Use of Fantasy in Serious Games to Assist Physical Rehabilitation

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A PhD thesis submitted in partial fulfilment of the requirements of Bournemouth University for the degree of Doctor of Philosophy

July 2025

Abstract

This study explores fantasy's role in keeping people engaged and motivated to perform physical rehabilitation, specifically incorporating fantasy elements. Physical rehabilitation helps people recover from injuries and pain; however, due to its monotonous and tedious nature, many people are not interested in it or leave the process in the middle. This research addresses the critical issue of how to keep the user engaged with the exercises. Serious games are being used in the recovery process related to health. Fantasy in games is also important in keeping the user engaged and motivated to play the game repeatedly. In this respect, in this research, fantasy elements are incorporated into the serious game to determine the user's engagement and motivation to perform physical rehab exercises.

To answer the research question, a comprehensive literature review is conducted on serious games, the use of fantasy in games, and physical rehabilitation of back pain. A survey of the last five years of work in these areas has also been undertaken. After analysing the literature review, the research is further enriched by discussions with experts from the following fields: medical rehabilitation (rheumatologist and physiotherapist), physiology (physiologist and psychiatrist), and human-computer interaction. Incorporating the perspectives of experts clears many questions, and this interdisciplinary approach also enriches the research, providing diverse viewpoints and insights. Based on this literature review and the expert views, a trial is conducted using a game prototype with two distinct versions. One version incorporates a fantasy element, while the other is a non-fantasy-based environment. These versions serve as a tool to measure the impact of a fantasy-bas ed VR serious game. The trial is instrumental in assessing the significance of fantasy for users who may find their daily rehabilitation routine monotonous, thereby encouraging them to complete their required exercises.

The analysis of this tool employs a mixed-method approach in the questionnaire, combining qualitative and quantitative analysis. Data collection is done in two steps with the help of medical experts and participants. In stage one, the medical experts are requested to play the prototype and evaluate the proper implementation of exercises in the game. In stage two, participants are requested to play the game after the appropriate implementation of exercises in the game. They have assessed the game engagement and motivation by the usability of fantasy elements in serious games for physical rehabilitation. The findings not only demonstrate the potential of serious games with fantasy elements to enhance user engagement and motivation in physical rehabilitation but also suggest practical implications for applying the same work to other parts of the body.

ACKNOWLEDGEMENT

I sincerely thank my supervisors, Dr Oleg Fryazinov and Dr Rehan Zia, for their exceptional understanding, guidance, and mentorship throughout my PhD journey. Their unwavering support during challenging times kept me on the right track, and their insights and inspiration have enriched every interaction and meeting. I sincerely appreciate Dr Hammadi Nait-Charif for his continuous support and valuable advice. His presence and guidance during moments of need were invaluable. Furthermore, I wish to thank my lab mates, whose constant support has strengthened me throughout this journey.

Based on the nature of this research, I conducted various discussion sessions with professionals from both the medical and HCI fields. I would like to thank Dr Paul Fletcher, Dr Daria Kuss, Dr Sarah Hodge, Dr Asim, Kris, Dr Ivan Phelan, Ms Kristine Knudsen, and Ms Sarah Russell.

I also like to thank the students who played a role in creating this game. I would also like to express my gratitude to all the participants who participated in my research. Help from all of them makes this journey a prosperous and triumphant one.

I am deeply grateful to my husband and children, whose unwavering support sustained me throughout this challenging journey. I extend my heartfelt gratitude to my parents and parents-in-law for their belief in me and invaluable assistance in reaching this point. Additionally, I am thankful to my brother, friends, lab mates and extended family for their consistent presence and support whenever I required it.

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“Fantasy is hardly an escape from reality. It's a way of understanding it.”

Lloyd Alexander

1 Introduction

Digital technology has advanced more rapidly than any other innovation and has transformed all sectors of life, including education, law, government, and particularly the health sector. One critical aspect of healthcare is physical rehabilitation, which aims to restore the functional abilities of individuals affected by injuries, trauma, or chronic illnesses. The digital transformation has also influenced physiotherapy practices, especially in areas like telehealth and electronic documentation, thereby facilitating the work of physiotherapists (Estel et al. 2022).

Physical rehabilitation can be a challenging and repetitive process, particularly for patients suffering from conditions such as lower back pain. Many patients tend to skip or discontinue traditional physiotherapy sessions due to a lack of engagement, motivation, and the monotony of exercises.

Serious games offer a promising opportunity to transform rehabilitation into a more enjoyable and interactive experience. By making therapeutic exercises engaging, such games can encourage users to participate consistently. However, the effectiveness of a serious game depends largely on its ability to immerse users and maintain their interest, which, in turn, motivates them to adhere to their exercise routines.

Fantasy elements in game design are widely recognised for their capacity to transport players into imaginative and immersive worlds (see 2.5.4). Despite their potential, the integration of fantasy into healthcare, particularly physical rehabilitation, remains largely unexplored.

This research seeks to bridge this gap by exploring the potential of fantasy-based serious games to enhance patient motivation for performing physical rehabilitation exercises, particularly for back pain. The sections below define the core concepts and context underpinning this research.

1.1 Physical rehabilitation

Physical rehabilitation is a vital process aimed at recovering body functions that have been impaired due to injury, surgery, or chronic conditions (Bence 2024). It involves therapeutic

interventions designed to restore and improve functional abilities, with the ultimate goal of enhancing patients' quality of life and preventing complications during recovery.

Traditional rehabilitation methods include physical exercises, manual therapy, medication, and patient education on pain management, mobility improvement, and recurrence prevention. While these approaches are widely used, they face several limitations. From the patient's perspective, barriers include limited resources, fixed appointment schedules, long treatment durations, and travel constraints. For healthcare providers, challenges include workload, financial limitations, and access to specialised expertise. These issues can negatively impact patient motivation and adherence to treatment.

Technological advances both in hardware and software have opened new possibilities for technology-driven rehabilitation, enabling more active patient participation (Gaggioli 2009). These developments have also facilitated interdisciplinary collaborations, leading to innovative solutions in physical rehabilitation. For instance, robotics now provide precise and adaptive interventions and integrating gaming technologies has made rehabilitation more user-friendly and engaging.

In the context of physical health, back pain is one of the most prevalent global health concerns. While traditional rehabilitation for back pain includes physical therapy and medication, physiotherapy still faces challenges related to low engagement. Research has predominantly focused on the upper and lower limbs, leaving back pain relatively underexplored.

Approximately 50–80% of the global population, including in the UK, experiences back pain. Despite considerable government investment in research, it remains a persistent and complex issue (Society 2018; Zemedikun 2020). Active treatments like physical rehabilitation are essential, with patient engagement being a key determinant of recovery success.

1.2 Gaming technology

With the rising popularity of real-time and interactive technologies, serious games have found applications in various fields, including education, sports, and healthcare (Arnab 2012). These

games serve a purpose beyond entertainment and are designed to motivate, educate, or rehabilitate users.

One of the primary benefits of serious games is their immersive and interactive nature, which makes them particularly useful in physical rehabilitation (Arnab 2012; Din et al. 2023). They offer innovative solutions for individuals recovering from injuries, surgeries, or chronic illnesses. Several rehabilitation-focused games have already been developed to support balance training in older adults and motor recovery after strokes.

Serious games can be particularly helpful in making repetitive exercises more engaging, thus increasing patient satisfaction. Additional features such as progress tracking, real-time feedback, remote access, and customizable game experiences further enhance their utility. Examples include Jintronix, which targets motor skills after stroke, and Rehab Master, designed for musculoskeletal disorders. These games often rely on motion-sensing technologies such as Microsoft Kinect, Microsoft Azure, Nintendo Wii, and Virtual Reality systems, which allow users to perform physical exercises prescribed by healthcare professionals in a simulated environment (Liu et al., 2017).

1.3 Virtual reality: a catalyst for therapy

The integration of Virtual Reality (VR) in physical rehabilitation offers significant advantages for both patients and healthcare providers. For patients, VR provides an engaging, interactive experience. For practitioners, it offers tools to ensure patients remain motivated and perform their exercises consistently, even with minimal supervision.

VR immerses users in a virtual world where they can interact with their environment through haptic devices, head-mounted displays, and motion-capture systems. Unlike traditional therapy, which may lack excitement and engagement, VR can reduce boredom and increase adherence to exercise regimens.

The immersive quality of VR enhances motor skill development by simulating real-world environments and tasks. When VR incorporates natural landscapes and challenges that mimic daily life, patients can practice functional movements in a safe and controlled setting (Cameirão et al.

2010). This redirection of patient focus can lead to improved therapeutic outcomes (Adamovich et al. 2009).

Combining VR with serious games offers a powerful approach to rehabilitation. While serious games make the exercises fun and interactive, VR adds immersion and sensory feedback. Together, they can address the monotony of rehabilitation exercises and sustain patient motivation. These tools also allow for real-time feedback and performance tracking.

However, despite their potential, challenges remain. These challenges include motion sickness, latency issues, equipment costs, hardware requirements, accessibility barriers, and the need for clinical validation and training for healthcare staff (Weiss et al. 2004).

As digital technologies continue to evolve, the convergence of gaming, VR, and rehabilitation holds considerable promise. This interdisciplinary approach has the potential to revolutionise the field of physical rehabilitation. Within this context, fantasy emerges as a compelling and effective in serious games.

1.4 Role of fantasy in enhancing engagement

Fantasy plays an important role in enhancing motivation and engagement in digital games (Choi et al. 2013). Players often immerse themselves in fantasy games to escape from reality; the fantasy element offers a space where they can detach from real-life constraints and explore worlds of limitless possibilities (Sarkar and Sarkar 2022).

Fantasy elements such as fictional worlds, narratives, and characters serve to transport players beyond reality. These elements can enhance the engagement and motivational appeal of a game by offering escapism and fostering emotional connection. Incorporating such fantasy features into physical rehabilitation exercises can reduce monotony and make the experience more enjoyable.

In serious games, fantasy elements support engagement by creating a sense of adventure and emotional investment. The player's curiosity, the desire to complete challenges, and the fantastical features of the environment all contribute to sustained motivation (Habgood and Ainsworth 2011).

These elements encourage users to explore the game world and remain committed to progressing through it.

Immersing players in a fantastical environment also provides a safe, risk-free space to explore and practice without real-world hazards (Shaffer et al. 2005). The incorporation of narrative and storytelling can further captivate players, enhance immersion and sustain interest. In the context of rehabilitation, fantasy-based environments may thus play a valuable role in promoting adherence to therapeutic exercises.

1.5 Research questions

In today's fast-paced world, individuals often avoid repetitive and tedious physical rehabilitation tasks. Making these tasks more engaging requires innovative approaches such as combining VR**,** serious games**,** and fantasy elements**.**

Previous research has examined the use of serious games and VR in rehabilitation, and fantasy has been explored in educational immersive technologies with encouraging results. However, its application in health-focused serious games remains largely unexplored. The immersive quality of fantasy has the potential to keep patients engaged, distract from pain, and motivate through aesthetic appeal, game mechanics, levels, and achievement systems.

In this research, a novel approach is explored by combining fantasy with a VR-based serious game designed specifically for back pain rehabilitation. The study addresses the following research questions:

1. Can storyline and visual elements from the fantasy genre attract and engage users to perform physical rehabilitation exercises for back pain?

2. Can introduction of fantasy elements in serious games for health affect user engagement and motivation?

3. Can serious games, built around fantasy-based narratives and visual components, transform back pain rehabilitation into a more enjoyable and engaging experience?

These questions are explored while considering the limitations of the available technology.

1.6 Aims

The aim of this study is to contribute to the development of more effective rehabilitation solutions through game-based interventions. This research offers a comprehensive analysis of VR, fantasy elements, serious games, and physical rehabilitation, with the ultimate goal of proposing a serious game prototype for back pain therapy.

To achieve this goal and address the research questions (see 1.5), the study establishes the following aims:

1. Explore how fantasy elements in serious games can enhance motivation and adherence to physical rehabilitation exercises for back pain.
2. Compare user engagement levels between a game incorporating fantasy elements and one that does not, to assess differences in user participation and effort.
3. Examine how fantasy elements influence the overall user experience in serious games designed for rehabilitation, particularly in terms of immersion and engagement.

1.7 Objectives

To ensure measurability of research aims set in the previous section, this study uses research objectives. They help determine whether the inclusion of fantasy elements in serious games is effective in promoting adherence to physical rehabilitation. The specific objectives of this research are:

1. Investigate the relationship between fantasy genre elements and player engagement in video games.
2. Estimate efficiency of fantasy elements incorporated into serious games, particularly those designed for physical rehabilitation.

3. Evaluate the advantages of fantasy-driven serious games by designing and developing a prototype focused on lower back pain rehabilitation.

1.8 Thesis structure

This research study explores the impact of fantasy elements in serious games using VR to engage users in the physical rehabilitation of back pain. For this purpose, a VR-based prototype has been developed, consisting of two versions. One version, titled *Wishing Well,* incorporates fantasy elements, while the other, titled *Healing Well,* does not. These two prototypes serve as tools to measure the influence of fantasy in serious games related to rehabilitation. The prototype was developed with input from medical experts (See. 3.2).

After the prototype's development, participants would be recruited and divided into groups. Each group plays one version of the game and provides feedback. Based on this feedback, the study evaluates whether the inclusion of fantasy elements enhances participant engagement and motivation to perform physical rehabilitation exercises.

Following this introductory chapter, the thesis is divided into five additional chapters. As previously outlined, this work lies at the intersection of serious games, fantasy, and rehabilitation. Therefore, Chapter 2 presents a comprehensive literature review of these core areas. The first part of the review explores each area individually VR, serious games, rehabilitation, and fantasy and their relevant applications, with particular focus on immersive technologies used in gaming. The second part examines studies conducted at the intersection of these domains, identifies key findings, and highlights research gaps that inform the foundation of this study. This chapter also discusses the rationale behind the choice of hardware and software for the prototype.

Chapter 3 outlines the research methodology. It details the process of prototype development and describes the data collection methods, including the design of questionnaires.

Chapter 4 documents the design process of the prototype, including the rationale behind each design element. It also presents the game design document and elaborates on the development of both versions of the prototype.

Chapter 5 begins the evaluation phase and discusses *User Study 1*. It presents the feedback from medical experts, suggested improvements, and the implementation of these changes. It then introduces *User Study 2*, focusing on data collected from healthy volunteers. This chapter combines both qualitative and quantitative data to evaluate the prototype's effectiveness. Results from both user studies are discussed, along with insights gathered from participants.

Chapter 6 concludes the thesis by reviewing the findings, summarising key contributions, and discussing the study's limitations. It also outlines future research directions and explores user expectations and implications for future applications of the prototype.

2 Literature review

2.1 Overview

Various studies are being carried out to motivate patients to do rehabilitation exercises. In those studies, different options are being explored, such as virtual reality (VR), augmented reality (AR), mixed reality (XR), games, and various art forms. This chapter provides an overview of the literature about VR, serious games, fantasy and physical rehabilitation. A brief survey of these topics from the last five to seven years is also provided in Table 2.1 and Table 2.2. This survey helps to identify the areas in the current knowledge state and the gaps in the area to be carried out in this study. This information will guide the researcher about the theoretical and practical implications of designing and implementing this type of study. It will show how this interdisciplinary approach can influence users engagement in rehabilitation.

Following the research questions stated in section 1.5, this study explores the intersection of areas of video games, VR, physical rehabilitation and fantasy (see Figure 2.1). Each of these areas is explored individually in the following sections, and their interconnections are used to construct the conceptual framework for this study.

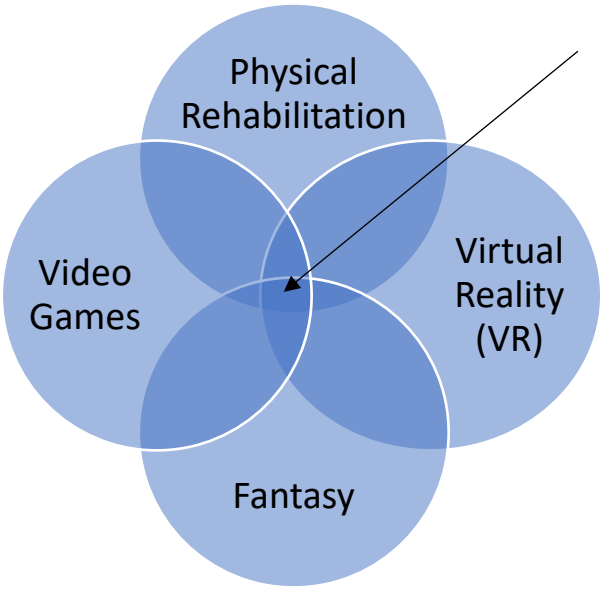


Figure 2.1: Venn Diagram of Fantasy, Games, Virtual Reality and Physical Rehabilitation Research

2.2 Rehabilitation

Rehabilitation is a process that helps individuals recover and improve following an injury or disability (Physiotherapy 2017). Its goal is to restore functional abilities and promote as much independence as possible (Organization 2024). It supports the recovery of mobility and communication skills (O'Young et al. 2022). However, the interpretation of rehabilitation varies among individuals (Wade 2020), and there is no universally accepted definition (Negrini et al. 2022). According to the NHS, rehabilitation is the recovery process from pain, injury, or illness (Lorman 2013). Broadly, it refers to restoring a person's physical and/or mental health following disease or injury (Bennett et al. 2014). The World Health Organisation (WHO) defines rehabilitation as the training and retraining of a person to achieve optimal functional abilities through coordinated medical, social, and educational measures (Nazmi et al. 2016).

Rehabilitation aims to enhance patients quality of life (Suputtitada 2023) by increasing activity levels and reducing recovery time (Wade 2020). It is beneficial across a wide range of injuries and conditions that result in persistent disability. For optimal outcomes, rehabilitation should begin as early as possible (Physiotherapy 2017). Studies show its effectiveness across various conditions, diseases, and age groups (Nazmi et al. 2016). Although rehabilitation can be categorised by age, condition, or disease, these categories often overlap and are not as distinct as they may seem (Wade 2020).

Specialised therapists play an essential role in rehabilitation centres, delivering targeted therapies based on individual needs (Wolf et al. 2018). These centres offer physical treatments that address disabilities which cannot be treated with medication alone (Ward 1997). However, rehabilitation often requires a combination of therapy and medication to support the healing process (Iqbal et al. 2017). Rehabilitation is typically tailored to each patient's specific needs (Silver and Siebens 1994), with the ultimate goal of restoring function and improving quality of life following illness or injury (Gupta et al. 2018). Rehabilitation can take place in various settings, including hospitals, clinics, community centres, and homes (Silver and Siebens 1994).

The form of rehabilitation depends on the condition being treated and may include physical rehabilitation, occupational therapy, cognitive therapy, or speech therapy (O'Young et al. 2022). This research focuses specifically on physical rehabilitation.

2.1.1 Physical rehabilitation and its common applications

It is a healthcare process used after illness, injury or surgery to improve health and restore physical functions (Granger et al. 2009). It is often referred to as rehabilitation or physical therapy (SmolenskiC et al. 2014). Physical rehabilitation is widely recognised as a treatment pathway essential for helping individuals recover from various health conditions, including musculoskeletal injuries, neurological disorders, cardiovascular diseases, and post-surgical recovery (Khokale et al. 2023). This treatment is delivered in diverse settings such as hospitals, clinics, homes, and sports facilities, with personalised plans tailored to the needs of each patient (Kunjarkar et al. 2022).

The physical rehabilitation process is highly individualised, allowing the treatment course to be adjusted according to the patient's evolving needs (Kunjarkar et al. 2022). The patient's health status and the expertise of the rehabilitation team are also critical factors influencing treatment outcomes (Granger et al. 2009). Despite this flexibility, the core principles of rehabilitation can generally be categorised into several key components: assessment**,** goal setting**,** treatment planning**,** and implementation (Futrell and Rozzi 2019).

Physical rehabilitation is applied across various medical fields and conditions and is typically an essential component of the treatment process (Kunjarkar et al. 2022). The most common applications include post-surgical recovery, neurological disorders, cardiopulmonary rehabilitation, paediatric rehabilitation, geriatric rehabilitation, sports rehabilitation, and musculoskeletal injuries (Carr 2005). Post-surgical rehabilitation is a necessary procedure following several types of surgeries, such as orthopaedic joint replacements, spinal surgery, and cardiovascular surgeries (e.g., heart bypass and valve repair). Rehabilitation helps reduce pain, promotes scar tissue formation, improves joint mobility, and restores muscle strength (Ranawat et al. 2003). It enables patients to resume normal activities in a timely manner (Kirkby Shaw et al. 2020). Neurological Rehabilitation is essential for patients with neurological conditions such as stroke, multiple sclerosis, Parkinson's disease, and traumatic brain injury (Aqueveque et al. 2017).

It aims to restore lost functions by improving mobility, coordination, balance, and cognitive abilities (Nakano 2020). Cardiac and pulmonary rehabilitation programs are designed for individuals recovering from major cardiac events, surgeries, or chronic respiratory conditions such as chronic obstructive pulmonary disease (Ries et al. 2007). These programs offer physical exercises, nutritional guidance, and lifestyle counselling to improve cardiovascular and respiratory function (Flint et al. 2019). The goal is to enhance overall health, reduce the risk of future complications, and improve daily functioning (Wu et al. 2020). Paediatric rehabilitation benefits children with disabilities or injuries (Nakano 2020). Conditions such as cerebral palsy or traumatic injuries may affect a child's mobility, communication, or ability to perform self-care tasks (Helders et al. 2001). Paediatric rehabilitation centres provide physical, occupational, and speech therapies that help children develop motor skills, independence, and communication abilities (Gunel 2009).

Sports Rehabilitation is designed for athletes recovering from injuries or surgery. These programs focus on restoring strength, flexibility, and performance (Araneda et al. 2020). They are tailored to the physical demands of the athlete's specific sport while minimising the risk of re-injury (Wu et al. 2020). Various techniques are used to help athletes regain full functionality and ensure a safe return to competition (Sweeney 2020). Musculoskeletal rehabilitation addresses common injuries such as fractures, sprains, strains, and dislocations (Helders et al. 2001). These injuries may result from accidents, sports, repetitive stress, or ageing, and they often lead to pain, stiffness, and reduced mobility (Cameron and Monroe 2007). Treatment typically includes a combination of pain management, therapeutic exercises, manual therapy, and assistive devices such as braces or orthotics to promote healing and restore function (Silver and Siebens 1994).

Physical rehabilitation is a key factor in improving patients' quality of life. Its benefits are evident across physical, psychological, and interpersonal dimensions (Goddard and Cuthbertson 2012). Restoring Physical Function is one of the primary benefits of rehabilitation (Helders et al. 2001). For individuals recovering from injury, surgery, or chronic illness, rehabilitation supports the recovery of strength, mobility, and independence (Bence 2024). These improvements enable patients to perform daily activities such as walking, dressing, and driving (Sweeney 2020). Regaining physical function not only enhances quality of life but also reduces the need for long-term assistive care (Kappel et al. 2018). Chronic Pain is a common issue following injuries or surgeries and can significantly diminish quality of life (Schim and Stang 2004).Rehabilitation

applies various techniques including manual therapy, exercise, electrical stimulation, and ultrasound to reduce pain and inflammation (Bennett et al. 2014). These interventions address the root causes of pain, reduce dependence on medication, and support a more comfortable and active lifestyle (Arena and Jump 2012).

For patients recovering from surgery or injury, rehabilitation plays a crucial role in preventing complications such as joint stiffness, muscle atrophy, blood clots, and infections (Ranawat et al. 2003). Early mobilisation and targeted exercises improve blood circulation, reduce swelling, and accelerate healing (Helders et al. 2001).

In patients with brain or heart conditions, rehabilitation can help prevent secondary complications such as pressure sores, respiratory infections, and cardiovascular events (Kaufmann and Diez-Morel 2022). Psychological well-being is also improved through physical rehabilitation. Many patients struggle with completing basic tasks after injury or illness (Lalwani et al. 2022). Rehabilitation provides a structured, step-by-step recovery plan that empowers patients to regain independence (Helders et al. 2001). Achieving small goals restores confidence and a sense of purpose (Pratt et al. 2013).

Rehabilitation is a versatile and essential component of modern healthcare (Nugraha and Gutenbrunner 2021). It supports patients' physical, emotional, and social recovery (Jesus et al. 2019), helping them regain control over their lives (Liu et al. 2023).

Physical rehabilitation has broad applications, addressing conditions such as musculoskeletal injuries, neurological disorders, and cardiovascular diseases (Tanielian et al. 2018). By promoting long-term health and independence, it significantly improves quality of life (Jesus et al. 2019; Sivan and Negrini 2024).

For many individuals, reduced mobility results in social withdrawal, as they can no longer participate in activities they once enjoyed (Helders et al. 2001). Rehabilitation helps restore physical strength, enabling participation in social and recreational activities (Nugraha and Gutenbrunner 2021), such as family outings and hobbies (Bence 2024). Rehabilitation supports both short-term recovery and long-term health maintenance (Taylor et al. 2020). Patients are taught skills such as posture control, proper body mechanics, exercise, and nutrition. These practices help

prevent further injury and support ongoing well-being (Schwartz et al. 2021). For those with chronic conditions like arthritis or heart disease, rehabilitation provides self-management strategies to reduce flare-ups and prevent deterioration (Silver and Siebens 1994).

Beyond health improvements, rehabilitation also brings economic benefits (Cieza et al. 2020). It can accelerate recovery, reducing the need for long-term care and disability benefits, ultimately decreasing healthcare costs (Bachmann et al. 2020).

From restoring physical function and relieving pain to enhancing mental health and preventing complications, rehabilitation offers a structured path to recovery, allowing individuals to regain autonomy and control over their lives (Cieza et al. 2020). Its wide-ranging applications address the needs of people with musculoskeletal, neurological, and cardiovascular conditions (Zasadzka et al. 2016). Physical rehabilitation provides a sustainable route to health and stability by improving quality of life. However, patient motivation remains essential for rehabilitation success (Maclean et al. 2000).

2.1.2 Lower back pain and its causes

Back pain is one of the most common musculoskeletal problems globally (Hartvigsen et al. 2018). Millions of individuals across different age groups are affected by this condition (Manchikanti et al. 2014). In the long term, it can be highly distressing, as it often leads to immobility and limits the ability to perform physical exercise (Ali and Nas 2018). Chronic pain is also associated with mental health issues, such as depression and anxiety (Meulenbroek 2021).

Lower back pain (LBP) is the most prevalent disorder of the musculoskeletal system, affecting millions of people worldwide (Ali and Nas 2018). The lower back bears the majority of the body's weight, making it highly susceptible to injury (Wu et al. 2020). LBP is a leading cause of disability, significantly limiting physical movement and daily activity (Manchikanti et al. 2014). It is typically experienced as discomfort in the region between the rib cage and the buttocks (Ali and Nas 2018). According to the World Health Organisation (WHO), one in every ten people globally suffers from LBP, making it the leading cause of disability worldwide (Traeger et al. 2017). Muscle strain or ligament sprain can occur when patients have excessive physical activity or sudden, uncontrolled movement of the muscles and ligaments in the lower back can result in strain or sprain

(Ali and Nas 2018). Disc degeneration occurs with age; the intervertebral discs located between the vertebrae lose water content and elasticity, reducing their ability to absorb shock. This deterioration can lead to chronic pain (Migliore and McGee 2021). Spinal stenosis involves the narrowing of the spinal canal, which compresses the nerves and causes pain (Katz and Harris 2008). Spondylolisthesis: In this condition, one vertebra slips over another, leading to misalignment and discomfort (Ali and Nas 2018). Osteoarthritis is a condition when the degeneration of joints can lead to osteoarthritis, which affects the facet joints of the spine and contributes to lower back pain (Sinusas 2012).

Lower back pain (LBP) can be classified as acute (lasting less than 6 weeks), subacute (6–12 weeks), or chronic (persisting for more than 12 weeks) (Hartvigsen et al. 2018). Rehabilitation is essential for managing LBP, as it helps restore function and improve mobility (Pergolizzi Jr and LeQuang 2020). While LBP may have various causes, physical rehabilitation focuses on restoring normal movement, strengthening muscles, and reducing pain (Celletti et al. 2020).

Physical rehabilitation is especially important for individuals with LBP, as it significantly influences their quality of life (Hoy et al. 2014; Bachmann et al. 2020). Chronic pain is a leading contributor to limitations in daily activities, reduced work productivity, and decreased social participation (Chou et al. 2009).

The economic burden of LBP is substantial. In the United States, it results in more than $200 billion in annual losses due to healthcare costs and lost productivity (Casiano et al. 2019). In the United Kingdom, approximately £2.8 billion is spent annually on back pain treatment (Carregaro 2021). Traditionally, LBP rehabilitation combines physical exercises with behavioural interventions (Bachmann et al. 2020). This integrated approach helps patients restore mobility and flexibility, alleviate pain, and prevent future injuries (Chou et al. 2009).

Physical rehabilitation is one of the most common and effective treatments for lower back pain (LBP). Its interventions include spinal muscle strengthening, flexibility improvement, and pain relief (Ali and Nas 2018). Manual Therapy involves spinal mobilisation techniques aimed at restoring proper alignment and reducing pain caused by excessive strain on the back muscles (Coulter et al. 2019). Research highlights the value of manual therapy in both traditional and

technology-supported treatment (Rubinstein et al. 2019). Stretching and Strengthening Exercises help increase spinal flexibility and build core muscles. Common examples include pelvic tilts, bridges, and planks (Choe and Kim 2020). A stable core allows the body to function naturally and reduces the risk of future injuries (Barr et al. 2005).

Low-impact Aerobic Exercises, such as walking, swimming, and cycling, improve cardiorespiratory function and overall physical health (Lin et al. 2011). These movements also help decrease muscle and joint soreness (Choe and Kim 2020). A review of existing studies found that exercise therapy is highly effective for reducing pain and improving function in individuals with LBP (Hayden et al. 2005).

Poor Posture and Incorrect Ergonomics are leading causes of LBP (Pillastrini et al. 2010). Patients should be trained to maintain proper posture when sitting, standing, and lifting objects to reduce spinal strain and prevent reinjury (Dable et al. 2014). Improper posture can lead to musculoskeletal disorders (Galof and Šuc 2021). Using lumbar support during sitting is an ergonomic intervention that helps protect the lower back (Taifa and Desai 2017).

Thermal Therapy, including hot packs, helps relax muscles and improve blood circulation. Cold therapy, such as ice packs, reduces swelling and numbs the injured area (Kim et al. 2015). Alternating between heat and cold can be an effective strategy for treating acute back pain and providing immediate relief (Chou and Huffman 2007).

Massage Therapy, particularly deep tissue massage, can reduce muscle tension, decrease inflammation, and enhance circulation in the lower back area (Portillo-Soto et al. 2014). Although massage therapy is widely used, it is considered a short-term solution for managing LBP (Furlan et al. 2015).

Patient Education is crucial for successful recovery from LBP (Fatoye et al. 2023). It includes instruction on safe body mechanics, proper lifting techniques, ergonomics, and the benefits of regular physical activity (Saner et al. 2018). Educated patients are more likely to take self-directed actions and become actively involved in managing their daily routines (Ali and Nas 2018).

Psychosocial Factors such as stress, depression, pain perception, and fear-avoidant behaviours play a significant role in LBP management (Arena 2002). Addressing these through psychological interventions is essential in comprehensive rehabilitation programs (Ralphs and Corcoran 1997).

Cognitive Behavioural Therapy (CBT) is an effective mental health intervention for improving both psychological and physical well-being in patients with LBP (Vibe Fersum et al. 2013). CBT teaches patients how to manage their pain by changing negative thought patterns and adopting healthier behaviours (Hooff van et al. 2010). One study demonstrated that CBT, when combined with physical therapy, reduced pain and improved functional outcomes (Hoffman et al. 2007).

Mindfulness-Based Stress Reduction (MBSR) uses mindfulness meditation to help individuals focus on the present moment and reduce the emotional burden of pain (Greeson and Eisenlohr-Moul 2014). A randomised controlled trial showed that MBSR significantly improved both pain intensity and functional limitations in people with LBP (Cherkin et al. 2016).

With ongoing technological and medical advancements, innovative nerve-strategy treatments such as VR-based therapies and serious games have emerged (Ahern et al. 2020). VR rehabilitation fosters immediate engagement, interactive exploration, and enjoyable participation, especially for those who prefer playful and immersive environments (Cochran and Hout 2021).

2.1.3 Integration of traditional and digital ways for rehabilitation

Integrating traditional and digital methods allows for a better and more varied process to be created that best fits and has the advantages of both (Vetitnev et al. 2020). Traditional therapy provides supervised direct teaching of body positions and training corrections (Perlow et al. 2016). In contrast, digital tools such as VR and AR stimulate motivation and reliability by demanding the trainees to run after the illusion they see in the headset (Mulders 2020).

2.3 Virtual Reality

Virtual reality (VR) refers to a computer-simulated environment that closely resembles real-life settings or may be entirely imaginary (Du and Yu 2020). VR allows users to immerse themselves in experiences that range from realistic scenarios to fantastical, imaginative worlds (Holubek et al. 2021). Advancements in VR have moved beyond two-dimensional interactions to fully immersive

three-dimensional experiences, where users can move and interact with virtual environments using specialised devices such as headsets, haptic gloves, or controllers (Georgiev et al. 2021).

Users are transported into virtual worlds that can feel remarkably realistic, engaging multiple senses and offering a unique combination of interaction, immersion, and realism (Routhier 2018). While VR has traditionally been associated with entertainment especially gaming, it has expanded significantly into other sectors, including education, training, healthcare, and rehabilitation (Checa and Bustillo 2020). The use of VR in rehabilitation exemplifies a powerful fusion of technology and medicine, highlighting its potential to enhance both physical and mental health outcomes (Wiederhold and Riva 2019).

VR-based rehabilitation systems also support progress tracking, real-time feedback, and targeted therapeutic outcomes (Laver 2020). These features can empower patients by encouraging active participation in their recovery and enhancing their motivation to engage in exercises, an essential element in effective rehabilitation. VR interventions have demonstrated promising results in treating conditions such as stroke, brain injuries, and Parkinson's disease (Laver 2020). By enabling patients to practice tasks and improve functional independence, VR supports more effective and engaging rehabilitation.

The incorporation of interactive exercises and simulated therapies helps engage patients in focused activities that promote healing and strengthen targeted areas (Dörner et al. 2016). VR-based physical therapy leverages the immersive nature of virtual environments to captivate patients and encourage their active involvement in the recovery process (Arnab 2012).

2.3.1 Key technologies and advantages of Virtual Reality

The VR systems, which are composed of a number of parts that promote a cohesive user experience (Georgiev et al. 2021). Some of the key technologies include VR headsets, which are eye-catching devices that totally immerse users in a virtual world with the help of visual and sound stimuli (Kim et al. 2020). Examples are the Oculus Rift, HTC VIVE, and PlayStation VR. A head-mounted display, which is used to track the head's position and consequently adapt the visuals accordingly, makes a headset an immersive tool (Moreno et al. 2019).Advanced VR systems are created in a way to detect not only the head but the whole body, which makes the experience more realistic

(Man 2010). Using advanced VR systems, users can easily interact with the virtual environment (Teixeira et al. 2013).

Haptic feedback systems are devices that give the user actual feedback, making the simulation of the feeling of touch in the virtual world possible (Biswas and Visell 2021). Using haptic gloves, users can feel objects and textures of the virtual space (Iacob and Popescu 2019).

Immersive VR with high-quality spatial audio is an important part (Summers and Jesse 2017). One of the ways 3D audio is used to produce a VR environment is to use sounds coming from a certain direction, thus immersing the user in a realistic environment (Kim et al. 2020).

VR is a technology that has demonstrated significant benefits across a range of contexts and applications. Immersive experience is one of VR's primary advantages, as it allows users to fully immerse themselves in a virtual environment. Through the use of headsets and auditory tools, users feel as though they are physically present in the virtual space, enhancing the overall interactive experience (Kim et al. 2020).

In a VR setting, users can interact with their surroundings, manipulate virtual objects, and move through the environment. This interaction is enabled by devices such as handheld controllers and motion-tracking systems (Khan et al. 2020).

A key reason VR elicits strong emotional responses is its ability to generate a sense of "presence," in which users feel genuinely situated within the virtual world (Checa and Bustillo 2020). This illusion becomes even more convincing when bodily motions are tracked and mirrored by the VR system (Kim et al. 2020).

2.3.2 Difference between Virtual Reality and Augmented Reality

VR provide the feeling of being in a different world by taking the person to a virtual world (Aggarwal and Singhal 2019). On the other hand, Augmented Reality (AR) adds digital information or images on top of the real world (Motejlek and Alpay 2021). In AR, users can still see and interact with the natural world while receiving additional virtual enhancements, such as digital annotations, virtual objects, or information overlaps (Aggarwal and Singhal 2019). The distinction between VR and AR can sometimes be blurred in some situations (mixed reality), but

the two technologies are different and have their own functions (Rosa et al. 2016). VR is more appropriate in those cases when an alien environment is required, and absolute immersion is provided to the users, whereas AR enhances the user's perception of the real world (Parekh et al. 2020).

2.3.3 Virtual Reality in rehabilitation

It is a widely accepted fact that Virtual reality (VR) has become the new sensation in the physical rehabilitation world, mainly due to its ability to make otherwise boring therapy more interactive, attractive, and adjustable. This can be attributed to the fact that VR takes the patient into an artificial world, which can still be modulated to their wishes without fail. In return, not only is the patient satisfied with the recovery process, but the result is also better (Laver 2020).

Recent studies show that VR is a very effective tool for treating many diseases, such as stroke, Parkinson's disease, musculoskeletal problems, and chronic pain. By using VR, patients can complete their physical therapy tasks with enthusiasm and engagement. VR offers a novel approach to physical therapy, which can be significantly more engaging and thus easier to comply with than traditional physical therapy (Matheve et al. 2020). The use of this technology makes the entire rehabilitation process more engaging and motivating, which is precisely what patients need for success (Lewis and Rosie 2012).

In a review of the literature and using the meta-analytic method, Aminov et al. (2018) found that VR interventions positively influenced the outcome of functional deficits in post-stroke recovery, indicating a strong beneficial effect of neuroplasticity in interactive environments (Aminov et al. 2018). The researchers showed that VR interventions not only led to the reduction of pain but also eliminated the patients' behaviour of fear and avoidance through the use of visual narratives.

One of the newer directions of the development of VR systems is the employment of fantasy and narrative-based serious games. Employing such elements can transform repetitive activities into goal-oriented tasks with rich context, and therefore has the potential to boost motivation. For example, research carried out found that user engagement and perceived exertion improved when fantasy themes were added to VR rehabilitation, making it more possible for patients to complete longer sessions or have them more frequently (Pantelimon 2022).

VR in the field of rehabilitation remains an area with significant potential, but it also presents several challenges that need to be addressed. The limitations of VR in rehabilitation are still substantial, such as high costs, technical challenges, and the lack of standardised protocols (da Silva Cameirão et al. 2011). However, it is worth noting that the development of patient-centred rehabilitation experiences, primarily through the facilitating role of VR driven by serious games with fantasy elements, still holds great potential.

Embodiment in VR Rehabilitation is one of the key concepts in VR, the concept of embodiment, which refers to the inner state of possessing and being in control of a body, particularly a virtual body or an avatar in a virtual environment (Klingenberg et al. 2024). Embodiment is a multifaceted concept that is approached in various ways across different research areas. While the core principle of feeling "inside" a virtual body remains consistent, the specific focus, goals, and methodologies used to investigate and utilise embodiment can vary significantly (Gall et al. 2021).

In rehabilitation through embodiment, patients may recognise themselves in the virtual body, as a result of which motor learning takes place, pain perception changes, and functional outcomes in rehabilitation are improved (Matamala-Gomez et al. 2019). VR embodiment offers a fundamental concept, consisting of three key aspects, body ownership (the perception that the virtual body or limb is part of the user), agency (the act of starting and managing the virtual body's movements by oneself), self-location (the awareness of the location of one's own body in space as being within the virtual body) (Kilteni et al. 2012). When these ingredients are combined in the VR system, they provide a powerful sense of presence and, simultaneously, have a therapeutic effect on virtual worlds (Slater et al. 2010).

Physical presence is an essential aspect of motor recovery. Both seeing or directly manipulating a virtual body from an egocentric view induces the activation of motor areas of the brain, which stimulates neuroplasticity and recovery, especially in cases of stroke or spinal cord injury rehabilitation (Cameirao et al. 2012). This finding is in line with the evidence from mirror therapy and motor imagery of imagined or observed movements, which affect the sensorimotor circuits (Lloréns et al. 2015).

When it comes to issues like chronic pain, and especially lower back pain, VR localisation is known to help the affected not include the physical image of the body in the brain's pain map. The

work by Matamala Gomez et al. (2019) has shown that patients with chronic pain who underwent embodiment in VR experienced not only reduced pain but also a decrease in fear of movement, as a more accurate body schema was re-established (Matamala-Gomez et al. 2019). Likewise, Boesch and his team have also demonstrated in their experiment that video game visual aesthetics can reduce pain through triggered multisensory integration and increased embodiment (Boesch et al. 2016).

2.3.4 Virtual Reality in lower back pain rehabilitation

VR has become one of the leading methods in rehabilitation (Wang et al. 2023a). Due to VR, patients get fully absorbed in the treatment and follow the program (Garrett et al. 2018). This technique consists of applying different VR exercises and body movements (Sousa de and Balbino 2018).

VR is a successful means of restoring the range of motion, balance, and coordination in the spine (Yeo et al. 2019). Patients' movements, like bending, reaching, or lifting, can be experienced in the virtual world (Cochran and Hout 2021). A study reported that VR-based movement therapy improves trunk control and balance in patients (Karamians et al. 2020).

VR can be a tool for distraction therapy, where patients are put through relaxing and calm virtual environments such as beaches or forests, thus helping them to direct their focus away from pain (Hoffman et al. 2020). A study explored the VR-based distraction technique, which showed a significant decrease in pain intensity on the level of chronic pain in LBP patients (Garrett et al. 2018).

There are various advantages of VR for LBP rehabilitation, i.e. VR systems can give real-time feedback on a patient's performance, helping them stop wrong movements and decrease the possibility of injury (Chheang et al. 2023). VR platforms can adapt to every patient by changing the intensity and difficulty of exercises depending on their development (Qian et al. 2020). Patients are provided with a dynamic experience and personalised exercise program that does not mean they cannot handle the situation (Hwang et al. 2020). The greatest issue with rehabilitation is the lack of patient motivation (Rapolienė et al. 2018). VR handle the treatment as a game that makes therapy more exciting by adding other sensory cues, such as eyesight and hearing (Sousa de and

Balbino 2018). As a result, patients are more likely to stick with their exercise programs when they find the experience to be more fun (Bourgeois et al. 2023).

2.4 Video games

Video games are a genre that has been popular among the masses for an extended period (Predescu and Mocanu 2020). They have evolved from a journey of pixelated graphics to immersive experiences that have captivated people's attention worldwide (Alpert 2007). The evolution of video games gives rise to two major categories: entertainment and serious games (Gazis and Katsiri 2023). Both categories use an interactive environment with a digital twist (Alpert 2007). However, they have distinct areas and different target audiences (Motejlek and Alpay 2021). The features and drawbacks of the two categories are explained in the subsections below.

2.4.1 Entertainment games

Entertainment games are games played for fun, enjoyment, and leisure (Laamarti et al. 2014a). They can be categorised into different genres: action, adventure, role-playing, simulation, sports, and puzzle games (Zhang 2022). The main goal of these games is to give the players an immersive experience that attracts their focus, challenges their skills, immerses them in the story, and provides a diversion from reality (Qaffas 2020).

Entertainment games provide an incredible user experience with narrative plots, brilliant graphics, and fun mechanics that involve people in their virtual worlds (Laamarti et al. 2014a). "The Legend of Zelda," "Call of Duty," and "The Sims" are just a few examples of how storytelling and interactive elements can create a compelling experience (Smed 2014).

