5 and provided insights into areas that future research can further explore and expand. In this chapter, we discuss our findings and how they addressed our research questions. Additionally, we examine the limitations of our study and offer recommendations for improving the design of AR-driven mobile interventions to promote PA.

6.1 PetBuddy App Promoting Physical Activity through Walking

From our analysis of the intervention's impact on promoting PA, we uncovered several interesting findings that will be discussed in the subsequent subsections.

6.1.1 Effectiveness of the Intervention in Influencing Healthy Behavioural Change

We aimed to determine the effectiveness of our intervention in promoting PA through

RQ1: "How effective is the PetBuddy app in motivating physical activity in adults?"

The comparative analysis of participants' weekly PA levels, both before and after the intervention, as outlined in Section 5.2.1, reveals a significant increase in PA among users. This suggests that our intervention was successful in encouraging participants to alter their behaviour and engage in more exercise.

Initially, participants' PA levels did not meet the WHO recommended weekly PA level of 600 MET. However, after using the PetBuddy app for 10 days, participants' PA levels surpassed this threshold. This improvement highlights the app's capability to foster healthier behaviour and elevate users' PA to meet or exceed recommended levels demonstrating the effectiveness of our intervention when combining game experience with persuasive strategies.

Our results show that, the post-intervention increase in PA levels was significant across various participant groups. Those who initially had low PA levels, falling below the recommended 600 METs per week, showed significant improvements, with their scores

rising above the minimum threshold. This demonstrates the app's effectiveness in motivating individuals who are less active to become more physically engaged. This crucial finding suggests that the app can successfully target and benefit those who need it the most, individuals who are initially less active and at risk of the negative health impacts associated with a sedentary lifestyle.

Conversely, participants who were already engaging in frequent PA before the intervention managed to maintain and increase their activity levels post-intervention. This consistency indicates that the app did not simply benefit those with low activity levels but also provided value to already active individuals by helping them sustain and increase their PA routines. This dual impact shows that the PetBuddy app is versatile and effective across different user demographics, making it a broadly applicable tool for promoting PA. When designing apps to capture a wide range of audiences, interventions should consider both groups (active and less active) by offering features that provide initial motivation and sustain ongoing engagement.

These findings are consistent with prior research by Chaudhry et al. [122] that investigated the impact of step-count monitoring interventions on PA levels, which also reported decrease in the number of participants failing to meet PA guidelines by WHO after implementing similar interventions. Another study by Ali Shameli et al. [123] focused on evaluating the effects of gamified elements on users' PA levels demonstrated that features like leaderboards and real-time progress updates effectively motivated users to increase their activity levels by enhancing enjoyment and competitiveness, resulting in a significant increase in their daily step counts compared to their baseline activity levels. Our qualitative analysis further supports these findings reported by other researchers suggesting that integrating gamification elements, such as competition, reward and self-monitoring encourage engagement in PA.

Overall, these findings demonstrate that the PetBuddy app successfully motivated users to increase their PA, making it an effective tool for promoting healthier behaviour and sustained engagement in PA. The consistent elevation in PA levels among participants highlights the app's potential to drive meaningful improvements in physical health.

6.1.2 Gender and Age Differences in the Effectiveness of PetBuddy

Examining potential gender and age disparities in the effectiveness of our intervention revealed distinct patterns from participants' feedback before and after the study. Our intervention was intentionally tailored for adults without specific considerations for age or gender distinctions. As detailed in Section 5.2.2, a thorough analysis revealed that the overall effectiveness of our intervention in promoting PA remained consistent across different gender and age categories.

The analysis indicated significant increase in PA levels across all age groups and genders. The 18-25 age bracket showed a notable increase in PA levels post-intervention, highlighting the app's strong impact on younger adults. Similarly, the 26-35 age group demonstrated substantial improvements, illustrating the app's effectiveness in motivating individuals within this demographic. Despite a smaller sample size in the 36-45 age group, participants still experienced a noticeable rise in PA levels. Those over 46 years old also saw increased PA levels, indicating the app's effectiveness across a broad age range. This result suggests that participants aged 26-35 years showed the greatest improvement in PA levels compared to the other age groups , possibly due to their higher engagement with mobile phones. [124].

Regarding gender, both males and females experienced higher PA levels after the intervention. Males showed significant improvement, underscoring the app's appeal and effectiveness for male users. Females also demonstrated considerable gains in PA levels, suggesting successful motivation for increased PA among female participants. The analysis indicates that females exhibited the highest increase in PA from before to after the intervention. Since the emotional connection with the dog was considered a persuasive feature for increasing PA, females likely connected more emotionally with the dog, motivating them to walk more to make the dog happy. This can be explained by previous research by Löffler and Greitemeyer [125] indicates that women tend to excel in tasks that emphasize empathy compared to men. In contrast, males might prefer activities such as running, playing sports, or going to the gym to stay healthy. Relatedly, Reading and LaRose [126] also found that women preferred moderate-intensity exercise, whereas men favoured intense strength training in form of exercise to stay healthy. For future research

and development, developers should consider incorporating features that cater to both emotional connections and varied physical activities to effectively engage both female and male users.

Once again, these findings underscore the versatility and effectiveness of the mobile application in promoting PA across different demographics. The intervention's success in enhancing PA levels among young adults and females is particularly noteworthy, as these groups showed the most significant improvements. This suggests the PetBuddy can be a powerful tool in public health strategies aimed at increasing PA, especially when designed with diverse user needs in mind. Future studies should examine the age- and gender-specific requirements to develop an app that caters to each category's unique needs. The increase in PA levels across all groups demonstrates the app's potential to improve health behaviours, making PA more accessible and engaging. This is important as digital solutions become more integrated into daily life, providing convenient and effective ways to promote healthier lifestyles.

6.2 Perceived Persuasiveness of Game Experience

To address our second research question, ***RQ2: "How effective are the game experience in the app in motivating physical activity?"*** we assessed the perceived persuasiveness of three distinct game features within the app: AR, Emotion (happy/sad dog face), and Idle Game design. Our quantitative analysis indicated that all game experiences were effective in motivating physical activity among participants.