Most entertainment games come with multiplayer-friendly modes that let players connect with their friends or compete against others globally (McCauley et al. 2017). Company gaming socializing enriches the gaming experience and builds a community and collaboration bond between players (Zhang 2022). Entertainment games on multi-platforms such as consoles, PCs, and mobile phones can be found (McCauley et al. 2017). Its universal liking by all age groups is also due to its accessibility(Fritsch et al. 2006). The gaming sphere has enhanced its range of marketing devices by using one-time fees, subscribing to a service, and micro-transactions (Zhang

2022). These models enable the creators to obtain the revenue they require to develop the game, updating it with new content for the players (Xu 2023).

Entertainment games have a significant impact on culture and society (McCauley et al. 2017). They help develop cognitive skills and improve the coordination of body parts. They can also serve as an artistic expression and relieve stress (Zhang 2022). However, various concerns related to gaming have also emerged, like the excessive gaming's impact on mental health and the effect of games on culture and religion (Jones et al. 2014). Experts are already looking for solutions to these concerns (John et al. 2019).

2.4.2 Serious games

"Serious Game" is a term used to describe a wide range of applications, from educational tools to simulations used in professional training. In contrast to entertainment games, serious games are designed with a primary purpose beyond mere enjoyment (Göbel 2016). These games establish a helpful tool for trainers, learners, etc. (Sudarmilah et al. 2018). When discussing serious games, an important point is the idea of serious games and how they work (Susi et al. 2007). In that respect, many definitions are available (Mentges et al. 2023). There are a lot of definitions available for serious games, but the main idea, on which most agree, is that serious games are not for mere entertainment but have other purposes embedded in them (Göbel 2016). Its broad-spectrum usage includes health, education, military, government, etc (Laamarti et al. 2014b).

Serious games are commonly used in various fields, such as health care, military training, or corporate education (Laamarti et al. 2014b). Serious games are also infused with educational content, enabling players to learn new skills or concepts entertainingly (Din et al. 2023). A good example is the "Kerbal Space Program" game, in which players learn about physics and engineering principles by designing and launching a spacecraft (Ning et al. 2022).

Numerous studies have proven that these games effectively educate critical and analytical skills (Takeuchi and Vaala 2014). Players usually encounter obstacles that require strategic planning and decision-making(Saravanan and Juliet 2018). All the above features make these games a great addition to cognitive development (Gorbanev et al. 2018). For example, "Virtual Patients" is a serious game that enables medical students to train their clinical skills by diagnosing and treating

virtual patients (Ellaway et al. 2009). Thus, they will learn without risking actual patients (Gorbanev et al. 2018)

Clark C Abt gave the idea of the serious game in the following terms: "*We are concerned with serious games in the sense that these games have an explicit and carefully thought-out educational purpose and are not intended to be played primarily for amusement"*(Laamarti et al. 2014b). Designing a serious game to be motivating is still a challenge (Din et al. 2023). Due to the storyline or design factor, sometimes serious games are less immersive than entertainment games and fail to reach the motivation potential that is expected from them (Zuo et al. 2022a). More research is required to make serious games more engaging (Li et al. 2022).

Even though entertainment and serious games serve different purposes, entertainment games are considered to be more engaging and immersive than serious games (Laamarti et al. 2014b). This suggests that both game types have the potential to complement each other (Caserman et al. 2020). Many entertainment games add teaching elements, and serious games often use the same mechanics as entertainment titles (Ning et al. 2022). This mixing of genres can lead to the invention of new gaming experiences that will entertain and educate (Hollins and Whitton 2011).

As an illustration, "Minecraft" has been employed in an educational context to teach various subjects, including mathematics, history, and environmental science (Nebel et al. 2016). One of the game's main strengths is its open-world design, which supports creativity and exploration and thus can be used as an experiential learning tool (Suwannik 2022).

One reason for the engagement and immersive nature of entertainment games can be the use of various mechanics and fantasy elements (Ning et al. 2022). Serious games can be designed to boost their purpose value with fantasy elements and gamification frameworks like MDA (Engström and Backlund 2022). This may lead to more enjoyable and compelling experiences due to increased motivation and engagement (Buckley et al. 2018). This feature of fantasy in serious games is widely explored in education (Zuo et al. 2020). Now, it can be explored in other fields, like health, to make the process enjoyable and entertaining for its users (Arnab 2012).

2.4.2.1 Serious games in health

In the digital age, serious games have been at the forefront of health facilitation, with their application to various areas such as physical rehabilitation, mental health support, medical training, public health education, and lifestyle management (Graafland and Schijven 2018). In health care, serious games can be deployed in different situations (Ricciardi and De Paolis 2014). For example, an application could facilitate physical rehabilitation exercises, provide cognitive and emotional therapies, educate medical professionals, teach patients about disease management, and promote public health (Randriambelonoro et al. 2020).

A key feature of serious games in health care is that they can convey information more interactively and appealingly, which improves motivation and compliance (Ricciardi and De Paolis 2014). Patients use virtual tasks to practice their movements in a controlled and supportive setting, which in turn promotes a better recovery process.(Arnab 2012) A study proved that the implementation of serious games for knee replacement patients' rehabilitation after surgery led to improved clinical results and more patient involvement and satisfaction (Larsen et al. 2013) .

Serious games in mental health intervention are no small wonder. The use of digital games, not only in physical but also in mental rehabilitation, is widespread (Mandryk et al. 2017). It is well-known in the last decade that the use of serious games is possible to address a wide range of psychological issues, like depression, anxiety, post-traumatic stress disorder (PTSD), and many others (Lau et al. 2017).

Exposure therapy is used to treat stress and anxiety disorders (McLean and Foa 2011). Patients are gradually exposed to the sources of their trauma or fear in a controlled setting (Leskin et al. 1998). Virtual-reality-based serious games can provide realistic environments to patients where they can face different fears first in a gradual, supportive manner (Kamkuimo et al. 2021). "Bravemind," developed by the University of Southern California, is a VR-based game that helps veterans suffering from PTSD confront their fear of combat (Waldrop 2017). The game allows therapists to control the virtual environment, i.e., war-related scenarios, and expose patients to these scenes at their comfort levels (Kamkuimo et al. 2021).

One of the therapeutic means that is most often employed for the treatment of mental health issues like depression and anxiety is Cognitive Behavioural Therapy (CBT) (Rathbone et al. 2017). One prominent example is SPARX, a game produced in New Zealand, designed to provide CBT for adolescents with depression (Cheek et al. 2014). In SPARX, players carry out quests that instruct them on CBT techniques, such as recognising and disputing irrational thoughts (Fleming et al. 2019). Due to the game's design, adolescents can access therapeutic content in a way that feels real and fun, thereby decreasing the stigma linked to mental health care (Cangas et al. 2019). A randomised controlled trial found that SPARX was as effective as face-to-face CBT in reducing depressive symptoms in adolescents (Fleming et al. 2019).

As serious gaming becomes more popular in the education and training of healthcare professionals, serious games are being used as patient-facing applications (Nap and Diaz-Orueta 2014). These games are a no-risk zone where both students and practising doctors can develop their skills, master new techniques, and train their decision-making (Haoran et al. 2019). Moreover, besides applications focused on patients, serious games are becoming increasingly popular in the education and training of healthcare professionals (Graafland and Schijven 2018). Medical Intelligence has been around for a long time, and it is commonly used as a teaching tool for medical professionals (Kulikowski 2015). However, serious games now provide an alternative, more fun and interactive way for a virtual rehearsal of real-life situations (Ning et al. 2022). Games such as "Pulse!!" and "Trauma Centre" depict medical emergencies and let players practice surgical procedures, diagnose patients, and troubleshoot medical crises in a virtual environment (Haoran et al., 2019). These simulations are a top-notch feedback mechanism, which helps the players develop and improve their decision-making skills without the risk of harming a real patient (Dargar et al. 2015).

A systematic review found that serious games to train surgical skills were highly effective, as they enabled learners to simulate procedures multiple times without risk in a controlled environment (Graafland and Schijven 2018). A high-impact advantage of serious video games in medical training is the fact that they can provide simulations of cases that are very rare or of high risk, which doctors do not often face in real life (Nap and Diaz-Orueta 2014).

Another key application of serious games in medical education is their use in promoting collaborative learning and teamwork (Tubelo et al. 2019). Quite on the contrary, most games are

multiple challenges by necessity, which implies that the players must engage in communication, delegate tasks, and teamwork to obtain a common goal (Raija et al. 2018). Such games are more often used in training healthcare teams than other kinds of educational games because they are quite effective in teaching how to work under pressure (Peppen et al. 2022).

Serious games have demonstrated great potential in public health education (Ricciardi and De Paolis 2014). By producing participatory-oriented and interactive serious games, developers can engage people and effectively deliver major health information to the general public (Ahuja et al. 2023).Serious games are utilised to encourage users to accept the habit of living healthy using sports, nutrition, and quitting smoking (Caserman et al. 2020). Games have also raised awareness of infectious diseases and promoted preventive measures (Okitika et al. 2015). During the COVID-19 pandemic, several games were developed to educate the public about the importance of hygiene, social distancing, and vaccination (Balakrishnan 2020). Titles such as "COVID-19 Simulator" and "Stop the Spread" employed engaging scenarios to show how viruses are transmitted and how people can protect themselves and others (Kermavnar et al. 2023).

These games give the right information and thus improve the situation (Politowski et al. 2021). By making health education more accessible and engaging, serious games can play a crucial role in reducing the spread of disease by promoting preventive behaviours (Mitchell et al. 2021). The science-based training of games in the healthcare sector has made it a space with many advantages. Moreover, VR provides an immersive world, and serious games provide engaging ways to keep the patient motivated to do exercises (Deutsch and Crotty 2012). The rehabilitation process can be made engaging and motivating by combining the strengths of VR and serious games. This combination can alter traditional rehabilitation techniques, making the process engaging and effective. Serious games using VR are already being used to distract patients from the pain (Phelan et al. 2023). This technique can be used to motivate patients to do exercises by distracting them from the pain and monotonous routine (Laver 2020). Serious games with VR having embodiment (see 2.4.3) improve the engagement and adherence to therapy, specifically the stage when the task is regularly repeated (Perez-Marcos 2018).

Serious games designed for back pain rehabilitation are interactive and add exercises to game mechanics to convert the users' pain into a smile (Ferreira and Menezes 2020). Take an encounter

where patients demonstrate a set of movements on the screen (Belotti et al. 2022). User on-screen character performs them; such exercises not only work on the corresponding back muscles but also enforce the needed changes in the body (Babydov et al. 2023). Patient of back pain are treated with long-stretching exercise therapy to help the pain (Traeger et al. 2017). However, a lot of patients find it challenging to stick to the routine (Babydov et al. 2023). Due to this, many patients refuse to do the exercises regularly (Saner et al. 2018). Patients complain about the boredom they face during the exercises, which leads them to skip the workout (Fokkenrood et al. 2013).

In the case of back pain rehabilitation, serious games enable the patients to execute therapeutic exercises in a virtual environment similar to a game (Moldoveanu et al. 2017). By performing movement in a game, patients get distracted by gameplay and do the exercises (Ali and Nas 2018). When exercises are presented as challenges or tasks within a game, users find them easy to perform (Vasconcelos et al. 2018). With the help of point levels and rewards, serious games make the movement fun for user (Remolar et al. 2021).

Many serious games keep a record of a patient's performance and allow therapists to measure the progress made by the patients over a period of time (Belotti et al. 2022). They can see improvements in terms of mobility, flexibility, and pain levels. (Caserman et al. 2020). Serious games are often played at home, making them useful for patients who are unable to visit a therapist regularly (Checa and Bustillo 2020). By use of serious game, the patients at home can still get physical rehabilitation treatment (Vasconcelos et al. 2018).

Programs that consist of both in-person and digital interventions, such as VR exercises for home use, show how successful this method is in supporting patient outcomes (Reilly et al. 2021). A hybrid model improves engagement and accessibility for patients who cannot attend regular sessions (Essery et al. 2017). Future research will play an important role in improving these hybrid techniques (Reilly et al. 2021).

A comprehensive overview of games designed for back pain rehabilitation is presented in Table 2.1.

	Age Range	Input Method	Game Type	Body Part movement	Aesthetics/ Design elements	Hardware and Software used for Game development	Clinical/lab or Home setting	Reference
Lower back pain	-	Gyroscope sensor on a phone, Accelerometer, Magnetometer	Rabbit run (Challenge)	Trunk flexion (forward bending), trunk extension (backward bending), lateral flexion, trunk rotation	-	Android and ISO mobile platform	Done in lab/ home setting with Google Cardboard	(Alazba et al. 2018)
Lower back pain	-	Gyroscope sensor on the phone, Accelerometer	Fish movement: Challenge	Trunk flexion-extension Lateral Flexion Trunk rotation	-	Android and ISO mobile platform	Home setting with Google Cardboard	(Alazba et al. 2019)
Lower back pain	12-24	Oculus Rift	Fly through hops	(soreness test)	-	-	Clinical	(Applegate et al. 2018)
Upper back (shoulder and neck)	Office worker	Health Posture Protector Raspberry Pi to integrate IMU as sensor, I2C Multiplexer	Four different games (Robot game, shot game, study game, Firework game)	Upper Trapezius, Latissimus Dorsi Muscle, and rhomboid muscle, and strengthen the Pectoralis Major muscle and trapezius muscle by Shoulder Shrug	-	Raspberry Pi 3, ARM Cortex-A53 1.2ghz, Raspbian GNU/Linux 9 (stretch), 4.9.59-v7+, MPU9250 16GB SD Card, six sensors of 30Hz/sensor	-	(Chen et al. 2018)
Musculoskeletal issues (fracture, prosthesis, falls and low back pain) (abstract only)	65+	The rehabilitation equipment activity and the wearable sensor	-	-	-	-	Clinic & home	(Dominika Kozak 2019)
Chronic lower back pain	18-60	12 Camera Vicon Bonita system	Matchality, Fishality, and Dodgeality	Lumbar flexion excursions	Challenging	Motion Monitor software, Unity, head-mounted display, hand controllers, VIVE™ trackers.	Lab setting	(France and Thomas 2018)
High Kinesiophobia and chronic lower back pain	43-60	Kineassistant-mx consists of a pelvic mechanism. The HTC-VIVE system tracked head and hand position	Save wildlife from monsters	Bending and long-lasting loads	Challenging	Kineassist-mx treadmill and a VR system Unity to develop VR run on Windows 10	Lab setting	(Hennessy et al. 2020)
Chronic Specific Low back pain	18-65	Wireless motion sensor (Valedo® Professional)	Guiding a caterpillar Guiding a fish	Lumbar spine and pelvis, pelvic tilt	-	Laptop, TV	Clinical Setting	(Matheve et al. 2020)
Chronic Non-specific Low back pain	18-65	ValedoMotion® system, Remote control and three inertial wireless motion-tracking sensors	Coconut game	Thoracolumbar dissociation	-	Laptop,	Clinical and Home setting	(Matheve et al. 2018)
Chronic non-specific low back pain	40	Microsoft Kinect Xbox	Soccer ball	Lumbosacral movement	-	-	-	(Mbada et al. 2019)
Head and Neck	18-50	Oculus Rift DK2 VR headset, Personal computer The headset contains accelerometer, gyroscope, and magnetometer, audio headphones Positional tracking via external camera Near-infrared CMOS sensor	-	Head movement to right and left till shoulder and head movement of front till chest and up	To make the scene close to real-life rendering the scene, the Unreal engine UE4 is used.	Displays are based on 5.7″ Super AMOLED technology Software: unity “Challenge”	Home setting	(Mihajlovic et al. 2018)
Lower Back pain due to sports injury	18-25		Shooting game	Trunk movements (flexion, extension and lateral flexion)	-	-	Clinic	(Nambi et al. 2021)
Lower back pain	>65	Dell visor VR118, Wireless/ Wired VR headset	Coin collection	-	-	PC, smartphone	Clinic	(Stamm et al. 2020)
Chronic lower back pain	>55	Paper documentation	-	-	-	Nintendo Wii U console with Wii Fit U software, HDMI-compatible television	Home	(Zadro et al. 2020)
Chronic lower back pain	>55	Paper documentation, red cap electronic data capture tools	Commercial games	Hip and knee flexion	-	Nintendo Wii U console with Wii Fit U software, video game equipment	Home	(Zadro et al. 2019)

Table 2.1: Summary of studies on serious games and back pain[1]

[1] Empty columns/ - sign show no data provided about it in the study

2.4.2.2 Challenges in serious games

One of the big hurdles in making serious games is the money spent on producing highly developed and suitable games (Hollins and Whitton 2011). It requires teamwork from game designers, health professionals, and researchers, which can be a lengthy and costly process to create a serious game (Göbel 2016). The use of serious games in clinical settings is usually the cause of the purchase of some specialised machines, like motion sensors or VR headsets, which may be costly for some institutions (Tannous et al. 2018).

Moreover, the challenge of integrating serious games into the existing healthcare system has to deal with the issue of industry players lacking knowledge about serious games (Mandryk et al. 2017). A lot of healthcare providers do not have experience with the use of serious games in therapy (Blumberg et al. 2014) . They may be very concerned about the effectiveness and safety of these effects, causing their reluctance to adopt serious games (Graafland and Schijven 2018). To bridge this gap, the clinical effectiveness of serious games should be better documented, and evidence-based guidelines for their usage in health care should be developed through research (Sudarmilah et al. 2018).

For games to be relevant, they have to be accessible to every user, including those who suffer from physical or cognitive disabilities (Yuan et al. 2011). Game developers must ensure that their games are programmed to cater to the needs of people with different disabilities and give them customisable options (Evett et al. 2013). Also, games should be available on various platforms, including mobile devices, VR, and consoles, to cover as many users as possible (Evett et al. 2013).

As serious games become more integrated into health care, problems around data privacy and security are likely to arise (Ricciardi and De Paolis 2014). Many serious games collect sensitive health data, such as information about a patient's physical or mental condition, which must be protected to secure the patient's confidentiality (Hoffmann and Wilson 2018). Developers and healthcare providers cooperate in establishing strong data privacy policies and adhere to regulations regarding the secure storage of patient data (Chiruvella and Guddati 2021).

Serious games are unique and offer an original and imaginative way of solving various health problems, from physical rehabilitation and mental health treatment to public health education

(Yuan et al. 2011). Due to their engaging and interactive features, serious games can increase the patient's adherence to prescribed treatment and achieve good health outcomes (Ning et al. 2022).

The creation and application of serious games in health care is difficult (Ricciardi and De Paolis 2014). Tackling issues of cost, accessibility, and data privacy is fundamental for the future development of this sector (Graafland and Schijven 2018). Although technology is improving, the way serious games are dealt with in health care is still unclear (Yuan et al. 2011). However, the future looks so bright and healthy, as it promises more and more personalised services, all thanks to the development of AI, VR, and other new technologies (Schiavone and Ferretti 2021).

2.5 Fantasy

The definition of fantasy may vary for every scholar, but its description is the same as mental images that arouse imagination and identification (Choi et al. 2013). It allows us to experience a world of unlimited possibilities (Hunt and Lenz 2004). Not restricted only to learning, it is a crucial idea of curiosity, exploration, and engagement in any task, and humans are genuinely fantastic thinkers (Zuo 2023).

Fantasy is considered a fairy tale that could not be found in the real world and can only happen in the imagination (Zuo et al. 2019). A fairy tale is built on a story, and a good fantasy story should be consistent and logical, like the real world (Long 2011).

Fantasy is defined as a transmedia genre (Laetz and Johnston 2008), however no distinct line exists to separate it from other genres, such as horror, science fiction, religious fiction, and mythology. Different genres, like fantasy, fiction, etc., distinguish their facts, but a few points create an overlap in different genres (Mendlesohn 2014), i.e. if we see myths and fantasy, we can view their presence in lord of the Rings, etc. In other studies, it was suggested that fantasy is not always inspired by myths (Laetz and Johnston 2008). The fantasy genre shows impossible events of real life in an alternate world based on something like magic or technology (Long 2011). The alternative world should resemble the real world, as a user can feel related to that world (Wolf 2018).

As a genre, fantasy can be an alternative to the imagination (Zipes 2009) and animation can be its best example. Animation can easily represent various conscious states like dreams, fantasy, and

memory, Alice in Wonderland and Spirited Away are wonderful examples of fantasy concepts (Fahmi 2017). In the past, low-level technology, like in the medieval era, was expected in stories like swords and herbal medicine, but now, in modern times, urban fantasy has taken its place. In urban fantasy, technology has taken the place of magic, i.e., gunshots, which are invisible like magic (Long 2011).

2.5.1 Origin of fantasy

The origin of fantasy goes back to ancient mythology, i.e. the story of Prometheus and Zeus or the story of Apollo (Caldwell 1993). Then its traces can be seen in the poems Bewulf (century 700), Mort d'Arthur (c.1485), and The Once and Future King (1939-1958) (Allen et al. 2006). In the next step, A Midsummer Night's Dream (c.1595) by Willam Shakespeare took us to the fairy tale (Shakespeare 2024), while Gulliver 's Travels (c1726), written by Jonathan Swift, informed us about giants and dwarfs (James 2005). Brothers Grimm's visit to the village of Germany in 1800 connects us to the folk tales of those villages, like Cinderella, Snow White, and Rumpelstiltskin (Lipson 2001). Brothers Grimm and Charles Perrault, with many others, worked on children's fairy tales (Perrault 2010). Then comes The Nutcracker (1816) by E.T.A. Hoffman (Hoffmann 2012), a masterpiece in literature followed by Hans Christian Anderson and Lewis Carroll (Lovett 2005), who add magic to stories, yet they fill the magic by bringing present-time things (Schlobin 2011). In the 20th century, Edith Nesbit changed and revived fantasy stories and laid out some rules for using magic (Frank 2013). After that came the golden era of the Fantasy genre, with The Hobbit in 1937, followed by the trilogy of Lord of the Rings by J.R.R. Tolkien (Stoddard 1984) along with Chronicles of Narnia by C.S. Lewisthe ' (Quinn 1984), and the series of Earth Sea by Ursula K. Le Guin's (Le Guin 2012). The development in science and technology gives more ideas and thoughts to fantasy while also giving the human mind the thought of what fantasy offers, like other universes, time shifts, etc. (Allen et al. 2006).

2.5.2 Categories of fantasy

There are generally four categories of fantasy defined by Farah Mendlesohn: the portal quest, the immersive, the intrusion, and the liminal. In the portal quest when you enter a fantastic world through some sort of portal, the people in the portal can move both ways, but the magic cannot cross over to the other side, e.g., Chronicles of Narnia (Mendlesohn 2014). While in an immersive

world, the user becomes part of that world and can understand the assumptions connected to that world. i.e. avatar(Mendlesohn 2014; Agrawal et al. 2019). Intrusion is when someone intrudes into our world like a beast or alien, creating chaos. This type of fantasy is not always destructive, but things get back to normal whether the intruder returns. While liminal, is like an intrusion, but the protagonist (main lead character) appears normal, as unicorns appear on Monday, but why do they appear on Monday this time? For the reader, it creates blurred lines and places things mainly on the reader/viewer's imagination (Mendlesohn 2014).

2.5.3 Sub-genre of fantasy

Fantasy also has a subgenre in which the three essential qualities of fantasy magic, alternative worlds, and technology are sometimes mixed (Long 2011).

High fantasy is defined by powerful magic (Flint et al. 2019). Wizard knows which spell to cast, how long its effects will remain, and the cost of those spells (Lamont 2017). This gives birth to wonders like unicorns or dragons used by knights, crowns of gems or anything miraculous (Lamont 2017). As a gamer and sometimes a reader, the dragons and dungeons make more sense by the aesthetic and nature of role-playing games than by reading a book (Houghton 2023). High Fantasy gives the chance to create amazing, enchanted stories. No matter what rule is being used, the high fantasy gaming campaign has to include dragons and dungeons (Gygax 1978). Examples of High Fantasy include the Dungeons & Dragons gaming campaign, Master of the Five Magic by Lyndon Hardy, and others.

Low fantasy is the opposite of high fantasy. In this sub-genre of fantasy, there is low magic or no magic at all (Ryzhchenko 2018). Magic sometimes appears, but characters have no or minimal control over it. Examples of Low Fantasy include Kurtz’s Deryni stories, novels of Guy Gavriel Kay, etc (Price 2021).

Monumental love stories of heroes who struggle to win a war or battle against enemies, sometimes overwhelmingly powerful (Allison and Goethals 2011). It can also be called a Meta sub-genre, which has a high or low fantasy in it. Its concept is based on the quest to reach the desired end goal (Wang et al. 2023a). In some cases, the heroes travel worldwide to achieve their goals (Mathaudhu 2017). The hero becomes spiritually and personally strong during their struggle to reach their goal

(Allison and Goethals 2011). The hero meets new people, makes friends, and discovers new areas (Wang et al. 2023a). Some friends join their mission, while others are part of the story. Even in some cases, the hero has a different goal than the one they started for (Allison and Goethals 2011).

Epic fantasy examples include The Lord of the Rings and Patricia McKillip's "Riddle-Master" trilogy (Long 2011). The following points better define Epic fantasy: heroic qualities, free will, powerful enemies, and preserving a good, well-ordered world.

It is a meta sub-genre involving high, low, or epic fantasy (Long 2011). In this sub-genre, the protagonists go to another world, and they have some power or ability that residents lack, to solve problems (Stableford 2009), like in Chronicles of Narnia or The Weirdstone of Brisingamen (Long 2011). Crossing the world means the story is between the natural and alternate worlds (Dolezel 1989). Examples of Cross world Fantasy include The Chronicles of Narnia by C. S. Lewis (Lewis 2001) and J.K. Rowling's "Harry Potter" novels (Rowling 2013).

The following conventions define the crossword fantasy: allegory, analogy, and metaphor (Stern 1990). For example, Lion Aslan symbolises Christ in Narnia, and there is a lack of humanity, i.e., there are no humans in Labyrinth. Talk, i.e., animals, plants, and non-living objects, can all talk like humans and converse with them social commentary (Long 2011).

It is an action-adventure story known as heroic fantasy. Its focus is on warriors who fight terrible monsters, help weak ladies, and prevent wicked schemes (Chieffalo 2021). The emphasis is on action, fighting, and dealing with danger, but most game designers and developers slightly amend the rules for a more gaming-friendly environment (Armansyah and Pratiwi 2018). Examples include Robert E. Howard's Conan stories, Niall of the Far Travels, and many more.

It is also known as modern fantasy and mixes magic with recent time settings. It mostly deals with hidden history and alters it in a way that a commoner is unaware of (Ryzhchenko 2018). The magic show is low-powered (Long 2011). In this fantasy type, heroes mostly get involved in conflict with evil and use magic to sort societal issues (Subbotsky 2014). The difficult part is explaining these mystic powers to the world, as government agencies sometimes also look for the lead character (Subbotsky 2014). The question is, can magic and technology work together? Can fantasy characters also live in normal society? Can magic protect itself? In today's society, this type of

fantasy is really popular. Its examples include many of Jim Butcher's "Harry Dresden" novels, The Vampire Slayer television show, and the game World of Darkness (Long 2011). In reference to its difference from cross-world fantasy, the action takes place in the real world, while in the cross-world, it takes place in the alternate world (Long 2011).

2.5.4 Fantasy elements:

Fantasy is characterised by key elements that allow players to dive into a world of imagination (Armitt 2005). Whether in literature, games, or other media, these elements set it apart from other genres (Zuo et al. 2019). The incorporation of fantasy elements in a story makes the story exciting and appealing to the audience (Armitt 2005). There are various elements of fantasy that can be added to keep the audience engaged. A few elements of fantasy are as follows.

1. Imaginary worlds and settings:

These fabulously imaginative environments offer remarkable backgrounds that enable the audiences to leave behind the actual world and step into an all-embracing imagined world (Trowbridge and Stapleton 2009). The Lord of the Rings is famous for its World of Middle-earth, created by J.R.R. Tolkien, a complete world with diverse races, languages, and cultures (Drout et al. 2014). The other famous fantasy story for the secondary world is the Chronicles of Narnia by C.S. Lewis, a magical land with its creatures, forest, and stories (Wood 2008).

2. Magic and supernatural elements:

Magic systems in fantasy usually represent a set of rules or limits, showing that a credible and mysterious aura will overcome the world (Rolfe 2014). The Harry Potter series by J.K. Rowling deals with magic as a central element. In the wizard world, spells and magical creatures are introduced as a daily routine. Patrick Rothfuss's King Killer Chronicles introduces the complete magical framework (Wolosky 2010).

3. Narrative:

The overall structure and sequence of the story unfold the story to the audience (Booker 2004). All stories, such as Harry Potter, Lord of the Rings, Game of Thrones, and Wheel of Time, have their

narrative (Hogan 2003). Each story has its own narrative, which is different from the other but keeps the audience engaged (Boyd et al. 2020).

4. Heroic archetypes and quests:

The quest is the main topic of fantasy, usually involving a young or unexpected person who develops those skills while trying to escape the darkness (Hogan 2003). Star Wars, Barbie, and Harry Potter are the best examples of Heroic Archetypes and Quests.

5. Conflict between good and evil:

Fantasy usually focuses on absolute morality, most often in scenarios where good heroes fight with dark powers, which draws themes of bravery and sacrifice (Allison and Goethals 2011). Harry Potter by J.K. Rowling and Lord of the Rings by J.R.R. Tolkien also depict a conflict between good and evil (Barber 2012)

6. Mythical and legendary references:

Mythical allusions provide fantasy tales with a timeless allure, thus pulling in cultural archetypes that are relatable, in a sense, to people from several generations (Ellis Davidson 1976). In Lord of the Rings by J.R.R. Tolkien, Gandalf's character is taken from the Norse god Odin, and the dwarf's name is from Norse legend (mythology of Norse and Anglo-Saxon) (Kuusela 2014).

7. Exaggerated or extraordinary abilities:

Most of the time, in fantasy, characters are presented with supernatural abilities that represent the possibility of people gaining their authentic power, experiencing changes, or even the moral issues caused by managing the power (Larasati and Hapsarani 2020). Alomancy, the power to ingest or burn metals, can be seen in Brandon Sanderson’s Mist born series (Kuusela 2014). The same sort of power is seen in the X-Men series. In The Vampire Diaries, witches can channel their energy to the other world (Croft 2009).

8. Escapism and immersion:

Fantasy allows people to escape from their real lives and expand their understanding of life beyond their expectations, which is a source of personal development and imaginative creativity (Larsen 1996). J.R.R. Tolkien's essay "On Fairy Stories" provides an escape from reality and allows the reader to enjoy beauty and joy (Ivanova and Ryzhchenko 2019). Ursula K. Le Guin's Earthsea series crafts an immersive world where escapism is blended with meaningful exploration of beauty (Dunn 1982).

9. The Unknown and mystical exploration

The fascination with the fantasy exterior represents the power of human curiosity, which is the driving force that makes the actors proceed to the very core of their beings, besides the fact that supernatural elements may test them (Thomson and Jaque 2023). Mystical exploration is mainly found in H.P Lovecraft's works (Lévy 1988). Susanna Clarke's Jonathan Strange and Mr Norrell explores the magic of mysticism, knowledge, and hidden powers of England (Lehtiö 2008).

2.5.5 Fantasy in games

Although serious games are often considered motivating, there is still limited evidence to support their engagement potential (Nugroho et al., 2020). According to Choi imagination and identification in digital games are enhanced through player interaction with events and control mechanisms (Choi et al. 2013). Fantasy in games extends beyond tangible elements like visual decorations; it also includes intangible components, such as narrative and story.

The significance of fantasy in gameplay is greater than often assumed. Asgari and Kaufman (2009) argue that a game devoid of fantasy is reduced to mere symbols. Fantasy, as a core design element, plays a crucial role in determining a game's success or failure. It enables players to experience scenarios that are otherwise impossible in real life (Laetz & Johnston, 2008).

Game designers blend fantasy with playfulness to make games more engaging, but merging seriousness and playfulness is still tricky (Caserman et al. 2020). The biggest issue in this merger is fantasy's numerous themes and perspectives, making it challenging to implement in serious games (Thomson and Jaque 2023). It is also expected that fantasy might affect the learning efficacy

of the game (Yeni and Cagiltay 2017). Another thought is that fantasy can play a significant role in designing instructional sound games (Byun and Loh 2015). We can use it as a “hook” to activate other game factors, i.e., curiosity, control, competition, and interactivity (Thomson and Jaque 2023). The use of fantasy in mental activities and games is visible, but a combined perspective is missing (Byun and Loh 2015). Based on sound and visual representation of the story, game genres are believed to be influenced by film genres (Vu 2017). However, due to interactivity, game genres differ significantly from the literature and movie genres. In the game design, many genres are mixed to get the final product (Zuo et al. 2019).

The main idea of fantasy in the game is to engage the players in an imaginary world that seems so realistic that they get a feel of tangible, and game rules or mechanics cannot obstruct that (Zuo et al. 2022a). In creating a game like Final Fantasy XV, the designer wants to add a more realistic feel, and for that purpose, they add the scales of fish on the dragon Leviathan (Byun and Loh 2015). The designer also used the features of a fish mouth in a dragon mouth (Nakano 2020).

2.5.6 Fantasy in Virtual Reality

Fantasy in virtual reality (VR) has become a driving force behind the development of experiences that are both immersive and engaging (Cowan and Ketron 2019). Studies have shown that in VR, a fantasy structure can transport one into an unreal world where the user can forget about reality and take a virtual adventure, thus increasing the user's engagement degree (Georgiev et al. 2021). Additionally, one of the aspects that make VR stand out is that it can engage users in alternate realities where they indulge in activities that seem to be boring (Wiederhold and Riva 2019).

In addition, a study done by Repetto et al. (2013) found that inexperienced users were highly motivated to pass consumer education by feeling that the game tasks were not very hard in a VR world with fantasy elements. By building up the task as part of a fantasy storyline, users felt such a deep level of engagement, which led to more task compliance (Repetto et al. 2013).

VR systems in fantasy settings have been proven to have a lot of mental health benefits, mainly by helping to deal with anxiety and pain (Park et al. 2019). It helps pull attention away from the pain, primarily by the creation of a positive environment (Dzardanova and Kasapakis 2022). VR

disconnects the users' sensations from reality to such an extent that the experience of fantastical and surreal VR can be the most painless one (Humann 2019).

Moreover, it was found that VR-based therapy patients who were involved in the process showed effective pain reduction compared to sensational therapy. Participants were thus able to venture out into another world where they totally forgot about their pain by diverting their attention to the virtual environment (Hoffman et al. 2020).

Fantasy settings in VR utilise the inherent reward systems to help retain user loyalty. Fantasy-based virtual environments were a good source of intrinsic motivation. For instance, magic skills and the discovery of new areas are a crucial element of the therapy (Saposnik et al. 2010). This gamification of therapy makes it possible to say that fantasy-based rewards are useful in boosting the initial behaviour by giving people a sense of success (Horne-Moyer et al. 2014).

The fantasy-themed VR games that were implemented in the treatment setting were successful because they were linked to the virtual goals of the patients, besides having proper game-based experiences that made the process of therapy more rewarding to the patients themselves (Zheng et al. 2024).

The narrative potential of VR fantasy settings can boost cognitive and emotional engagement, therefore having a positive influence on therapy outcomes (Kamkuimo et al. 2021). The narrative technique in VR rehabilitation enables the patients to relate to reality. As Banos et al. (2011) assert, the user perceives the activities as a part of a story, not as the same repetitive task (Baños et al. 2011).

This view of the approach is compatible with a study which showed that users who got involved in VR with a fantasy-themed storyline were more engaged and had a more positive attitude toward task completion. Narrative immersion is not just a method to make the user more interested in the process but also to make them more focused (Orliac et al.).

In VR fantasy worlds, users will have the opportunity to execute movements in a way that resembles exploration or quest-based actions (Abtahi et al. 2022). For example, the article by Smith et al. in 2018 mentions that VR can be used to make virtual walking, bending and twisting

movements, but in the imaginary world, they become meaningful actions such as picking up magical artefacts among the obstacles (Smith 2018).

A patient suffering from back pain who was enrolled in VR-based rehabilitation claimed they preferred activities that included fantasy themes rather than just functionality. This had a major impact on the contentment and, therefore, led to disengagement briefly from the course (Alazba et al. 2018).

The implementation of fantasy elements in VR for rehabilitation can use the imagination, incentives and insight of fantasy to enhance the quality and patient outcomes of the process (Kamkuimo et al. 2021). Fantasy in VR projects can be efficient when it is about reducing the perceived difficulty of the motions/tasks you deal with, if used for pain management, it enhances intrinsic motivation, and all in all, it turns into a precious approach to the physical recovery program (Hoffman et al. 2020).

2.5.7 Types of fantasy in games and Virtual Reality

Fantasy in games and virtual environments can be divided into several types, each with distinct implications for engagement, immersion, and user experience (Foxman et al., 2021). In the case of serious games for physical rehabilitation, understanding these types helps developers tailor game elements to enhance motivation and improve adherence to therapeutic exercises (Nap & Diaz-Orueta, 2014). This, in turn, can lead to better patient outcomes (Ning et al., 2022).

Cognitive Fantasy involves creating mental images or scenarios that stimulate intellectual engagement. It promotes changes in perspective, decision-making, and other cognitive skills through imaginative and challenging tasks (Blackwell, 2021; Sedig & Haworth, 2014). In rehabilitation, cognitive fantasy can be demonstrated through puzzles or problem-solving tasks that are embedded in therapeutic exercises (Lincoln et al., 2011). For example, a VR-based rehab game may include visual or spatial puzzles that link physical movements with therapeutic goals (Chen et al., 2018).

Emotional Fantasy targets the player's emotions, enabling them to experience excitement, joy, empathy, or nostalgia (Choi et al., 2013). It typically relies on characters, stories, and environments

to evoke emotional responses (Best, 2021). A rehabilitation game might use emotional fantasy by casting the patient as a superhero or adventurer whose success depends on completing specific exercises (Vaknin & Wiseman, 2021). This can foster emotional connection and personal identification with the rehabilitation process (Ross 2019).

Sensory Fantasy focuses on transporting the player's senses beyond reality through rich and immersive audiovisual environments (Uhlmann 2021). In VR, sensory fantasy can provide unparalleled immersion, whether it recreates real-world settings or purely imaginative spaces (Penn and Hout 2018). This type of fantasy can help patients mentally escape the clinical context by embedding rehabilitation tasks in lush forests, underwater worlds, or dreamlike landscapes (Luo and Liu 2021). The distraction from physical strain improves engagement (Xue and An 2019).

Narrative Fantasy incorporates storytelling, placing the player within a broader narrative or quest (Cragoe 2016). It gives meaning to player activity by transforming routine actions into purposeful missions(Zuo et al. 2022a). In a rehabilitation context, narrative fantasy could turn exercises into quests, such as climbing mountains or searching for ancient artefacts, aligning physical tasks with story-driven objectives (Huh et al. 2016).

Epic Fantasy casts the player as a heroic or monumental figure within a grand adventure (Choi et al. 2013). This genre typically involves themes of bravery, challenge, and triumph, fostering feelings of purpose, strength, and self-confidence (Long 2011). Patients may imagine themselves as warriors reclaiming their strength, reinforcing the meaning of their exercises (Shapi'i et al. 2015; Villiger et al. 2017). Through repeated actions, patients become the agents of their own healing (Gamito et al. 2011). Epic fantasy thus transforms routine therapy into acts of power and resilience (Randriambelonoro et al. 2020).

Social Associative Fantasy focuses on interaction with other characters or players within the game world. It encourages dialogue, cooperation, or competition (Tresca 2014). Social engagement is especially appealing to individuals seeking affirmation or belonging (Oh et al. 2018). For example, a multiplayer rehab game may allow patients to collaborate, compete, or learn from one another, simulating a social experience rather than solitary play (Goršič et al. 2017). In the category of Transformative Fantasy allows players to assume roles or develop abilities that may be impossible

for them in real life (Zuo 2023). It encourages self-exploration and the formation of new self-perceptions (Bowman 2018).

Innovative Fantasy enables patients to select characters with abilities that surpass their real-life limitations (Tarkkanen et al. 2018). For instance, a patient with mobility impairments might control a character who can fly or run freely, providing inspiration for real-world improvement (Randriambelonoro et al. 2020).

2.5.8 Fantasy in Serious Games

The fusion of fantasy and gaming has led to a variety of captivating experiences that engage players in transformative ways. The summary is illustrated in Table 2.2.

Sr. No	Game Name	Application Area	Age Group	Input/ Output method	Game Type	Software Used	Fantasy Theme	References
1	Fantasy climate	Climate news	Sports players	PC	Prediction game	-	-	(Dzodom et al. 2020)
2	Lost city of MER	Awareness of carbon emission	Open to all	HTC VIVE Pro, smartphone, laptop and monitor screen.	Undersea	Unity then transferred to unreal due to graphics requirement	Mythological fantasy	(W. Bennett and Canner 2019)
3	Chemi Kami AR	Educating chemistry	Students	Android phone with camera access, sound on, set printed cards	Card game overlapping with 3d animation	Unity 3d 2020.2.7f1, Vuforia engine 9.7	Mixed fantasy	(Zuo et al. 2021a)
4	In the kingdom of phonemes	Educational game for kids with neurodevelopmental disorders	Kids	System, keyboard and mouse	Rescue game by facing challenges	Unity, C++ or JavaScript	-	(Rybarczyk 2018)
5	Last mission	Educating History of World War I & II	18-20	HTML browser on PC or smartphone	Shooting game	GML programming language	-	(Ghannem et al. 2019)
6	Math Mythos AR	Educating mathematics	Primary school kids	Mobile	Card-based game	Unity and AR engine Vuforia	Immersive fantasy	(Zuo et al. 2020)
7	Math Mythos AR	Educating mathematics	9-10	-	Card game based on a magician's avatar	-	Immersive fantasy	(Zuo et al. 2021b)
8	Math Mythos AR 2	Educating mathematics	7-11	Two Huawei Mate 30 cell phones running Android, two Lenovo think book computers with Windows 10, and two storybooks were set up on the gameplay table. GoPro Hero 9 (record behavioural data)	Magic and monsters	Unity and Vuforia	Intrinsic	(Zuo et al. 2022a)
9	Math Mythos AR 2	Educating English and word problems of maths,	7-11	Mobile	Card game based on a magician's avatar	Unity and AR engine Vuforia	Immersive fantasy	(Zuo et al. 2022b)
10	Play'n ride	Foster physical activity in daily life	10-89	Road bike, u-notched wheel with 4 notches, Arduino card with a sensor and 3d-printed support computer with the game engine	Simple runner game	Unity	Extrinsic fantasy	(Lelardeux et al. 2020)
11	Ruby warrior	Educating computer science	Undergraduate students	PC	Warrior based game	Ruby	-	(Watson and Richter Lipford 2019)
12	See more roar	Educating mathematics	7-8 years primary students	Mobile	Survival game	Unity, Vuforia plugin for AR features	-	(Li et al. 2018)
13	Super bark	Educating Path Exploration for Hearing-Impaired Students	7-11	Mobile and QR code for digital interaction	Board game	-	-	(Cano et al. 2020)
14	Vessel	Cultural heritage game	Open	Photographic scanner, Windows PCs	Puzzle game	Unity game engine, Autodesk Maya, Visual effects (VFX) system	-	(Bissell et al. 2021)
15	-	Movement in daily life	18-34	Opti track, Oculus Quest, paper and feather-based wing and PC	Flying based game	3d max and unity	-	(Mashal et al. 2020)
16	-	Educating mathematics	7	The touch screen of the mobile device, joystick, AR camera	Challenge-based game	-	Intrinsic fantasy	(Li et al. 2022)
17	-	Educating to read or/and identify spelling skills to dyslexic children	5-12 years	Mobile	Rescue game	-	Eponymous fantasy	(Holz et al. 2018)
18	-	Educating pharmacy	Students	Leap Motion	Heroic	-	Post-apocalyptic fantasy	(Yap et al. 2020)

[2]Table 2.2: Summary of serious games using fantasy

Empty columns/ - sign show no data provided about it in the study

2.6 User study

The important part of this research is the user study. This study's research is carried out with the help of medical experts and healthy participants. The number of participants also needs to be finalised. The role of medical experts in health-related studies and the number of participants in various studies are discussed below.

2.6.1. Medical experts and their role

Medical Experts are those who have completed sufficient training and education in the field of medicine and healthcare (Moldoveanu et al. 2017). They have expert skills and experience in treating ailments, curing, and managing different health conditions (Murugan 2020). Additionally, they have significant experience in medical research, clinical trials, and healthcare policy, making them essential contributors to health-related studies and the development of medical practices (Hartzler and Pratt 2011).

Medical specialists provide clinical insights, structure study plans, interpret data from a medical perspective, and ensure that the studies remain within ethical standards. Their expertise is indispensable in transforming scientific findings into practical, safe, and effective health programs (Sonstein and Jones 2018).

The expertise provided by medical professionals is widely considered expert opinion and is often used in the research literature as a reference. Medical experts are extremely important in providing the knowledge base for many studies which, if they are not there, may fail to cross the necessary thresholds of ethical approval, clinical significance and scientific rigour; these are the criteria that the publishers of leading medical journals are looking at before accepting for publication (Innocenti et al. 2022). Medical experts are extremely important in providing the knowledge base for many studies which, if they are not there, may fail to cross the necessary thresholds of ethical approval, clinical significance and scientific rigour; these are the criteria that the publishers of leading medical journals are looking at before accepting for publication (Innocenti et al. 2022). Medical experts play a vital role in society, and their contributions are evident across various domains, including health research, focusing on sound scientific methodology, clinical relevance, and ethical responsibility (Trimble and Hamilton 2016). They help ensure the validity of research

findings, support appropriate study designs and data interpretation, and confirm that the results can be safely implemented in clinical practice (Sonstein and Jones 2018).

Medical professionals are uniquely qualified to uphold scientific rigour throughout the clinical trial process (Moldoveanu et al. 2017). They possess the insight to identify precise research questions, apply suitable methodologies, and accurately interpret complex clinical data (Kandi and Vadakedath 2023). Their expertise in interpreting findings is invaluable. This is considered one of the most challenging responsibilities in healthcare, and doctors are specifically trained for it (Trimble and Hamilton 2016).

Medical professionals often serve on Institutional Review Boards (IRBs), where they ensure that studies adhere to ethical standards and protect participants' rights and safety (Moldoveanu et al. 2017). They assess the balance of risks and benefits, ensuring that studies align with safety principles and minimise potential harm (Stark 2022).

Medical specialists play a critical role in translating research into real-world clinical settings (Seibold et al. 2023). They help convert research findings into treatments, therapies, and interventions applicable in day-to-day healthcare (Straus et al. 2013).

Studies that involve healthcare professionals are often seen as more credible and trustworthy. Their involvement adds authority and increases the likelihood that findings will be accepted by the medical community and healthcare policymakers (Zolkefli 2018). Healthcare professionals contribute vital knowledge that enhances the development of effective treatments and interventions. Their understanding of disease progression and patient needs ensures that future research leads to meaningful improvements in patient care (Dash et al. 2019).

2.6.2. Number of participants

Numerous studies have different numbers of participants depending on discipline, research method and nature of study (Saunders and Townsend 2016). Key factors and guidelines kept in mind during this study are as follows:

Quantitative studies require a sample size based on previous studies' expected effect size, statistical power and variability (Schäfer and Schwarz 2019). In these studies, the number of experiment

participants can be 30-50 in one group (Brysbaert 2019). Depending on precision and population size, the number of participants in survey studies may be in the hundreds (Perneger et al. 2015). In qualitative studies, sample size is based on data saturation (Guest et al. 2020). The typical range for experiments is 10-30 participants, while for focus groups, there are 3 to 5 groups and 6-8 participants in each group (Francis et al. 2010). A balance between quantitative and qualitative considerations leads to different sample sizes for mixed methods (Hennink and Kaiser 2022).

In clinical studies, the number of participants in each phase varies. In Phase 1, the number of healthy volunteers is between 20 and 100 (NHS 2024). For physical rehabilitation, preliminary studies are also conducted before clinical studies (El-Kotob and Giangregorio 2018). For the preliminary study, the median sample size for 761 studies is 30 (20-50) (Totton et al. 2023). In this regard, a few doctoral studies are also seen to confirm the number of participants. The detailed information about these studies, with the number of participants who took part in those studies, is mentioned in Table 2.3.

Sr. No	Name of Thesis	University	Number of Games	No of days/ sessions	No of Participants
1	The Development and Applications of Serious Games in the Public Services: Defence and Health, 2014 (Paraskevopoulos 2014)	School of Engineering and Design, Brunel University	3	1 day five session	3 for the initial test (stroke)
			2	-	5 (Parkinson's disease)
2	Scoping the Potential Use of Serious Games for Public Engagement with Tree and Plant Health, 2018 (Docherty 2020)	Division of Computing Science and Mathematics University of Stirling	-	Field test of games	396
				Experiment at the RBGE	42
3	Motion-Based Video Games for Stroke Rehabilitation with Reduced Compensatory Motions, 2011 (Alankus 2011)	Washington University in St. Louis	9	Six weeks	4
			3	45 mins	11
4	Quality of Life and Digital Gaming Technology, 2022 (Cutler 2018)	Bournemouth University, UK	-	6 weeks, one session a week for 2 hours (12 hrs total_	16
5	Serious Game Approach for Improving Healthcare Logistics, 2020 (Zhang 2020)	Technology and Health KTH Royal Institute of Technology Stockholm, Sweden	-	1 week (trial)	51
				1 day (final version)	36
6	Research and Development of a Digital Game-Based Learning Framework for Education: Designing for Educators and Students, 2016 (O'Sullivan 2016)	Worcester Business School University of Worcester	1	1 day/ min 30 min to max 1 and ½ hr	17
				1 day/ min 30 min to max 1 and ½ hr	6
				1 day/ min 30 min to max 1 and ½ hr	5
7	The Effects of Game-Based Learning on the Motivation and Engagement of Career Technical Education Students in the High School Chemistry Classroom, 2022 (Lackey 2022)	University of South Carolina	5 games	6 weeks (unit teaching)	6
8	Unsupervised Robot-Assisted Therapy: From the Clinic to the Home, 2024 (Devittori 2024)	ETH Zurich, Zurich.	1 game	Maximum 10 hours	13
9	Designing and Testing a Virtual Reality Intervention for Improving Patient Mental Health and Wellbeing in Secondary Care, 2021 (Jerdan 2021)		1 game	6 sessions (20 minutes)	7
10	Designing with Fantasy in Augmented Reality Games for Learning, 2023 (Zuo 2023)	Eindhoven University of Technology	1	20 minutes	31
			1	20 minutes	34
			1	20 minutes	124
11	Performing Fantasy and Reality, 2016 (Seregina 2016)	Aalto University School of Business Department of Marketing	-	Half an hour to 3 hours	9

[3]Table 2.3: Number of Participants in the Studies

[3] Empty columns/ - sign show no data provided about it in the study

2.7 Conclusion

When it comes to serious games for physical rehabilitation, fantasy should be the kind that shows the essence of therapy and patient requirements. For instance, fantasy elements such as cognitive, emotional, and heroic may be the best choices for creating motivation. The senses, storytelling, and social games improve patient engagement and immersion in the fantasy. A fantasy epic, heroic and transformative, can help patients develop self-efficacy and a positive attitude toward their rehabilitation journey. Therefore, the right mixture of fantasy genres in serious games can make rehabilitation exercises more fun, lessen the perception of monotony, and develop a supportive environment for physical and emotional healing. VR also create engagement, which is required for physical rehabilitation.

This review established a basic understanding of serious games and their role in physical rehabilitation, especially regarding back pain. Serious games with fantasy elements provide an opportunity to enhance user engagement, motivation and overall rehabilitation experience. With fantasy elements in serious games, users can be attracted to the VR environment. The mind-capturing narrative and user interaction with objects in a calming environment attract the user to be in that world. A recent study of using fantasy elements in teaching also established that merging serious games with XR, AR, VR, and fantasy makes a positive contribution.

There has been great success in these fields. However, gaps still exist. The theory provides the ground for this research. Practical research needs to be done to explore the effect of different fantasy elements on rehabilitation. Empirical research will provide the answer to whether fantasy elements can play any role in keeping the user engaged and motivated to do exercises. Following the review of the related works, the following gaps were identified:

a) Fantasy is being explored in other applications of serious games, but its impact on health has yet to be explored.

b) Patients lack the motivation to do rehabilitation exercises, leading to delays in patients' recovery in a timely manner.

The next step of this study is to define a rationale for the methodological approach.

3 Methodology

3.1 Overview

In crafting the methodology for this study, the potential of fantasy within serious games, particularly in the context of physical rehabilitation, is considered. Fantasy elements, when used effectively within gameplay, have the power to captivate the imagination, boost user motivation, and transform the traditional way through which rehabilitation and research are both experienced and understood. This study positions fantasy not merely as a stylistic choice but as a design component that influences engagement outcomes. This chapter begins by describing the rationale for this research.

Given that the creation of the game prototype is not an extra activity but an integral part of the research process, it was essential to adopt a structured yet accessible methodology for game development. In industry contexts, game design typically follows a formal development pipeline. To make this process more suitable for an academic research environment, a simplified yet systematic game design and development framework was adopted. This adapted pipeline not only supported the iterative creation of the prototype but also clarified the stages of development within the broader research methodology. By embedding the game development process directly into the research design, the study achieve clarity, enabling an integration of creative practice. This chapter also provide the methodological strategies applied for prototype creation, evaluation and assessments aligned with the research goals.

3.2 Rationale for this study

The literature review identified key gaps (see 2.7) based on which this research is carried out. This study aims (see 1.5) to explore how fantasy affects the rehabilitation process. However, the terms “fantasy” and “rehabilitation” are very broad and include multiple approaches, techniques, and activities that are impossible to explore entirety. Therefore, this work will explore only a selected area of rehabilitation. The rationale for selecting the specific area is done by discussions with medical experts (NHS affiliated rheumatologist, physiotherapist (Khurshid 2021; Clark 2022; Knudsen 2022; Williams 2022). The key findings from these discussions are listed below.

3.2.1 Rationale for selecting back pain as a body part for rehabilitation

This study explores the rehabilitation of back pain. This area is seemingly underexplored compared with different body parts, as shown in the literature (see 2.3.3) as well as suggested by medical professionals (Khurshid 2021; Clark 2022; Knudsen 2022; Williams 2022).

The selection of back pain as a body part led to the target audience, as 18-50 years is the common age range of people suffering from back pain (Khurshid 2021; Clark 2022; Knudsen 2022; Williams 2022). The reason for the selection of this age group is that more people of this age group play games and are interested in VR and serious games than older people. At the same time, young people are facing more back pain issues (Angst et al. 2017; Pergolizzi Jr and LeQuang 2020).

3.2.2 Rationale for using fantasy

Fantasy can be used to engage players. This study discovers the diversion of thoughts using fantasy that can impact the user. Fantasy visual and narrative elements can be vital to capture patients' attention and motivate them to play the game. The impact of visual looks on human psychology is proved by a literature review (see 2.5) and discussion with the physiatrist and psychologist. In that respect, during the discussion with the physiatrist and psychologist, a few points came into consideration.

Fantasy can engage users to distract them from monotonous routines. However, defining a fantasy that can attract everyone aged 18-50 is a big challenge (Fletcher 2022; Hodge 2022; Kuss 2022). The user's mental state to get relief from boredom and pain plays a main factor in the usage of fantasy for health and medical purposes. A healing environment can play an important part (McClary 2007). In this aspect, fantasies that have the effect of a healing environment are helpful. Colours, lighting, and objects in the environment also affect your mood and can play a significant role in engagement. This leads to the selection of a natural environment, which can reduce stress and boredom and support healing.

3.2.3 Rationale for prototype creation

The purpose of this prototype creation is to address the research questions. The exercises incorporated into the prototype are taken from the Back Skills Training Programme by the NHS

(National Health Service) (NHS 2021). However, before beginning the game development process, it was necessary to finalise the game design and development requirements. In this respect, both the literature review and expert consultation guided decisions regarding the prototype's design specifically, the art style**,** software**,** and input/output methods**.**

Initially, the research explored realism fused with natural and fantasy elements. However, expert consultation (Otten 2022) revealed that creating a realistic art style in a fantasy manner is challenging in the game world. Keeping the technology limitations in view, creating visually appealing content that does not hinder the runtime performance is complex.

For a game focused on exploring fantasy, the visuals need to be immersive and lifelike. The environment should feel like the real-world, or "primary world" experience even though the user is in a virtual or "secondary" world, fostering a deeper connection with the virtual environment. Considering the target age group and system performance requirements**,** a Physically Based Rendering (PBR**)** style was selected. This style effectively supports the creation of a fantasy-themed environment without performance loss.

After selecting the game style, the next question is the software used. Various game engines are available for game creation. In that respect, Unreal was chosen considering the requirements of the prototype and the researcher's hands-on experience.

Following the selection of the game art style and software selection, the subsequent question about the choice of input/output method to be used. At this stage, three important questions came into consideration. One is the game's output, which can be the best device from a mobile, monitor or VR. The second question is the method to take input from the gamer. Third is how to track the motion of the user to check whether that exercise is being correctly done or not. There are various devices available to answer these questions. However, the best suitable for our game can be decided using a literature review, discussion with experts, and experimentation with the best possible picks. The experiments are carried out with a mobile screen, LCD, monitor screen, and VR headset.

The game output is required on the medium, which is easy to deal with and also keeps the user engaged and motivated. For back pain exercises, the body and hands need to move in different

directions. This snag took the option of a mobile phone out. The next option is a screen; however, as the movement is in different directions, the whole room cannot be filled with screens. This took the option of computers and LCD screens out as well.

Another option is a VR headset. The headset is fixed on the person's head, making body movement easy and engaging the person with the VR environment. For this reason, the following options were evaluated: Oculus Quest, Azure Kinect, and HTC VIVE.

The first study was conducted using Oculus Quest. After working with it, the point that came under consideration is that it is a good option for engaging users with the help of a VR headset. Gamers can have output through a headset and can provide input in the game using hand controllers. However, tracking Quest controllers can only be used for tracking hand and head movement. For back pain rehabilitation exercises, movement of the back of the body needs to be captured, which makes Quest, Quest 2, and Rift not a standalone suitable solution.

After experimentation with the Quest, the next device is the HTC VIVE. VIVE is also a headset device like Oculus Quest, which makes it good for engaging. However, VIVE cannot be used as a standalone device for this prototype because it cannot track the back movement.

However, the VR headset has problems like motion sickness and eye fatigue. There are ways to deal with these issues and ethical considerations connected to them. The solution to these problems is discussed in the section 3.4.

Then, Azure Kinect was considered as a device to capture the movement of the player, despite the device is discontinued and is now widely considered as obsolete. Azure Kinect can be used to get input from players and track motion. Though the output is on the monitor in front of the player, the body needs to be moved in different directions for back exercises. This makes it essential to have screens on all sides of the room; otherwise, it is a less engaging experience for the player. While developing, some challenges and limitations that were identified during experimentation are:

1. No standalone device can work for these exercises, and we need to combine technology to get the desired output.

2. Oculus Quest can be used for immersive experiences, increased engagement, and input. Capturing body movement can be done using a video camera.

Keeping these limitations in mind, Oculus Quest is used for user input and output, while the monitor screen helps the researcher guide the user. A video camera will be used to record the user's body movement. Game requirements were settled after investigating the rationale and a detailed literature review. A fantasy-based prototype version named “Wishing Well” would be created. However, no gold-standard data is available with which a fantasy-based prototype version can be compared and evaluated. In that regard, another prototype non-fantasy version needs to be made, named “Healing well” The discussion above has also finalised the requirements for this version.

3.3 Methodological approach

The game's creation is embedded in the research study; a game design and development pipeline is used for the methodological approach. The game development cycle is an iterative process divided into three interconnected phases. Each phase in itself is also iterative. In the game development cycle, it helps to focus on a few processes in order to isolate certain problems; however, when the processes are combined or moved to the next phase, new problems may emerge and need to be figured out. Keeping this in mind, the research phases in this study are also designed to be iterative, as illustrated in Figure 3.1.

In phase 1, a detailed literature study is conducted (see Chapter 2), and the rationale for the research is discussed (see 3.2). The detailed method of finding a gap and reason for the fantasy-based narrative and environment selection, as well as their importance in design prototypes, is explained. Here, the decision to create two versions of the prototype is made. Based on the study questions, a fantasy-based version of the prototype is created, while for its comparison, another non-fantasy-based version is made (Figure 3.2). In phase 2, the journey of the prototype creation is described (Figure 3.3). In phase 3, evaluation by medical experts is given (see Figure 3.4). Based on their feedback, the implementation of the suggested reforms is explained. In the same phase, the trial of healthy volunteers is done (see Figure 3.4: Phase 3 (a)Figure 3.5). All of these phases are interconnected, and the researcher is moving back and forth between these phases for answers to questions required at that research stage. Results are based on the completion of all these phases. All the phases are described below in detail.

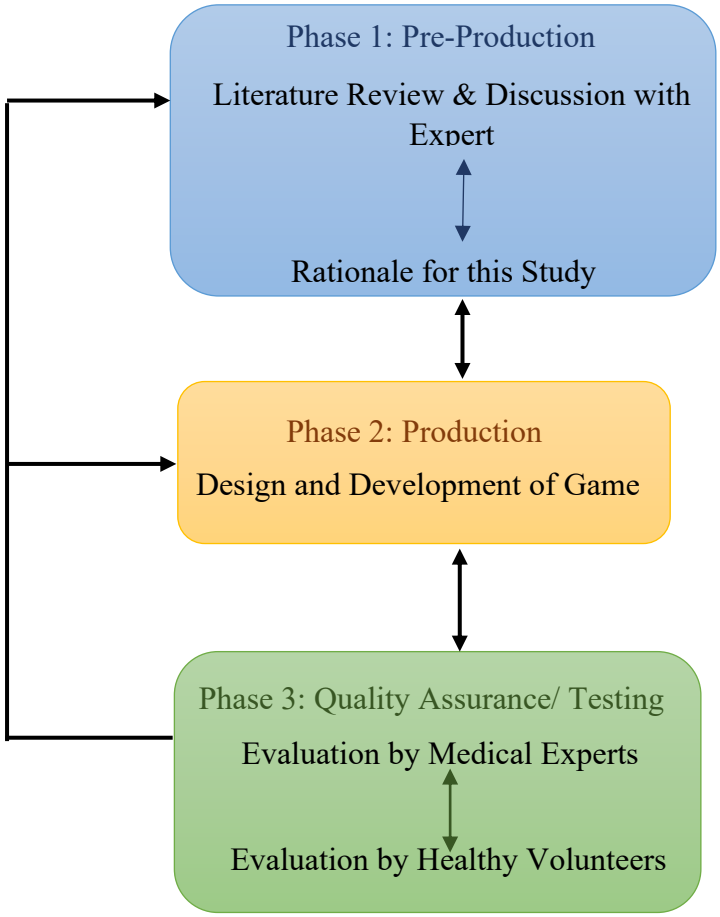


Figure 3.1: Methodological Phases

3.3.1 Phase 1: Identifying the knowledge gap and rationale for study

The literature review helps to identify the gaps (see Figure 3.2). Most of the physical rehabilitation research tends to be focused on certain body parts such as the shoulder, neck, upper limbs and hand, while few body parts, like the back and especially the lower back, tend to have less emphasis as research study topics.

Rheumatologists and physiotherapists are key collaborators in this research study, playing a critical role in identifying the body area that requires the most attention. Guided by insights from the literature review, discussions with these experts were conducted to determine the focus area for

physical rehabilitation that would offer the greatest research value (see 3.2). The rationale for selecting the target body area**,** age group**,** and community is discussed in detail in section 3.2**.**

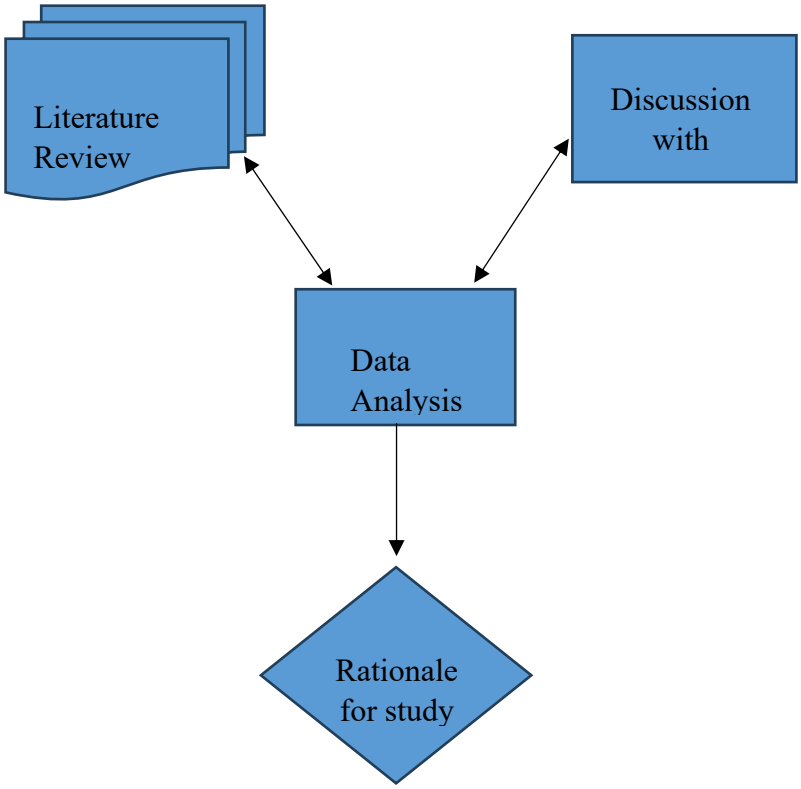


Figure 3.2: Phase 1

After selecting the body part that would be the focus of the research study, exploration was undertaken into how the story, colours, visual look, and world-creating objects impact healing. At this stage, the conception of the prototype fantasy game to aid physical rehabilitation for lower back pain began to emerge. Different environment styles were considered that would make the game more engaging. A literature review and discussions with industry experts were undertaken to find the style that would be the most effective given the technology constraints (see. 3.2.3). The completed game design of fantasy and non-fantasy versions is discussed in chapter 4.

While studying the serious game for rehabilitation, many devices came across for input and output from games like Oculus Quest, HTC VIVE, gyroscope sensor, accelerometer, Magnetometer, 12-

camera Vicon Bonita system, Kinect, Azure, etc. Doing experiments with all of them is not possible. A literature review and industry experts are also required at this step to finalise the input and output method for the game. The rationale for selecting the input/output method is made with their help (see. 3.2.3.)

After clearing all the questions for the game prototype, the next step is an assessment of this prototype for which questionnaires are designed, and ethical and risk considerations are checked before starting this study. The details of ethical approval and risk assessment are provided (see 3.4).

3.3.2 Phase 2: Experimental design and prototype development

After selecting all the things that are necessary for game creation, prototype creation started. The process of prototype creation is divided according to the prototype development (see 3.2.3). Two prototypes are created. One version will incorporate fantasy, while the other will not (see 3.2.3).

a) **Fantasy prototype**

In the game design phase, two versions of the prototype are created. For one version, 'Wishing Well', the narrative is finalised, and the game design document (GDD (see Appendix B)) is made. After this, the work is divided into two parts; in part 1, the design team works on the design of the game elements and their environment, and in part 2, the Implementation of the VR part is carried out.

b) **Non-fantasy prototype**

In this version of the prototype, the game design details are also finalised. The most important thing in this version is that the same exercises are placed as in the wishing well, and there are fewer differences in the development side of this prototype with the fantasy version. Complete details of phase 2, design and building of VR intervention, are provided in chapter 4.

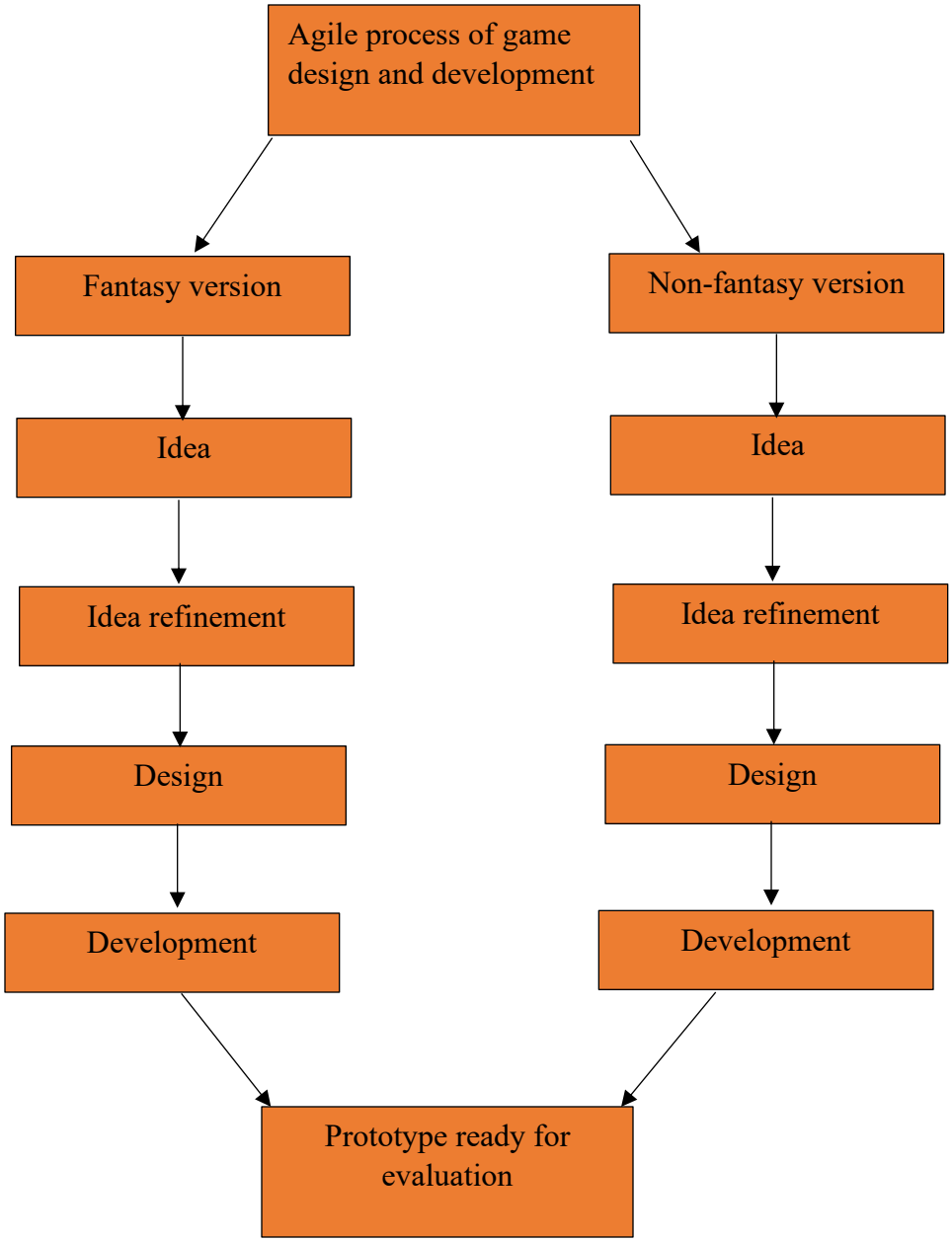


Figure 3.3: Phase 2

3.3.3 Phase 3: Prototype evaluation

In this phase, the prototype's evaluation started. User Study 1 of the prototype (see detailed discussion in 5.2) was done with the help of medical experts (Figure 3.4). The medical experts played the game and provided valuable insight into its design and development, like changes in the walking path, garden surface, etc., which are thoroughly discussed in Chapter 5.

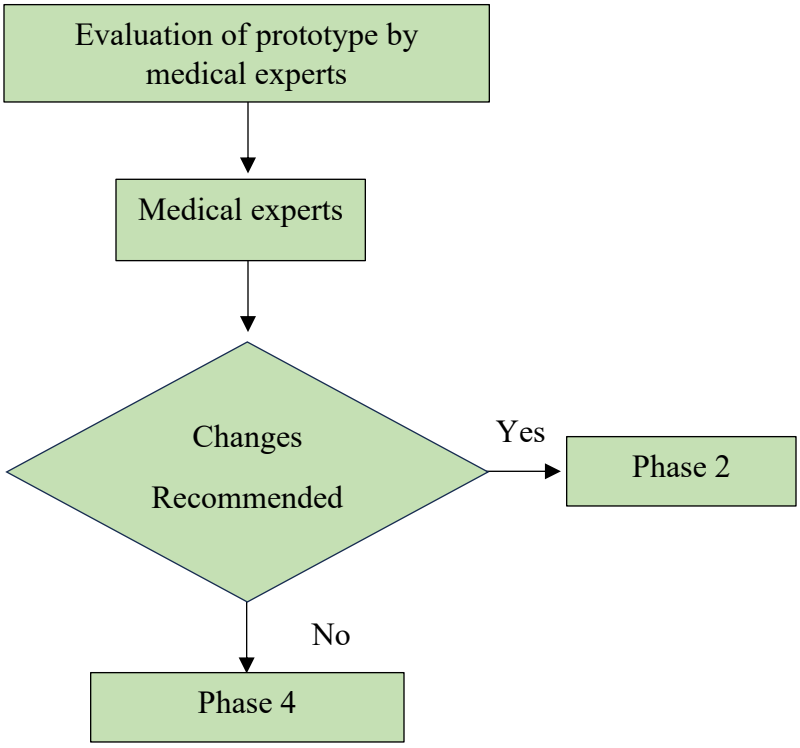


Figure 3.4: Phase 3 (a)

After receiving the list of required updates (see 5.2.2), the main problem is the implementation of all of these updates. All the required changes are made. After implementing all the necessary changes, the medical experts are contacted back to play the game again. After getting their feedback that the exercises are appropriately implemented and that if all the instructions are correctly followed, the game will not be harmful. The second phase of evaluation started.

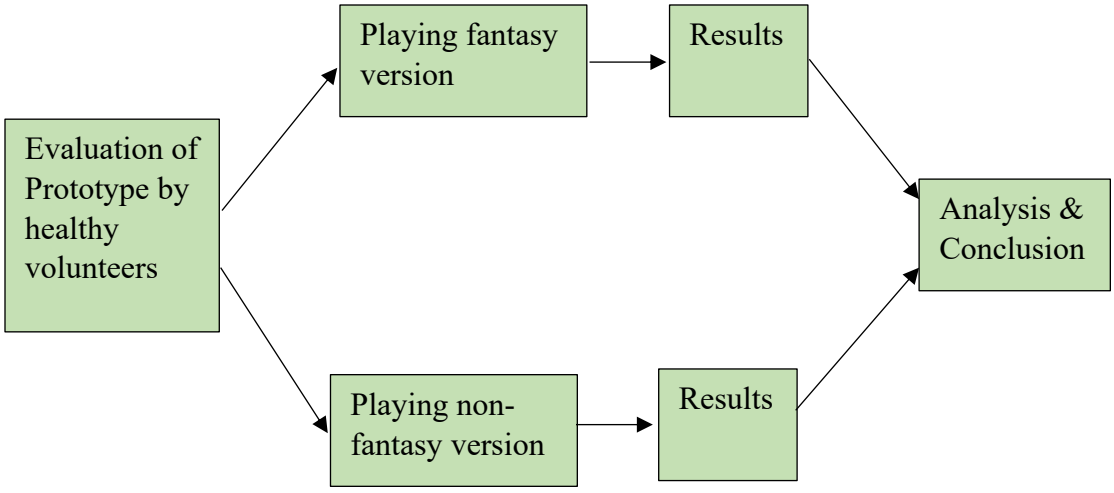


Figure 3.5: Phase 3 (b)

In this phase, the second phase of the prototype is carried out (see 5.3). Healthy volunteers are expected to play the game and provide feedback according to the fantasy aspects of the game. In this phase, the registered participants are distributed into two groups. One group played the fantasy version of the game, while the other group played the non-fantasy version. Best efforts are made to make both prototypes exactly similar in implementation. The results are analysed for both prototypes, and the conclusion is made.

3.4 Ethical considerations and Questionnaire design

This research deals with fantasy, VR-based serious games, and physical rehabilitation. Each term has its implications. Physical rehabilitation exercises need to be implemented cautiously, and ethics and risk assessment for participants are necessary. VR-based serious games also have certain requirements that, when used for patients, require more considerations than expected.

For the evaluation of this research, feedback from medical experts and healthy volunteers is required. For evaluation purposes, ethics approval was required. For that purpose, ethics approval was obtained, checklist number 47873, in May 2023. The evaluation process is divided into two phases; in phase 2a of the evaluation process, the medical experts will evaluate the game. After approval, healthy volunteers will evaluate the game in phase 2b. The design of the questionnaire approved for this study is as follows.

This research uses mixed methods, including quantitative and qualitative questions, to obtain additional support from both methods. In phase 1, the discussions were carried out using a qualitative approach. For this purpose, medical, IT, and human psychology experts are approached.

For phase 2 a & b, in the design of questionnaires, the Kelle approach is followed (Kelle 2006). Firstly, quantitative questions are placed, followed by qualitative questions for further evaluation. For designing questionnaires, aid is taken from the study on game experience (Ijsselsteijn et al. 2013). For a fantasy study on the intrinsic motivation inventory (Choi et al. 2013) is used. Data collection for both methods occurred simultaneously, and all data was used to understand the investigation process and obtain results. Analysis of mixed-method results provides a better understanding of the answers to research questions. One questionnaire has 12 questions designed for experts (See Appendix A). Of these twelve questions, ten are quantitative, while two are qualitative.

For healthy volunteers, two questionnaires are designed. One is a pre-game questionnaire with nine questions (See Appendix A). One question is qualitative, while the other eight questions are quantitative. The pre-game questionnaire is mainly related to the participants' views on the game and whether they have faced any issues while playing games or using a VR headset. The other is a post-game questionnaire mostly linked to this study. It contains thirteen questions; eleven are quantitative, while two are qualitative (See Appendix A).

The quantitative analysis provides the perspective of medical experts and volunteers regarding the game's aesthetics, enjoyment and functionality. For the creation of these questions, help is taken by the Likert Scale. The analysis is being carried out using the mean, standard deviation and T-test methods. The qualitative analysis shares the views of medical experts and volunteers. All the data is read and organised. Using NVivo, common themes are created, and shared relationships are extracted to upgrade the game.

An important point regarding VR that is mentioned in the inclusion criteria for the medical experts and volunteers is that they

1. Do not have any health issues with playing video games like CVS (computer vision syndrome), epilepsy, etc.

2. Do not have any problem with VR or wearing a headset.

This makes it easier to move to the next stage of research. After the approval of the research ethics checklist and risk assessment (see Appendix A), the next step is playing a game by medical experts. Medical experts need to verify the proper implementation of physical rehabilitation exercises. The researcher read all the data provided by medical experts. Data provided by medical experts helped to make the prototype better. After the implementation of suggested changes in the game, healthy volunteers played the game, and data provided by volunteers will play the main role in finalising the answer to the research question.

3.5 Summary

The literature review and experts' analysis provide a methodological approach suitable for the intervention. It plays an important role in finalising the intervention design and settings. Experts involved in this study are giving their best and expecting the best for this research, though not all the suggestions can be implemented. Considering all the tips and limitations, the best possible options are picked for finalising the game. After completion of the pre-production phase, the next is the production phase. In this phase, the creation of a GDD was carried out. More details on the production phase are shared in the next chapters.

4 Design and development of prototype

4.1 Overview

As mentioned in the previous chapter, this research uses serious games to address research questions and adapts the game development pipeline. As mentioned previously, the context of serious games is their use for non-entertainment purposes, such as increasing the user's motivation to perform physical rehabilitation exercises (see 2.4.2).

Creating any serious game for health purposes, the impact of the elements used in the game can also play a vital role (Lieberoth 2015). The prototype development is based on two different versions (see 3.3). In the first version of this game, fantasy elements are added to keep the user engaged. This chapter explains why and how fantasy elements are made and used in this prototype creation. The second version provides a game without fantasy elements.

The basic design requirements for this study were discussed in 3.2. These requirements helped create a fantasy-based version of the prototype, “Wishing Well,” and a non-fantasy version, “Healing Well.” Below, more in-depth details of the design of the two prototypes are discussed.

4.2 Content creation

After determining the rationale 3.2 for all the elements that need to be part of the prototype, a game design document (GDD) is created (Appendix B). In the initial concept of GDD, nine levels were designed; however, for the serious game prototype used in this study, the design of only one level was deemed feasible. Therefore, design elements of only one level are created.

During the design stage, the number of exercises to be implemented in the game was guided by suggestions from NHS physiotherapists (NHS 2021). However, the provided book contains various options for exercises. Not all the exercises from the NHS guidelines could be implemented in this prototype. After discussions with NHS professionals (Khurshid 2021; Knudsen 2022), it was decided to choose five exercises that have sufficient variety on the one hand, and were feasible to be used in the designed serious game. In Table 4.1 these five exercises are presented in detail.

	Stand with your feet hip width apart with your knees slightly bent. Slowly bend your head and back forwards, sliding your hands down the front of your legs. Bring yourself back upright and repeat.
	Stand with your feet hip width apart, hands on your back just above your bottom. Slowly move your shoulders back and your hips forward as you arch your back. Bring yourself back upright and repeat.
	Sit on a firm chair. Use your arms to start the movement and slowly twist your back around as far as you can so that you are looking behind you. Repeat to the other side. If this is comfortable and you want to make the stretch a bit stronger, use your hands to hold onto the back of the chair.

	Sit on the edge of a sofa or on a low stool, Stand up without using your hands to help you. Slowly lower yourself back down onto the sofa or low stool without using your hands to help you. Repeat.
	Sit on the floor or a bed with your legs out as straight as you can and with your arms straight out to the side. Tighten your tummy muscles and slowly lean back at the same time as moving your arms back until your hands rest on the floor. Breathe in. Tighten your tummy muscles and slowly bring yourself back upright. Do not jerk when doing this exercise.

Table 4.1: Exercises implemented in the game

The same exercises are implemented in both versions of the game, although both versions have different environments. In either case, the same set of exercises should be used to keep the consistency of the study and decrease the potential bias.

4.2.1 Fantasy version

The focus of designing this prototype is on incorporating fantasy. In that context, there are different ways in which fantasy can be integrated (see 2.5). In this study, the focus is on narrative, world-building and visual elements. To incorporate a fantasy by narrative, the story inspiration is taken from the folklore of the Wishing Well, whose concept started in Europe (Daily 2019). As the game is based on the Bournemouth area, the existence of a wishing well in the Dorset area makes it easy

for the people of the area to link with the story (Eames 2021). This narrative and world-building process adds a layer of creativity and innovation to game design.

The next step is to identify the period for the game's setting. Following the literature review regarding fantasy elements (see 2.5), the fantasy elements in this prototype were taken from the era of the medieval age. (Grollemond and Keene 2022), and it is the reason that the medieval age can be seen from Lord of the Rings to Game of Thrones (Young 2015). Many games are based on a medieval timespan (Charts 2023) (San Nicolás Romera et al. 2018). While creating this game, the main thing that needs to be looked for is the player's comfort (see 3.2). Players feel comfortable in an environment where they can link themselves to the things around them. To achieve that goal in this prototype, the idea is to merge a few elements of the medieval period with a recent time span to build a comfortable environment for the player.

The next step is to consider the environment to be built for which colour theory is taken into consideration. Each colour and environment have a particular impact on humans. A natural green scene can help recover, decrease stress and improve physical health (Pretty et al. 2017). Therefore, a natural scene has been chosen for the environment. Normally, green natural scenes can be found in jungles, mountains, and gardens. The mountain design can initiate oro-phobia (Sheehan 2008) for people, plus the rocks and mountain path can be uneven, which makes it difficult for people to use this application. Then, the jungle option is taken out due to xylophobia (Sheehan 2008). The option opted in this study is garden. Research has been done on the concept of the Healing Garden (Pouya and Demirel 2015), and its elements are adapted in this prototype creation. The next step is the finalisation of the light (Liberman 1990). In that respect, the natural light of morning time is decided.

The idea of using fantasy creatures like Dragons and Unicorns to impact healing came into consideration. Dragons and unicorns are considered fantasy elements, while a few natural elements from daily life are also incorporated, such as bears, frogs, fountains, and water. Although wells, flowers, and ponds are grounded in real-world imagery, in the context of the prototype, they are stylised and contextualised within a fantastical environment, featuring glowing textures, magical interactivity, and narrative-driven symbolism, to enhance player immersion and maintain a fantasy

aesthetic. Likewise, studies by Ye (Ye et al. 2024) and Masters (Masters et al. 2023) use real-life elements and convert them into fantastical elements.

Initially, it was planned to animate the models for a natural feel. However, that idea was dropped due to zoophobia (Sheehan 2008). Eventually, the game utilises a selection of fantasy creatures associated with specific exercises. As mentioned earlier, five exercises would be implemented in this game, so a total of five fantasy creature models are needed. One model is to be placed with each exercise. In that respect, a few more elements that have a healing impact are also considered to be placed in the garden setting. All the models are discussed below in detail.

4.2.1.1 Dragon

Dragons are considered fantasy creatures, which mostly bring the feeling of being dangerous and harmful (Ingersoll 1999); however, in various places where they are placed, they seem helpful and protective too (Callum McKelvie 2022). The healing power is connected to the blood and bones of a dragon (Ingersoll 1999). The white colour and marble texture are added to all the statues to represent a calming effect (MYKU 2024). In this study, the dragon statue (see Figure 4.1: Statue of Dragon) is added based on the healing power associated with them.

Figure 4.1: Statue of Dragon

4.2.1.2 Bear

Bears are also considered mythical creatures in the fantasy genre. The bears are used as fantasy creatures (Eason 2007), such as in the “his dark materials” series by Philip Pullman, “Goldilocks and the Three Bears”, etc. Their connection with healing has been known from history(Lev 2003) to date (Kikuchi 2012). In this prototype, their inclusion is done in the form of a statue (see Figure 4.2).