The most persuasive aspect of the app was AR game experience, with participants finding it highly engaging and fun to use. The AR experience's high engagement and persuasiveness suggest that incorporating AR elements in health apps can significantly boost user motivation for PA. This is likely due to the immersive and interactive nature of AR, which transforms mundane activities into enjoyable experiences. This finding is consistent with previous study by Farič [127] suggesting that AR offer promising tools for increasing PA by making exercise more engaging, enjoyable, and accessible.

The Emotional aspect of the game experience, featuring the happy/sad dog Face, also received high ratings. Although not as highly rated as the AR experience, the Emotion game had a strong persuasive impact, likely due to its emotional engagement with users. This element effectively captures users' attention and fosters a deeper connection with the game. This suggest that users develop a strong connection with the dog, feeling a sense of responsibility towards it. This connection likely encourages users to engage in PA because they want to keep the dog happy. The Dog's display of emotions makes users more likely to empathize with it and increase their activity to improve dog's mood.

The Idle Game experience, while rated lower than both the AR and Emotion experiences, was still perceived as more persuasive than the neutral value. This indicates its effectiveness in engaging users, perhaps through its casual and ongoing interaction style. Despite being less interactive, the Idle Game maintains user interest and provides continuous engagement.

The quantitative data was strongly supported by the qualitative results, highlighting the synergy between both data types. Participants' feedback mirrored the statistical findings, emphasizing the motivational aspects of the gamification elements. The AR experience, with its immersive and interactive nature, was frequently mentioned as a significant driver of engagement, aligning with its high quantitative rating. Similarly, the emotional engagement provided by the Happy/Sad dog face in the Emotion experience resonated with participants, supporting its strong quantitative score.

However, in the qualitative analysis, none of the participants mentioned the idle game design when discussing what motivated them to engage in PA. This may be because people generally prefer to receive rewards immediately upon completing a task rather than having to wait. This can be explained by a study conducted by Ainslie [128] showing that individuals tend to prefer immediate rewards over delayed ones. As such, future studies could investigate the effect of gamer types, such as Hexad model [129], to determine which type of experiences are preferred by each group and identify if there is a specific group for which the idle game design is more persuasive.

For future developments, participants expressed a desire for more AR food objects, which they believe would further enhance the experience and increase engagement by adding variety and fun to their interactions with the app. This finding aligns with the Hedonic Adaptation Prevention model [130], which suggests that variety can sustain higher levels of happiness and engagement by preventing users from becoming accustomed to repetitive experiences. They also expressed a desire for pet diversity and the ability to select preferred pet. Additionally, they requested animation for the dog, believing these changes would enhance the game's appeal and engagement. By offering more choices and adding animation, the game could become more interactive, increasing its likelihood of adoption and encouraging sustained motivation for PA. Research indicates that visual and interactive design significantly influences initial user evaluations, made within milliseconds, which serve as gateways for further engagement with mHealth apps [131]. Allowing users to choose a preferred pet can increase feelings of autonomy [132], encouraging continued participation in PA.

Health and fitness app developers should prioritize integrating AR feature and emotional connect to enhance user experience and maintain long-term engagement. To prevent users from becoming bored and disengaged, app developers should continually introduce new and varied content. Regular updates with new AR objects, varied animation for the dogs and introducing levels and challenges can keep the user experience fresh and exciting.

6.3 Effectiveness of Persuasive Strategies

The integration of persuasive strategies based on the PSD model [27] is crucial for defining the structure of our intervention. Subsequently, we thoroughly analyse the effectiveness of combining these strategies with the intervention features to address ***RQ 3: "How effective are the persuasive strategies implemented in the app for healthy behavioural change toward physical activity?***"

6.3.1 Persuasive Effect of the Gamification Elements

To evaluate the Effectiveness of Persuasive Strategies—Profile (Self-Monitoring), Shop (Customization), Points (Reward), and Leaderboard (Competition), we employed the

Perceived Persuasiveness scale. We demonstrated that all implemented gamification elements were found to be persuasive by the participants, with some features being perceived as more persuasive than others. Among these, the Leaderboard element, representing the Competition strategy, was the most persuasive feature. This indicates that competitive elements strongly enhance the perceived persuasiveness of the intervention. This finding aligns with research by Vorderer, Hartmann, and Klimmt [133] , which showed that competitive elements significantly enhance motivation and engagement by adding a heightened sense of challenge. Similarly, Ali Shameli et al. [123] found that leaderboards effectively increased activity levels by boosting enjoyment and competitiveness, a conclusion supported by our data. Our findings align with these earlier studies. The motivational aspects of competition can drive users to outperform others, thereby increasing effort and maintaining engagement with the intervention.

The Points element, representing the Reward strategy, was also perceived very positively, indicating that rewarding users is an effective persuasive strategy. The motivational power of rewards is evident, as participants responded enthusiastically to this feature. Rewards provide tangible recognition of users' efforts, which can significantly boost motivation and engagement. This finding is consistent with previous literature by Oyibo and Vassileva [134] suggesting that users who rank highly on leaderboards could receive incentives like points, badges, levels, medals, and other rewards. These incentives aim to further motivate them to enhance their competitiveness in performing the target behaviour.

The Profile element associated with Self-Monitoring was also found to be persuasive. This suggests that enabling users to track their own progress effectively enhances the perceived persuasiveness of the intervention. As previously discussed about prior research in Section 6.6.1 by Chaudhry et al. [122] highlighted the effectiveness of step-count monitoring in promoting PA in community settings. The ability to monitor progress provides users with tangible evidence of their achievements and improvements. This visualization fosters a sense of control and motivation, making the intervention more compelling and effective in promoting sustained PA. It also empowers users by giving them direct feedback on their efforts. This empowerment can enhance their commitment to maintaining or increasing their PA levels, as they can see the direct impact of their actions on their fitness goals.

Future app developments should focus on integrating more advanced self-monitoring tools.

The Shop element, associated with Customization, received positive feedback but was rated lower than the other elements. This indicates that while customization is appreciated by users, it may not be as compelling as other features.