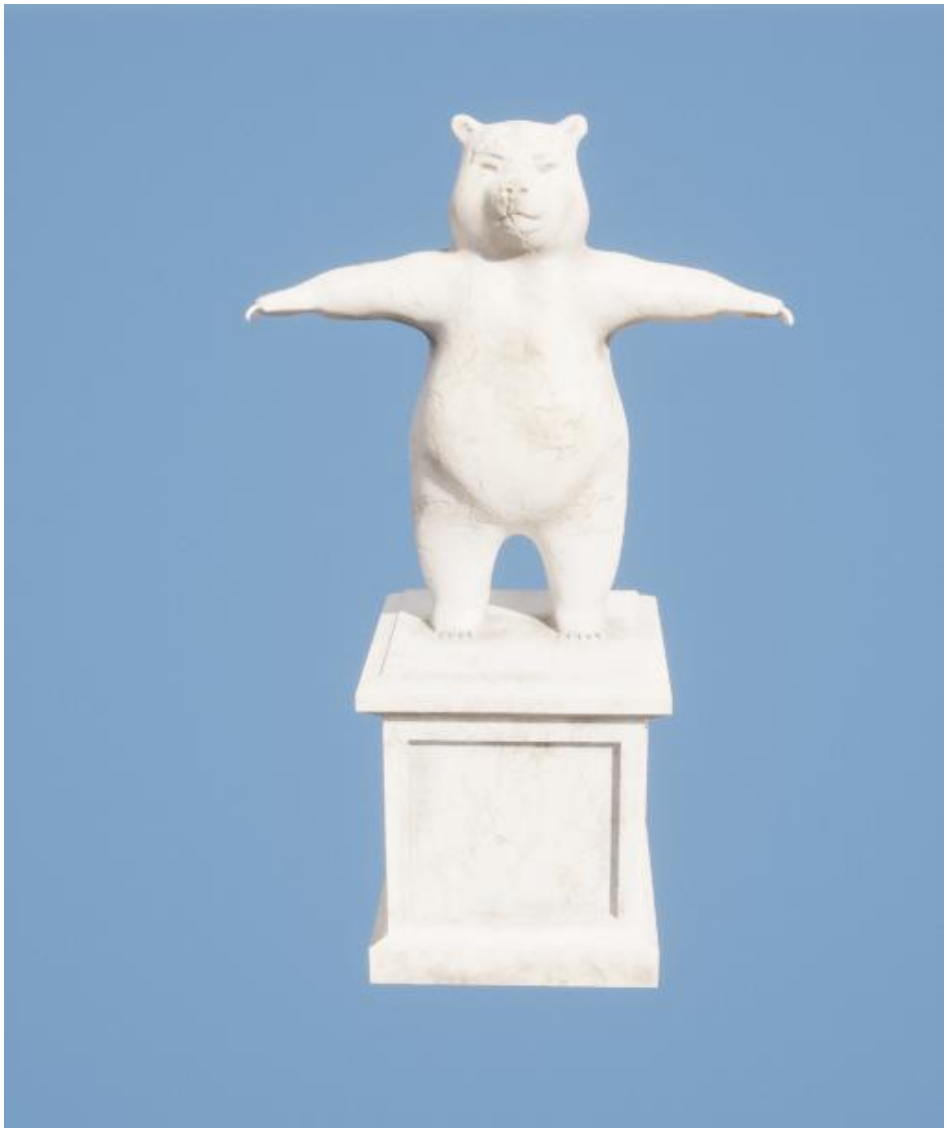


Figure 4.2: Statue of Bear

4.2.1.3 Unicorn

The unicorn is a well-known fantasy creature described as being pure and gentle. It is another mythical creature known for its healing powers (Robertson 1926). The concept of unicorns having healing abilities has been widely popularised through various works of fiction and has become a common motif in fantasy literature (Scamander et al. 2017). Due to its relationship with mythical elements and healing properties, it is added to the prototype as shown in the Figure 4.3.

Figure 4.3: Statue of Unicorn

4.2.1.4 Frog

It is commonly known as a symbol of magic and transformation in fantasy. Its example can be seen in The Frog Prince, The Princess and the Frog and many more. In some cultures, the frog is known for its spiritual healing properties. Scientific evidence of healing by frog skin is also being found (Conlon et al. 2004; Liu et al. 2014). Its association with mythical elements and supported healing properties make it an excellent fit for incorporation into the prototype depicted in Figure 4.4.

Figure 4.4: Statue of Frog

4.2.1.5 Butterfly fountain

a) Fountain

Fountain presence in fantasy is prevalent, as seen in the fountain of Imladris in the city of Rivendell in The Lord of the Rings by J.R.R. Tolkien (Tolkien 1992). Fountain provides calmness, focus and positive emotions (pond 2023).

b) Butterfly

Butterflies are mostly used in fantasy characters, like in the book A Butterfly Fantasy (Bernard 2014). The symbolic meaning of the butterfly is hope and a new beginning (Royal 2022), which is why it is used in healing.

In this prototype, the fountain and butterfly are combined to form the fountain of butterflies. It will give the patients a feeling of serenity, provide a positive emotion, and beckon new hope (see Figure 4.5).

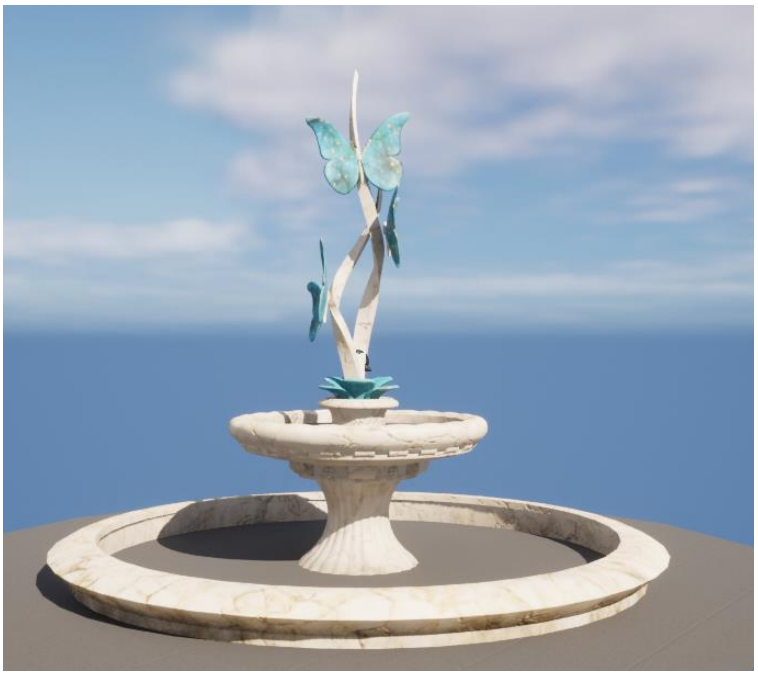


Figure 4.5: Statue of Butterfly Fountain

4.2.1.6 Well

It is decided that, being the proof of concept, all levels are not created in this prototype. Only one level is created (see (Appendix B). The whole idea of the game is based on the well (see 4.2.1). Thus, the well is required in level one of this game, and working on the design of the well is initiated. The design inspiration is taken from images of different wells with a history of wishing wells. In the end, the design (see Figure 4.6) is finalised.

Figure 4.6: Well

4.2.1.7 Flowers

Different flowers have different impacts on body healing. Keeping the flower colours in mind, flowers of various colours are picked and used in the garden.

Figure 4.7: Different types of flowers in the Garden

4.2.1.8 Water pond

Healing with water is a common idea, as water provides calmness and peace. In that reference, the idea of adding a pond to the garden (Smith 2020) is considered.

Figure 4.8: Pound

4.2.2 Non-Fantasy version of the game

In this prototype, to keep the prototype free from fantasy elements, the same set of exercises was placed in another environment, later referred to as the non-fantasy/Healing Well in this document. The main design goal for this non-fantasy environment was to provide peace and a soft feeling to the player (Sternberg 2009).

4.2.2.1 Environment

In that respect, a few ideas appeared, like adding the exercises in the office of the GP room or placing exercises in the bedroom or living room setting or placing exercises in an empty room. To keep the user's interest just in exercises, the best idea was to add the exercises in the bedroom or living room environment. However, humans have feelings connected to a bedroom or living room and can have fantasies in their minds, (Rohanshah 2023) which can affect the results of this study. The next place was a GP room or medical professional room, however, having exercises can give a feeling of hope to some patients while rest feel that the environment not optimistic for them (MacAllister et al. 2016). This led to the next thought, which was designing an empty room. An empty room has the potential to give the feeling of blank space, which can be filled with colours and hope, while it also provides mental clarity by having freedom from distraction (Chauran 2015).

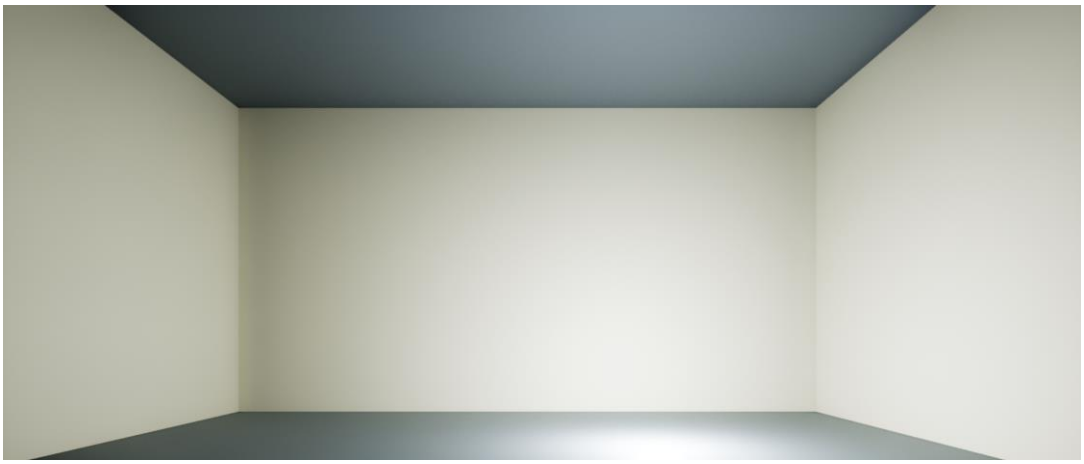


Figure 4.9: Exercise room

4.2.2.2 Elements in the environment

As mentioned above, the user can have a previous connection with the things placed in the environment. It can be a tiny object or a bed placed in that room. They can have feelings for those things and can have fantasies attached to objects. Keeping this point in mind, no elements are added to the room except for the arrow sign to show the direction of exercises to the user who is playing the game (Figure 4.10: Elements in room).

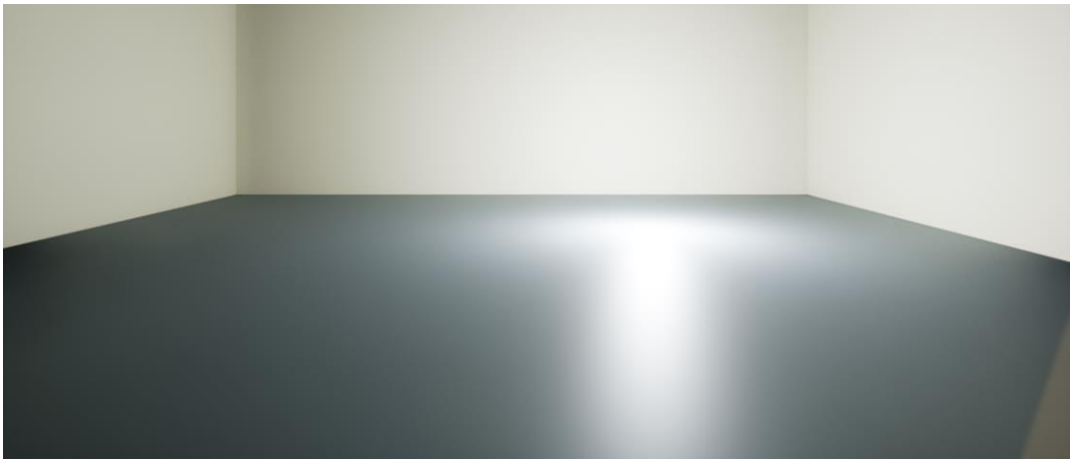


Figure 4.10: Elements in room

4.2.2.3 Objects in the room

A door has the feeling of hope, to have opportunities and a new beginning in life (Starlight 2023). A door is placed in the room to give a feeling of hope (Chan-fai 2004).

Figure 4.11: Door in room

4.2.2.4 Colours

Every colour can have an impact on the mood of the person (Schweitzer et al. 2004). This factor is used in this research. The wall of the room is beige. The beige colour gives the feeling of stability

without affecting the hype in the senses (Silva 2023). Mostly, earthly tones like beige, brown, and grey are combined together in health-related places; they provide a sense of stability (Silva 2023). Here the roof is given a grey colour. Mixing these two colours will keep the user from linking it to anything in their mind while positively affecting mood. The door of the room is given a golden colour as this colour has a positive effect on a person's mood and sends positive energy to the spine. It provides a sense of positivity and affects a person's well-being (Wills 2013). The effect of sunlight entering from the door is to show hope of new beginnings. For the final look of the room see Figure 4.13.

4.3 Implementation of the environment design

After the creation of GDD (Appendix B) and all the game content for both versions of the prototype, the next stage is placing these objects into the game environment. Important to note that the environment design not done properly can affect the results by introducing bias. Still, the implementation of the environment in the game engine was done based on the design document, with some assets implemented by a third party.

4.3.1 Wishing Well

For the design of the fantasy version, the GDD (Appendix B), with all the details linked to it, is handed over to the group of undergraduate students to prepare for the game environment. The design team of six students started working on it. They only need to design the prototype, and the development is carried out later. Feedback meetings were held every week. All the models added above are screenshots taken during the game design phase. During the game's design phase, the student team designed those models of fantasy creatures.

The final look after designing the whole garden is in Figure 4.12 (a, b, c): Final look of garden.

(a)

(b)

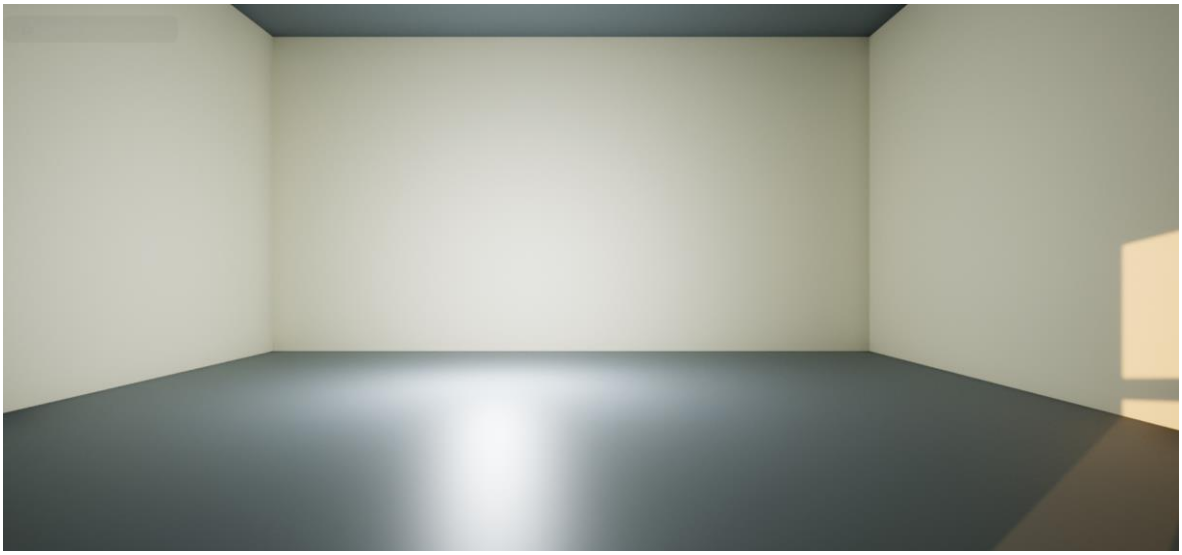
(c)

Figure 4.12 (a, b, c): Final look of garden

4.3.2 Healing Well

As discussed in Non-Fantasy version of the game 4.2.2, the non-fantasy version of the game, named “Healing Well”, has a simplistic look to ensure the look of the environment does not affect the user’s visual perception. Implementation of the environment was straightforward, and the result can be seen in Figure 4.13

(a)



(b)

Figure 4.13 (a, b): Final look of room

4.3.3 Designing of doctor's room

Apart from designing and implementing the main game environments, it was decided to create a doctor/GP room to serve as a pre-exercise space resembling real-life rooms that the user could

experience going to physiotherapy. This part of the design was added to both prototypes. For that aspect, the GP room was designed using reference images from the web. Additional elements were added, like curtains in place of blinds and a wall-sized poster on one wall, which will act as a portal to take users to the actual game. The final form of the doctor's room is shown in Figure 4.14: Doctor's room.

Figure 4.14: Doctor's room

4.4 Implementation of prototype

After designing both prototypes, a third-party game developer with VR experience was hired to implement the exercises in both prototypes. A portal quest idea was implemented to move from the doctors' office to a prototype version (see Appendix B).

In the fantasy prototype, the exercises are placed in front of different statues to keep the user engaged. While implementing the exercises, a significant issue is the points at which the body movement can be made. This challenging task is sorted for this prototype by not putting any

specific element to grip at certain points (as it is proof of concept for the idea). This allows users to move a bit freely, and after finishing each exercise, a key will show in front of the statues. The user will grip that key and throw it into the Wishing Well. The user can move in any part of the garden in this prototype. When the user completes all the exercises and throw all the keys in the well, fireworks will be seen from the well to show that the task is completed. The user would go back into the doctor's office.

In the non-fantasy version, the user performs all the exercises at one point, and they cannot move around the whole room to do the exercises. After finishing each exercise, the next exercise appears, and after completing all the exercises, the user is moved back to the doctor's room.

4.5 Summary

The design elements of both prototypes, along with their rationale, are finalised, and exercises are implemented in VR. After designing and implementing both prototypes, the next stage is the evaluation of these prototypes by medical experts, as discussed in the next chapter.

5 User studies

5.1 Overview

This chapter discusses the evaluation of the prototype created for this study. As mentioned previously (see 3.2) the evaluation was split into two distinct parts. In the first stage, medical experts tested the prototype to confirm its usability in actual scenarios (see 3.3). The results play an essential role in finding issues that can be potentially dangerous to users. Based on these evaluations, this prototype has been improved. After implementing the suggested changes, game-playing sessions were conducted with the same medical experts to verify the prototype's workings and move the study to the next stage.

In the next stage, a user-based evaluation was carried out to assess the fantasy aspects of the prototype (see 3.3). This chapter provides information about recruiting healthy volunteers for user-based evaluation. These volunteers played the game and provided their feedback on the fantasy aspect of games that were being used in this game. This chapter starts with the data collection process, followed by demographic information. The demographics of this study are presented, along with descriptive statistics of the sample. Later findings from the two questionnaires used in this study are provided in detail. The pre-and post-study questionnaires provide the volunteers with a detailed perspective. For both questionnaires, quantitative data is discussed first, followed by qualitative data.

Different methods for evaluation were tried to find the answer to the research question (see 1.5). Individual analysis of each question based on percentage, mean, standard deviation, and T-test method were carried out for the quantitative part. For qualitative data, the themes were created to evaluate the data provided for the improvement of the prototype. The end of the chapter discusses the key findings of user studies 1 and 2.

5.2 User study 1

5.2.1 Evaluation

A smooth and engaging user experience is the core of any game. An essential step for this smooth experience is game evaluation. The hard and rigorous evaluation determines the effective game to be launched for users. Game evaluation provides information for any issues that can emerge during actual use. It is a process to ensure that the user's journey of playing this game was seamless. A single issue can ruin the user experience and tarnish all the work of game design and development. For this reason, extreme importance was given to this step.

The evaluation of the game prototype more critical in the case of any application that was designed for health purposes. In this case, it would be a two-step journey:

In step 1 of the prototype evaluation, it was checked whether the exercises were implemented properly or not. If the exercises were not implemented properly, it could lead to various types of injuries, such as muscle sprains, muscle damage or motion sickness, which could harm the person and was a major issue. Understanding this stage of evaluation was very crucial as a minor check left at this stage can harm any person's health in the long run.

After completing phase one, in step two of the evaluation, the game was checked for its design and implementation phase. This step helps to evaluate the effectiveness of the study. A compromise in evaluation at this stage can lead to an incorrect assessment of this research idea and may impact future feasibility and clinical evaluation phases.

As discussed, (see 2.6.1) to keep the user away from any health issues, medical experts were requested to be a part of the preliminary evaluation of this prototype. To make this prototype as workable as possible, it was expected to have the views of 2-4 medical experts. They would perform all the exercises added to these prototypes to check the usability of the prototype for users. They were requested to play the game for one session at the moment to check that all the exercises were implemented correctly. Following the NHS guidelines for usual physiotherapy sessions, this session lasts between 30 minutes and one hour, depending on the patient's VR experience.

Inclusion and exclusion criteria for the user sample: The experts had subject expertise in physical rehabilitation/ physiotherapy/ rheumatology. They do not have any health issues related to playing video games, such as CVS (computer vision syndrome), epilepsy, or problems with VR or wearing a headset. These criteria were established to minimise the risk associated with using VR.

Sample: Medical experts (Rheumatologists/physiotherapists) were recruited from Bournemouth University and the NHS (outside the clinical service of the NHS). The experts were recruited using a simple random sampling technique (Noor et al. 2022). Invitations were shared through email. A minimum of 2 to a maximum of 4 experts (see 3.3) were invited for this study at this stage.

A brief overview of this research was provided to the experts, informing them that it was a preliminary study. This is an early stage of evaluation for this research. In this phase, the experts would be requested to provide their feedback. The method to deal with the VR prototype was explained. Experts were then asked to play the game. After playing the game, experts were provided with a questionnaire where they could provide answers related to their experience and suggest ways to improve the prototype. Changes would be made with the help of their suggestions.

Data Collection: This study employs a mixed-methods research approach. Medical experts were requested to play with the prototypes, and, in the end, a questionnaire (see 3.4) based on mixed methods (qualitative and quantitative methods) was shared with them. The first part of the questions was based on quantitative data collected using the Likert scale. Then, to determine the reasons behind these numbers and suggest improvements, quantitative questions were addressed. During the experiments, their interaction in the VR environment could be visible on a computer screen. This led to dealing with the issues experts faced during these sessions. Their movements were also recorded. The observation of their movement also helped linking the motion data to the later response to the questionnaire. These findings are discussed below.

5.2.2 Findings and analysis of data

In this phase, the answer provided by experts would be discussed, along with the changes they suggested. The implementation of these changes would be addressed under the section 5.3, refinement to the prototype. In this research, three experts agreed to participate in this phase. They

provided their feedback on the game. Although it was not part of the inclusion-exclusion criteria, two experts had never used a VR headset before, while one expert had previously used one. Also, coincidentally, two experts were in the target audience's age range.

In the evaluation phase, the same exercises were implemented on both prototypes. The experts were requested to play one prototype and review another prototype to assess the implementation of exercises in the game. The changes suggested for one version of the prototype would be implemented in the other version of the prototype. The prototype picked for playing by the experts was fantasy-based.

During this evaluation phase, expert feedback was required to assess the implementation of exercises. It confirms that the exercises were correctly implemented and that the way they were implemented is neither harmful nor disengaging for the user. The quantitative feedback part had questions based on the implementation of exercises and the game's environment. Figure 5.1 Shows the detailed replies of the experts. Three questions were taken out at this stage. One question concerned the selection of exercises based on game level. Only one level was created at that stage, so no expert had replied to this question. For the following two questions, as the prototype was in the preliminary evaluation phase, the experts suggested removing the last two questions from the questionnaire. The previous two questions pertained to the expert's opinions on the role that games can play in patient recovery and the recommendation of this game to patients. Considering the experts' views, the last two questions were also excluded from the results.

The replies of the qualitative sections were shown in Figure 5.1. This graph shows that the more experts agree that the game is engaging, the more they believe the visuals are motivational, and the more they find the storyline appealing, which helps keeping the user engaged and motivated to perform the exercises. While replying to the question about whether this game is a good approach to perform exercises, they neither agreed nor disagreed. At this stage, specific changes

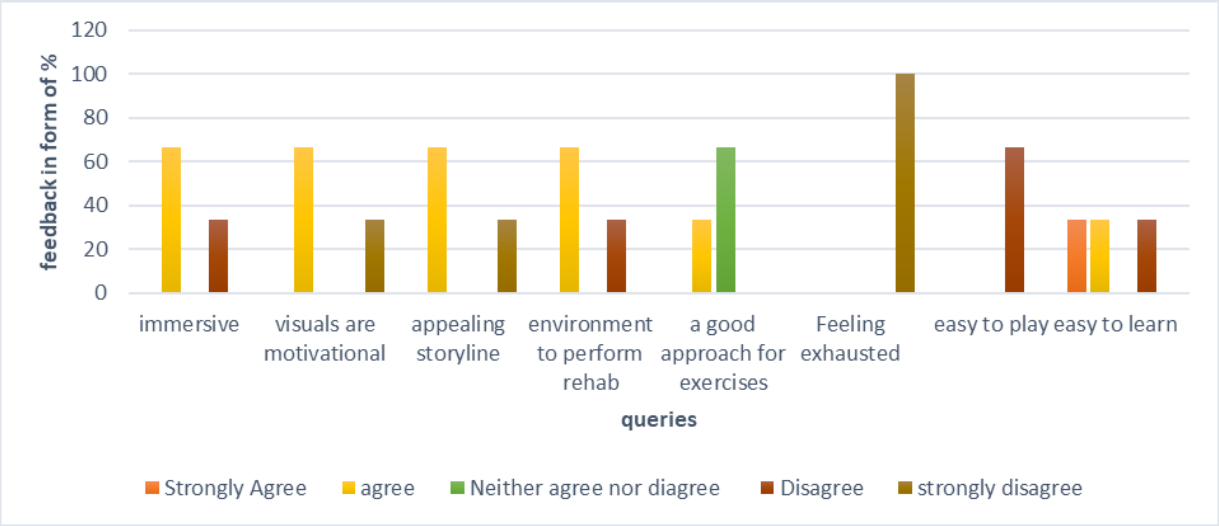


Figure 5.1: Experts feedback

were considered necessary to improve the game. After the modifications suggested by experts, the same question would be asked again to view the responses of experts.

The response to the question about feeling exhausted after playing this game was in total strong disagreement. The same reaction by all experts encourages the researcher that the research is going in the right direction.

Several suggestions were made in the quantitative section, which are described as follows. Firstly, the common changes suggested for both versions of the prototype were shared, followed by individual changes for each prototype.

- **Clear instructions on how to play the game**

  The paths and moments in the game were described to the experts at the start of the game. However, while playing the game, no instructions were provided on where to move or the path

to follow to reach the exercises. This can make it frustrating for the user to perform the exercises.

a) Clear button details

Before the start of the game, the experts were described the functionality of the buttons. Yet, during gameplay, experts forget the function and workings of a few buttons and get confused. This makes the requirement of the help menu a critical add-in. If the user wants to quit the game at any stage, a quit button for the user was also required.

b) Clear instructions for keys

The experts were verbally informed about the methods for collecting the keys and their purpose in the game. They suggest providing this detail in the game and making it available for users as well. It was tricky to pick up the keys after completing one exercise and drop them into the well before initiating the other exercises. Experts suggested having a way to hold the keys and drop them together in the well.

c) Different exercises in different modes

Experts verified the required number of exercises in a single physical rehabilitation session. They suggested five exercises in one session. Five exercises were placed in the game, three on one side of the garden and two on different parts of the garden. The set of exercises chosen for the game start with different positions of the player, such as sitting, standing and lying down. In this prototype, all the exercises were at the same environment. This makes it difficult for the user to sit or lie down for one exercise and then stand up for another. The expert suggested placing the exercises in different modes or environment, such as lying down, sitting, and standing.

d) Guide for exercises

Arrow guides are required to show the correct place of the exercises. Another issue was the order of the exercises. The pattern in which the exercises need to be performed was kept open. However, according to experts, it would be ambiguous for the users. Experts suggested organising the exercises.

e) Instruction guide

The instruction guide was provided with each exercise in static text format. The experts suggested that the instructions should be animated to describe the movement better. The next point was to add the instruction guide according to the user's eye level. If they stay at the same point, it can initiate neck pain for the user.

f) Music/sound in the game

Experts suggest having background sounds and / or background music in the prototype.

g) Shifting the game from VR to mobile Phone

One expert suggested shifting this game from VR to mobile platform, as mobile users outnumber those with VR-related equipment.

h) Changes suggested for fantasy version

a. Pathways

The path in the garden was made of rocks and seemed a bit bumpy. The user suffering from back pain would feel uncomfortable walking on that path.

Figure 5.2: Pathway

b. Garden surface

The user can move anywhere in the garden. However, the garden surface was not a plain, balanced surface. It had stones and uneven surfaces. The user needs to move on these surfaces to reach the exercises, which can be uncomfortable.

Figure 5.3: Garden Surface

i) Changes suggested for non-fantasy version

In this version, all the exercises are in one place, which was a bit more challenging compared to the fantasy version. In the fantasy version, volunteers moved from one place to another, while in non-fantasy version, volunteers had to complete all the exercises at once, which makes the comparison somewhat biased.

After receiving all these suggestions for additional reviews of the game, both prototypes were also showcased in the technical demo session for healthy volunteers to collect further feedback before conducting the formal user study. Five volunteers played the game. Those volunteers also suggested a few changes to the prototypes, mostly the same as those made by the medical experts. Few were different, such as the movement perspective; according to them, it's good to jump around on rocks or move without fixed paths. They require exercises to be placed with indications.

The next stage was to implement all the possible changes. After the game was refined, the same experts were requested to play it again. The evaluation and refinement of the game had a several iterations of development and testing. This process was repeated until experts confirmed that all

the exercises were implemented correctly. When experts confirm that healthy volunteers can now participate in this game, the game evaluation can proceed to the next stage.

An important point to mention is that all the changes suggested by experts were attempted to be implemented, except for shifting this game to a mobile version. This suggestion of turning the game into a phone was placed in future work. The remaining changes suggested by medical experts aimed to improve this version, which would be presented in the same medium. They are done as they would play an essential role in moving the game to the next stage of the preliminary study.

5.2.3 Refinement of prototype

In this phase, all the required changes suggested by the experts were analysed. The crucial ones that would affect the game's usability were implemented. Details of all the changes carried out at this phase were described as follows:

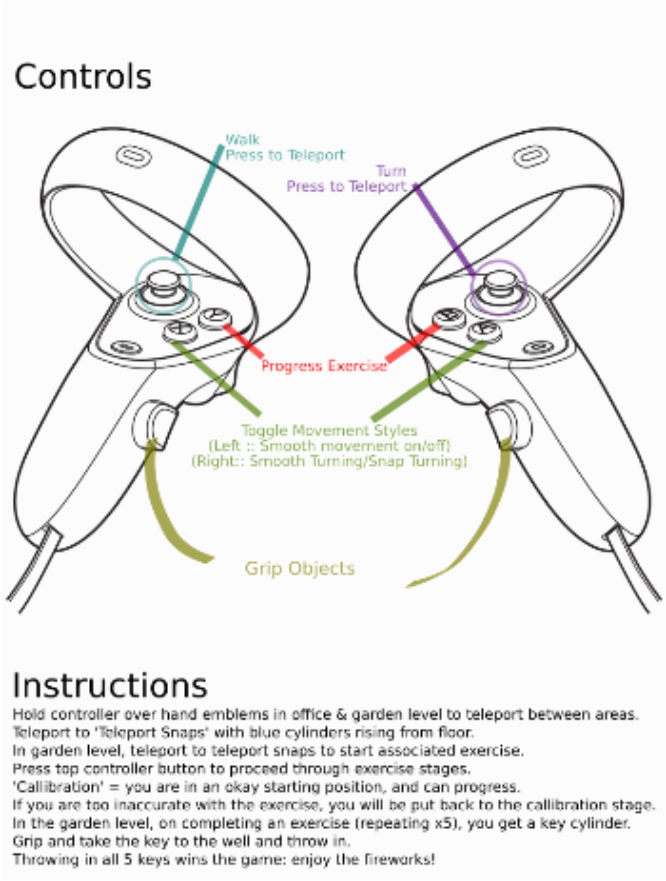
5.2.3.1 Clear instructions on how to play the game

As mentioned before, the paths were guided to the experts; however, while playing the game, no information was provided. Following the recommendation of medical experts, a help menu was added to the game. If the player forgets the next step, they can move to the help level to obtain information about the buttons and the steps to follow to complete the game.

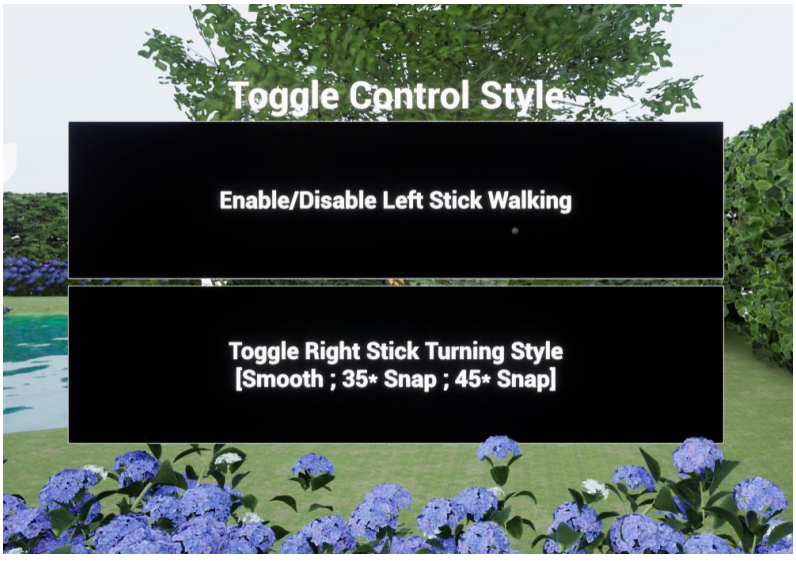
Figure 5.4: Help menu for instructions

5.2.3.2 Clear button details

In the 1st trial version, all the details about the buttons working were explained verbally and more information was shown in Figure 5.5 (a). However, after receiving experts' feedback, the need for buttons to select levels, control changes, and quit the game at any step seems essential. To help the user move to their desired places, all the buttons were added to the main screen and on all levels, as shown in Figure 5.5 (b & c).


Controls
Walk
Press to Teleport
Turn
Press to Teleport
Progress Exercise
Toggle Movement Styles
(Left :: Smooth movement on/off)
(Right:: Smooth Turning/Snap Turning)
Grip Objects
Instructions
Hold controller over hand emblems in office & garden level to teleport between areas.
Teleport to 'Teleport Snaps' with blue cylinders rising from floor.
In garden level, teleport to teleport snaps to start associated exercise.
Press top controller button to proceed through exercise stages.
'Callibration' = you are in an okay starting position, and can progress.
If you are too inaccurate with the exercise, you will be put back to the callibration stage.
In the garden level, on completing an exercise (repeating x5), you get a key cylinder.
Grip and take the key to the well and throw in.
Throwing in all 5 keys wins the game: enjoy the fireworks!

(a)


Toggle Control Style
Enable/Disable Left Stick Walking
Toggle Right Stick Turning Style
[Smooth ; 35* Snap ; 45* Snap]

(b)

(c)

Figure 5.5: Buttons inserted for fixing.

5.2.3.3 Clear instructions for keys

The central aspect of this game's story was the key collection. Since it was not possible to inform every user verbally about the story, the details were shared in the game's introduction video.

According to the experts' suggestion, after every exercise, the key would be released into the ball near the wishing well, as shown in Figure 5.6. After completing all the exercises at each level, the player can go to the well. Near the well, the player can grip the ball and throw it into the well. The grip button, primarily used for gripping, was utilised in this game to control the ball. The help menu also had details related to key collections and dropping them into the well.

(a)

(b)

Figure 5.6: Instruction for Keys ((a) at the start of usability evaluation, (b) after fixing)

5.2.3.4 Different exercises in different modes

Multiple exercises were added to the game. The exercises were based on various body postures and movements, including sitting, standing, and lying down. In the trial version of the prototype, all the exercises were at the same level (see Figure 5.7). In that prototype, the user can do exercises in any order (see Figure 5.8). Blue lines indicate the exercises, each based on a different posture. This made it difficult for the user to sit in a chair for one exercise, lie down for the next, and stand up for the third. The suggestion of experts is considered. Based on their feedback, exercises were moved to different levels. The names of the levels were based on the expert's feedback, i.e., easy (lying down), medium (sitting), and difficult (standing).

(a)

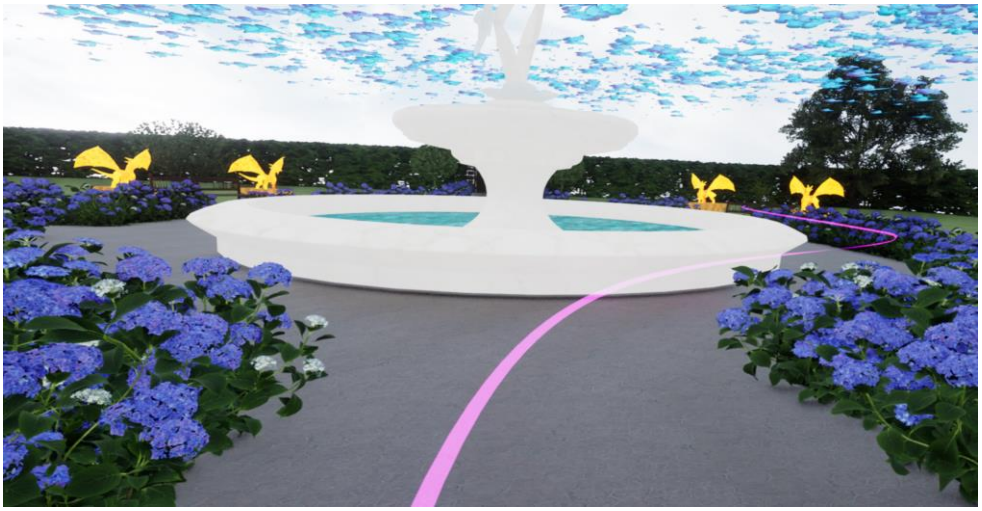
(b)

Figure 5.7: Levels ((a) at the start of usability evaluation, (b) after fixing)

5.2.3.5 Guide for exercises

As previously discussed, in this trial version, users can perform any exercise in any order they require. However, there was an issue with the user being unable to find the exercises, as no indication was present. The expert suggested numbering the exercises and guiding the user about their place. In that respect, the user was provided a line as a path. Following that path, the user can perform exercises, and the same path leads to the next exercise and then to the well.

(a)



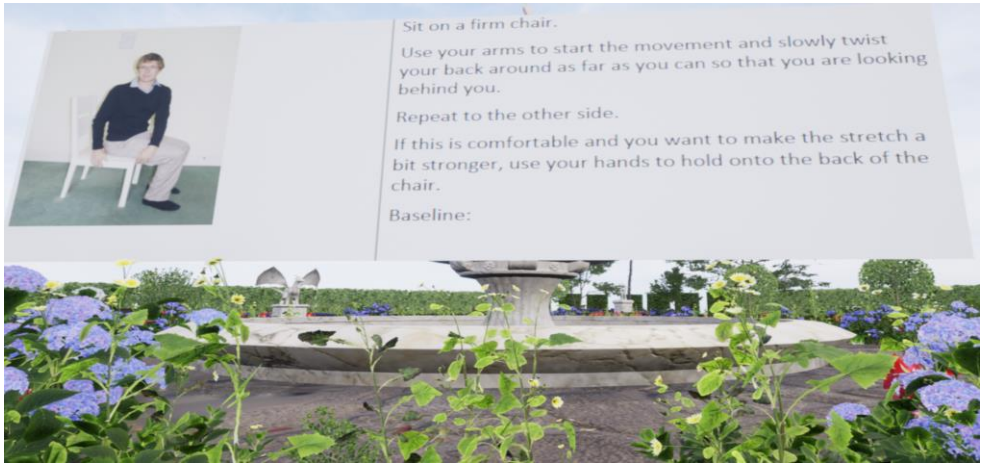
(b)

Figure 5.8: Guide for exercises ((a) at the start of usability evaluation, (b) after fixing)

5.2.3.6 Instruction guide

The expert provided two critical suggestions, which would not impact the game's functionality. The first was in place of static instructions (see Figure 5.9), the exercises should be in animated instruction form. This was done for all the exercises by animating the Tara character (Figure 5.10). The next suggestion was to keep the instruction screen at the user's eye level. Previously, the screen remained static and stayed in the same position for all exercises. At this stage, the screen was

scripted in a manner that allows it to move with the user's eye level for both sitting and lying down exercises.



(a)

(b)

Figure 5.9: Instruction Guide ((a) at the start of usability evaluation, (b) after fixing)

5.2.3.7 Music/sound in the game

The idea of music is excellent; however, it had two complications. The first is that research is based on narrative, visuals and world-building; however, fantasy music is not part of this study. The second point is that games had two prototypes; if music is used according to one prototype, it

would not be according to the other prototypes. While conducting this research, everything except narrative, visuals, and world-building is kept in the same manner to assess the effect of fantasy according to these points.

After some research, it was thought that both prototypes could have the same piece of healing music ((McClary 2007; Reynolds 2023). This music would have a similar effect in both versions, thereby discouraging the comparison point.

5.2.3.8 Refinement in fantasy version

As many changes were made from the usability perspective of the user, a few more changes were made in the fantasy version. These changes are as follows:

- **Pathways**

While creating the path, the material was taken from Megascan (Quixel 2022). As this material was a real-life scan from the garden pathway, the rock texture was not initially considered uncomfortable. However, after looking at the path from the perspective of medical experts, it was realised that the user would not feel comfortable walking on that path. So, other materials were explored.

(a)

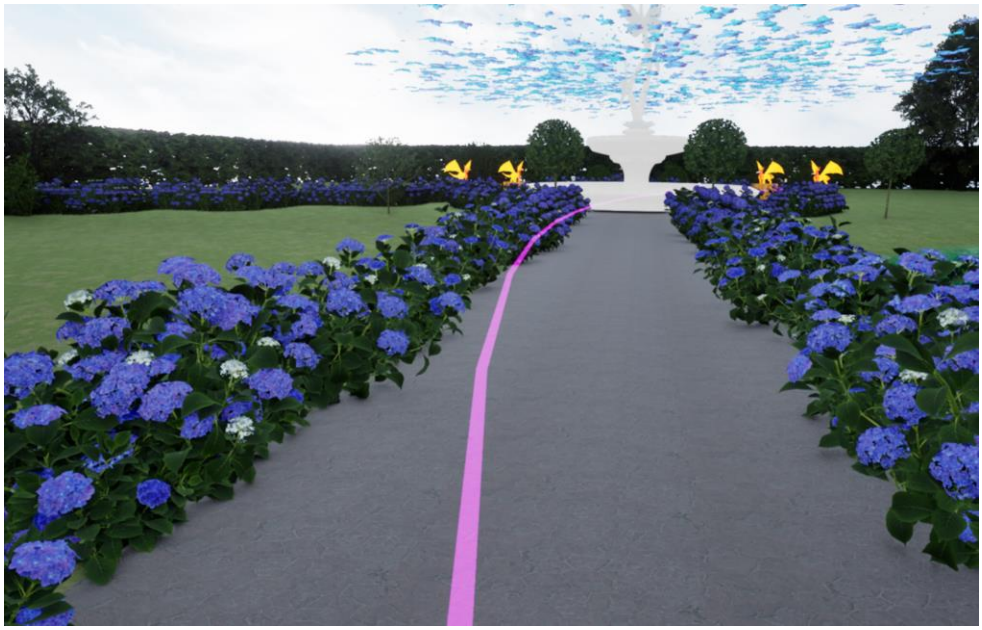
(b)

Figure 5.10: Pathway ((a) at the start of usability evaluation, (b) after fixing)

- **Garden surface**

Garden surfaces contain stones and uneven surfaces. They were put in to give the garden a realistic look. However, after consulting with experts, the garden surface was modified to a plain surface to make it more comfortable for end users. All the rocks that were placed to walk on to reach the exercise were also removed. As shown in Figure 5., pathways were created to get every exercise. This would also help the user move along plain paths and avoid jumping from one stone to another.

(a)



(b)

Figure 5.11: Garden Surface ((a) at the start of usability evaluation, (b) after fixing)

- **Butterfly on butterfly fountain**

Making the butterfly part of the fountain does not evoke a feeling of fantasy. Keeping that in mind, butterflies were added to the butterfly fountain to give it a more fantastical look. The material of the fountain and the water were also changed. The final look of the fantasy fountain was shown in Figure 5.12.

Figure 5.12: Fantasy Fountain

- **Flowers of the Same Colour**

In the trial version, flowers of different colours, such as red, blue, and purple, were placed in the garden. Each colour had a distinct psychological effect on the human mind. In the updated version, all the flowers were updated with cool blues and subtle purples. Flowers with cool blues and subtle purples release stress and give a feeling of calm (stead 2023).

Figure 5.13:Flowers

- **Statue of Fairy**

Fairies are often portrayed as helpful characters (Deveau, 2022) and are featured in stories such as Tinker Bell and Peter Pan (Davis, 2005). In the updated version, a white statue of fairies is placed to evoke a psychological sense of magic and provide a sense of help.