The qualitative feedback from participants further illuminates the impact of these gamification elements on their engagement and motivation. Participants expressed a range of experiences with the app, often highlighting the motivational aspects of its design. The leaderboard element particularly motivated participants to engage more frequently with the app, turning exercise into a fun competition.

The quantitative data was strongly supported by the qualitative results, highlighting the synergy between both data types. Participants' feedback underscored the motivational aspects of the gamification elements, mirroring the statistical findings. The leaderboard's competitive nature was frequently mentioned as a significant driver of engagement, aligning with its high value.

This result highlights the need to prioritize certain features for future development or maintenance of the application. For instance, since customization was less effective than other features in motivating users to increase PA, future development may either lower its priority or redesign it to enhance its impact. Competition and rewards proved to be the most effective strategies for driving motivation, so these should be a priority in future developments. Enhancements should therefore emphasize integrating and expanding competition and reward mechanisms, such as offering users the ability to invite others for friendly competitions and implementing a level-based reward system which will enhance user engagement. At the same time, the role of customization should be reassessed and potentially revised. Customization should extend beyond mere accessorizing of pets to include options for personalizing their appearance, grooming, and adding unique tricks that only their pet can perform.

6.4 Usability and Simplicity of the Intervention

The participants' perspectives on the intervention were assessed based on its ease of use and overall usability. The average SUS score for PetBuddy was determined to be "above average," signifying that the app's usability was positively perceived by the participants. These favourable responses reinforce the conclusion that the PetBuddy app exhibits significant usability characteristics.

An important aspect of our investigation involved assessing the simplicity of our intervention among a diverse demographic of participants. Recognizing the significance of gauging the intervention's user-friendliness, we conducted a comprehensive evaluation. We incorporated simplicity scale questions derived from four distinct domains: Information Design, Task Complexity, Visual Aesthetics, and Satisfaction. The graphical representation of the simplicity scale as shown in Figure 5.11 illustrates participants' perceptions of our intervention's simplicity, indicating positive responses in aesthetics, satisfaction, information design and task complexity. These results suggest that our intervention was user-friendly and straightforward in its application.

Based on the calculation of the mean score on the SUS scale, the application was rated as usable with a score of 75.12. This represents a decline from the mean SUS score of 78.80 obtained in the pilot study. The decrease can be attributed to the larger and more diverse participant sample used for the main study evaluation compared to the pilot study.

Additionally, qualitative feedback from participants appreciated the calming colour scheme and found the app straightforward and easy to use. The combination of a game experience and gamification elements were particularly well-received, indicating the app's engaging and user-friendly design. These qualitative insights support the quantitative findings, underscoring the PetBuddy app's effective usability and simplicity.

To improve usability in future updates, effort should be invested in making the step count feature more seamless, as it currently relies on the Android sensor. This can be achieved by integrating with wearable devices to provide more accurate tracking, optimizing the

app's compatibility with a broader range of devices, and offering users customizable settings to better fit their individual needs and preferences.

6.5 User Experience and Intrinsic Motivation of the Intervention

To evaluate the user experience and intrinsic motivation of our intervention, we conducted comprehensive analyses using both the Short UEQ and a modified version of the IMI. These analyses provided insights into various dimensions of user experience and intrinsic motivation among participants.

The Short UEQ analysis revealed positive feedback across both pragmatic and hedonic dimensions. The pragmatic quality, reflecting the practical aspects of usability, consistently received positive evaluations, indicating that participants found the intervention to be highly usable. The hedonic quality, encompassing the emotional and aesthetic appeal, also yielded positive responses. Both dimensions received an "Excellent" rating compared to benchmark data, positioning our intervention within the top 10% of similar products and indicating a high level of user satisfaction.

The IMI scale results indicated significantly higher intrinsic motivation among participants, demonstrating that the intervention successfully enhanced their intrinsic motivation. The large effect size further suggests that the intervention had a substantial impact on participants' motivation. We incorporated modified IMI scale questions including two distinct domains: Value/Usefulness and Interest/Enjoyment. The graphical representation of the scale, as shown in Figure 5.12, illustrates participants' perceptions of our intervention, indicating positive responses in both Value/Usefulness and Interest/Enjoyment. These results underscore the efficacy of our approach in capturing participants' engagement and validating the perceived benefits and enjoyment derived from our intervention.

Additionally, qualitative feedback highlighted several key themes that supported the positive user experience. Participants consistently praised the visual design which made the app engaging and enjoyable to use. Users appreciated the practical aspects of the app, such as ease of navigation and clarity of information. They found the app straightforward

and user-friendly, which contributed to a smooth and efficient user experience, enhancing overall satisfaction. However, some suggestions for making it more engaging included incorporating sounds and dog animations. Participants recommended adding a progress bar and displaying detailed progress segmented by days, weeks, and months to enhance user experience and motivation. Additionally, implementing goal setting for step count is essential, as participants expressed a desire to walk more than the default 500 steps. The designed features and the persuasiveness of the intervention were an important factor in encouraging participants to adopt healthier behaviour. These improvements could potentially increase user engagement and satisfaction with the application.

Overall, the results underscore the user-friendliness, appeal, and motivating nature of our intervention. The high scores in both pragmatic and hedonic qualities, along with the significant positive intrinsic motivation, reflect a well-rounded and successful implementation. Participants not only found the intervention easy to use and aesthetically pleasing but also felt intrinsically motivated, highlighting the intervention's value and effectiveness.

6.6 Design Recommendations

Based on participant feedback, several design recommendations emerged that could significantly enhance the PetBuddy app's user experience and engagement.

1. **Design Recommendation 1: Integrate levels and scenarios:** Participants expressed a strong desire for the app to include various scenarios and introduce levels that users can progress through. By adding levels, users could be rewarded with extra points for reaching the highest levels. This feature would create a more engaging and game-like experience, motivating users to continue using the app to unlock new scenarios and achieve higher levels. The addition of levels and rewards would make the app more dynamic and enjoyable, sustaining user interest over time.
2. **Design Recommendation 2: Enhance AR interactivity with diverse food items:** Another popular recommendation was the inclusion of more AR food items, which would make the app more visually appealing and interactive. Expanding AR features

would enhance the visual and interactive elements of the app, creating a more immersive experience for users.