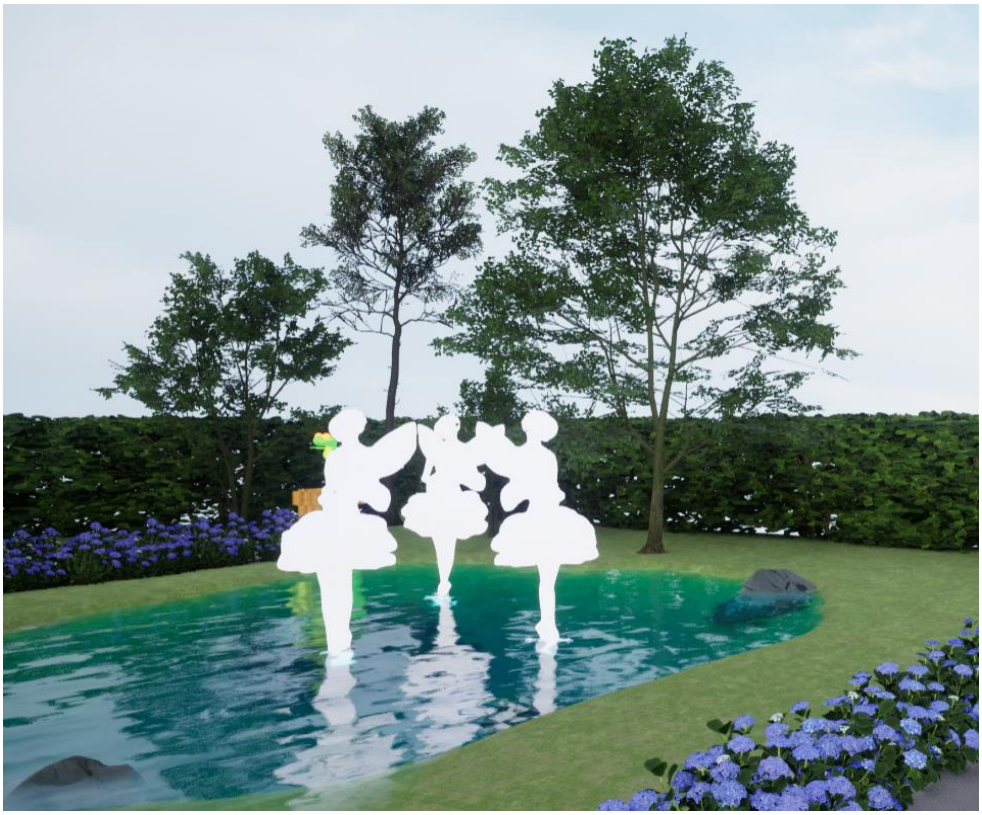


Figure 5.14: Statue of fairy

- **Statutes material**

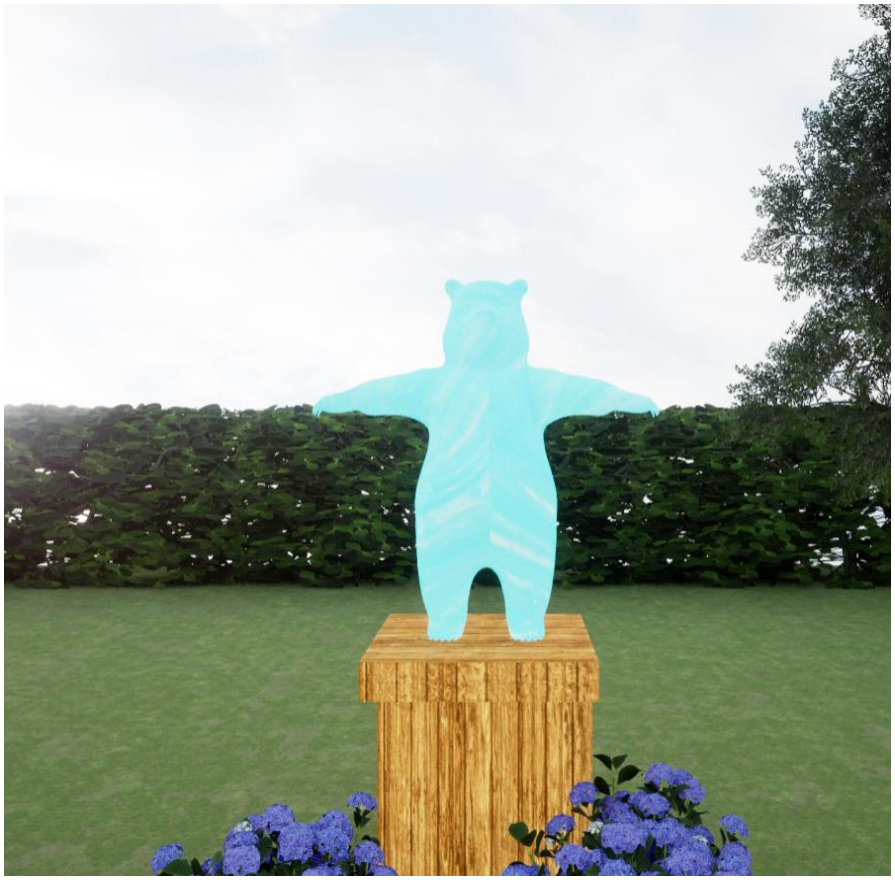
In the trial version, the material applied to all the statues was marble in colour and texture. However, to give it a more fantasy effect, a different colour scheme was used for every statue, i.e. for the unicorn, multiple colour material (see Figure 5.15(a)) was used, while for the frog green and yellowish green material (see Figure 5.15(c)) was used. The same sort of schemes was used for every statue (see Figure 5.15)

(a)

(b)

(c)

(d)



(e)

Figure 5.15: Fantasy statues

- **Tara**

An animated charterer was needed to shift the instructions for exercises into animated form. In that respect, the character of Tara was introduced in the updated version. Tara is an Irish origin word of origin that means star or light of the soul (Bagg 2023). The character was downloaded from Mixamo (Mixamo 2023) Because of a cartoonish and medieval look (see Figure 5.16)

Figure 5.16: Tara

5.2.3.9 Refinement in non-fantasy version

In this version, all the exercises were placed in the same manner as in the fantasy version. In place of statues, it had boxes on the front where exercises were placed. In the end, when the player approaches the well and throws the ball in, it takes the user back to the doctor's room.

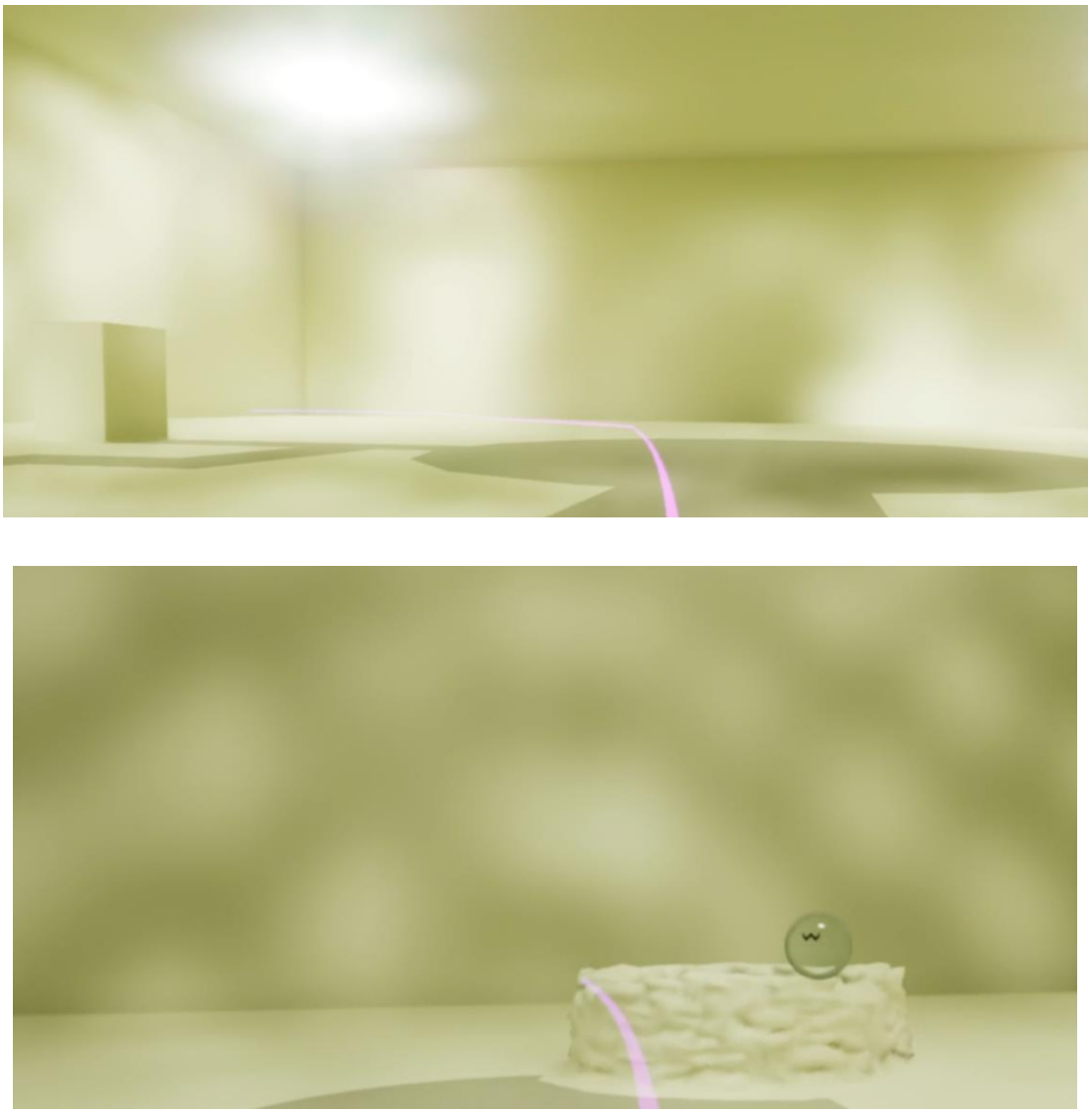


Figure 5.17: Changes in the non-fantasy version

5.2.4 Evaluation of game after refinement

After refining the prototype, the games were shared again with experts. Their opinion on the updated game was requested. They were informed about the modifications to the game and the changes that remained. Two medical experts from the earlier evaluation phase participated in this research phase. The detailed results of the quantitative part were shown in Figure 5.18.

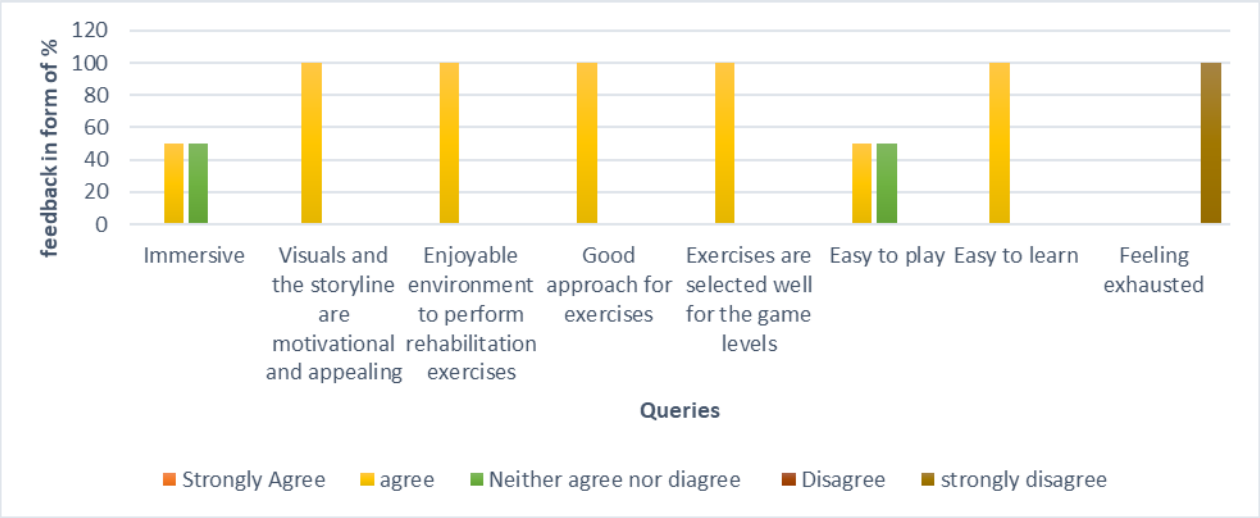


Figure 5.18: Experts' feedback after refinement

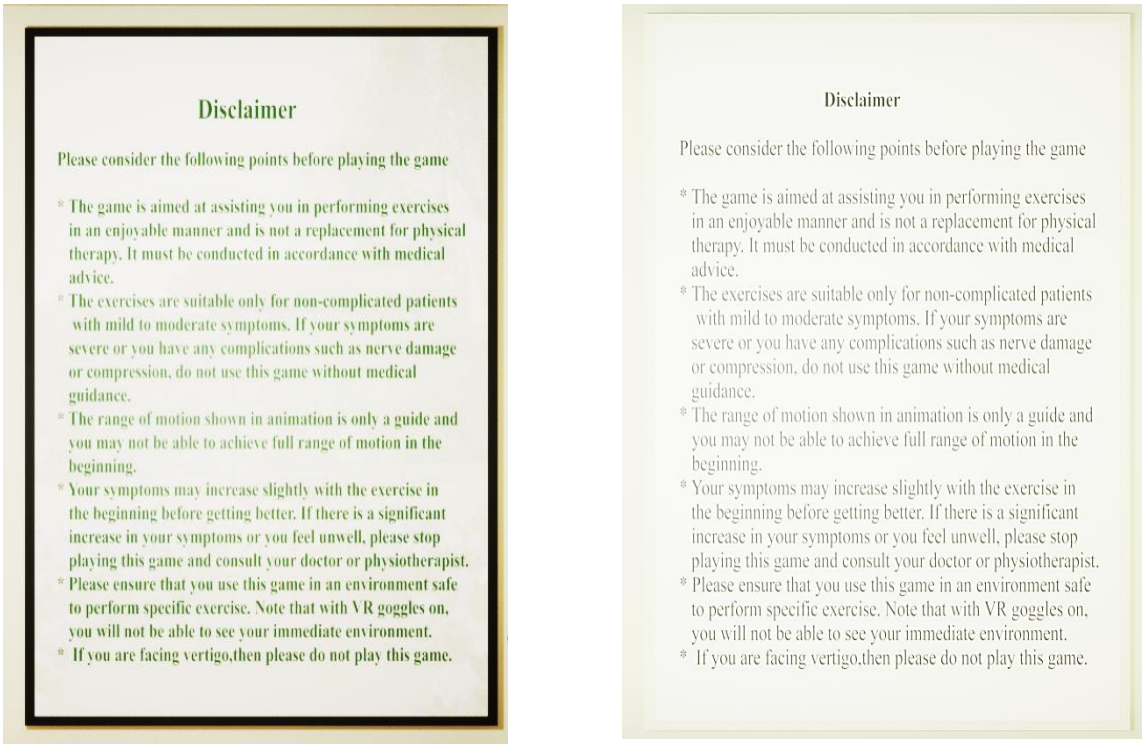
This time, in the quantitative section, nearly all the responses to the questions were positive. They also agree that it's a good approach for doing exercises. However, few other changes were suggested in the qualitative part. Many changes have been made. However, it was impossible to implement all the changes, such as adding an avatar to guide the player throughout the game. However, the intro, guided path, and video tutorials of exercises help deal with this change.

5.2.5 Enhancement of prototypes

In this version, the help menu was designed to guide the player in using buttons and exercises, although a guided tutorial could also be added for the user. It is worth noting that certain modifications could be made; however, they would likely introduce other issues. For instance, implementing control buttons more efficiently could be beneficial, but placing two functions on one button might confuse users. A few changes had not been implemented due to time and technology constraints, which will be discussed in Chapter 6. The following suggested changes were implemented:

5.2.5.1 Disclaimer

A few instructions for using the game were shared in the intro; however, medical experts suggested adding a disclaimer to the game. A disclaimer was added on the wall of the doctors' room to be used in both prototypes.



(a) (b)

Figure 5.19: Disclaimer (a is for the fantasy version, b is for the non-fantasy version)

5.2.5.2 Story of Wishing Well

In the fantasy prototype, the story of the core concept of the key collection was missed by players due to skipping the intro. For that reason, the Wishing Well story was also placed in the doctors' room to be used in fantasy prototypes.

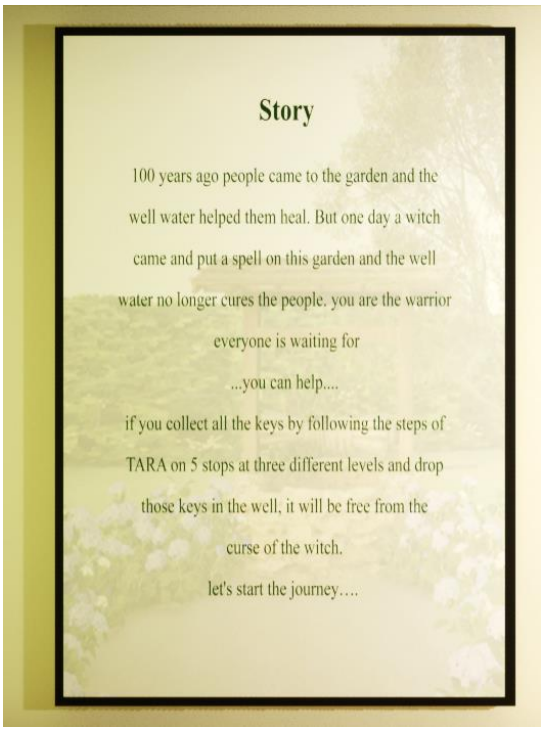


Figure 5.20: Story of Wishing Well

5.3 Participant study

5.3.1 Evaluation

The first evaluation phase by medical experts was completed and discussed in the section 5.2. The second step of the evaluation was conducted on healthy volunteers. The reason for selecting healthy volunteers instead of the actual patients was the different process of ethics approval that the research would require. While the user study on patients would enhance the credibility of the research, the process would involve risk management that would divert the process from the investigation of whether fantasy elements incorporated into a game enhance its engagement.

For preparing the participants' study for healthy volunteers, recruitment was done using email invitations, posters across Bournemouth University and posts in social media. The volunteers were recruited using a random sampling technique from Bournemouth University, BCP, and the local area. The goal was to recruit enough participants who would be suitable for the participant profile,

given the user sample and inclusion/exclusion criteria outlined below. A Google Form was created for participant registration. Based on age and gender, participants were divided into two groups. One group played the fantasy version of the game, while the other group played the non-fantasy version. Each participant from each group performed the activity individually and separately from other participants.

They were informed about the research stage and status of the game being checked by medical experts. They were given a pre-game questionnaire. The purpose of the pre-game questionnaire was to ensure that volunteers did not miss any points in the recruitment criteria. This step allowed the researcher to recheck whether participants experienced any issues while playing the game or had previously encountered problems with VR. Volunteers played the game. Based on the user's previous experience with VR, this session typically lasted between thirty minutes and one hour. After playing the game, the volunteers fill out the post-study questionnaire. In this questionnaire, they could share their experience with the game.

To ensure the proper and unbiased sample for the user study, the following elements were taken into consideration.

Inclusion and exclusion criteria for the user sample: The participants should have been within the age range of 18-50. They did not have any health issues with playing video games, such as CVS (computer vision syndrome) or epilepsy. They did not have any problems with VR or wearing a headset. These criteria were established to minimise the risk of using VR and experiencing health issues, such as muscle injuries or sprains.

Data collection: This study uses comprehensive mixed-method research (see 3.4). The volunteers were requested to fill out the pre-study questionnaire. After completing the pre-study questionnaire, volunteers were requested to play the game, allowing the researchers to observe their reactions and interactions. After playing the game, they received post-study questionnaires based on qualitative and quantitative methods (see 3.4), ensuring to capture their whole experience and feedback.

During the gameplay session with volunteers, the researcher observed their interaction in the VR environment on a monitor screen. This led researcher to handle the problems that participant faced during the session. The movement of volunteers was also recorded by a video camera. They were

informed about the movement recording. These recordings help to understand their responses to specific questions, such as improvements required in prototypes, and would also aid in future research on this topic.

Demographic information: This study included 56 participants who registered to play games. As the research is not funded, the participants who took part in this research received no monetary benefits. Fourteen participants did not turn up. Eight participants started playing the game however left in the middle. The researcher eliminates the data of two participants on the basis that it can create biased results. (One participant's data is discarded because they are working with VR research. Other participants' data is taken out because they worked as part of the game design group). Two participants were found to be of age over 50 and therefore were excluded from the study.

Eventually, data from thirty participants were sampled for the study. This sample contains participants in the age range of 18-50. These participants were split into two groups, each playing one version of the game assigned to them. After playing the game, they provide their feedback. Out of these participants, eight are from outside the university, five are staff members, and seventeen are university students from Bachelor to Postgraduate level. Overall, sixteen females and fourteen males participated in this research. To keep the research data consistent, the researcher tried to keep an equal number of participants in each age range of both groups. Detailed demographic information about the final participants who participated in this study is shown in Table 5.1: Participants information.

Prototype	Gender	18-29	30-39	40-50	M/F Ratio	Total
Fantasy	Male	3	3	1	7	15
	Female	2	2	4	8	
Non-fantasy	Male	3	3	1	7	15
	Female	2	3	3	8	

Table 5.1: Participants information

5.3.2 Findings and analysis

The questionnaires for both versions of the game had the same structure and contents for consistency reasons. The quantitative part of the questionnaire was designed following the game

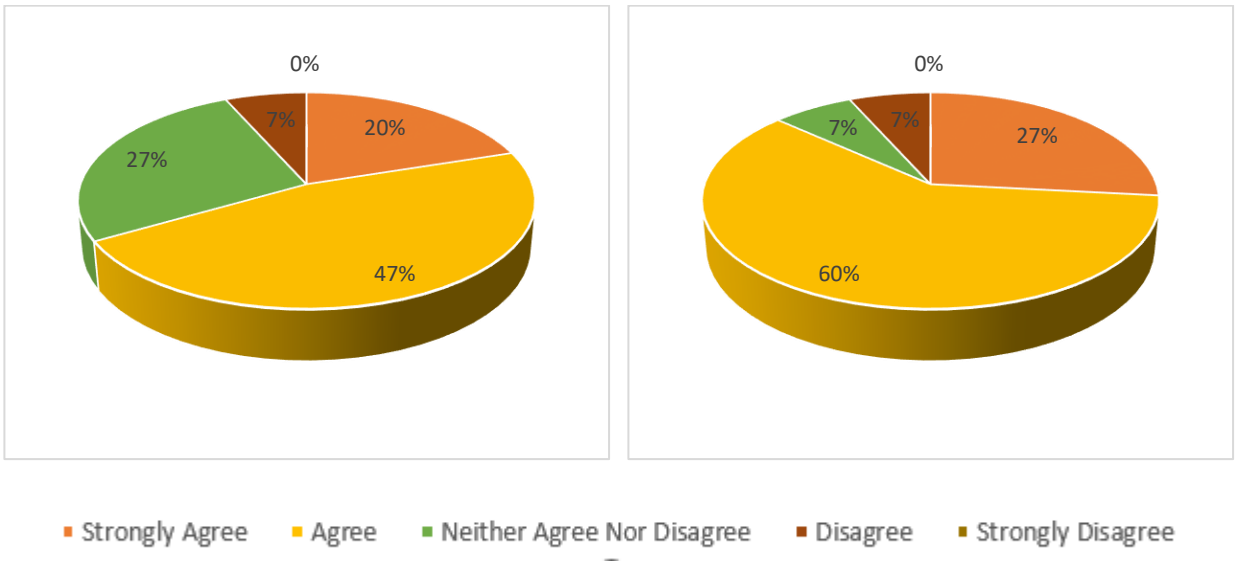
experience (Ijsselsteijn et al. 2013) and the intrinsic motivation inventory for fantasy (Choi et al. 2013). The word fantasy was also not used in the questionnaire to prevent the data from being biased.

5.3.2.1 Quantitative data; pre-game questionnaire analysis:

The pre-game questionnaire had eight quantitative questions and one qualitative question that was linked to the quantitative questions. In this study, three main themes were chosen from the questionnaire: physical activity, video games, and VR. All the questions related to these three themes were placed in a mixed order in the questionnaire (see Appendix A). These questions would help the researcher keep a record of patients and their preferences for playing games. Responses of both groups were shared in comparison to each other.

The feedback provided for each theme is provided in detail as follows:

- **Games**



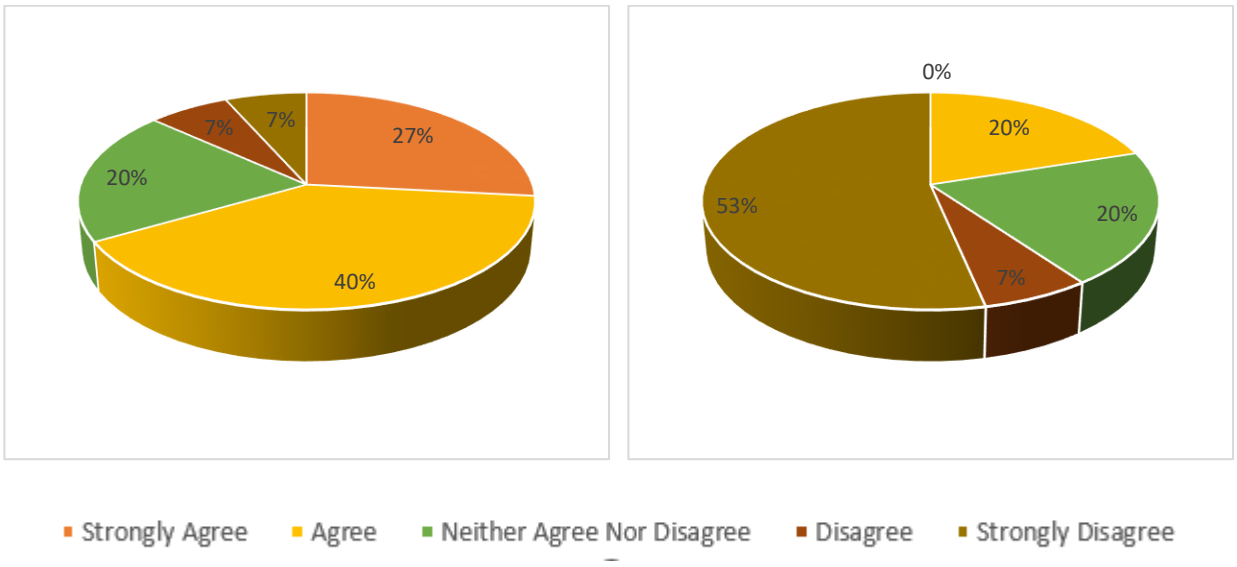
A: Fantasy Version B: Non-Fantasy Version

Figure 5.21: Winning the game provides me with a sense of accomplishment

As this research focuses on gaming, the question pertains to general games, rather than specifically video games. This question was added to capture the view of participants on the feeling of achievement when completing the game successfully. Both data sets exhibit the same type of

answers in the evaluation. If the results of 'agree' and 'strongly agree' are merged for fantasy (47% and 20%, totalling 67%) and non-fantasy versions (60% and 27%, totalling 87%), the results show that more than 60% of people agree that winning a game provides them with a sense of achievement.

While 27% of participants in the fantasy version were unsure, 7% of participants in the non-fantasy version were unsure indicating a significant difference between the two sets. One noticeable fact about these data sets was that only 7% in both datasets disagree, while 0% strongly disagree with this question. These findings show that most people who play any game find a sense of achievement when they win that game.

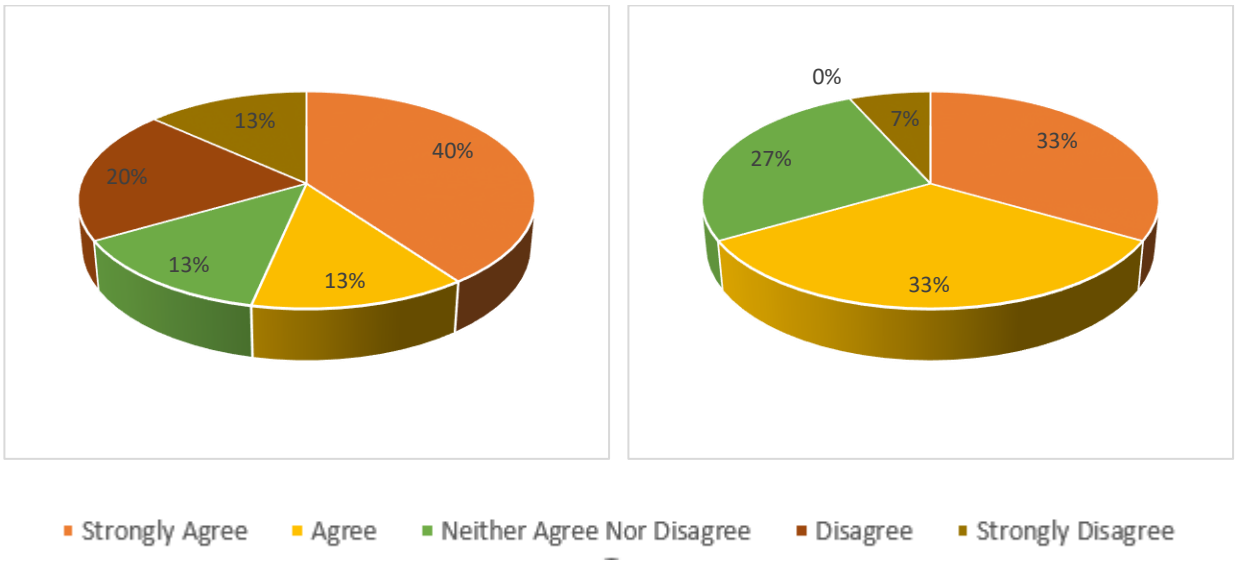


A: Fantasy Version B: Non-Fantasy Version

Figure 5.22: Games provide me with an entertaining activity in a challenging way

Another question related to general games was whether games provide an entertaining activity in a challenging manner. This data shows a significant variation in the responses provided by the two groups. In the fantasy group, nearly 70% favour that games provide them with entertainment in a challenging way. In the non-fantasy version, more than half of the sample population was not in favour of this statement. This information shows different answers in both data sets. While one point was important for both studies, the data set shows 20% results for neither agree nor disagree results. This data indicates that there was a significant shift in both cases, and more studies are required to find the reason for this. The people who do not consider that games provide them with

entertaining activities with challenges involved might have some other views. This question opens new prospects for further research outside of the scope of this study.

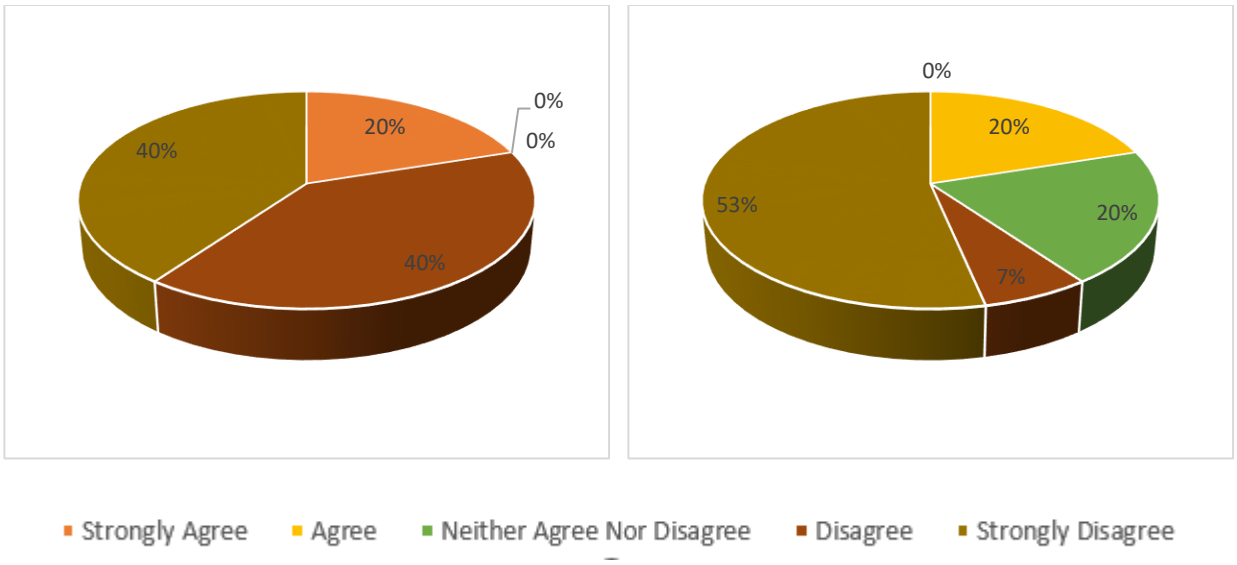


A: Fantasy Version B: Non-Fantasy Version

Figure 5.23: Player experience with playing video games

The next question in this theme was about the player experience of playing video games. Data from both versions of the game shows varying responses about the player's experience with playing the game (see Figure 5.23). A notable point in both data sets was that a significant portion of players strongly agree, at 40% and 33%, that they enjoy playing video games. In the agreed quota, participants who like to play video games were fewer in the fantasy version than in the non-fantasy version. The same result could be seen in the case of neither agree nor disagree.

While 20% of participants in the fantasy version did not enjoy playing video games, in contrast, no participant in the non-fantasy version disagreed with playing video games. This data shows a mixed feeling about playing video games. It also shows that not all participants were particularly video game lovers, which broadens the scope of the game. In this study, the researcher designed a game for individuals aged 18-50. The reply to this question confirms that the sample represents the sample well, with some users being game lovers and some not.



A: Fantasy Version B: Non-Fantasy Version

Figure 5.24: Previously had problems while playing a computer game

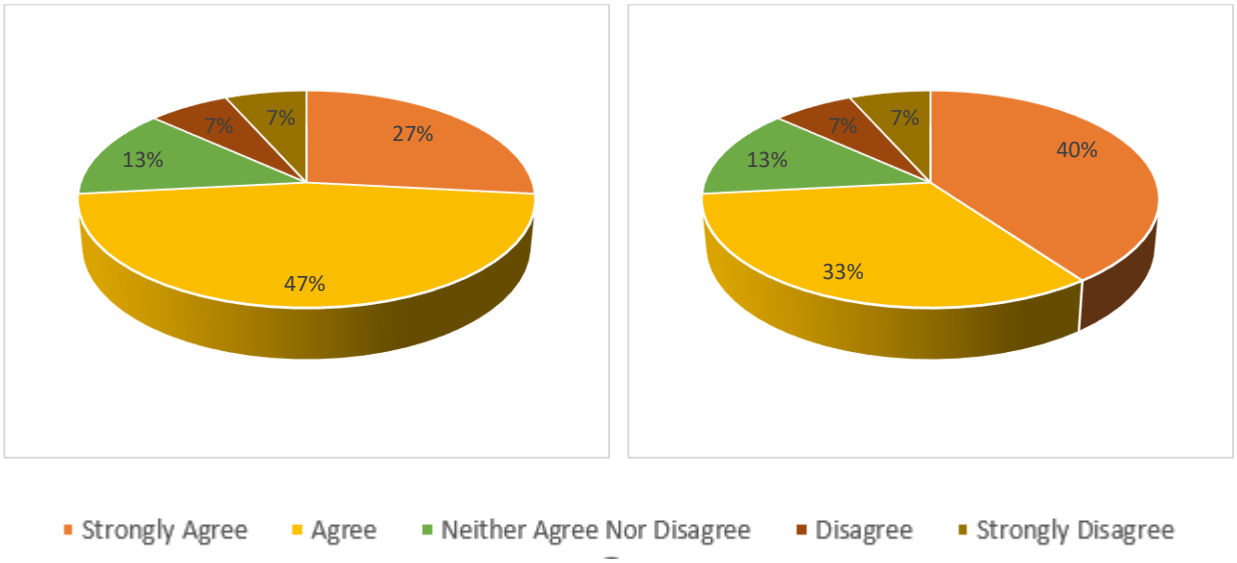
Another question was whether the participant had previously had any problems while playing a computer game. The reason for asking this question from the player was to confirm that they had read the recruitment criteria for this study. This information would also help the researcher determine whether participants had any serious issues with playing video games, allowing them to decide about their participation by discussing it with them.

The data shows that 80% (40% disagree and 40% strongly disagree) of participants in the fantasy version previously had no problems playing the game. While in the non-fantasy version, 60% (7% disagree and 53% strongly disagree) previously did not have any issue with playing the game.

20% in the non-fantasy version pick the option of neither agree nor disagree. While in the fantasy version, no one chose this option, in both versions, 20% agree (in the fantasy version, 0% strongly agree and 20% strongly agree, while in the non-fantasy version, 20% agree and 0% strongly agree) that they previously had problems with playing games. This question was asked to determine the severity of those issues; it was found that most participants who replied in agreement mentioned experiencing headaches or eyestrain while playing games for long hours. No participants experienced any serious problems that could have led to severe consequences.

- **Physical activity games**

The next theme on which the questions were asked was about physical activity games. As this game involved physical activity, it was already mentioned in the participants' information sheet that they might experience light muscle strains while playing. However, if they were already involved in any physical activity, the effect of physical activity on the body would be minimal.

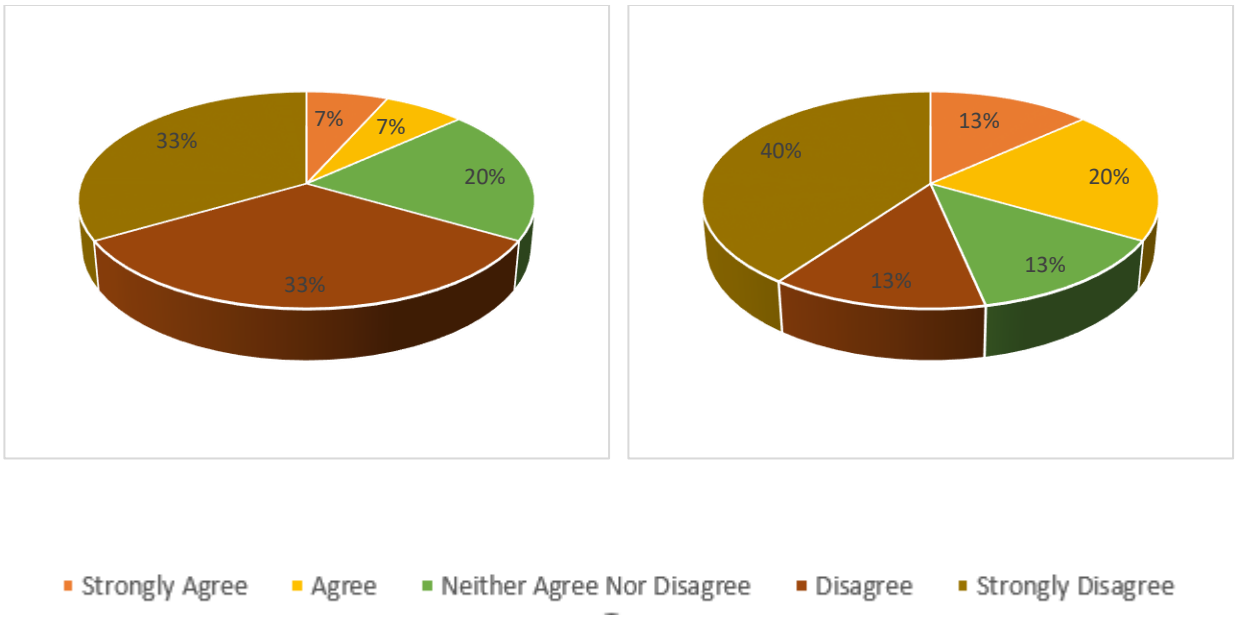


A: Fantasy Version B: Non-Fantasy Version

Figure 5.25: Like physical activity games

The first question in this theme was whether players liked to play physical activity games. The reason for asking this question was that the researcher sought to identify data in this specific age group through their research work. The data shows that 74% (47% agree and 27% strongly agree) of the fantasy version and 73% (33% agree and 40% strongly agree) of the non-fantasy version liked physical activity games.

13% of both groups neither agree nor disagree with the fact that they liked physical activity games. 14% (7% disagree and 7% strongly disagree) of both groups disagreed with the point that they liked physical activity games. The data shows that most participants in both groups who joined the study enjoyed doing physical activity.



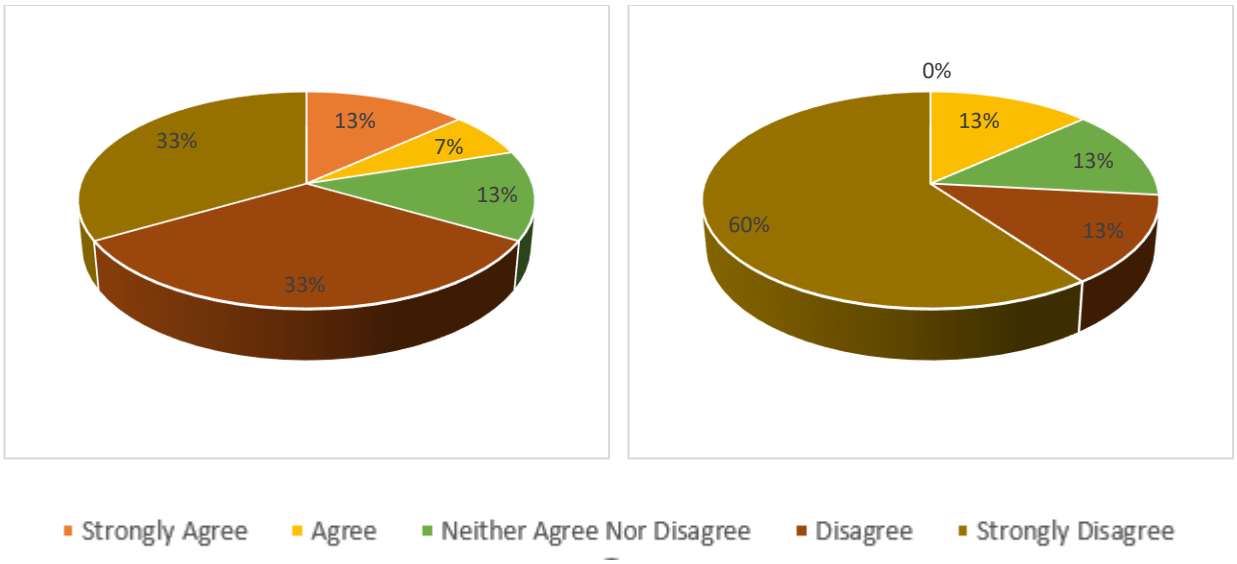
A: Fantasy Version B: Non-Fantasy Version

Figure 5.26: Physical problems with doing physical exercise

In this phase of research, only healthy volunteers were recruited. This question, "physical problems with doing physical exercise", was asked to ensure that participants had no serious issues with physical exercise. The datashowed that the maximum number of participants disagreed (fantasy: 66% and non-fantasy version: 53%) with the question of having any problems with physical exercises in both versions of the game. Meanwhile, 20% in the fantasy version and 13% in the non-fantasy version replied with neither agree nor disagree.

14% of the fantasy version and 33% of the non-fantasy version agreed that they have problems with physical exercise. Then, those participants were asked about the problems they were facing; they were not major issues. Still, they were reminded about the point in the participation information sheet that they could leave the study at any point.

The answers indicated that most participants did not experience any issues with physical exercises, and those who did had minor problems. This showed that participants were eligible to participate in this study.