3. **Design Recommendation 3: Incorporate notifications for daily reminder of app usage:** Incorporating notifications is another suggestion that would enhance user engagement by reminding users to interact with the app. Notifications could alert users when their pet is hungry or when they haven't used the app in a while, ensuring consistent usage. This feature would help maintain user engagement by prompting regular interaction with the app, thereby enhancing the overall experience.
4. **Design Recommendation 4: Add in-game activities and a complex points system:** Adding more in-game activities related to different physical exercises could make the app more engaging. Implementing a more complex points system to reward various activities would encourage users to diversify their exercise routines. This approach would not only make the app more interesting but also promote a wider range of physical activities, contributing to the app's health and fitness goals.
5. **Design Recommendation 5: Expand the shop market:** Expanding the shop market with more products and options would provide users with further incentives to earn points and stay active. A more extensive shop market would offer users a greater variety of rewards, making the points they earn more valuable and motivating them to continue using the app.
6. **Design Recommendation 6: Integrate Social Features to increase interactivity:** One recommendation was to enable users to send friend requests so they can connect, compete, check each other's progress, and engage in general conversations. This social aspect would add a layer of community and competition, further motivating users to stay engaged with the app.
7. **Design Recommendations 7: Allow users to set their own goals:** Enable users to customize their step goals by allowing them to set a target that best suits their personal preferences. Instead of the default step goal of 500 steps, provide an option for users to adjust this target according to their individual objectives and activity levels. This flexibility will accommodate a wider range of user needs and promote greater engagement with the goal-setting feature.

8. **Design Recommendations 8: Expand pet customization options:** Offering a wider variety of pets and allowing users to select their preferred pet type was suggested. The inclusion of various animal diversities in future updates can reach to a broader audience, making the app more personalized and engaging. Additionally, users should have the ability to customize their pets' appearances, grooming routines, and even unique tricks that their pet can perform. Introducing animations for pets will further enrich the user experience and add a dynamic, interactive element to the game.

In summary, enhancing the PetBuddy app by integrating levels and scenarios, expanding AR features, introducing notifications, adding more in-game activities, and improving the shop market can significantly improve user engagement and satisfaction. These recommendations, supported by participant feedback, highlight the potential for the app to become even more effective in promoting healthier behaviours through a fun, competitive, and interactive experience.

6.7 Limitation and Direction for Future Work

The limitations of this intervention and study are listed below together with how we plan to address them in future work:

1. **Platform Specificity:** This study relied exclusively on Android smartphones, which limits the generalizability of our findings to users of other smartphone platforms, such as iOS or feature phones. Different platforms may have varying hardware capabilities and user behaviour that could influence the outcomes of AR interventions differently. To enhance the relevance and applicability of future findings, researchers should consider incorporating multiple smartphone platforms in their studies.
2. **Compatibility Issues:** The use of AR Core for developing AR experiences introduced compatibility challenges with certain mobile models, potentially excluding segments of the smartphone user population from participating fully in the study. This limitation highlights the need for future studies to explore alternative AR development tools that ensure compatibility across a broader range of mobile devices. By diversifying the AR tools used, researchers can maximize participant inclusivity and obtain more representative insights into the effects of the interventions on smartphone behaviour

3. **Demographic Imbalance:** Our study identified significant demographic imbalances, particularly in age and educational levels among participants. Such imbalances can restrict the generalizability of study findings across broader populations. To address this limitation, future research should implement targeted recruitment strategies aimed at achieving a more balanced representation across different age groups and educational backgrounds. This approach will facilitate a more comprehensive understanding of how the interventions impact smartphone users across various demographic profiles.
4. **Short Study Duration:** Conducting the study over a brief period of 10 days may not capture the long-term effects of the intervention on smartphone usage behaviour. To delve deeper into the sustained impacts of the interventions, future studies should incorporate control groups concurrently and adopt longitudinal study designs spanning extended periods.

Additionally, other future work should investigate age- and gender-specific requirements to develop an app that caters to the unique needs of different user categories. A future study could examine how preferences for various game experience and features vary between different age groups and gender, such as comparing younger and older users in their engagement with specific features. A meta-analysis or systematic review could also be conducted to explore and analyse which game experiences are preferred by various gamer types and different gamer profiles.

Chapter 7: Conclusion

This research sought to investigate the potential of the PetBuddy app in promoting PA using persuasive strategies. The primary objective was to foster and sustain higher levels of PA by encouraging individuals to engage in regular walking. To achieve these goals, the intervention was implemented as a mobile application that integrated advanced technologies such as AR. By creating an engaging and immersive user experience, the app aimed to motivate users to increase their PA in a fun and engaging manner.

The significance of this research lies in its potential to provide the broader scientific community with alternative, enjoyable, and effective methods for promoting healthy behavioural changes. It has been found that people may lose interest if the games are not enjoyable and engaging. By leveraging game experience like AR and emotional connect and gamification elements, the PetBuddy app offers a novel solution that can inspire individuals to initiate and sustain their PA levels. This research thus contributes valuable insights into the development of innovative health interventions that can effectively address the challenge of sedentary behaviour.

By encouraging regular PA, the PetBuddy app can help mitigate the risks associated with sedentary lifestyles, such as obesity, cardiovascular disease, and diabetes. The insights gained from this research can inform the design of future health promotion strategies that are both effective and appealing to users. By demonstrating the feasibility and impact of AR-based interventions, this study paves the way for further exploration into how cutting-edge technologies can be harnessed to improve public health outcomes.

In addition, the research highlights the importance of user engagement and motivation in the success of health promotion interventions. The integration of persuasive strategies, such as rewards, self-monitoring, customization and competition, was shown to significantly enhance user experience and adherence to PA routines. These findings underscore the need for health interventions to be user-centric, leveraging elements that resonate with users' intrinsic motivations and preferences. By focusing on the user's experience and incorporating elements that make PA fun and enjoyable, health interventions can achieve greater success in fostering healthy behavioural change.

Furthermore, the PetBuddy app's use of AR technology represents a significant advancement in the field of health promotion. AR offers unique opportunities to create immersive and interactive experiences that can captivate users' attention and encourage sustained engagement. The use of AR in the PetBuddy app not only made PA more enjoyable enhancing their motivation to stay active. This research thus contributes to the growing body of evidence supporting the use of AR in health promotion and opens new avenues for future research and application.

In conclusion, this research has demonstrated the potential of the PetBuddy app to promote PA through the innovative use of persuasive strategies and AR technology. By offering a fun and engaging way to encourage regular walking, the app has shown that it is possible to inspire individuals to adopt healthier lifestyles. The findings of this study provide valuable insights for the development of future health promotion interventions, highlighting the importance of user engagement, motivation, and the effective use of technology. This research contributes to the ongoing efforts to improve public health by offering new and effective strategies for promoting PA and combating sedentary behaviour.

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Appendices

Appendix A:

Recruitment Notice

Project title: PetBuddy: Location-based AR exergame to increase physical activity

Lead researcher: Priyal Srivastava

Faculty of Computer Science, Dalhousie University.

Hello there,

We are recruiting participants to take part in a research study that evaluates a gamified augmented reality- (AR) driven mobile app, called ***PetBuddy***, that promotes physical activity and would appreciate your help. The study will contribute to the research area of Persuasive Technology for Healthy Behavior Change. You don't need any prior experience with the app, but you should know how to use a smartphone. The study lasts for 10 days, and we'll ask you to use the app for at least 15 minutes each day. After the 10 days, you'll fill out a short questionnaire about your experience.

To join, you need to be at least 18 years old and have an Android phone. To begin the study, please click her [link]. If you have question, please feel free to email me at Priyal.Srivastava@dal.ca.

Your participation is voluntary, and we appreciate it a lot. As a thank you, you'll have a chance to win a C$50 gift card (4 winners). If you don't finish the study, you won't qualify for the gift card. Your data will be kept confidential for research purposes only.

Thanks, and we hope to hear from you!

Kindest regards,

Priyal Srivastava.

Faculty Supervisor: Dr. Rita Orji (rita.orji@dal.ca), Faculty of Computer Science

Dalhousie Ethics approval number: [2024-7074]

Appendix B

Consent Form for the Study

Project title: PetBuddy: Location-based AR exergame to increase physical activity.

Lead researcher: Priyal Srivastava, Faculty of Computer Science, Dalhousie University

Academic supervisor: Dr. Rita Orji, Faculty of Computer Science, Dalhousie University

Contact person: Priyal Srivastava, Email: Priyal.Srivastava@dal.ca

Introduction

You are invited to participate in our research study. Your participation in this research study is voluntary. The study details are described below. The description summarizes about what is involved in the research and the nature of your participation: what you will be asked to do and about any benefit, risk, inconvenience, or discomfort you might experience. You can withdraw from the study at any time without penalty simply by emailing the lead researcher (Priyal.Srivastava @dal.ca) to inform that you would like to withdraw. If you have any other questions about this study, please contact Priyal Srivastava (Priyal.Srivastava @dal.ca).

Purpose and Outline of the Research Study

The purpose of the study is to evaluate the effectiveness of an app (PetBuddy) for promoting physical activity. In general, the study will evaluate if the app has the potential to improve the user's health behavior towards physical activity.

Who Can Take Part in the Research Study

You need to be 18 years old or above and own an Android phone with internet connection to be able to participate in this study. The survey has been developed in English, so you should be able to read and understand the English language.

What You Will Be Asked to Do

If you choose to participate in this research, you will be asked to fill out a pre-test survey, after which you will be given access to the link. This link will lead you to a pre-study questionnaire concerning your demographic details and physical activity level, and it should take around 10 minutes to complete. Thereafter, you will receive a link with an instruction on how to download, setup, and use mobile app for a period of 10 days. During the 10-day period, you will be asked to use the app daily (which will take at least 15 minutes). After the 10-day period, you will be asked to respond to the post-study questionnaire (which will take approximately 25 minutes) regarding your experience with using the app. If you would like to be contacted for an interview to provide additional feedback, you will have an option to provide your email-id for being contacted by the lead researcher. This is optional, and the interview will be audio recorded and will happen over Microsoft Teams. All your survey responses would be anonymous, and you would be provided with a participant id that you need to note down to be able to access the mobile app during the 10 day period.

Possible Benefits, Risks and Discomforts

The main goal of our study is to explore the potential of augmented reality technology to influence healthy behavior towards physical activity through walking. There are no known risks from the study. The direct benefit for participating in this study is that you may start maintaining your physical activity level intentionally. You might also gain a positive mood while using the app. At the end of the study, you can continue using the mobile app if you wish to.

Compensation / Reimbursement

Your email will be entered into a lucky draw for a chance to win 1 of 4 Amazon gift cards worth 50$ each whether you choose to complete the study or not. Please note that

only four people would be randomly selected to win the five 50$ worth Amazon gift cards.

How your information will be protected:

Your responses in the survey will be anonymous. This means that there are no questions in the survey that ask for identifying details such as your name. All responses will be saved on a secure Dalhousie server and password-protected computers to be used for analysis. The app data will be downloaded and saved on a secure Dalhousie server and password-protected computers to be used for analysis alone. Only the Lead Researcher and Research Supervisor (i.e., Priyal Srivastava and Dr. Rita Orji) will have access to the data (including your email-id to forward the participant ID and the compensation amount). The collected data would be retained for the period until the data is analyzed, and results are shared in the thesis report and conference or journal publications. The Lead Researcher (i.e., Priyal Srivastava) will destroy all the survey responses and app data after 3 years of reporting the study results to ensure that all study-related publications are completed. During the optional interview, your voice, or the information you provide might be identifiable only by the Lead Researcher and such identifiable information would not be disclosed.