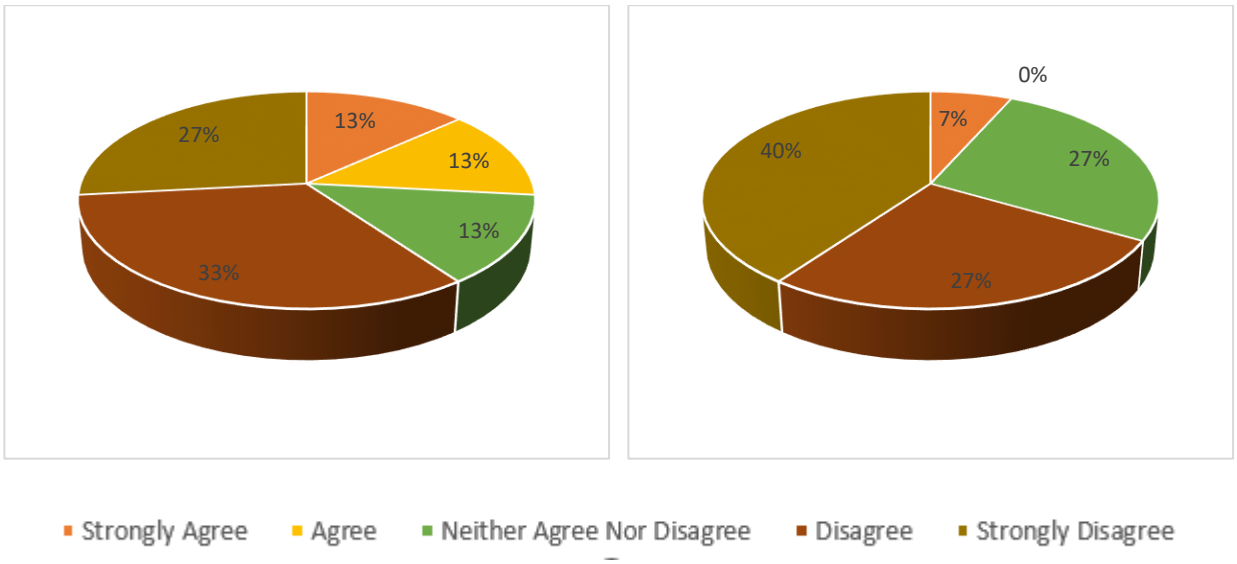
A: Fantasy Version B: Non-Fantasy Version

Figure 5.27: Physical problems with playing physical activity games

In this study, participants were required to engage in physical exercises. This question, “Physical problems with playing physical activity games”, helped to confirm that participants were not facing any issues with physical activity games. The question seems a bit similar to the previous one. However, the reason for posing this question was that some participants in the last question would only respond to physical exercises, not physical games.

The data show that 66% of fantasy versions and 73% of non-fantasy versions had no issues while playing physical activity games. 13% of both datasets replied with neither 'agree' nor 'disagree', while 20% of the fantasy and 13% of the non-fantasy versions reported problems playing games. The next question asked about the issues they faced during physical activity games. The replies were collected, and participants were informed about the point on the information sheet where they could leave the game at any stage. Those participants still decided to play the game and would educate the researcher in case of any issues they faced while playing.

- **VR**



A: Fantasy Version B: Non-Fantasy Version

Figure 5.28: Issues with VR, i.e. Oculus Quest, Rift, etc

This research focused on VR, which was why the recruitment criteria specified that participants had no health issues related to VR. However, as previously mentioned, participants sometimes missed the criteria for inclusion in the study. To reconfirm that participants did not have any issues with the VR, this question was added to the questionnaire.

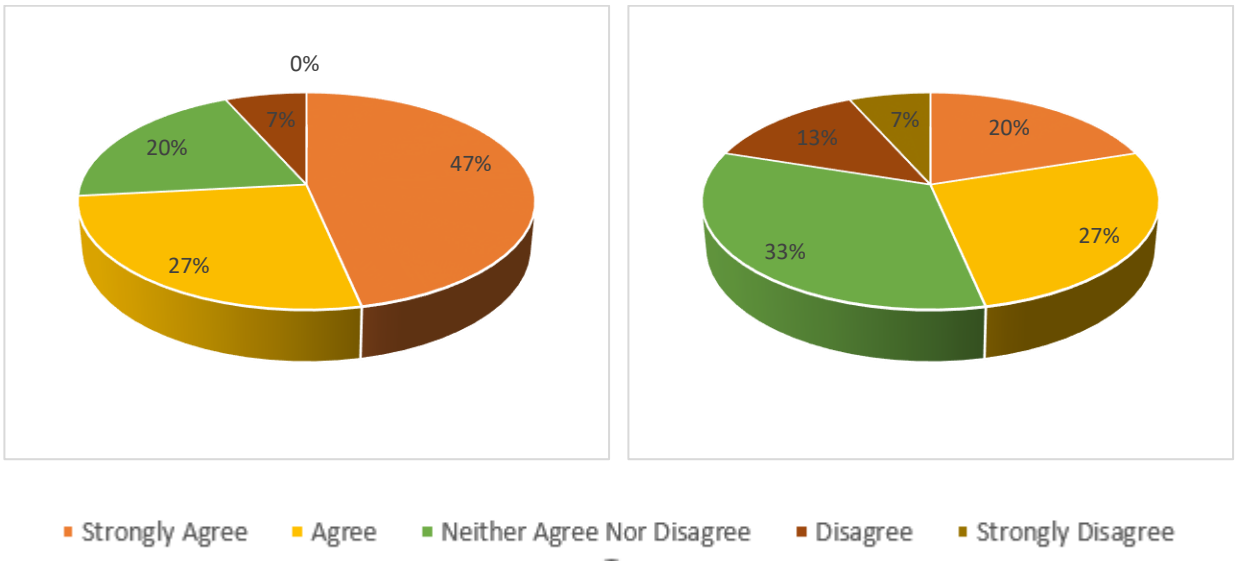
The data showed that 60% (33% disagreed and 27% strongly disagreed) of the fantasy versions, while 67% (27% disagreed and 40% strongly disagreed) of the non-fantasy versions, did not experience any issues while playing physical activity games. This data suggested that most participants who took part in the research did not have problems with using VR. The dataset showed that 13% of the fantasy version and 27% of the non-fantasy version went in the category of neither agree nor disagree. While 26% (13% disagree and 13% strongly disagree) of the fantasy version and 7% of the non-fantasy version had problems with VR. Then, they were asked a quantitative question about the issues they had with VR. Most respondents reported having motion sickness or headaches after prolonged use of VR. The participants were again informed about the point on the participants' information sheet stating that they could leave the game at any stage for any reason. The participants still decided to play the game and agreed to inform the researcher if they encountered any issues.

5.3.2.2 Quantitative data; post-game questionnaire analysis:

The next section of this chapter was about responses received for the post-game questionnaire. The post-game questionnaire consists of a total of thirteen questions: eleven quantitative questions and two qualitative questions. The qualitative questions were linked to quantitative questions. In this study, three main themes were identified in the questionnaire: Enjoyment/interest, Functionality/effort, and Visuals/aesthetics. All the questions related to these three themes were placed in a mixed order in the questionnaire (see Appendix A). These questions were used to get the final output of this whole research. This part of the study would help to evaluate the fantasy aspect of the game. To gain a clear understanding of the differences between the two groups (one that played the fantasy version and the other that played the non-fantasy version of the game), their responses were compared to each other.

The feedback provided for each theme is provided in detail below.

Enjoyment/interest: In this theme, participants from both groups ask questions related to enjoyment/interest.



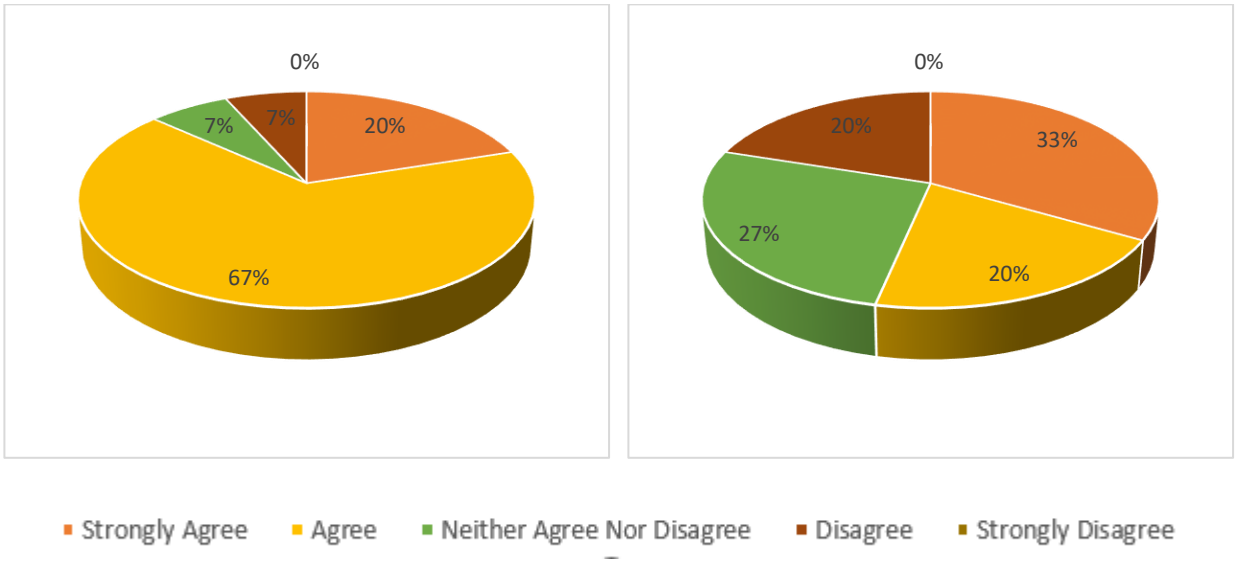
A: Fantasy Version B: Non-Fantasy Version

Figure 5.29: Enjoyed playing game

In response to the question about whether participants enjoyed playing this game, the answers differ between the two groups. In the fantasy version, 47% strongly agreed that they enjoyed playing this game. 27% agreed with this statement, which made a total of 74 % of the sample agree that they liked playing this game. In the non-fantasy version, 20 % strongly agreed, and 27% agreed that they enjoyed playing this game. That was a total of 47% of participants who like playing this game.

In the category of neither agreed nor disagreed, the percentage of the fantasy version was 20%, compared to 33% for the non-fantasy version. The disagreement with this question for the fantasy version was 7%, while for the non-fantasy version, it was 20% (13% disagreed and 7 % strongly disagreed).

The data showed that participants who took part in this study enjoyed playing the fantasy version more than the non-fantasy version.



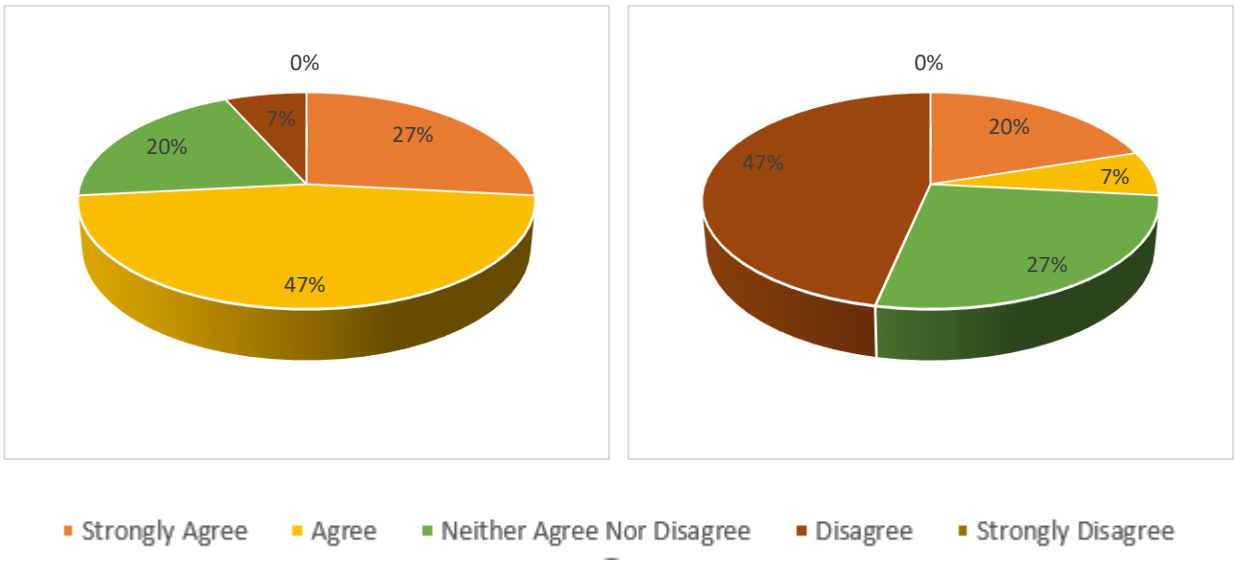
A: Fantasy Version B: Non-Fantasy Version

Figure 5.30: Lost track of time

The following query from the participants was that while playing the game, the experience was so engaging that they lost track of time. In this question, we could also view a significant variation between the two datasets of the participants who feel that they lost track of time, 87% of the fantasy

version (20 % strongly agreed and 67% agreed), 53% (20 % strongly agree and 67% agree) in the non-fantasy version agreed with this statement.

Another main difference was also visible in the option of neither agreeing nor disagreeing, where 7% of the participants in the fantasy version did not express an agreement or disagreement. In contrast, in the non-fantasy version, the range was 27%. The same shift in data was visible in responses to this statement. For fantasy, it was 7%, while for the non-fantasy version, it was 20%. Not a single participant strongly disagreed with this aspect. This data shows that players in the fantasy version feel the game was more immersive than players in the non-fantasy version.



A: Fantasy Version B: Non-Fantasy Version

Figure 5.31: Like to play again

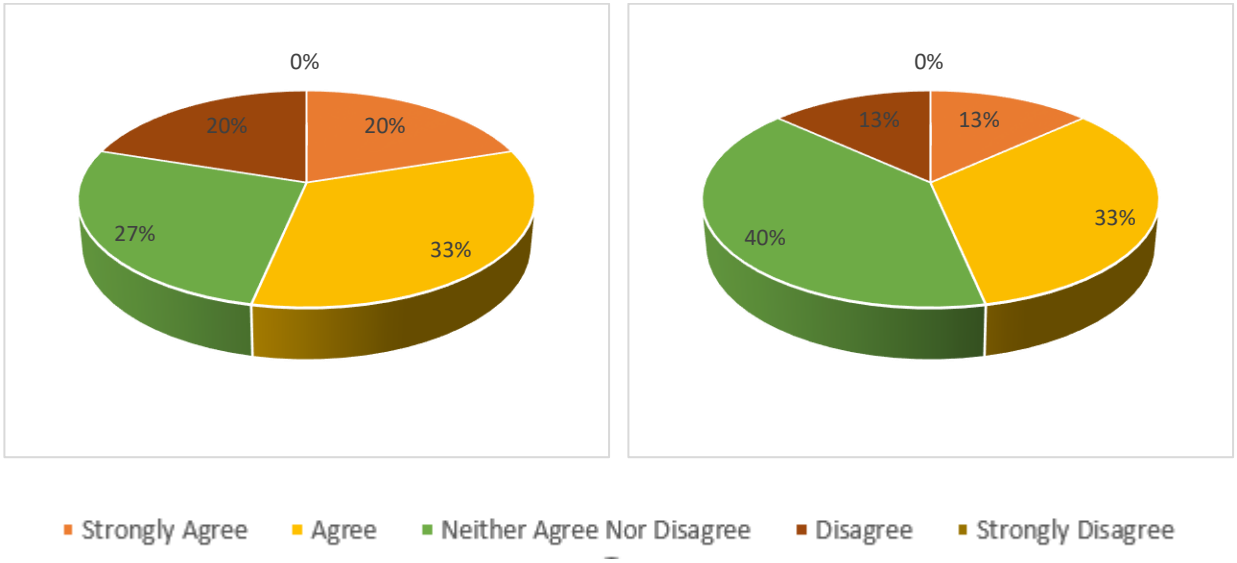
The last query in this theme was whether the player would like to play this game again. In response to that, 74% (27% strongly agreed and 47% agreed) of participants who played fantasy replied in favour of it. While 27% (20 % strongly agreed and 7% agreed) of participants in the non-fantasy version agreed with that. This shift in data reveals a clear indication of what participants were looking for.

The neutral response was a bit close with just a bit of variation, i.e. 20% for fantasy and 27% for non-fantasy. In contrast, there was again a huge data difference in the disagreed option. In this part

of the fantasy version, just 7% disagreed with the statement that they liked to play this game again, while in the non-fantasy version, 47% disagreed.

There is no reply in the strongly disagreed case in both versions of the game. Here, it could be said that more than seventy per cent of players of the fantasy version like to play this game again. It was found that the fantasy version was more popular among players compared to the non-fantasy version.

Functionality/effort: The functionality of the game was similar in both versions of the game. These questions would show the difference that players feel while playing both versions of the game.

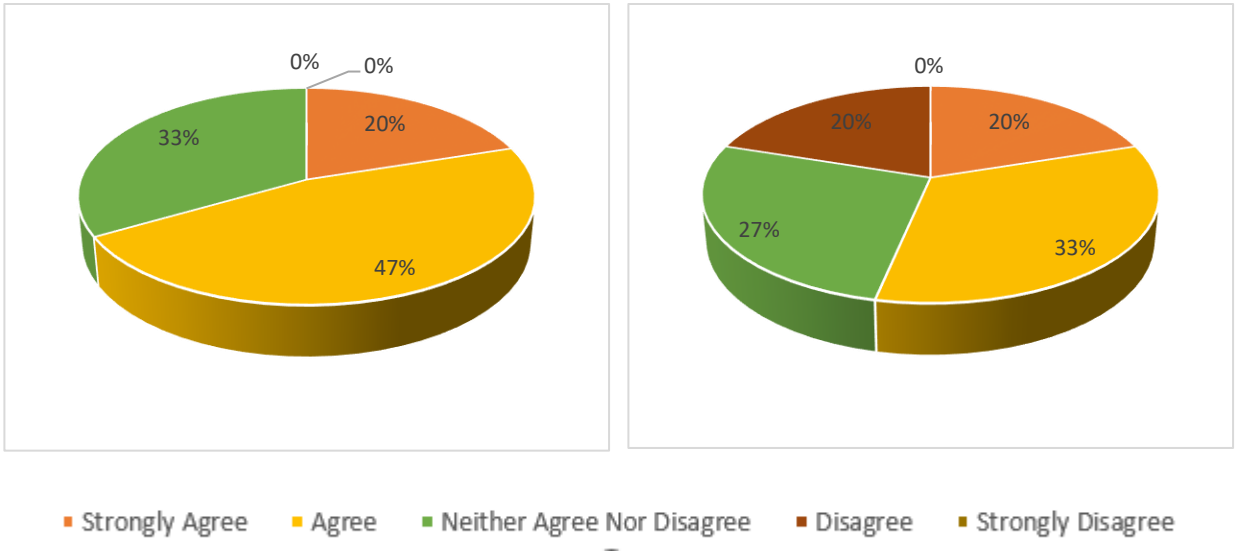


A: Fantasy Version B: Non-Fantasy Version

Figure 5.32: The gameplay was easy

As mentioned above, the functionality of the game was the same for both versions, which was evident in this question. In response to the question of whether the gameplay was easy, the data showed similar answers. 53% (20% strongly agreed and 33% agreed) in the fantasy version agreed with this statement, and 46% (13% strongly agreed and 33% agreed) in the non-fantasy version agreed with it.

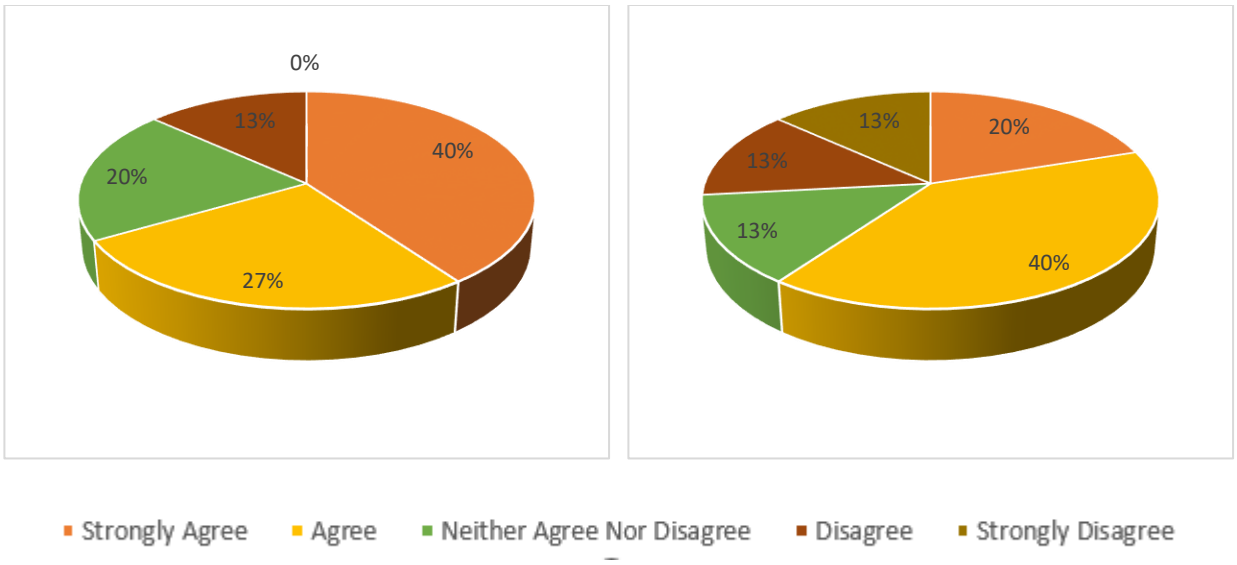
A slight difference was seen at the option of neither agreed nor disagreed, in which 27% of the fantasy version replied neutrally while 40% of the non-fantasy version replied neutrally. 20% of the fantasy version agreed with it, while 13% of the non-fantasy version disagreed with it. No one strongly disagrees with it in both cases. This shows that players of both versions observed the game functionality in a similar manner.



A: Fantasy Version B: Non-Fantasy Version

Figure 5.33: The game had a satisfactory level of interaction

The next question was about the satisfactory level of interaction. In this question, a variation of data was seen between the two datasets. 67% (47% strongly agreed and 20% agreed) of participants in the fantasy version agreed with the fact that this game provided a satisfactory level of interaction, while 53% (20% strongly agreed and 33% agreed) agreed with the non-fantasy version. 33% of fantasy version and 27% of non-fantasy version participants were indecisive about the game interaction level. In the non-fantasy version, 20% of participants disagreed with the fact that games provided them with a reasonable level of interaction. For the fantasy version, no player disagreed about the level of interaction. These answers show a bit of variation. More research would be required to assess the reason why this difference appears in a situation where both versions have the same type of interaction level.



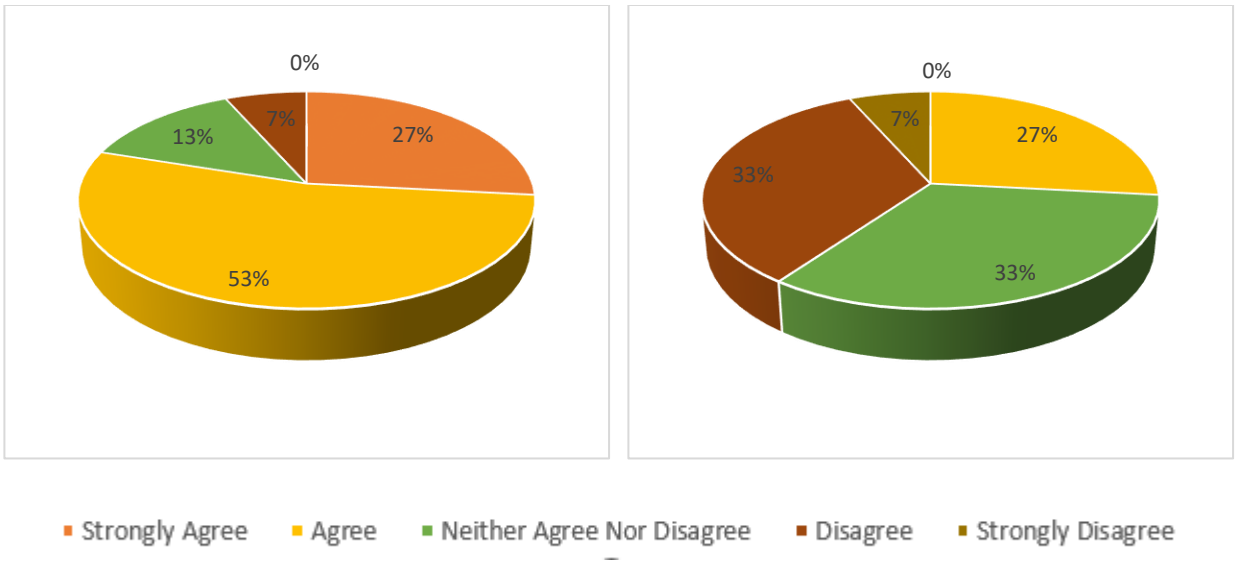
A: Fantasy Version B: Non-Fantasy Version

Figure 5.34: Use of physical effort in playing this game

The question about putting in the physical effort while playing this game was asked. The response in both versions was almost similar (67% in the fantasy version and 60% in the non-fantasy version) for agreement with this question. 20% and 13% provided neutral responses. In the fantasy version, 13% disagreed that they need to put in physical effort while playing this game, and in the non-fantasy version, 26% disagreed.

Overall, the data showed that most participants were required to exert physical effort while playing this game, and this was true for both versions. Replies contradicted the assumption that players would be engaged enough that the feeling of putting physical effort in the game to do exercise would be missed. We could find more about engagement in the next theme.

Visuals/aesthetics: After the enjoyment and functionality, now to discuss the theme whose findings would affect the findings of this whole research. The visuals and aesthetics used in both versions of the game differed, and answers to these questions would determine whether fantasy aesthetics and visuals would play a role in motivating players to play the game.



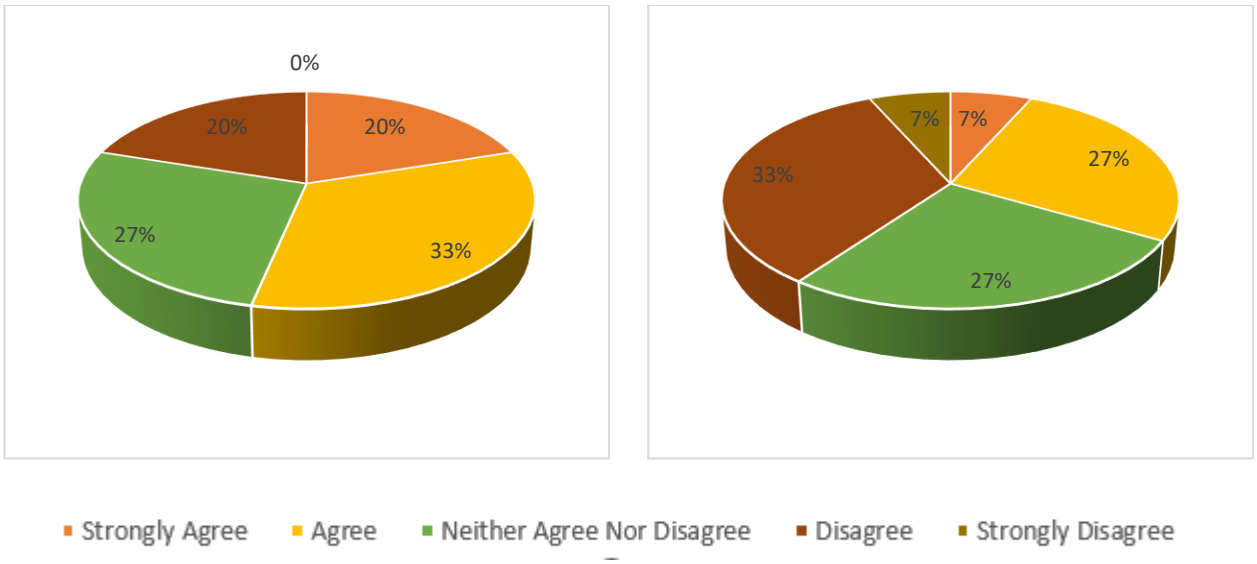
A: Fantasy Version B: Non-Fantasy Version

Figure 5.35: The game was engaging enough that I felt like part of the game

In the context of visuals and aesthetics, the first question asked of the participants was about their level of game immersion. The data in the two datasets vary significantly in the fantasy version, with 80% (27% strongly agree and 53% agree) agreeing that the game was engaging. In contrast, in the non-fantasy version, 27% (0% strongly agree and 27% agree) agreed that the game is engaging enough for them to feel like part of it. The difference is substantial enough to indicate a significant drift of the data to one side.

The same variation was visible in a neutral reply. In the fantasy version, it was only 13%, whereas in the non-fantasy version, it was 33%. For the option of not agreeing with this statement, in the fantasy version, 7% (0% strongly disagreed and 7%disagreed) disagreed. In contrast, in the non-fantasy version, 40% (33% strongly disagreed and 7%disagreed) disagreed, which was also a significant difference between the two datasets.

This significant difference in both datasets indicated that participants found the fantasy version more engaging than the non-fantasy version.

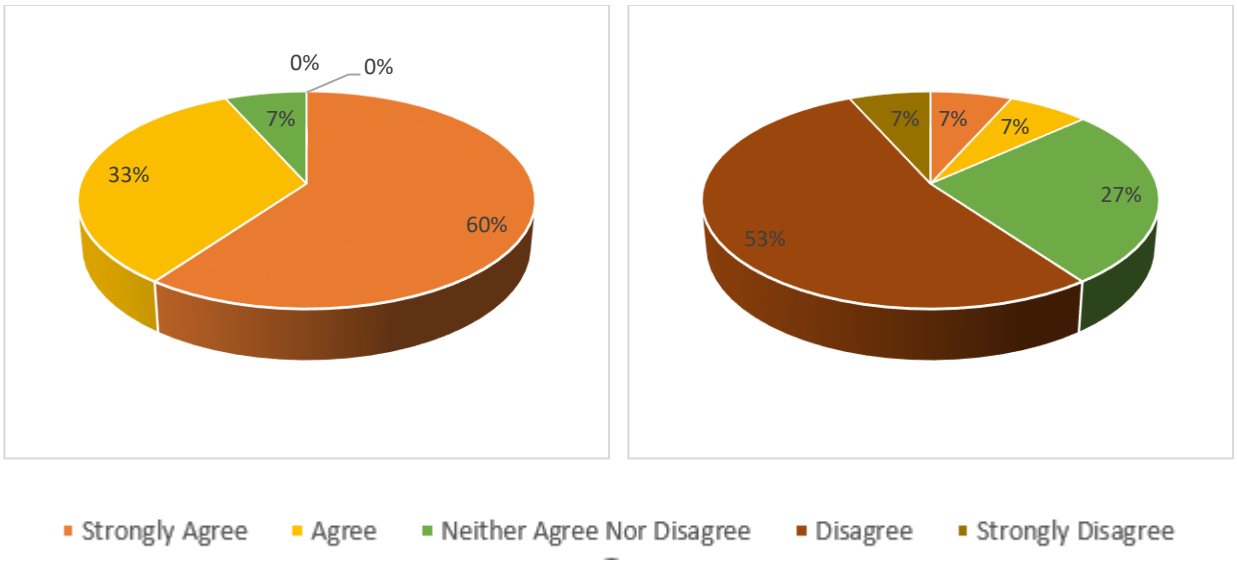


A: Fantasy Version B: Non-Fantasy Version

Figure 5.36: The game provides an enjoyable environment to perform rehabilitation exercises

The next question was about the environment of the game and whether the environment of the game was pleasant enough to motivate a person to perform rehabilitation exercises. Here again, the data was different for both versions of the game. In the fantasy version, 53% of participants agreed with this statement, while in the non-fantasy version, only 34%. The data in neutral was exactly similar for both versions. While the data for disagreement with this statement was a bit varied. In the fantasy version, participants who disagreed with this statement were only 20%, while for the non-fantasy version, it was 40%, which was double the ratio of the fantasy version.

This data suggests that the fantasy version of the game provided a more enjoyable environment for rehabilitation exercises than the non-fantasy version.

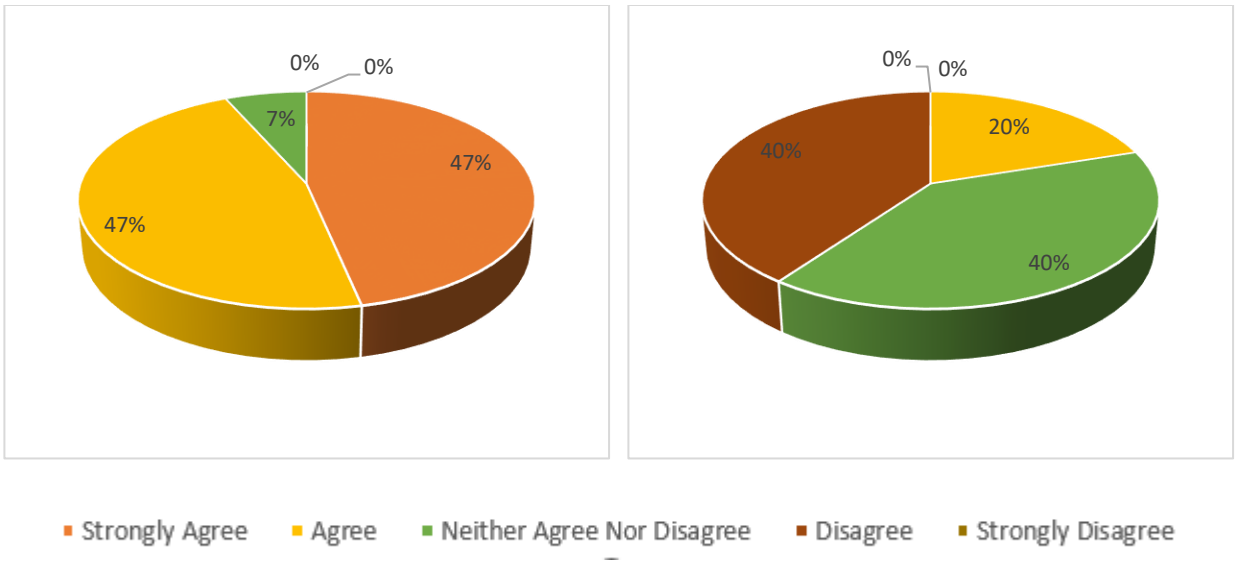


A: Fantasy Version B: Non-Fantasy Version

Figure 5.37: Liked the visuals of the game

This was the first direct question from the participants about the game visuals. The answer to this question would have a significant impact on the research findings. If data from the two graphs were compared, it could be seen that in the fantasy version, (60 % strongly agreed, 33% agreed) 93% of participants liked the visuals of the game. In the non-fantasy version, more than half of the participants, 60% (53% disagreed and 7% strongly disagreed), disagreed that they liked the game's visuals. The neutral data also varied, with 7% for the fantasy version and 27% for the non-fantasy version.

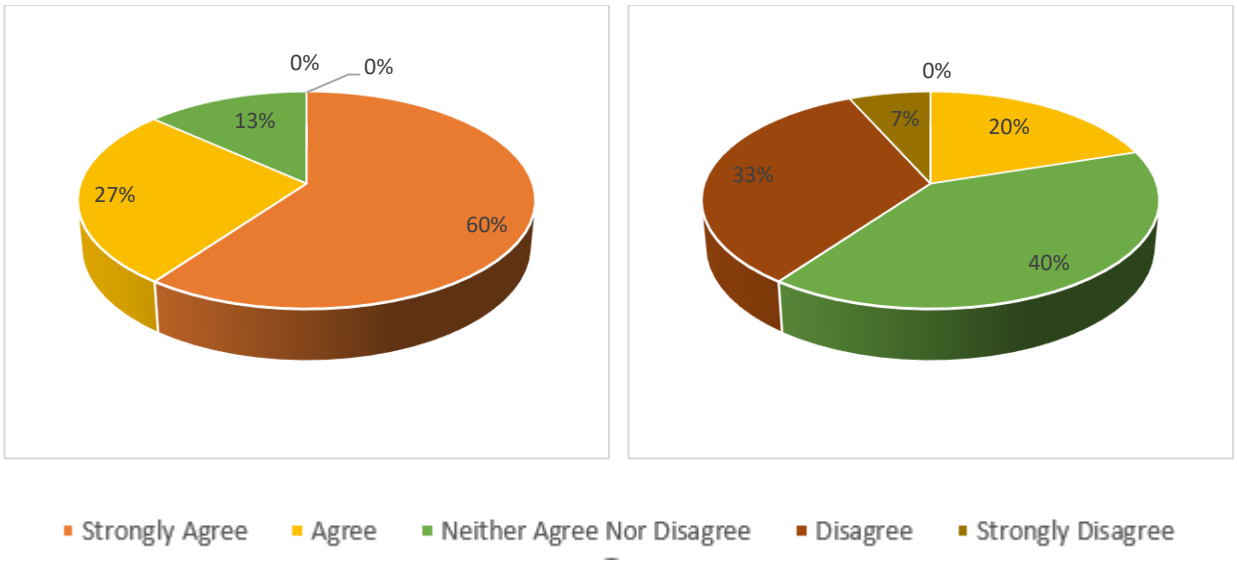
This data clearly indicated which version of the game had appealing visuals and which version the participants liked visuals. However, other tests are performed to confirm these responses.



A: Fantasy Version B: Non-Fantasy Version

Figure 5.38: The visuals and the storyline motivate them to perform rehabilitation exercises

The next question concerns the visuals and storyline of this game, specifically whether they were motivating enough to encourage users to perform rehabilitation exercises. In response to this question, a clear data difference was evident in both versions. In the fantasy version, 94% of participants agreed that the visuals and storyline were motivating enough to motivate them to perform exercises. In contrast, in the non-fantasy version, only 20% agreed. 40% of the non-fantasy version disagrees with this statement. Another notable shift is that 40% of respondents remain neutral in the non-fantasy version, whereas only 7% remain neutral in the fantasy version. The data show that all participants in the fantasy version responded to this statement by either agreeing with it or remaining neutral. No one disagrees with this statement, although it was a bit different in the non-fantasy version. This also leads to the fact that the fantasy version provides more interesting and exciting visuals and a storyline to the participants than the non-fantasy version.



A: Fantasy Version B: Non-Fantasy Version

Figure 5.39: The visuals of the game were engaging

The last question of quantitative analysis for this questionnaire was whether the visual and aesthetic aspects of the game were engaging. In response to this statement, 87% of participants in the fantasy version agreed with the statement, while only 13% stayed neutral. Yet, no one disagreed with the statement. In the non-fantasy version, 40% remained neutral, and 44% disagreed with this statement. Only 20% agreed with the non-fantasy version of this statement that the visuals/aesthetics of the game were engaging. The data shows that the fantasy version of the game had engaging visuals and aesthetics compared to the non-fantasy version.

5.3.2.3 Quantitative data; statistical analysis:

After analysing this data individually, let's examine the mean value and standard deviation of the data to confirm the research results in other ways.

- **Mean**

During this research, the mean values were initially considered. However, since mean values had equal weight for every number, the mean values were calculated by dividing the sum of all values by the total number, which was one in this case. The weighted mean value for the Likert scale was used to sort this issue. However, the data was first normalised before applying weights. (Witten IH 2016). This assigns values to each number according to its assigned weight. The researcher

attempted to eliminate ambiguity by using the same value assigned in questionnaires for the weights. After assigning weights, the value range of the weighted mean value was calculated as shown in Table 5.2.

Weight	Result	Range of Weighted Mean
1	Strongly Agree	1-1.8
2	Agree	1.81-2.6
3	Neither agree nor disagree	2.61-3.4
4	Disagree	3.41-4.2
5	Strongly Disagree	4.21-5

Table 5.2: Weighted mean range

After assigning the range to the weighted mean, the same themes for the questionnaire were used to study the impact of the weighted mean value on all the data. The first theme was enjoyment/interest.

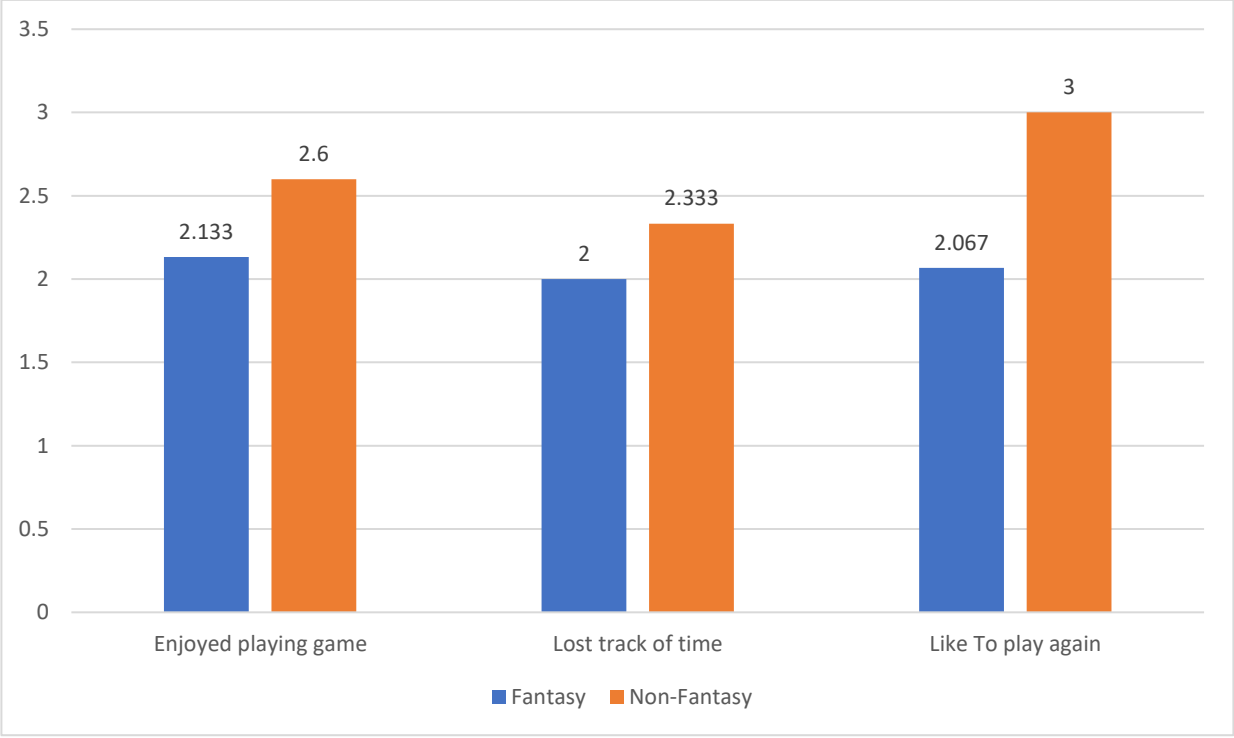


Figure 5.40: Enjoyment/Interest

In this theme, the mean values data from all three questions of both game versions were combined into a single graph. In all of these questions, it was evident that the fantasy mean value falls within the range of 1.8-2.6, indicating that participants agree with all three claims: they enjoyed playing the game, they lost track of time, and they would like to play the game again. In the non-fantasy version, one question, i.e., they wanted to play the game again, was in the neutral range, and two questions that stated they enjoyed playing the game, along with the fact that those participants lost track of time while playing, were in the agree range. However, when the data was examined separately for each question, it appeared somewhat scattered, and a clear picture from the data could not be discerned. The mean value provided clear information that in the fantasy version, the player agreed with these claims. In the non-fantasy version, participants provided neutral replies for one option while agreeing with two options. The standard deviation can indicate which data points were more varied and which were less varied.