If You Decide to Stop Participating

If you wish to stop participating, at any point, you can do so. Incomplete responses will not be included in the study. You can also withdraw from the study (survey or interview) at any time as long as the data has not been analyzed (i.e., approximately 2 months from beginning the study and approximately 1 month from the interview session). If you intend to withdraw, please contact the lead researcher at priyal.srivastava@dal.ca

Questions or concerns

If you have any questions, concerns, or need clarification about this study, please do not hesitate to contact me (Priyal Srivastava) via Priyal.Srivastava@dal.ca.

If you have any ethical concerns about your participation in this research, you may also contact Research Ethics, Dalhousie University at (902) 494-3423, or email: ethics@dal.ca

Consent

I have read the explanation about this study. I have been given the opportunity to contact and discuss any question related to study and my questions have been answered to my satisfaction.

I agree to take part in this study. My participation is voluntary, and I understand that I am free to not complete the survey if I choose.

I understand that my responses during the post-study optional interview, should I choose to participate, will be audio recorded.

I agree that direct quotes from my responses may be used without identifying me:

- □ No
- □ Yes, I consent, and I agree to participate.

Appendix C

Consent Form for the Optional Interview

Project title: PetBuddy: Location-based AR exergame to increase physical activity.

Lead researcher: Priyal Srivastava, Faculty of Computer Science, Dalhousie University

Academic supervisor: Dr. Rita Orji, Faculty of Computer Science, Dalhousie University

Contact person: Priyal Srivastava, Email: Priyal.Srivastava@dal.ca

Introduction

You are invited to participate in our research study. Your participation in this research study is voluntary. The study details are described below. The description summarizes about what is involved in the research and the nature of your participation: what you will be asked to do and about any benefit, risk, inconvenience, or discomfort you might experience. You can withdraw from the study at any time without penalty simply by emailing the lead researcher (Priyal.Srivastava@dal.ca) to inform that you would like to withdraw. If you have any other questions about this study, please contact Priyal Srivastava (Priyal.Srivastava@dal.ca).

Purpose and Outline of the Research Study

The purpose of the study is to evaluate the effectiveness of an app (PetBuddy) for promoting physical activity. In general, the study will evaluate if the app has the potential to improve the user's health behavior towards physical activity.

Who Can Take Part in the Research Study

You need to be 18 years old or above and own an Android phone with internet connection to be able to participate in this study. The survey has been developed in English, so you should be able to read and understand the English language.

What You Will Be Asked to Do

If you choose to participate in this interview, you will be audio recorded and will happen over Microsoft Teams. You will be asked to describe your experience with using the app, which will take approximately 30 minutes. The researcher will use their Dalhousie University credentials for the Microsoft Teams meeting. All your survey responses would be anonymous, and you would be provided with a participant id that you need to note down to be able to access the educational material.

Possible Benefits, Risks and Discomforts

There are no known risks from the study. An indirect benefit is that you would be contributing to new knowledge that would be helpful in designing better mHealth apps especially towards promoting physical activity. At the end of the study, you can continue using the mobile app if you wish to.

Compensation / Reimbursement

Your email will be entered into a lucky draw for a chance to win 1 of 4 Amazon gift cards worth 50$ each whether you choose to complete the study or not. Please note that only four people would be randomly selected to win the five 50$ worth Amazon gift cards. There is no extra compensation for the optional interview.

How your information will be protected:

Your responses to the survey will be anonymous. This means that there are no questions in the survey that ask for identifying details such as your name. During the optional interview, your voice, or the information you provide might be identifiable only by the Lead Researcher and such identifiable information would not be disclosed. All responses will be saved on a secure Dalhousie server and password-protected computers to be used

for analysis. Only the Lead Researcher and Research Supervisor (i.e., Priyal Srivastava and Dr. Rita Orji) will have access to the data. The collected data would be retained for the period until the data is analyzed, and results are shared in the thesis report and conference or journal publications. The Lead Researcher (i.e., Priyal Srivastava) will destroy all the survey responses after 3 years of reporting the study results to ensure that all study-related publications are completed.

If You Decide to Stop Participating

If you wish to stop participating, at any point, you can do so. Incomplete responses will not be included in the study. You can also withdraw from the study (survey or interview) at any time as long as the data has not been analyzed (i.e., approximately 2 months from beginning the study and approximately 1 month from the interview session). If you intend to withdraw, please contact the lead researcher at priyal.srivastava@dal.ca

Questions or concerns

If you have any questions, concerns, or need clarification about this study, please do not hesitate to contact me (Priyal Srivastava) via Priyal.Srivastava@dal.ca.

If you have any ethical concerns about your participation in this research, you may also contact Research Ethics, Dalhousie University at (902) 494-3423, or email: ethics@dal.ca

Consent

I have read the explanation about this study. I have been given the opportunity to contact and discuss any question related to study and my questions have been answered to my satisfaction.

I agree to take part in this study. My participation is voluntary, and I understand that I am free to not complete the survey if I choose.

I understand that my responses during the post-study optional interview will be audio recorded.

I agree that direct quotes from my responses may be used without identifying me:

□ No

□ Yes, I consent, and I agree to participate.

Appendix D

Recruitment Notice (social media)

Hi! I am a master's student at Dalhousie University, and I am conducting a study to evaluate an Augmented Reality (AR) driven mobile application for promoting physical activity through walking. You are invited to participate in our study. Please click on the link to participate.

This research has been approved by the Dalhousie Ethics Board (REB: 2024-7074)

Appendix E

Pre-test survey

Thank you for kindly agreeing to participate in this survey. Following are the criteria to participate in the study:

- 18 years or older
- Own an Android phone with internet connection
- Read and understand the English language
- Live in Canada

If you meet all the requirements listed above, you may proceed to the next page.

Your responses will remain confidential and anonymous (i.e., Your data will be coded using a participant ID i.e., P1, P2).

Appendix F

Pre-Intervention Questionnaire

Thank you for kindly agreeing to participate in this research and your time for completing this survey. Please answer all the questions to the best of your knowledge. If you are not comfortable answering any question, you can leave the survey at any time.