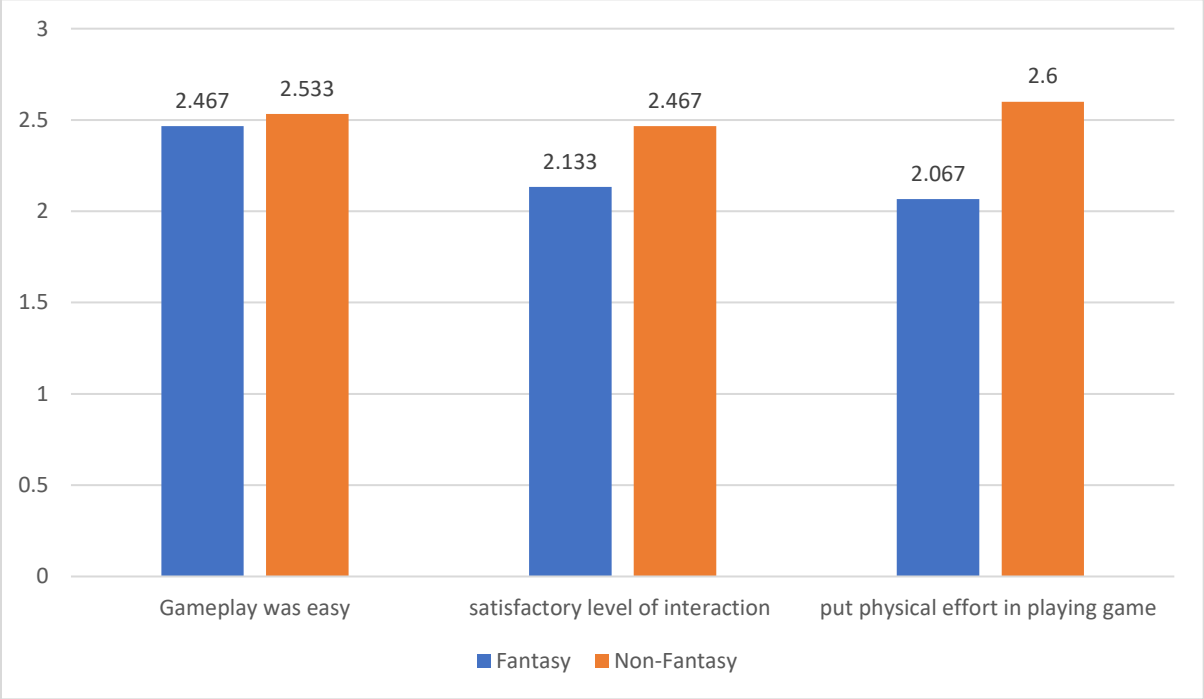


Figure 5.41: Functionality/Effort

The next theme deals with the game's functionality and the effort required to play it. As mentioned previously, the functionality of both game versions was similar. This point was also visible in the

mean data of both datasets. However, the data for the non-fantasy version was closer to the margin line, while the data for the fantasy version was almost in the middle of the range.

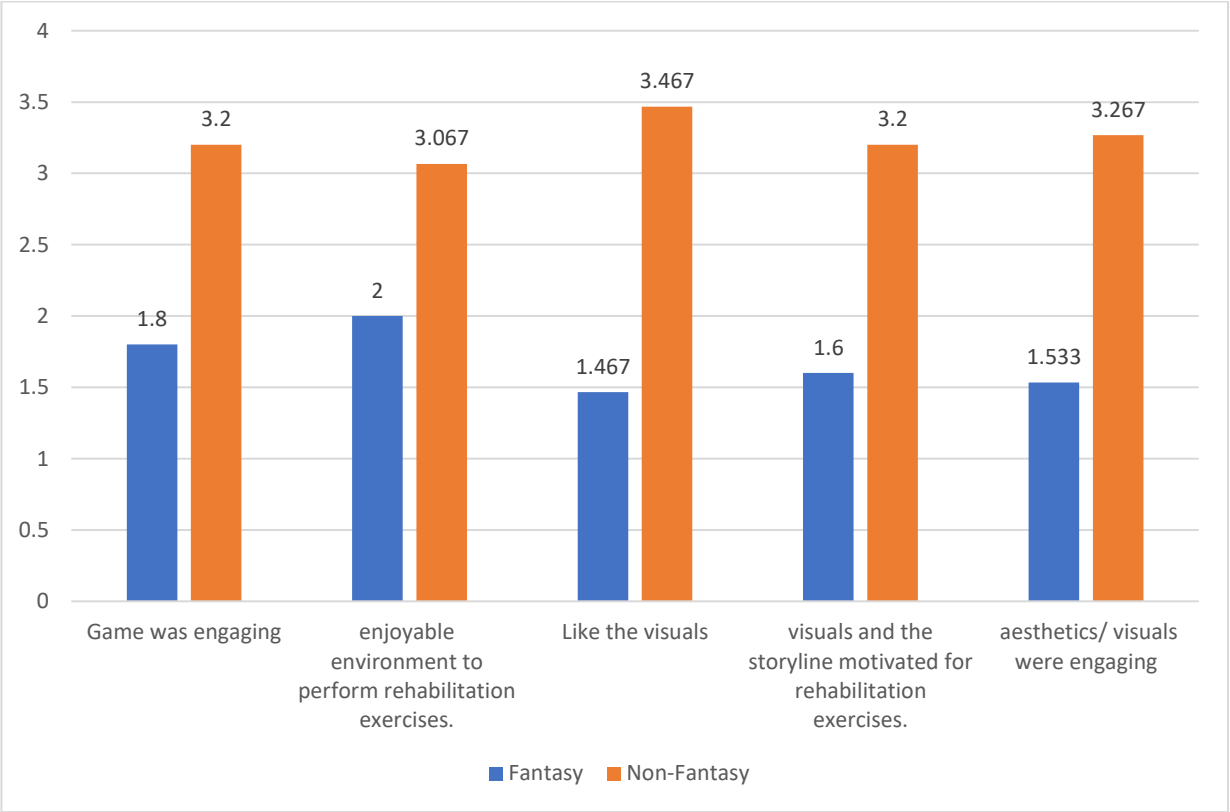


Figure 5.42: Visuals/Aesthetics

The mean value results of the final theme of this study, visuals and aesthetics, were shown in Figure 5.42. Five questions were part of this theme. The data for both versions of these five questions yield the same type of interpretation, as evident in the individual results. The answers to four questions (the game was engaging, the player liked the game's visuals, the visuals and storyline motivated the player to participate in rehabilitation exercises, and the game's aesthetics were engaging) for the fantasy version were in the strongly agree range. One question was whether this game provides an enjoyable environment for performing rehabilitation exercises, which was in the agreeable range.

The non-fantasy version data for four questions (the game was engaging, the visuals and storyline motivated the player to perform rehabilitation exercises, the game's aesthetics are engaging, and the game provides an enjoyable environment for rehabilitation exercises) were in the neutral range.

However, the data is closer to the end of the range, and the standard deviation can help here to determine how much the data varies. While the last question was whether the player liked the game's visuals, participants disagreed with this statement.

The data on this theme was different in both versions. The data show that participants agreed that the visuals and aesthetics of the fantasy version motivated them to exercise. In contrast, the data for the non-fantasy version indicate that participants' responses were neutral.

- **Standard deviation**

The data in the mean value tells the researcher about the average of the data. The mean value of the data supported the fantasy version, while the non-fantasy version yielded neutral results. The standard deviation can now help show that both datasets were close to the mean value or dispersed across the entire range of the data variance. It will ensure the results by confirming how much data was spread from the mean value.

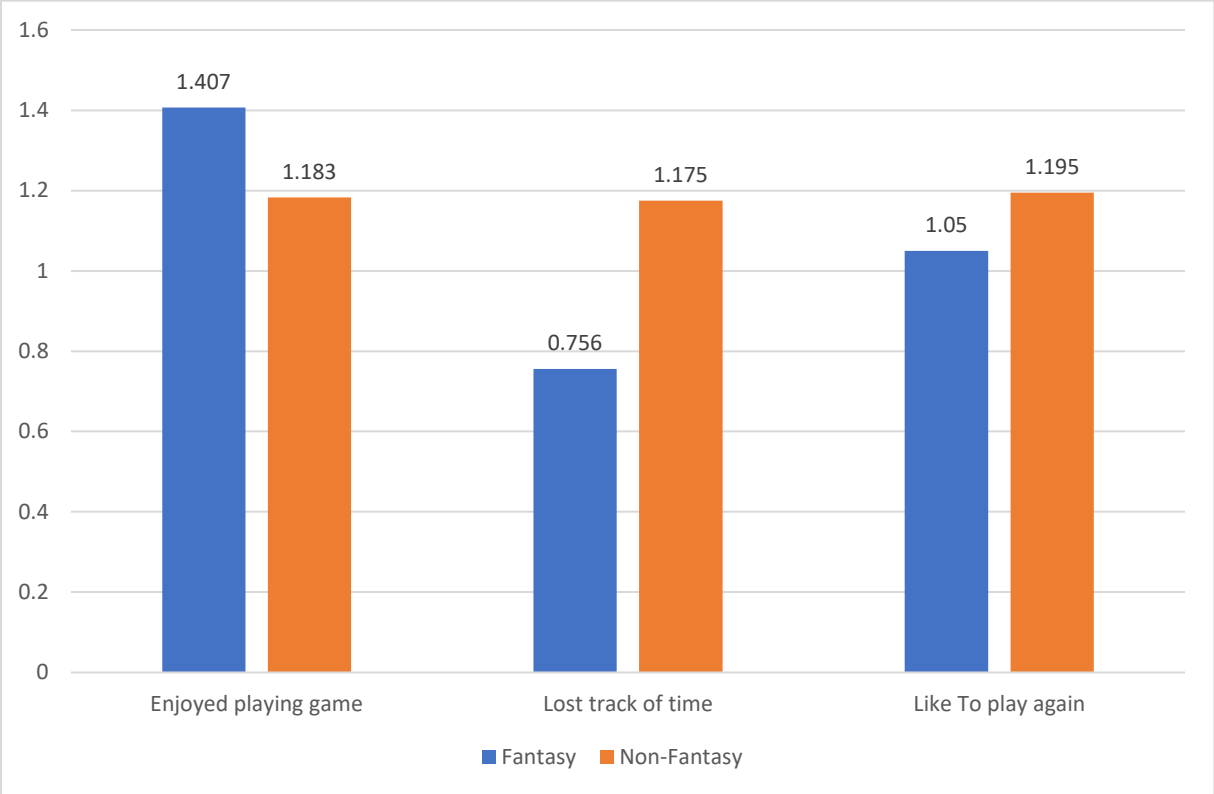


Figure 5.43: Enjoyment/Interest

In the theme of enjoyment/interest, the standard deviation of the data for question one of the fantasy versions was 1.407 units away from the mean, while for the non-fantasy version, it was 1.183. This shows that 1.407 had a greater dispersion of variability among the observations than 1.183. Data with lower dispersion was considered better than data with higher dispersion. This suggests that the non-fantasy version was superior to the fantasy version.

In case of a question about whether the game was engaging enough that the player loses track of time, the data of the fantasy version was way less dispersed than the non-fantasy version. It shows that for the second question, the data of the fantasy version was better than that of the non-fantasy version.

In the case of the third question, players expressed a desire to play the game again. The datasets of both versions demonstrate again that the fantasy version's datasets had a better data range than those of the non-fantasy version, as the fantasy version's dataset was less spread from the mean value than that of the non-fantasy version. Here, the dataset revealed that the mean value of the non-fantasy version was in agreement for two questions (enjoyed playing the game and lost track of time), while neutral for one question (liked to play again). For the fantasy version, the mean value was similar for all three questions when compared on both the basis of standard deviation and mean. The result of the fantasy version was better in one case, while it was equivalent in the other two cases.

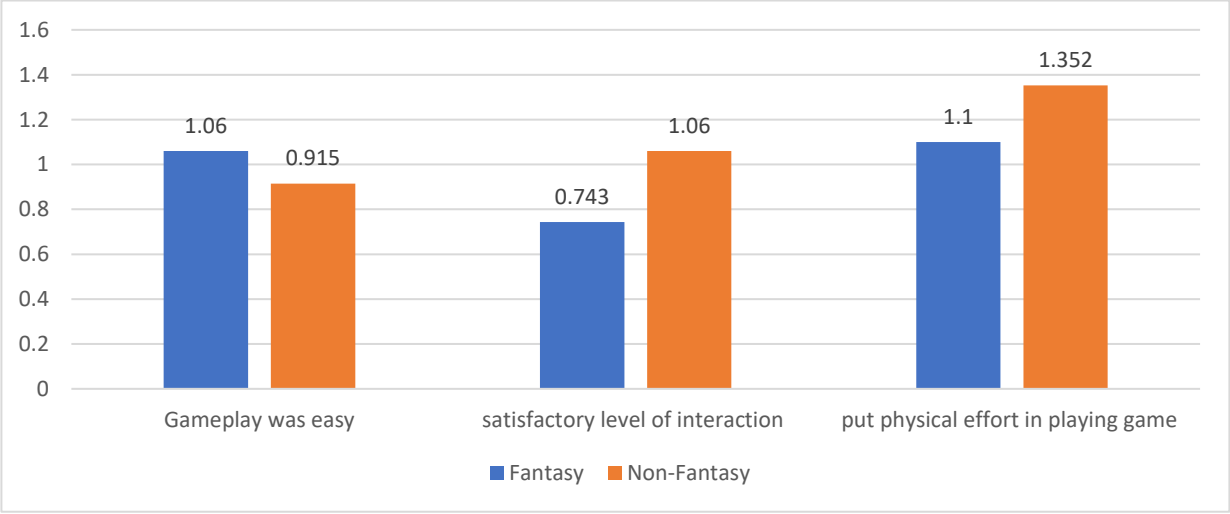


Figure 5.44: Functionality/Effort

The next theme focused on the game's functionality and effort. As mentioned earlier, the functionality of both versions of the game was similar, indicating that both versions required the same amount of physical effort to play.

The mean value of the datasets also indicates that they fall within the range of agreement for both versions of the game. The standard deviation of the fantasy version for question one was more than the standard deviation of the non-fantasy version, which makes the non-fantasy version of the data better than the fantasy version. In the rest of the two questions, the standard deviation data of the fantasy version was better than that of the non-fantasy version.

This data variation indicated that the values were slightly different in all the questions; however, the output of the data was consistent across all three questions.

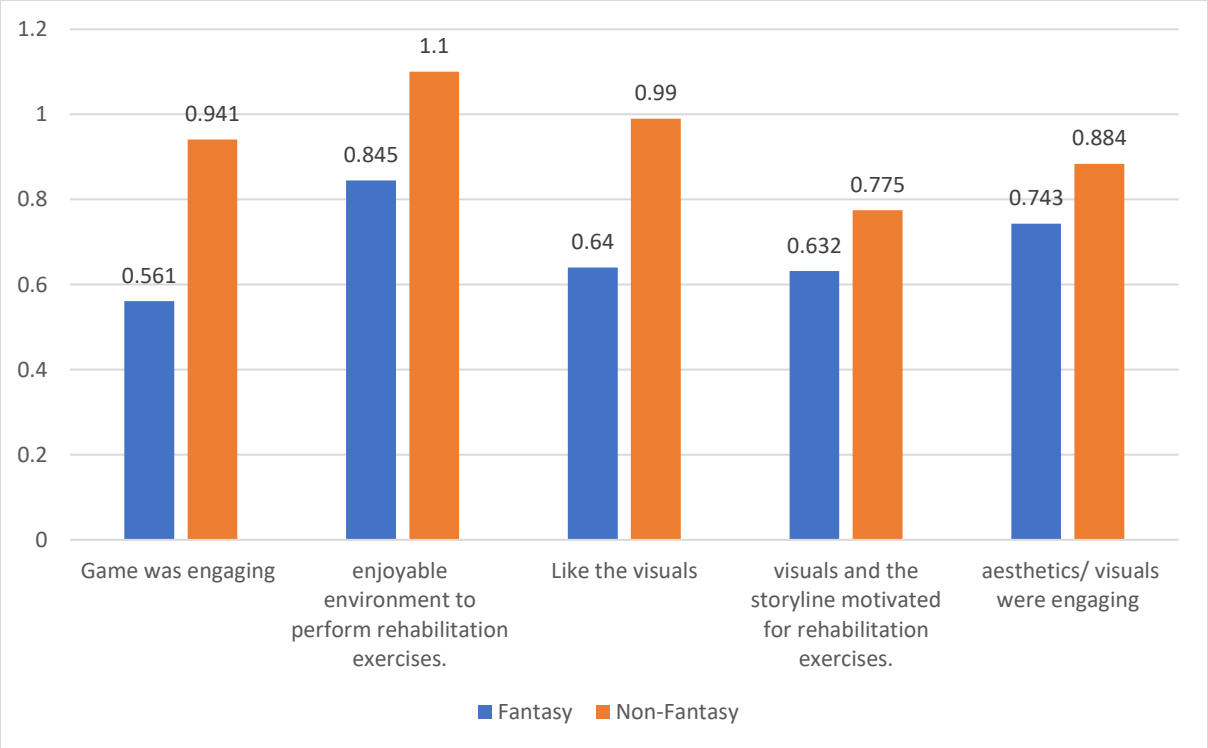


Figure 5.45: Visuals/Aesthetics

The final theme centred on the game's visuals and aesthetics. Here, a clear shift in data was visible. All the data for the fantasy version was closer to the mean value than the data for the non-fantasy version. If the data of each question was compared separately, it can be concluded from the values

that the data for both datasets, except for one question, was below the limit of one. This illustrates that all the data were close to the mean value and not scattered, and the data results can be trusted.

The statistical analysis, using mean value and standard deviation, provided evidence that the dataset of the fantasy version was more efficacious than that of the non-fantasy version. This brings researcher to the fact that data for questions displayed below confirm that fantasy-based storyline, visuals and atmosphere were more engaging than non-fantasy version: Player like visuals of the game, visuals and storyline are motivating enough to engage participants to do physical rehabilitation exercises, aesthetics and visuals of the game were engaging, and the game had an engaging environment- are displaying that fantasy-based storyline, visuals and atmosphere were more engaging than non-fantasy version.

- **T-Test**

The answer to research questions (see 1.5) were already found by the mean value and standard deviation. However, the researcher considered performing another test to validate the results. For this statistical method, a T-test or an ANOVA test was intended to be used. A t-test was used to compare data between two datasets, while ANOVA is a test to compare results between three or more datasets. In this research, a comparison between two datasets was required, for which the T-test was considered the most suitable method.

In this study, the independent sample two-tailed t-test was first performed to determine whether the dataset showed any significant difference. The test results indicated a difference between the two datasets, which were not similar to each other; therefore, a one-tailed test was performed. A one-tailed t-test was conducted on each dataset to determine which dataset was better.

- **Two-tailed T-test**

Firstly, the independent sample two-tailed t-test was applied to the datasets to confirm whether the null hypothesis was true or the alternative hypothesis was valid for all these questions. In general terms, the researcher sought to answer the research question. To determine the results of this study, eleven hypotheses were created. These hypotheses were also grouped into three themes, which were used to calculate the mean value and standard deviation. All these hypotheses were shared below, preceded with the information of results:

1. Enjoyment/interest

Null hypothesis: The player did not enjoy playing this game

Hypothesis: The player enjoyed playing this game

Null hypothesis: The player did not lose track of time while playing this game

Hypothesis: The player lost track of time while playing this game

Null hypothesis: The player would not like to play this game again

Hypothesis: The player would like to play this game again

2. Functionality/effort

Null hypothesis: The gameplay was not easy

Hypothesis: The gameplay was easy

Null hypothesis: The game did not have a satisfactory level of interaction

Hypothesis: The game had a satisfactory level of interaction

Null hypothesis: The player was not required to put physical effort into playing this game

Hypothesis: The player was required to put physical effort into playing this game

3. Visuals/aesthetic

Null hypothesis: The game was not engaging enough that the player felt like a part of the game

Hypothesis: The game was engaging enough that the player felt like part of the game

Null hypothesis: This game did not provide a player with an enjoyable environment in which to perform rehabilitation exercises.

Hypothesis: This game provided the player with an enjoyable environment to perform rehabilitation exercises.

Null hypothesis: The player did not like the visuals of the game

Hypothesis: The player liked the visuals of the game

Null hypothesis: The visuals and the storyline of this game did not provide the player with motivation for rehabilitation exercises.

Hypothesis: The visuals and the storyline of this game provided the player with motivation for rehabilitation exercises.

Null hypothesis: The aesthetics/ visuals of the game were not engaging

Hypothesis: The aesthetics/ visuals of the game were engaging

Result of two-tail T-test: After defining all these hypotheses, a two tails t-test was implemented on the datasets. The t-statistic value was calculated for each hypothesis, and then it was compared with the critical value. The threshold value of 0.05 was used. The critical value was calculated based on this threshold from the t-test chart.

Threshold: 0.05, Critical Value: 2.048

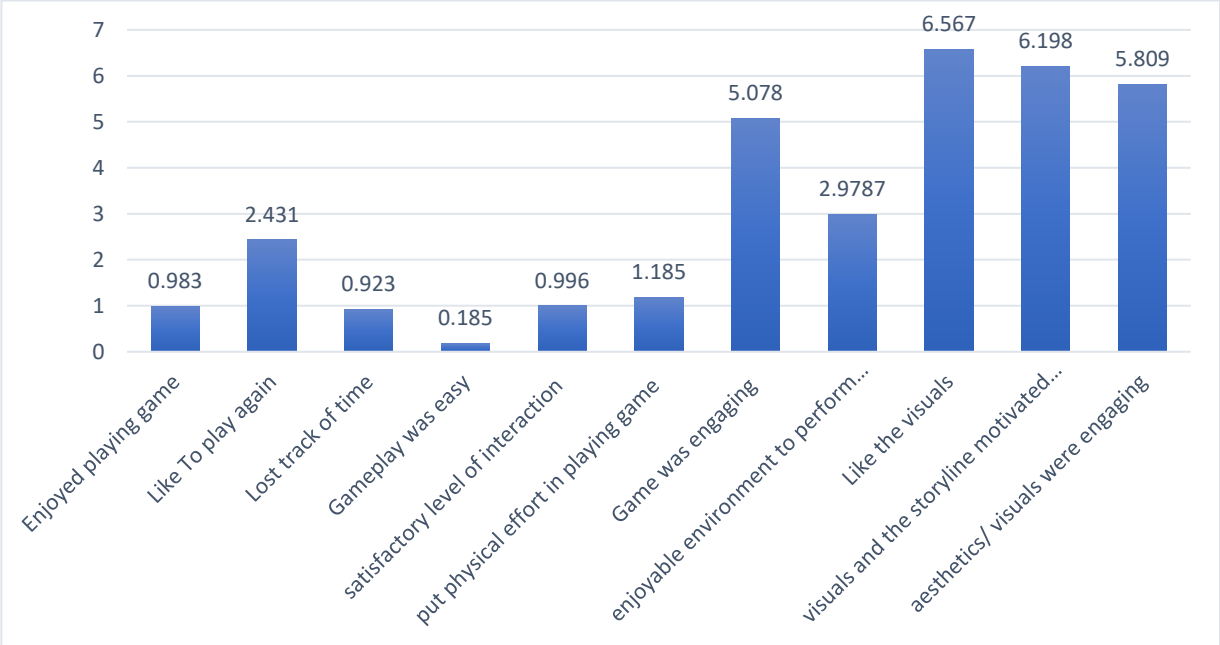


Figure 5.46: T-stat values

The value of the T-test was then compared with the critical value of 2.048. If the value of the t-test was larger than the critical value, then the hypothesis was true. However, if the value of the t-stat was smaller than the critical value, then the null hypothesis was true.

As can be seen, the value for t-stat was greater than the critical value in the following cases:

Theme: Enjoyment/interest

a. The player likes to play this game to gain

Theme: Visuals/aesthetic

b. The game was engaging enough that the player felt like part of the game

c. This game provided the player with an enjoyable environment to perform rehabilitation exercises.

d. The player appreciated the game's visuals.

e. The visuals and the storyline of this game provided the player with motivation for rehabilitation exercises.

f. The game's aesthetics and visuals were engaging.

The value of the t-stat was smaller than the critical value for the following cases, which makes the null hypothesis true for the following cases:

Theme: Enjoyment/interest

a. The player did not enjoy playing this game

b. The player did not lose track of time while playing this game

Theme: Functionality/effort

c. Players need to put physical effort into the game

d. The gameplay was not easy

e. The game did not have a satisfactory level of interaction

This proves the point that fantasy and non-fantasy versions differ in all cases where the hypothesis was accepted and the null hypothesis was rejected. The next step was to determine which of these versions is better. To find the answer to this question, a one-tailed T-test was performed on all these questions where the hypothesis was approved.

- **One-tail T-test**

For all the hypotheses mentioned above, a one-tailed t-test was performed. The t-stat value was calculated. Again, the threshold of 0.05 was taken. For a threshold of 0.05, the critical value is 1.761. Again, the t-stat value was compared with the critical value to confirm whether the null hypothesis was true or not.

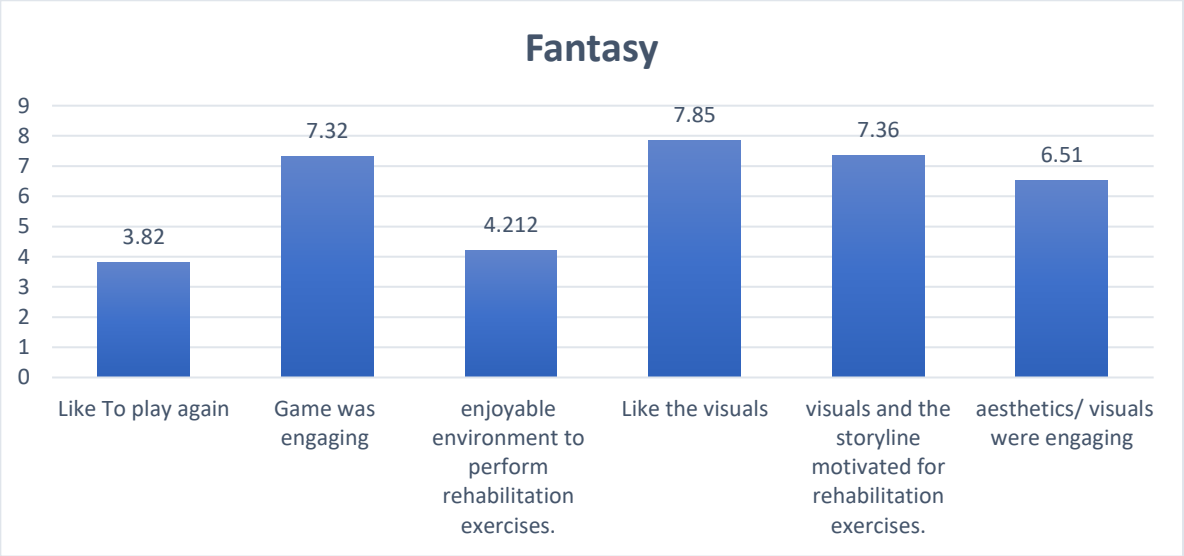


Figure 5.47: One-tail T-stat values of fantasy version data

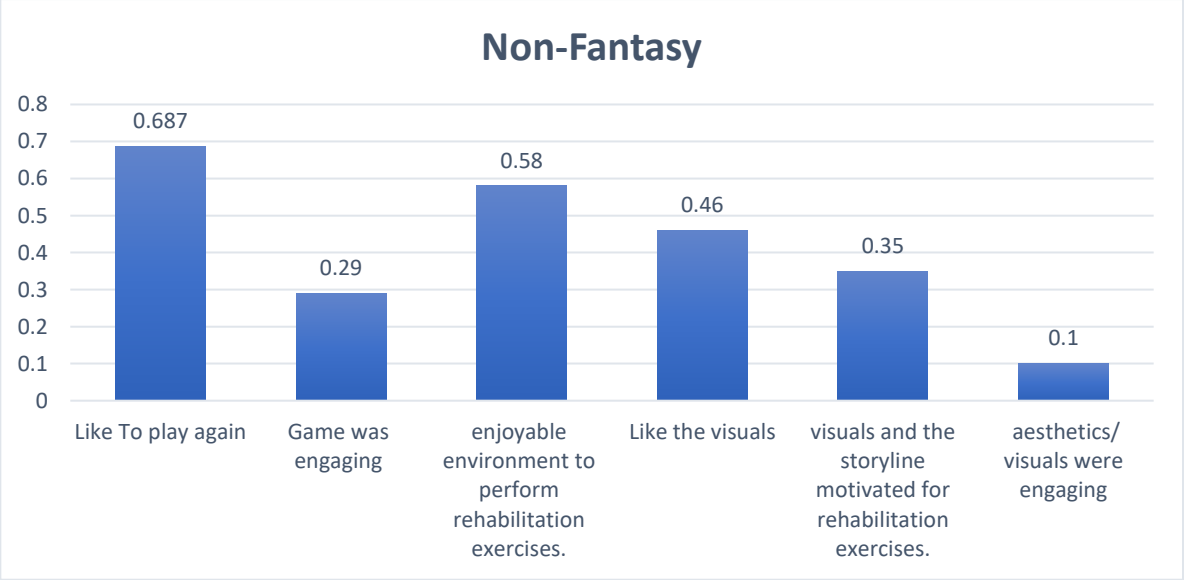


Figure 5.48: One-tail T-stat values of non-fantasy version data

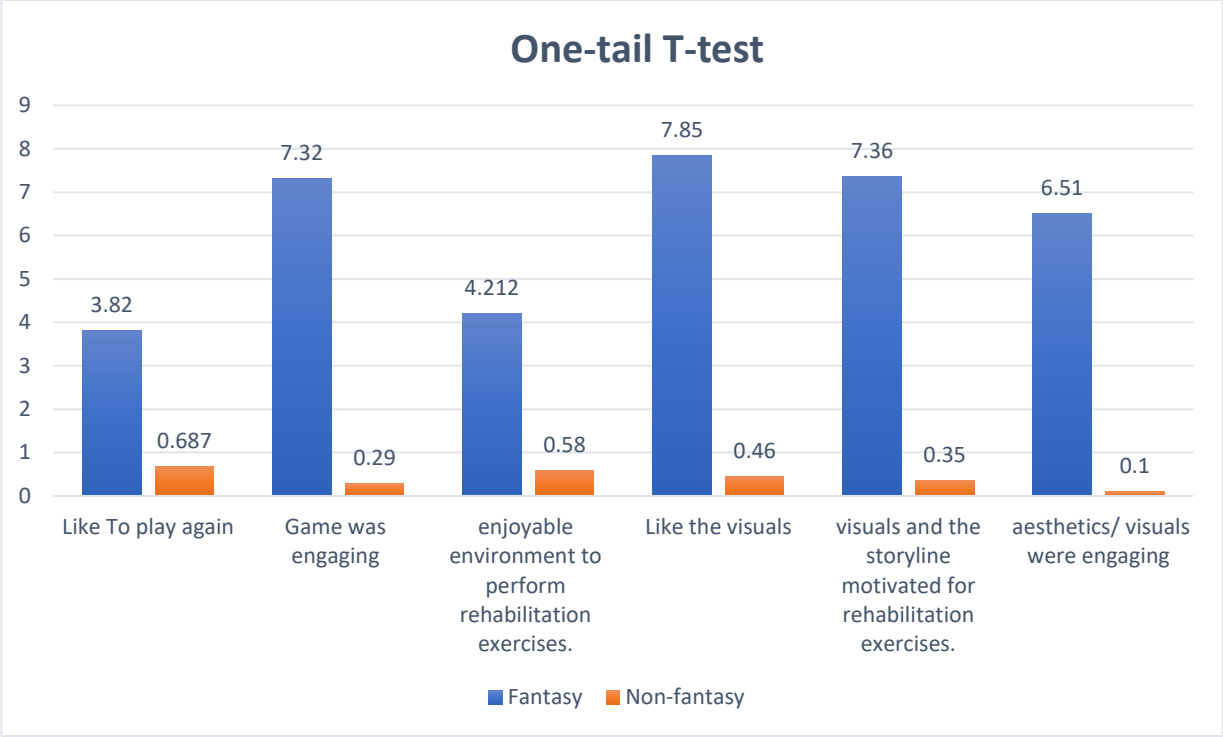


Figure 5.49: One-tail T-stat values of fantasy and non-fantasy versions

When the t-stat value of the fantasy version was compared with the critical value, it demonstrated that the null hypothesis was rejected for the queries. When the t-stat value of the non-fantasy version was compared with the critical value, all the null hypotheses were accepted. This analysis shows that the fantasy version data is more significant than the non-fantasy version. The aesthetics of the fantasy version capture the audience's attention and engage them to perform rehabilitation exercises.

5.3.2.4 Qualitative data analysis

After studying the data gathered from quantitative analysis, the next part focuses on data generated in qualitative research. The purpose of this qualitative research was to determine how the game can be improved for both versions. To determine the improvement required in game two, open-ended questions were added to this part of the questionnaire, and participants were asked to provide feedback about the game. To accomplish the purpose of the research, the researcher analysed the data by creating different themes under these questions:

A. What improvements can be made in the game?

B. If I play this game again, what would I like to add?

Themes were created to analyse the responses provided by the participants. The same themes are used for data analysis of both versions of the game. Using the same themes for both versions can result in insufficient data under some themes for one version and excessive data for the other version.

To reach the purpose of improvement in the prototype, these two questions were asked separately. However, both questions were linked to each other as their primary objective was improvement in the game. The reason for checking the same thing in two different ways was that many participants skipped the first question or could relate to the second question more directly, due to the direct interaction about improving prototypes for personal use.

The researcher first examined the fantasy version and then the non-fantasy version. The answers to the first and second questions were provided separately, and then the analysis of these answers was conducted. The following themes were being followed while answering these questions:

Thematic Category	**Main theme**	**Sub Themes**
A	Visual/Graphics	Colours Environment Figures
B	Audio	Soundtrack Sound effect Voice over
C	Functionality/ Interaction	UI VR Task/ goals Networking
D	Exercises	Workout/Exercise Instruction with exercises

Table 5.3: Themes identification

Fantasy Version

A. Under these themes, the feedback received for question one was as follows:

a. Visual/graphics

The sub-themes of colour, environment, and figures were addressed in this part. Participants like to see more interesting elements in the game with more colours and cheerful playgrounds. One participant also added to see the real figure and a more realistic background.

In the fantasy version under this theme, only three participants requested to make improvements. One response focused on improvements in visuals and aesthetic attributes, while the other two replies were linked to colour options. When researchers examined this particular sub-theme of colour, the point appeared to be challenging to determine. As one participant suggested, the addition of colour is a good idea, while another participant was not in favour of bright colours.

b. Audio

For audio, all the replies by the participants lead to the sub-theme of the soundtrack. Participants were looking for the addition of nice music, which was linked to the environment in which they were.

c. Functionality/interaction

In this theme, UI, VR, and task/goal sub-themes were addressed. Participants would like this game to be easier with clear controller instructions. In VR, participants again requested a wider calibration circle. In the task and goal sub-themes, participants preferred to have more tasks and more interactive objects to deal with.

Maximum suggestions were received under this theme, which fell into various sub-themes, including UI and VR. In UI, participants were primarily concerned with widgets and clear instructions. In VR, participants mainly sought a wider field of view for calibration, improvements in controller methods, and fewer game glitches.

d. Exercises

In this theme, sub-themes of instruction for exercises were mainly focused. The instructions for exercises were thought to work when the exercises were being executed, and if the participants move, then the instructions should also move with head movement.

B. The next question asked participants about the improvements they would like to see if they were to play this game again. The participants' replies were categorised under the same theme shared in Table 5.3 which were as follows:

a. Visual/graphics

b. Functionality/interaction

c. Exercises

In this theme, participants focused on more engaging workout options and more exercise options.

Non-fantasy version

Answers to both questions for the non-fantasy version using the same theme are shared below.

A. In response to question one, participants shared their views with respect to all themes and sub-themes as follows:

a. Visual/graphics

The participants like to see better visuals. They prefer an enticing environment that is close to nature and more realistic. In that respect, the replies of the two participants are as follows:

"If it were in a place such as the beach or forest"

"possibly a more natural environment. It already reminded me of a park, so some trees, etc, would be nice."

With these replies, it can be considered that participants are already expecting a natural scene in a non-fantasy place.

In the sub-theme of figures, participants want to have animated characters.

b. Audio

In the audio theme, the sub-theme of voice-over in videos was discussed to create a more friendly and non-robotic one.

c. Functionality/interaction

In this theme, most of the points highlighted have already been discussed in the fantasy version. In this sub-theme of UI, VR and task/goal are discussed. In UI, participants discussed the excessive number of buttons and the need for a more intuitive layout. For VR, the boundary size, security measures and tracker are discussed. In the task/goal, the addition of new missions and rewards is suggested. Another important sub-theme of networking was also addressed in this question.

d. Exercises

Here, under the sub-theme of the workout, the requirement for an avatar to guide the player was suggested.

B. After replying to the first question, the response to the second question is as follows:

a. Visual/graphics

In this theme, the sub-theme of colours, environment and figures was discussed by participants. Colours and better visuals were talked about. Participants suggested a natural look and environment. Figures to interact with the scenery in the background were also proposed.

b. Audio

In this theme, the sub-theme of the soundtrack, participants advocated for background music to be linked to the background. The sound effects and voiceover were also suggested, based on the completion of the exercises.

One participant suggested that on completion of the exercise, the following messages can be given "Well done, Good job".

c. Functionality/interaction

In this theme, the following sub-themes are discussed: UI, VR, Tasks/goals, and networking. In the game in UI, one participant suggested the CBT menu. Systematic treatment was also considered by giving proper guidance in UI. More levels were wished by participants. In VR, interactive mentors or assistants were thought to help the patients to do exercises. In tasks/goals, passing through between modes and levels could be a nice idea. In networking, social interaction was expected by meeting other users or communities in a room.

d. Exercises

Under the sub-theme workout/exercise, participants wished to had more exercise opportunities in the form of a library. For instructions, videos or avatars could be helpful to show movement during the performance of the exercise.

5.4 Key findings

This part aims to interpret and contextualise the findings presented in the last two sections within the broader context of existing literature, while also bearing in mind research questions stated in the beginning of this document (see Section 1.5).

As described earlier, the evaluation of this study was performed in two phases. In phase 1, discussed in 5.2, the assessment of exercise implementation and usability evaluation was carried out. Detailed information was provided on how these exercises were correctly implemented and what changes were made on the design side of the game. It also lays the ground for how this prototype was helpful if done according to the instructions provided at the start of the game. Phase 2, discussed 5.3, shows how the evaluation of the fantasy version was made. It shares data about the fantasy and non-fantasy versions of this game that healthy volunteers generate after playing it. This data would verify whether the fantasy elements motivate the user to play the game. To understand the results of this study, data from the post-questionnaire filled by healthy volunteers after playing the game was categorised into three sub-themes. The themes deal with the enjoyment/interest in the game, functionality/effort required by the user, and the visual/aesthetic of the game. Questions linked to these three themes were placed randomly in the questionnaire to

get unbiased results. All these themes provide us with comprehensive data on the factors that keep users engaged with the game.

As mentioned, the word fantasy was not used in the questionnaires to keep the data unbiased. Help was drawn from words like visuals, aesthetics, and storyline to determine whether the fantasy elements (visuals and story) play a role in attracting users and keeping them engaged and motivated to perform rehabilitation exercises. The result shows that the visuals and storyline of the game were admired by the users. They enjoyed playing this game and were so immersed in it that they felt part of it. They like the visuals of the game. The environment of the game provides them with an enjoyable experience. The visuals and aesthetics were engaging and kept them motivated to exercise. They enjoy playing this game and would like to play the game again.

These key findings show that players enjoyed playing this game, and the fantasy element attracted them to perform rehabilitation exercises. However, answers to a few questions also lead us to improve the game in the future, such as players need easy gameplay and a satisfactory interaction level. This could be achieved by improving the game's UI/UX. The details of these key findings were discussed in detail below.

5.4.1 Theme-based findings

It was evident from the results that fantasy elements in serious games could increase the immersion level of the user and could play a significant role in motivating patients to do rehabilitation exercises. In section 5.3, three themes were created based on which all the data was analysed. Here again, for better understanding, these themes are followed to keep the findings in line with the results:

- **Visuals/aesthetic**

The subtheme of visual and aesthetic deals mainly with questions related to the fantasy elements of the game. The answers for the questions on this theme show that fantasy elements play a significant role in serious games for health purposes. The justification comes from statistical analysis using standard deviation, mean value, and T-test. The literature also proved that fantasy in serious games for education is positively linked to motivation and plays an essential role in engaging students, even in subjects they do not like (Zuo 2023)

This study shows that users consider fantasy elements to provide an enjoyable, engaging environment that motivates them to do rehabilitation exercises. A fantasy environment, linked to our life, provides closeness to that environment. It allows the users to feel connected to real life in the immersive world. During the design of this game, this factor was kept in mind. The environment was designed so that users feel immersed and feel themselves as part of that environment. The environment links the user to the game; in this game, the researcher tries to link the monotonous exercises to the user with the help of an enjoyable environment.

The game storyline is generated keeping the user's interest in mind. The users mostly like to travel in different environments, and this thought was kept in mind while writing the nine levels of the game (Appendix B). Here, only one level of the game is designed to verify the concept first. In that level, the game starts with the garden environment. Participants who played the non-fantasy version requested the garden or beach setting. As proved in another research study, the garden, forest, and beach are the places most preferred by participants (Jerdan 2021). It links them to the natural environment. This study implements the same rule by initialising the game with a garden setting. The rest of the game will also be made in the setting of a natural environment to link the user to the game.

Participants liked the aesthetic and visuals of the game and considers them engaging. This gives researcher the confidence that fantasy elements are merged in the game in such a blended format that users like them in that environment and do not feel that those elements are out of place.

- **Enjoyment/interest**

This sub-theme has data that provides a range of results. Most of the users, when asked if they would like to play this game again, responded positively to the fantasy version, while for the non-fantasy version, their response was not in favour of playing the game again. This was one indicator to suggest that a fantasy-based serious game can have a positive output. This is in line with the literature, which states that users like to play fantasy games more than non-fantasy games. This also validates the research objective, which provides the validity that the research is going in the right direction.

In the next option, the answers varied when the player replied that they did not enjoy the game and did not lose track of time while playing the game. When the answer is based on mean value results, the fantasy version shows that users agree to the fact that they enjoy the game and lose track of time; however, the T-test provides a different answer. This can be due to the fact that data from non-fantasy users has impacted the result. However, to find the actual reason for variation is out of the scope of this study.

- **Functionality/effort**

Three questions related to the function and effort required to play the game. Again, the T-test result varies from the mean value results in this context. There can be various reasons behind and work on them is out of scope.

However, the user provided various suggestions for improvement in the game, and a few amendments were considered while working with the user. These findings are shared in 0.

5.4.2 General Findings

The time taken to learn to play the game varied across participants (both medical experts and healthy volunteers). The instruction for playing the game was provided at the start of the game, plus researcher was watching them during the complete time of game play and helped them if required. Mostly, users who have already used VR quickly pick the ways to play the game. The users who played games using computer mouse, also learned the game buttons relatively quickly.

In the button's menu, which was considered to be easy to select, players could hardly select a level, which did not give any issue to the developer or researcher. At the start, it was considered a glitch in the system, but it was not fixed to provide the same experience to all the users. However, one player who had never used VR picked the point that it is not a glitch in the system; the user needs to keep the hand controller in the specific direction to select the buttons. Moving in the garden was quickly picked up by participants, exercise instructions were clear, and all the exercises were placed at different levels following the same guidelines. This makes it comfortable for the user that after completing one exercise, they can do the rest of the four exercises independently without much help. In the end, when asked about the suggestions for improvement in the game, a few users suggested improving the UI/UX, plus variation in exercises in the game, so that exercises can be

done independently without any help. This suggestion was taken into consideration and will try to be implemented in future work.

Another point that became evident while doing the evaluation phase of the study is that there is a need for guidelines for new users to adapt to the VR environment. That information is placed in the help menu; however, to reach the help menu, the user needs to know the ways to use VR. For future research, two steps can be taken. One can be to provide the guidelines to the user before the start of the game. Next can be to take that part of the help menu and place it at the beginning of the game so that the user can have the knowledge to play game. This will help new users to get used to the game.