Appendix F1: Demographic

Collecting demographic information helps us understand the diversity of people in a population by knowing information such as their age, gender, employment status, and more. In this section, you will be asked to share your demographic information.

1. Choose your age group:
O 18-25
O 26-35
O 36-45
O Over 46
O I prefer not to say.

2. Choose your gender:
O Male
O Female
O Other (please self-describe): _____
O I prefer not to say.

3.Choose the highest level of education you have completed:
O Less than high school
O High school or equivalent
O College diploma
O Bachelor's degree
O Master's degree
O Doctorate degree
O I prefer not to say.
Other: _____

4. Choose your current employment status:
O Employed (full-time)
O Employed (part-time)
O Unemployed
O I prefer not to say.
O Other (please specify): _____

Appendix F2: Physical Activity Questions

In this section, you will be asked to share your Physical Activity information.

1. In a typical week, on how many days do you do moderate intensity activities (e.g., walking) for at least 10 min as part of your work?
O Everyday
O 6 days
O 5 days
O 4 days
O 3 days
O 2 days
O 1 day
O Never

2. In a typical week, on how many days do you walk or bicycle for at least 10 minutes continuously to get to and from places?
O Everyday
O 6 days
O 5 days
O 4 days
O 3 days
O 2 days
O 1 day
O Never

3. In a typical week, on how many days do you do moderate intensity sports, fitness or recreational (leisure) activities for at least 10 min (e.g., brisk walking)?
O Everyday
O 6 days
O 5 days
O 4 days
O 3 days
O 2 days
O 1 day
O Never

4. In a typical week, on how many days do you do vigorous intensity sports, fitness or recreational (leisure) activities for at least 10 min (e.g., running)?
O Everyday
O 6 days
O 5 days
O 4 days
O 3 days
O 2 days
O 1 day
O Never

5. How much time do you usually spend sitting or reclining on a typical day (i.e., total time spent sitting at work, in an office, reading, watching television, using a computer, doing hand craft like knitting, resting etc.)?

___ Hours

___ Minutes

Appendix G

Post-Intervention Questionnaire

Thank you for kindly agreeing to participate in this research and your time for completing this survey. Please answer all the questions to the best of your knowledge. If you are not comfortable answering any question, you can leave the survey at anytime.

Appendix G1: Physical Activity Questions

In this section, you will be asked to share your Physical Activity information.

In this section, you will be asked to share your Physical Activity information.

1. In a typical week, on how many days do you do moderate intensity activities (e.g., walking) for at least 10 min as part of your work?
O Everyday
O 6 days
O 5 days
O 4 days
O 3 days
O 2 days
O 1 day
O Never

2. In a typical week, on how many days do you walk or bicycle for at least 10 minutes continuously to get to and from places?
O Everyday
O 6 days
O 5 days
O 4 days
O 3 days
O 2 days
O 1 day
O Never

3. In a typical week, on how many days do you do moderate intensity sports, fitness or recreational (leisure) activities for at least 10 min (e.g., brisk walking)?
O Everyday
O 6 days
O 5 days
O 4 days
O 3 days
O 2 days
O 1 day
O Never

4. In a typical week, on how many days do you do vigorous intensity sports, fitness or recreational (leisure) activities for at least 10 min (e.g., running)?

O Everyday
O 6 days
O 5 days
O 4 days
O 3 days
O 2 days
O 1 day
O Never

5. How much time do you usually spend sitting or reclining on a typical day (i.e., total time spent sitting at work, in an office, reading, watching television, using a computer, doing hand craft like knitting, resting etc.)?
___ Hours
___ Minutes

Appendix G2: Perceived Persuasiveness Questions

The four questions below apply to all the persuasive strategies. The idea is to create visually appealing mock-ups for all 6 persuasive strategies. Each mock-up will consist of screen designs representing the strategy as a scripted interaction between the user and the proposed PetBuddy app. Afterwards, the participant will answer the questions below for that strategy.

Statements	Strongly Disagree	Disagree	Neither	Agree	Strongly Agree
1. This game element would influence me.	O	O	O	O	O
2. This game element would be convincing.	O	O	O	O	O
3. This game element would be personally relevant for me.	O	O	O	O	O
4. This game element would make me reconsider my physical activity habits.	O	O	O	O	O

The persuasive strategies adopted, and their corresponding descriptions are summarized in the table below:

Persuasive Strategies	Description

Competition	Allows users to compete to perform the desired behaviour.
Self-monitoring	Provide means for users to track progress or performance.
Customization	Allows users to adapt a system's contents and functionalities to their needs and choice.
Rewards	Provide virtual rewards for users to give credit for performing the target behaviour.
Social comparison	Provide means for comparing performance with the performance of other users.
Reminders	Remind users of their target behaviour during the use of the system.

Appendix G3: Perceived Game element Questions

The four questions below apply to all the game elements. The idea is to create visually appealing mock-ups for all 6 game element. Each mock-up will consist of screen designs representing the game element as a scripted interaction between the user and the proposed PetBuddy app. Afterwards, the participant will answer the questions below for that strategy.

Statements	Strongly Disagree	Disagree	Neither	Agree	Strongly Agree
1. This game element would influence me.	O	O	O	O	O
2. This game element would be convincing.	O	O	O	O	O
3. This game element would be personally relevant for me.	O	O	O	O	O
4. This game element would make me reconsider my physical activity habits.	O	O	O	O	O

The game element adopted, and their corresponding descriptions are summarized in the table below:

Game element	Description
Augmented Reality (AR)	Augmented reality is an interactive experience that enhances the real world with computer-generated perceptual information. To collect points to earn the food resources by collecting them through the utilization of augmented reality technology.
Emotion	The pet will feel unhappy when hungry and joyful when the player feeds it.
Idle game	Player can step away from the app for sometime while their pet is enjoying the food. Once the pets have finished their meals, players can return to collect the points.

Leader board	Players will compete with others through leaderboard.
Points	Players can collect points upon gathering the food item. Using these points, they can buy accessories for their pets.
Shop	Allow players to buy accessories for their pets available in shop.

Appendix G4

The System Usability Scale

Please rate your level of agreement or disagreement with each of the following statements:

	Statements	Strongly Disagree	Disagree	Neither	Agree	Strongly Agree
1.	I think that I would like to use this app frequently.	O	O	O	O	O
2.	I found the system unnecessarily complex.	O	O	O	O	O
3.	I thought the system was easy to use.	O	O	O	O	O
4.	I think that I would need the support of a technical person to be able to use this system.	O	O	O	O	O
5.	I found the various functions in this system were well integrated.	O	O	O	O	O
6.	I thought there was too much inconsistency in this system.	O	O	O	O	O
7.	I would imagine that most people would learn to use this system very quickly.	O	O	O	O	O
8.	I found the system very cumbersome to use.	O	O	O	O	O

9. I felt very confident using the app	O	O	O	O	O
10. I needed to learn a lot of things before I could get going with this app	O	O	O	O	O

Appendix G5: **Simplicity**

Please rate your level of agreement or disagreement with each of the following statements:

Statements	**Strongly Disagree**	**Disagree**	**Neither**	**Agree**	**Strongly Agree**
1. The screen design is neat.	O	O	O	O	O
2. The screen design is modern	O	O	O	O	O
3. The screen design is well-balanced.	O	O	O	O	O
4. The app provides content systematically.	O	O	O	O	O
5. The app is designed to provide functions consistently.	O	O	O	O	O
6. Information in the app is well structured and systematic	O	O	O	O	O
7. The app groups similar menu items in the same category.	O	O	O	O	O
8. The app offers onestep function to run certain menus.	O	O	O	O	O
9. The app offers onestep function to change settings.	O	O	O	O	O

Appendix G6: **Intrinsic Motivation Inventory modified**

For each of the following statements, please indicate how true it is for you:

	Not at all true			Somewhat true			Very true
1. I enjoyed using this app very much	1	2	3	4	5	6	7
2. This app was fun to do.	1	2	3	4	5	6	7

3. I thought this was a boring app.	1	2	3	4	5	6	7
4. This app did not hold my attention at all.	1	2	3	4	5	6	7
5. I would describe this app as very interesting.	1	2	3	4	5	6	7
6. I thought this app was quite enjoyable.	1	2	3	4	5	6	7
7. While I was using this app, I was thinking about how much I enjoyed it.	1	2	3	4	5	6	7
8. I believe this app could be of some value to me.	1	2	3	4	5	6	7
9. I think that using this app is useful for increasing physical activity	1	2	3	4	5	6	7
10. I think this app is important to use because it can help me be physically active	1	2	3	4	5	6	7
11. I would be willing use it again because it has some value to me.	1	2	3	4	5	6	7
12. I think using this app could help me to be physically active.	1	2	3	4	5	6	7
13. I believe using this app could be beneficial to me.	1	2	3	4	5	6	7
14. I think this is an important app.	1	2	3	4	5	6	7

Appendix G7: **User Experience Questionnaire Long**

Please select the number that best matches your experience using the PetBuddy app.								
annoying	1	2	3	4	5	6	7	enjoyable
Not understandable	1	2	3	4	5	6	7	understandable
Creative	1	2	3	4	5	6	7	Dull
Easy to learn	1	2	3	4	5	6	7	Difficult to learn
Valuable	1	2	3	4	5	6	7	Inferior
Boring	1	2	3	4	5	6	7	Exciting
Not interesting	1	2	3	4	5	6	7	Interesting

Unpredictable	1 2 3 4 5 6 7	Predictable
Fast	1 2 3 4 5 6 7	Slow
Inventive	1 2 3 4 5 6 7	Conventional
Obstructive	1 2 3 4 5 6 7	Supportive
Good	1 2 3 4 5 6 7	Bad
Complicated	1 2 3 4 5 6 7	Easy
Unlikable	1 2 3 4 5 6 7	Pleasing
Usual	1 2 3 4 5 6 7	Leading edge
Unpleasant	1 2 3 4 5 6 7	Pleasant
Secure	1 2 3 4 5 6 7	Not secure
Motivating	1 2 3 4 5 6 7	Demotivating
Meets expectations	1 2 3 4 5 6 7	Does not meet expectations
Inefficient	1 2 3 4 5 6 7	Efficient
Clear	1 2 3 4 5 6 7	Confusing
Impractical	1 2 3 4 5 6 7	Practical
Organized	1 2 3 4 5 6 7	Clustered
Attractive	1 2 3 4 5 6 7	Unattractive
Friendly	1 2 3 4 5 6 7	Unfriendly
Conservative	1 2 3 4 5 6 7	innovative

Additional questions:

1. Please provide any suggestions you may have for improving the app below:

2. Please provide any additional thoughts you may have about your experience with the app below:

3. Do you think there are any other features you'd like to see in the app?

I agree to take part in the optional interview.

My participation is voluntary, and I understand that I am free to not participate if I choose.

□ Yes
□ No

Thank you for your time. If you are interested in participating in an optional interview, please enter your email address below and the researcher will email you more information.

Email address: _____

Appendix H

Optional Interview Questions Guide

1. Can you please tell me about your general experience with the PetBuddy app?
    a. What did you think of it?
    b. What is your overall impression of it?

2. What specific features or functionalities do you like about the app? Why?

3. What specific features or functionalities do you dislike about the app? Why?

4. Was there anything that you found confusing with the app? Can you provide an example?

5. What would you recommend for improving the app in terms of its content? How about its functions?

6. Is there anything you would recommend for improving the app's interface? What? Any examples?

7. Did you feel or notice any change in your overall physical activity level? Please explain.

8. Did anything from the app cause an attitude change to you towards physical activity?

    a. What was the change? Why?

    b. How did it affect your physical activity levels?

9. Did you feel happy after feeding the pet in the app? Why or why not?

10. Is there any feature of the app that attracts you most in using the app? What?

11. Will you recommend the app to someone else? Why or why not?

12. Do you have anything else you would like to share regarding your experience of the study in general that I have not asked you?

Appendix I

PetBuddy Application screenshots