In this study, the game was built and packaged for a VR headset. In the start, when medical experts evaluated the game, it was not packaged. However, in the next phase of evaluation, the game was packaged to keep the same experience for all users. In editor mode, changes can be made in Unreal, making the experience different for different users. So, the game was packaged and placed in the Oculus directory; however, it was not shifted to the headset. This allows researcher to see users' movement on laptops while users are immersed in a game. By doing this step, researcher can inform the user when they are stuck and help them move forward to the next stage. This step of keeping the game packaged in the Oculus directory on the computer will help to see what the user saw in the headset. It also guides the researcher about the game's actions and the user's reaction to each step of the game.

The usability evaluation of this prototype was carried out during the first user study. They tried their best to check the limits of this prototype. However, a few more limitations were identified during the healthy volunteer evaluation. Volunteers were of different human physiques, so when they were doing exercises, users who were more than average in height or size had their hands or body parts out of the circle created to do exercises. Due to this, some moments are not done as expected. In that respect, in future, a wider circle is expected by users to perform exercises.

There were various suggestions by the participants to increase the number of exercises. This suggestion was also given by a medical expert, who said that in the case of actual patients, users can have the option to increase or decrease the number of times they are required to perform exercises. This will help them to carry on exercises according to the suggestion of their

physiotherapist. Every patient has a different pain level, and some can do more movement than others. The minimum number of times the physiotherapist suggests these exercises is five; however, the actual number of exercises can be recommended on patient evaluation.

Participants also suggested variations in the exercise to have more freedom to pick the exercise. The medical experts also suggested adding more exercise options, as well as muscle-strengthening exercises, to the game. In this way, users can have more options for doing exercises. After doing the rehabilitation exercises, users are required to perform the strengthening exercises, so if they are part of this prototype, it will be easy for the users to do it in the home environment as well.

In this study, one point that was taken care of was to first go for a preliminary study, which means that this study is based on reviews by medical experts and healthy volunteers with a sample size which caters to all age groups of this study, plus the gender is also given importance. In previous studies (Jerdan 2021; Phelan et al. 2023), the experiments were mostly carried out directly on patients with small volunteer groups, which made it hard to know the actual results. It is also considered that a suitable number of participants will be recruited in the feasibility study and clinal study phase so that non-biased results can be achieved.

The impact of VR to keep users distracted from pain is already being studied and considered working. However, the studies mentioned stated that the research was carried out on a small sample, and the result can be more accurate if the sample size is big. This study is carried out on thirty participants (El-Kotob and Giangregorio 2018), which verifies that ideas are workable and can be taken to the next phase.

Previous studies on VR mentioned the need for comparison between non-immersion, semi-immersion, and fully immersive studies. This point was taken into consideration in this study, the fact that VR systems are immersive was already proven. The next point was to prove that fantasy in VR is engaging enough to keep the user motivated to do the rehabilitation exercises. To prove this fact, two different versions of VR games were created. One is based on a fantasy environment, while the other is based on a non-fantasy environment. However, the rest of the factors, like exercises and moments to reach those exercises, are kept the same in both environments.

The other thing that was taken care of in this study is that both versions use the same type of Oculus Quest. Games are even created on the same system with the same version of software to compare the games in a manner that no biased features can impact the effectiveness of the results.

One of the most important findings is that users wish to listen to music relevant to that environment. However, in this prototype, the sound of mediation was added, which can be used in the same manner in both versions of the prototype. As mentioned in the literature, natural sounds can play a vital role in reducing stress and making people comfortable in the environment. (Song et al. 2023). The meditation sound creates a relaxing atmosphere for the user.

One participant suggested adding more colours, while the other said they felt dizzy due to the colours. However, dizziness can be due to VR settings as well. People who use VR for the first time feel slightly dizzy and have headaches. For one participant, this much speed for movement gives them a dizzy effect, while for another participant, the suggestion was to increase the speed of moving in the game as the research shows that the movement in VR needs to be kept above 60fps for smooth movement while above 90 for less motion sickness (Wang et al. 2023b) . This rule is being followed while designing this game. In risk assessment, it was also made sure that in case of any emergency, medical professional/ first aid is near the venue of experiments. In the future, this rule will again be followed, and other checks will be ensured to keep people safe from dizziness, motion sickness, and other similar issues.

The results indicate that the visual and storyline of the fantasy version are more significant in capturing users' attention than the non-fantasy version. One fantastic point was that in the fantasy version, one participant suggested having real figures, while in the non-fantasy version, participants wished to see the animated character in mind.

Another suggestion was to add more interactive objects, like the ball, to throw in the well. In the future, an attempt will be made to add more interactive stuff to the game. However, implementing every suggestion is not always possible; the best try will still be made to do as much as possible.

5.5 Summary

Creating a game that is perfect for everyone sounds impossible. However, for this research on the creation of this game, the proactive approach is considered. The reason for taking this approach is the importance of medical experts in this study (see 2.6.1). Medical experts have the best knowledge of their field, and they know the reason for using the game for the exact purpose; their views of this game are taken positively. The changes suggested by them were tried to be implemented in the best manner. Amending things that are recurring for many users would improve the game's usability.

Before requesting the healthy volunteers, sixteen changes were implemented in the prototypes on the suggestion of medical experts. Making these changes at this stage saves the end user from a lot of discomfort. This does not mean that further changes would not be required. However, for the preliminary study for the implementation of these exercises in the best manner, all changes are tried to be made in the best manner.

After the implementation of these changes, medical experts were requested to try this game again. The experts, after playing the game again, give the go-ahead for the next phase. This provides the confidence that exercises are correctly implemented in a VR atmosphere. The game is then tested on healthy volunteers. These prototypes are used to verify which prototype can keep users engaged with the game and motivated to do the exercises.

Here, step one of the evaluation phase completed. Completing this stage ensures that exercises are properly implemented and cannot harm the user until the user follows all the instructions provided in the manual. For the preliminary study, this part of the evaluation by medical experts proves that the game is medically satisfactory. Now, this game's fantasy part was evaluated by healthy volunteers to confirm the fact that fantasy is immersive and engaging enough to keep the user motivated to play the game. Overall, this chapter provides information about the outcomes that emerge by seeing participants' replies. Quantitative data assess the role of fantasy aspects in serious games dealing with physical rehabilitation. While qualitative data provide subjective information about the improvements in the game. The next chapter will have discussion and conclude this research.

6 Discussion and conclusion

6.1 Overview

This chapter serves as a comprehensive summary of the study, highlighting the significant findings and research contributions of this interdisciplinary study. It also underscores the critical need for further research in this area, discussing the limitations and proposing future research ideas. The importance of this research lies in its potential to bring a change in physical rehabilitation by enhancing user engagement and motivation for rehabilitation exercises, thereby improving the effectiveness of physical rehabilitation. This potential for significant impact inspires further exploration in this field.

6.2 Reflection

This study explored the use of fantasy, particularly fantasy elements, in serious games for physical rehabilitation of back pain**.** Drawing on existing literature, in this study, I tried to find ways to integrate the fantasy elements in serious games for health, specifically rehabilitation, that can enhance user engagement and motivate them to perform rehabilitation exercises. The literature highlights the growing interest in this field. It shows that VR-based serious games have several advantages: they are immersive, engaging, and provide a feeling of escape from pain. However, the integration of fantasy in serious games is explored for education, but its impact on health is still unexplored.

This study which aimed to assess the impact of fantasy in serious games for physical rehabilitation, used not only literature review, but also input from experts through empirical research. The research conducted in this study serves to validate the potential of fantasy elements in serious games to enhance engagement with physical rehabilitation. Fantasy elements can create an immersive, enjoyable and motivating experience that encourages the user to perform rehabilitation exercises.

As mentioned previously, this study is a preliminary study. The data presented in this study is derived from an analysis based on medical experts and healthy volunteers. This study is proven by

medical experts for exercises, and fantasy elements are evaluated by healthy volunteers of the target group 18-50.

The primary purpose of this research is to explore how fantasy elements can enhance user motivation and disrupt the monotony of exercise routines for physical rehabilitation. This purpose is achieved by incorporating various fantasy elements into a serious game to assess their impact on user motivation. Another aim that arises during this exploration process is to determine the difference between traditional rehabilitation gaming methods and those that incorporate fantasy elements. Existing serious games were found to have different aims or not focusing on the back pain exercises and, therefore, were not suitable as a starting point. The solution to this is achieved by creating a prototype with two different prototypes of the same game, one with fantasy elements and the other without fantasy elements. The game mechanics of both versions are kept the same to assess the impact of fantasy elements on user experience.

The final aim of this study is to explore how fantasy elements can influence the overall user experience, particularly in terms of engagement and immersion. The same prototype is used in experiments and the results achieved by the user feedback provide the way to achieve this aim.

The results of this research proved the hypothesis that using fantasy elements in serious games can engage users and motivate them to perform exercises. The feedback from users can be summarised into the following points:

1. The visuals and storyline of the game were engaging. The visuals were noted to be immersive enough to involve the user in performing the exercises.
2. The environment motivates the user to do rehabilitation exercises.
3. Users are likely to play the game again.

6.3 Implications for practice

In the past, research has been carried out that shows that VR intervention is used for pain distraction and reduces stress and anxiety effects (Indovina et al. 2018). Research done on VR and games shows that medical experts use it to practice pain distraction techniques (Phelan et al. 2023). In contrast, the use of fantasy in engagement is noteworthy (Zuo 2023). These factors provide a

ground for this research, and by getting the results, it can be worth saying that a combination of fantasy, VR and serious games will be compelling for physical rehabilitation. This whole research provides a new insight into the research by showing the relationship between serious games, VR, fantasy elements and physical rehabilitation. It will open a new door for researchers and provide a new side to the industry.

Researchers can use this data to explore the elements of fantasy that can influence game engagement, especially in physical rehabilitation. The role of game mechanics and their impact on the user's experience can be understood. Game developers can use this information to understand the game design while designing the games for health purposes. Health professionals can consider the impact that serious games and fantasy can bring to the state of the art, to employ more fantasy-themed serious games in their practice.

These findings can provide a way for more engaging rehabilitation methods. Games, HCI and medical experts can use this technology to cater to physiotherapy requirements. During the making of this physiotherapy routine, they can also keep patients' physical and psychological needs in view. This can lead to options that can make it a customised routine for every patient.

This study will provide an innovative approach to improve the quality of life for patients requiring physiotherapy, especially patients with back pain. VR-based serious games using fantasy elements can encourage patients to do exercises and motivate them to complete the rehabilitation time.

The findings of this study suggest that incorporating fantasy elements into serious games can be a highly effective strategy for improving patient engagement and outcomes in physical rehabilitation. For practitioners, this means that designing rehabilitation programs that include narrative-driven, immersive experiences may lead to better patient adherence and recovery rates. However, it is essential to tailor the game according to the findings to maximise the benefits.

6.4 Study contribution

Starting with the strengths of this study, this research made an important contribution to the field. It has opened a new path for research by demonstrating how effective fantasy can be in serious games for health. Previously, research showed that fantasy is being used by many users for

entertainment purposes, while its usage in serious games is only being researched in education, especially children's education. It has made an important contribution by creating a link between fantasy, games, health, and VR. Previously, research found that only the use of VR intervention distracts patients from pain. This research shows that digital creative practice can be used in the health sector to keep patients motivated.

Another positive point that this research provides is the reason for using each fantasy element. This will provide a way for the user to understand this research. If some researcher carries on this research, they will have a complete layout of which fantasy elements are used and the reason and logic behind using those elements.

In this study, one major point that came into view is that fantasy is also an engaging factor in rehabilitation games. Previously, it was studied (Lee 2015; Zuo 2023) that fantasy plays a prominent role in an educational game where the target audience is of early age, or fantasy games are liked for entertainment purposes by the young and middle age group; however, its impact on the rehabilitation process was previously unknown.

While the results are promising, this study has several limitations. The study was limited to short-term outcomes, and the long-term effects of using fantasy in serious games for rehabilitation remain unclear. As it was a preliminary study, the experiment with each participant was carried out in the short term. For future phases of research, long-term study will be beneficial in evaluating the sustained effect of fantasy. Long-term studies will also be helpful in evaluating the impact of these exercises on the user's health.

The music was not relevant to the game prototype. This point is felt by many users; keeping the user's suggestion in mind, the future version will have the music exactly according to the scene. One point proven by this study that the fantasy version is better than the non-fantasy version. So, future studies will focus on how patients take this intervention and its long-term impact on keeping the user engaged and motivated to play the game. In that respect, it will be easy to implement the music according to the environment designed for that specific game.

6.5 Limitations

The overall research design was according to the needs of the user. However, while considering the literature, the thing that caught researcher attention is that most of the research related to health is usually carried out in clinical settings one expert from that domain is hired to be a part of this research phase. This research was carried out by the researcher only; however, for future research in which patients will be involved, it is recommended to have a physiotherapist in the venue to avoid any difficult situation.

Another major limitation faced during this study was the venue for experiments. As for conducting each experiment, a different venue was allocated. The rooms are designed for conducting classes or seminars. Every time, before the start of experiments, things are required to be moved to make room for experiments. Which takes the time of the researcher, plus setting up all the experiment material like video camera, system, etc takes time. This whole step was possible as experiments are short-term based; however, in future research, which is considered to be a long-term study, a full-time experiment venue will be required.

Few participants taller than 6 feet or facing obesity issues could not perform exercises properly. The movement out of the circle of VR, makes it difficult for them to perform those exercises. This point will also be considered in future studies.

This study was based in the area of Bournemouth, UK, which makes the results specific to a location. Findings may not be presenting the whole population. To enhance the validity of an idea, a more diverse and broader sample from different demographic locations can be taken in future research.

While conducting the study, a need for a designer and developer was considered. As the research was not funded, for design purposes, a team of students was taken on board to design the game, and a development professional was hired from the market. The students designing the game were given this task as a course project. A few students in the group took it seriously, while others were not very interested in it. In the end, of course, the project handed over was not in its expected form, so many changes were carried out by the researcher. The next question arises when the prototype

needs updates. The students' submissions were made, and they were no longer interested in working on this project. So, the researcher did all the refinement work on the design side.

The next step was the development of the prototype. For hiring a developer, funding was issued by the Bournemouth University research fund. The developer was a professional; however, sending the stuff to the developer and getting it back on time was an issue. In future research, hiring a research assistant is expected to be helpful.

When this research started, it was considered that the link between the headset and the game would be through a wireless connection. When the initial work was carried out, it was working fine. However, when the experiment started, the wireless connection did not work properly, which might be due to different Wi-Fi availability at the experiment venue. Due to this obstacle, all the experiments were conducted with the cable connection, which hindered the participant's movement and might have slightly affected the results.

Another obstacle was hiring volunteers from inside and outside the university. As most of the studies carried out by researchers are paid studies, or credit is given to them in their course. In this study, many participants were interested in the start, however, as no credit option was given on any account, that made the participants lose interest in participating in study. This is one of the big reasons many people registered to participate in this study, but did not appear at the last moment and did not inform the researcher about the reason for not showing up.

Future research should address these obstacles.

6.6 Future work and practical applications

This study's future is promising. It opens a great opening for future research. Below are a few suggestions for carrying this research forward.

1. This study can be developed to be personalised for the patient's needs. Exercises can be adjusted according to the pain level and preference of the user. In future, this game can also add the feature of an avatar or user mate who can guide the user on what to do and how to do it. This option will make the game more relatable to the user, and the user will be more comfortable to play this game.

2. At this stage, the study is only focused on back pain. The back is the area where it's difficult to implement exercises due to sensor obstacles. In future, research can be carried out on back exercises as well as different parts of the body. The same study is suggested by physiotherapists for muscle strength exercises. This idea can also be explored in other rehabilitation areas like stroke recovery, post-surgical rehabilitation, etc.
3. As suggested by participants, a library of exercises can be created where users can pick the exercises with the help of a physiotherapist and can perform those exercises in a clinic or at home.
4. This research was focused on the Bournemouth area. Future research on rehabilitation can be extended to other parts of the country as well as other parts of the world.
5. At this stage, only one game is created to view the difference. In the future, stories and myths originating from different parts of the world can create different fantasy worlds. This will give the user more freedom to explore different fantasies of their choice. Different environments can attract more users and engage them to perform the exercises.
6. In this study, only a few visual fantasy elements are worked on. The list of elements has so much more to explore (Schell, 2008). In future research, the effectiveness of fantasy elements from visual and other perspectives can be taken into consideration.
7. As a prototype, motion capture of the user was not mandatory. However, in future studies, motion sensors will be required for a comprehensive monitoring system to capture the patient's actual motion and responses. This will provide data to healthcare providers, and more precise adjustments to rehabilitation programs can be suggested.
8. To take this study forward, the help of a funding body is necessary. Funding can be applied at various forums where potential benefits can be shared with the help of the initial result of this study.
9. Future research can be carried out with patients of different demographics like older people and children.
10. The idea of using fantasy can also be explored in other areas of health to engage patients.
11. Future research can also look into the integration of AI in this game to create an environment according to the needs and progress of patients.

This research made a promising contribution to the research world by proving that integrating fantasy elements in serious games for physical rehabilitation engages the user and motivates them

to perform exercises. With the help of fantasy elements, serious games can make the rehabilitation exercises engaging for the user. This can help remove the barriers associated with rehabilitation exercises and engage users in performing these exercises. The problems linked to traditional rehabilitation practices can be sorted with the help of this technique. This study offers patients an interactive and effective path to recovery.

This study opens new possibilities for researchers to enhance the experience of users and motivate them to perform exercises. It shows the importance of interdisciplinary collaboration in the health sector. In this evolving world, this research highlights the need for continued research in health and provides a solid foundation for future research. This research is another step to prove that the integration of technology in health care is a vital and ongoing process.

6.7 Summary

As mentioned earlier, this is a preliminary study. In this regard, a discussion was carried out with the medical experts to find out the best way to implement this intervention. Literature was also considered before finalising the ways to move forward. In that respect, it was decided to keep this study in a preliminary phase and work with medical experts and healthy volunteers to verify the usability of this intervention. If the usability of this intervention is verified, then feasibility study and clinical testing will be covered in the next phases, which are beyond the scope of this study.

As games and their use in VR is a growing field, future studies will include many updates to headsets and software. In the middle of this study, two new versions of Unreal were released, and Oculus Quest 3 was released on the market. These updates can be used in the study in the same manner, and they do not affect how this research is carried out, but they can be used in future. A few movements will not be performed in the way they were expected to be performed. To solve this scenario in future, motion controllers will be required to figure out the actual movement of the user.

Overall, this research shows that when combined with serious VR-based games, fantasy can positively affect the user's engagement and motivation to do the exercises. The long-term impact on users, especially patients, cannot be anticipated now; it will be evident in the next phase of this study, which can be carried out in the future.

This study has demonstrated that fantasy elements in serious games can play a crucial role in enhancing patient engagement and improving therapeutic outcomes in physical rehabilitation for back pain. While further research is needed to confirm these findings and explore new avenues, the current evidence suggests that incorporating fantasy into serious games is a promising approach to making rehabilitation more effective and enjoyable for patients.

Glossary

VR: Virtual Reality

AR: Augmented Reality

XR: Extended Reality

LBP: Lower Back Pain

UK: United Kingdom

US: United States

BU: Bournemouth University

CBT: Cognitive Behavioural Therapy

GDD: Game Design Document

IRBs: Institutional Review Boards

MDA: Mechanics–Dynamics–Aesthetics Framework

PTSD: Post-Traumatic Stress Disorder

MBSR: Mindfulness-Based Stress Reduction

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Appendices

Appendix A

Bournemouth University

Research Ethics Checklist

About Your Checklist	
Ethics ID	47873
Date Created	03/02/2023 05:31:36
Status	Approved
Date Approved	04/05/2023 10:33:41
Risk	Low

Researcher Details	
Name	Tahmeena Javaid Adeel
Faculty	Faculty of Media & Communication
Status	Postgraduate Research (MRes, MPhil, PhD, DProf, EngD, EdD)
Course	Postgraduate Research - FMC
Have you received funding to support this research project?	No

Project Details	
Title	Use of fantasy aesthetic as a mode of escapism in the serious game to assist the rehabilitation process for patients with chronic back pain
Start Date of Project	15/11/2021
End Date of Project	15/11/2025
Proposed Start Date of Data Collection	15/05/2023
Original Supervisor	Oleg Fryazinov
Approver	Christopher Pullen

Summary - no more than 600 words (including detail on background methodology, sample, outcomes, etc.)

The main question that this research explores is whether fantasy can motivate patients with chronic lower back pain to perform physical rehabilitation exercises.
Back pain is a problem that is faced by 8 out of 10 people during their lifetime (MedlinePlus, 2016). In the UK alone, more than 12 billion pounds are used each year for the treatment of back pain (Thompson et al., 2020). Reducing the cost of back pain treatment can bring extensive savings for the NHS.
Rehabilitation can help patients relieve some pain symptoms. However, keeping patients engaged with the rehabilitation routine and exercises can be difficult, and some patients may drop out during therapy. Keeping the patient engaged with physiotherapy becomes a challenging task for medical professionals.
Motivation is the key factor for physical rehabilitation (Colombo et al., 2007). To find a way to motivate patients, serious games - a form of digital games for specific purposes - will be used to assist with the rehabilitation of patients.
Fantasy is widely used in entertainment games and now its use in serious games can also be seen. However, the effectiveness of the fantasy to aid medicinal therapeutic processes is yet to be explored. This study will help us to determine the impact of fantasy in serious games for rehabilitation purposes.

To achieve the answer to the research question stated above following steps will be carried out:

1. Discussions with field experts in medicine (rheumatologist/physiotherapist), psychology (psychiatrist/psychologist), and IT experts (dealing in games) will be carried out. The output of these discussions will lead to the final design of the game. As this rehabilitation game will be for UK residents, all the experts for discussion will be taken from the UK.

2. After making the rehabilitation exercise game:
a. medical experts (rheumatologists/physiotherapists) will be requested to play the VR game by wearing a headset and doing the exercises that are implemented in the game to confirm that rehabilitation exercises are implemented properly.
(Rheumatologists/physiotherapists will be recruited from Bournemouth University and NHS (experts will be recruited outside the clinical service of NHS)).
b. after evaluation from medical experts the healthy participants will be requested to play a VR game to validate the immersion and engagement.
(Participants in the age range of 18-50 will be recruited from Bournemouth University, BCP and the local area)

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THOMPSON, T., DIAS, S., POULTER, D., WELDON, S., MARSH, L., ROSSATO, C., SHIN, J. I., FIRTH, J., VERONESE, N. & DRAGIOTI, E. 2020. Efficacy and acceptability of pharmacological and non-pharmacological interventions for non-specific chronic low back pain: a protocol for a systematic review and network meta-analysis. Systematic reviews, 9, 1-11.

Filter Question: Does your study involve Human Participants?

Participants

Describe the number of participants and specify any inclusion/exclusion criteria to be used

In this study, there are 2 phases, and each phase has different inclusion criteria which are described as follows:

Phase 1: Discussions with field experts in medicine (rheumatologist/physiotherapist), psychology (psychiatrist/psychologist), and IT (dealing in games). The output of these discussions will lead to the final design of the game.

Inclusion Criteria: As this rehabilitation game will be for UK residents, all the experts for discussion will be taken from the UK.

Phase 2 (Evaluation of Prototype) After creating the game prototype:

a. medical experts (rheumatologists/physiotherapists) will be requested to wear a headset and play the VR game and confirm that rehabilitation exercises are implemented properly.
(Medical experts will be recruited from Bournemouth University and NHS (experts will be recruited outside clinical services of NHS)).

(No of participants: min=2, max=4)

Inclusion Criteria

Subject expertise in physical rehabilitation/physiotherapy/rheumatology.

b. The VR game will be played by healthy participants, (Participants will be recruited from Bournemouth University, BCP and the local area)

(No of participants: min=5, max=10 in Age range: 18-50 years)

Common inclusion criteria for phase 2: do not have any health issues with playing video games like CVS (computer vision syndrome), epilepsy, or any sort of problem with VR or wearing a headset.

Do your participants include minors (under 16)?	No
Are your participants considered adults who are competent to give consent but considered vulnerable?	No
Is a Disclosure and Barring Service (DBS) check required for the research activity?	No

Recruitment

Please provide details on intended recruitment methods, include copies of any advertisements.

Participants for Phase 1 will be recruited from the UK. Participants will be contacted through email.

Participants for phase 2 (a) will be recruited from Bournemouth University (BU) and National Health Services (NHS) (experts will be recruited outside the clinical services of NHS). Participants will be contacted through email.

Participants for phase 2 (b) will be recruited from Bournemouth University, BCP and local area). Copies of the advertisement will be put on the walls of BU University and shared through social media.

Advertisement for Phase 2 (b)

Research Participants Needed

Investigate the impact of fantasy using a serious game for the physical rehabilitation of patients with lower back pain.

You need to be in the age range: of 18-50 years

Do not have any health issues with playing video games like CVS (computer vision syndrome), epilepsy, etc.

Do not have any problem with VR or wearing a headset.

Location: Talbot Campus Bournemouth

To participate, please fill out the online survey.

Click here or scan the QR code

For more information please contact: Tahmeena Javaid Adeel

tadeel@bournemouth.ac.uk

Do you need a Gatekeeper to access your participants?	No

Data Collection Activity

Will the research involve questionnaire/online survey? If yes, don't forget to attach a copy of the questionnaire/survey or sample of questions.	Yes
How do you intend to distribute the questionnaire?	
face to face	
Will the research involve interviews? If Yes, don't forget to attach a copy of the interview questions or sample of questions	No
Will the research involve a focus group? If yes, don't forget to attach a copy of the focus group questions or sample of questions.	No
Will the research involve the collection of audio recordings?	No
Will your research involve the collection of photographic materials?	No

Will your research involve the collection of video materials/film?	Yes
Will any photographs, video recordings or film identify an individual?	No
Please provide details	
Motion trackers will be used to check the movement of the back and to keep the data anonymous their faces will be blurred	
Will any audio recordings (or non-anonymised transcript), photographs, video recordings or film be used in any outputs or otherwise made publicly available?	No
Will the study involve discussions of sensitive topics (e.g. sexual activity, drug use, criminal activity)?	No
Will any drugs, placebos or other substances (e.g. food substances, vitamins) be administered to the participants?	No
Will the study involve invasive, intrusive or potential harmful procedures of any kind?	No
Could your research induce psychological stress or anxiety, cause harm or have negative consequences for the participants or researchers (beyond the risks encountered in normal life)?	No
Will your research involve prolonged or repetitive testing?	No
What are the potential adverse consequences for research participants and how will you minimise them?	
Their are no potenial adverse consequences still particpants will be requested to play the VR game according to the provided instructions	

Consent

Describe the process that you will be using to obtain valid consent for participation in the research activities. If consent is not to be obtained explain why.	
Participant agreemnet form will be used to get the consent of participants.	
Do your participants include adults who lack/may lack capacity to give consent (at any point in the study)?	No
Will it be necessary for participants to take part in your study without their knowledge and consent?	No

Participant Withdrawal

At what point and how will it be possible for participants to exercise their rights to withdraw from the study?	
Participants will have the right to withdraw data at any stage of the study	
If a participant withdraws from the study, what will be done with their data?	
As regards already collected information before participant withdrawal from the study, if it's starting phase of the trial data of participants will be deleted, but if it's in the middle of the study or near the completion of the study, data will be kept for having accurate results.	

Participant Compensation

Will participants receive financial compensation (or course credits) for their participation?	No
Will financial or other inducements (other than reasonable expenses) be offered to participants?	No

Research Data	
Will identifiable personal information be collected, i.e. at an individualised level in a form that identifies or could enable identification of the participant?	Yes
Please give details of the types of information to be collected, e.g. personal characteristics, education, work role, opinions or experiences	
In phase 1 medical, psychology and IT experts will be requested to share their names, designation, and association. in phase 2 (a) Medical experts will be requested to share their name, designation, and association while participants of phase 2 (b) name, age and gender will be requested.	
Will the personal data collected include any special category data, or any information about actual or alleged criminal activity or criminal convictions which are not already in the public domain?	No
Will the information be anonymised/de-identified at any stage during the study?	Yes
Will research outputs include any identifiable personal information i.e. data at an individualised level in a form which identifies or could enable identification of the individual?	Yes
If Yes, please give details (e.g. project leaflets, project website, blogs, publicly accessible database, publications)	
Data collected in Phase 1 and Phase 2 (a) from experts will be identifiable and they will be informed about it. The data will be used in thesis write-up, conferences and journal publications.	

Storage, Access and Disposal of Research Data	
During the study, what data relating to the participants will be stored and where?	Participants' information and their replies to our queries will be placed on a password-protected computer. The data will be in encrypted form and each participant will be given a unique ID, the list of IDs will be with the researcher and only the researcher can identify the participant information.
How long will the data relating to participants be stored?	The data will be stored till the completion of PhD research (Min 3 years-Max 5 years).
During the study, who will have access to the data relating to participants?	During the analysis stage, data will be stored in a password-protected computer. Research Team (containing researcher (Tahmeena Javaid Adeel) and her supervisors (Oleg Fryanizou and Rehan Zia) can access data.
After the study has finished, what data relating to participants will be stored and where? Please indicate whether data will be retained in identifiable form.	After finishing the study the data which have replies from participants with their information will be submitted to BU's Online Research Data Repository "BORDaR". Data will be in anonymized form and the sheet having the unique id of participants with their details will be saved as password protected sheet only the research team will have access to the password
After the study has finished, how long will data relating to participants be stored?	The data will be kept for 3 year.
After the study has finished, who will have access to the data relating to participants?	Research Team can access data relating to the participants
Will any identifiable participant data be transferred outside of the European Economic Area (EEA)?	No
How and when will the data relating to participants be deleted/destroyed?	The data will be destroyed after 3 years by the researcher if the researcher does not have access to the system. it will be requested to the supervisors to delete that data.

Once your project completes, will your dataset be added to an appropriate research data repository such as BORDaR, BU's Data Repository?	Yes

Dissemination Plans

How do you intend to report and disseminate the results of the study?
Peer reviewed journals,Conference presentation,Other Publication

Will you inform participants of the results?	No

If Yes or No, please give details of how you will inform participants or justify if not doing so
There is no plan of sharing the result of the study with the participants. However, if any participants want to know the results then the result will be shared with them.

Final Review

Are there any other ethical considerations relating to your project which have not been covered above?	No

Risk Assessment

Have you undertaken an appropriate Risk Assessment?	Yes

Researcher Statement

JOURNALISM / BROADCAST RESEARCHERS: I confirm that I have consulted and understand the Research Ethics Supplementary Guide: For Reference by Researchers Undertaking Journalism and Media Production Projects (available on the Research Ethics page)	Yes

Attached documents

Phase 1 Participant Agreement Form for Experts.docx - attached on 17/04/2023 05:12:28
Phase 1 Questionnaire for Expert.docx - attached on 17/04/2023 05:12:43
Phase 1 Participant Information Sheet for Experts.docx - attached on 17/04/2023 05:22:11
Phase 2a Participant Agreement Form for Medical Experts.docx - attached on 17/04/2023 05:22:17
Phase 2a Participant Information Sheet for Medical Experts.docx - attached on 17/04/2023 05:22:21
Phase 2a Questionnaire for ethics for Medical experts.docx - attached on 17/04/2023 05:22:34
Phase 2b Participant Agreement Form.docx - attached on 17/04/2023 05:22:39
Phase 2b Participant Information Sheet for Participants for Validating Fantasy.docx - attached on 17/04/2023 05:22:44
Phase 2b Pre study Questionnaire for Validating Fantasy.docx - attached on 17/04/2023 05:22:49
Phase 2b Questionnaire for ethics Validating Fantasy.docx - attached on 17/04/2023 05:22:55

Bournemouth University

Risk Assessment Form

About You & Your Assessment

Name	Tahmeena Javaid Adeel
Email	tadeel@bournemouth.ac.uk
Your Faculty/Professional Service	Faculty of Media & Communication
Is Your Risk Assessment in relation to Travel or Fieldwork?	Yes
Status	Approved
Date of Assessment	02/10/2023
Date of the Activity/Event/Travel that you are Assessing	15/10/2023

What, Who & Where

Describe the activity/area/process to be assessed	VR Game prototype will be assessed by the field experts
Locations for which the assessment is applicable	Room at Bournemouth University
Persons who may be harmed	Other - Rehabilitation field expert

Hazard & Risk

Hazard	Injuries due to wrong exercise
Severity of the hazard	High
How Likely the hazard could cause harm	Medium
Risk Rating	High
Control Measure(s) for Injuries due to wrong exercise: If the participants feel any pain they can stop the exercise at any stage Clear instructions for game playing will be provided beforehand and will be reminded in the game	
With your control measure(s) in place - if the hazard were to cause harm, how severe would it be? Medium	
With your control measure(s) in place - how likely is it that the hazard could cause harm? Low	
The residual risk rating is calculated as: Low	
Hazard	Bumping into walls or obstacles

Severity of the hazard	High
How Likely the hazard could cause harm	Medium
Risk Rating	High

Control Measure(s) for Bumping into walls or obstacles:

the safe clear space volume of 6.5 feet by 6.5 feet will be ensured to play the VR game

The spotter present at the venue will be watching the participants while playing the game and will inform them in case of any issue

With your control measure(s) in place - if the hazard were to cause harm, how severe would it be? Medium

With your control measure(s) in place - how likely is it that the hazard could cause harm? Low

The residual risk rating is calculated as: Low

Hazard	Motion sickness
Severity of the hazard	Medium
How Likely the hazard could cause harm	Medium
Risk Rating	Medium

Control Measure(s) for Motion sickness:

A spotter will be watching the participants, and will immediately stop the game if he/she feels anything is not normal or if participants inform about motion sickness.

A frame rate above 60 frames per second is followed which is proved by study published in 2020 "Investigation on Motion Sickness in Virtual Reality Environment from the Perspective of User Experience"

A frame rate below 60 fps triggers the motion sickness keeping that in view 60 fps is used in this game to avoid motion sickness.

Help will be taken from the first aid team

With your control measure(s) in place - if the hazard were to cause harm, how severe would it be? Low

With your control measure(s) in place - how likely is it that the hazard could cause harm? Low

The residual risk rating is calculated as: Low

Hazard	Covid 19
Severity of the hazard	Medium
How Likely the hazard could cause harm	Low
Risk Rating	Low

Control Measure(s) for Covid 19:

The safety measures will be taken in compliance with BU University.

With your control measure(s) in place - if the hazard were to cause harm, how severe would it be? High

With your control measure(s) in place - how likely is it that the hazard could cause harm? Low
The residual risk rating is calculated as: Medium

Review & Approval

Any notes or further information you wish to add about the assessment	
Names of persons who have contributed	
Approver Name	Rehan Zia
Approver Job Title	Supervisor
Approver Email	rzia@bournemouth.ac.uk
Review Date	

Uploaded documents

No document uploaded

Questionnaire for Experts

Name: **Designation**

Association

Questions to be asked in the Discussion:

Medical experts:

Is implementing physical rehabilitation exercises in video games a good idea?

In which area of body intervention is required and why?

What can be the target age group for this intervention?

Psychology experts:

How do you see fantasy?

Can fantasy provide escapism to patients and motivate them to do exercises?

How fantasy can be implemented in video games for physical rehabilitation?

What type of fantasy is liked by different age groups?

What subgenre of fantasy can be used in games for physical rehabilitation?

IT experts:

What input/output method can be used in video games for physical rehabilitation?

If you have any information about projects of the same type already being researched?

What style can be followed for the creation of physical rehabilitation game?

Questionnaire for Medical Experts

Name: **Designation**

Association

Rate all the questions on a scale of 1 to 5

1: Strongly agree 2: Agree 3: Neither agree nor disagree 4: Disagree 5: Strongly disagree

Sr #	Question	1	2	3	4	5
1	This game is immersive enough that I feel like part of the game					
2	This game provides an enjoyable environment to perform rehabilitation exercises					
3	This game is easy to play					
4	The method to play this game is easy to learn					
5	The exercises are selected well for the game levels					
6	The visuals and the storyline are motivational and appealing					
7	This game contains a good approach for performing exercises					
8	Physical activity is intense to get patients feeling exhausted					
9	This game can play a role in patients' quick recovery					
10	I would recommend this game to my patients					

11. What improvements can be made in the game?

(Please state answer on the separate sheets provided)

12. If my patients play this game what would I like to add to this game?

(Please state answer on the separate sheets provided)

Pre-game study Questionnaire for participants

Name **Age**

Gender

Rate all the questions on a scale of 1 to 5

1: Strongly agree 2: Agree 3: Neither agree nor disagree 4: Disagree 5: Strongly disagree

Sr #	**Question**	**1**	**2**	**3**	**4**	**5**
1	I like playing video games					
2	I like physical activity games					
3	Games provide me with an entertaining activity in a challenging way					
4	I had problems previously while playing computer game					
5	I had issues with VR i.e. Oculus Quest, Rift, etc.					
6	Winning the game provides me with a sense of accomplishment					
7	I had any physical problems with playing physical activity games					
8	I had any physical problems with doing physical exercise					

9. If the answer to questions 4, 5, or 7 is option 4 or 5, what problem did you face, and for how long they affected you?

Questionnaire for participants

Name **Age**

Gender

Rate all the questions on a scale of 1 to 5

1: Strongly agree 2: Agree 3: Neither agree nor disagree 4: Disagree 5: Strongly disagree

Sr #	**Question**	**1**	**2**	**3**	**4**	**5**
1	I enjoyed playing this game					
2	I lost the track of time while playing this game					
3	The game was immersive enough that I feel like part of the game					
4	This game provided me with an enjoyable environment to perform rehabilitation exercises.					
5	The gameplay was easy					
6	The game had a satisfactory level of interaction i.e., providing feedback, sending reminders					
7	I liked the visuals of the game					
8	The game provided me with sufficient opportunity for personalisation					
9	The visuals and the storyline of this game provided me with motivation for rehabilitation exercises					
10	I was required to put physical effort into playing this game					
11	The aesthetics of the game were engaging					
12	I would like to play this game again					

13. What improvements can be made in the game?

(Please state the answer on the separate sheets provided)

14. If I play this game again what would I like to add?

(Please state the answer on the separate sheets provided)

Appendix B
GDD of wishing well

Wishing Well
Wishing you well

Version 1
Date: 15/1/2022

1. Game Overview

1.1 Game Concept: In this game, players will be doing exercises. To keep them motivated to exercise, a fantasy situation is created in which a wizard casts a spell on them. The player must retrieve nine keys and throw them into a well to break the spell. The player will do exercises to reach the key and get all the keys to break the spell.

1.2 Genre: Adventure Game

1.3 Target Audience: 18-50 years

1.4 Game Flow Summary: On successful completion of each round, a player will get keys. When the player completes the whole round of exercises, they will get enough keys to release the ball. The player will complete each level within ten days and earn a key after completing ten days of regular exercise. Upon obtaining each key, the player will advance to the next level. After completing nine levels, the player will have nine keys and reach the wishing well. Drop the keys in the wishing well. The magical explosion happens, the spell will be broken, and healing will be granted to all the patients.

1.5 Look and Feel: The game is set in a fantasy world. Its scenes will have fantasy elements in combination with the scene. The world will be created using natural scenes, as scenic views of nature have a profound impact on human health and well-being, even in the twentieth-century concept of healing gardens. The entire game will adhere to PBR's visual style.

2. Gameplay and Mechanics

2.1 Gameplay

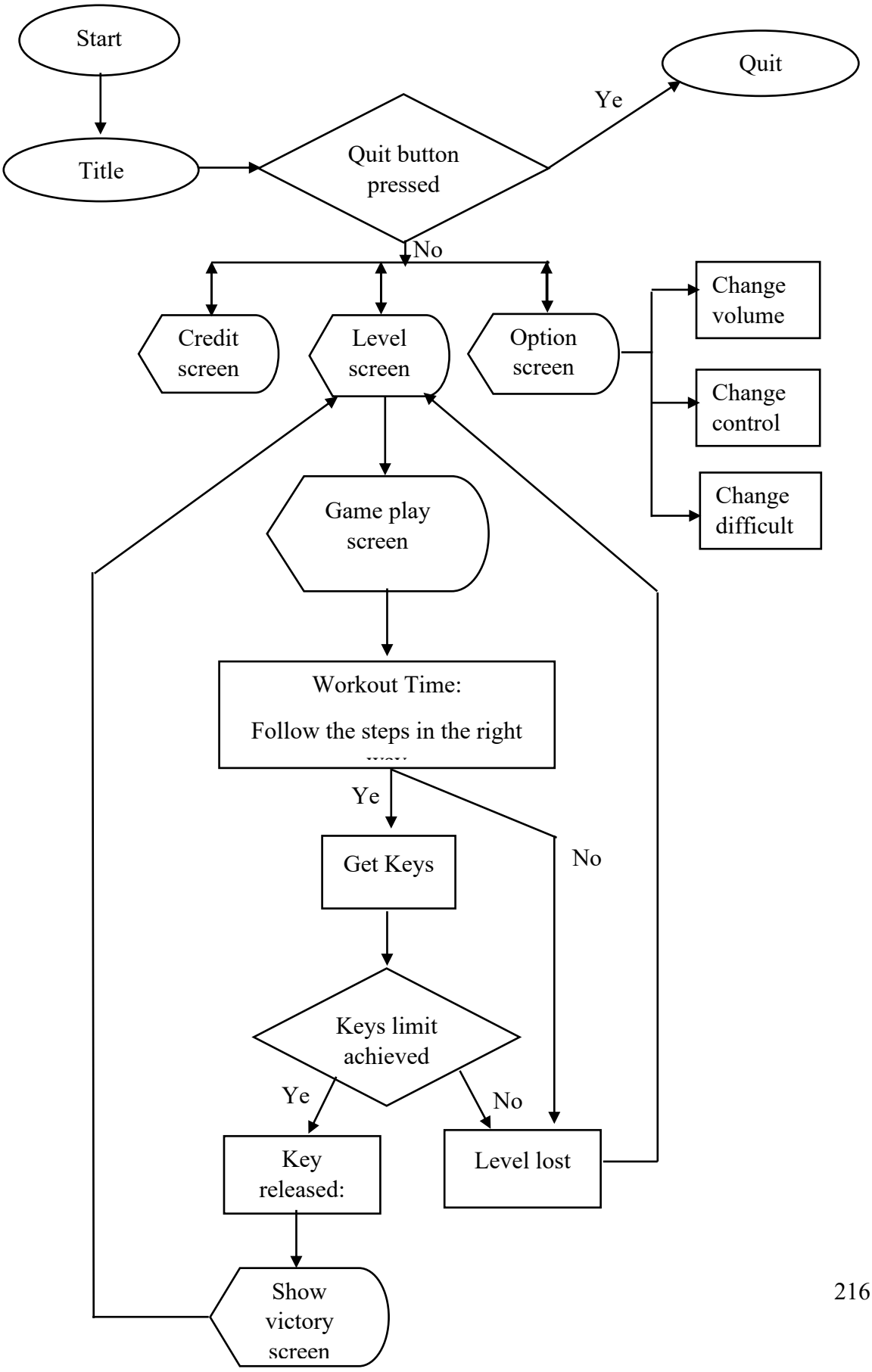
2.1.1 Game Progression: A patient must complete specific exercises that are incorporated into a game from a patient book designed by physiotherapists. After completing the exercises, the player will get a certain number of keys, and a ball will be released upon getting the required number of keys. And after getting all the keys, the patient will complete his game, and he can drop the ball with the keys in the well.

2.1.2 Mission/Challenge Structure: In this game, the primary mission for the player is to collect all the keys that they must drop into the wishing well. To obtain the ball in each level, the player must collect a certain number of keys. To acquire each key, the player must perform the exercise in the same manner as shown on the screen.

2.1.3 Puzzle Structure: The puzzle of this game is to get the key in each level to move to the next level, and after getting all these keys, the player has to drop those keys in a wishing well. The main question is how to obtain the key; the player must complete specific exercises mentioned at the start of each level to collect the key. The key will be released and hidden near the player, which will be shown to the player who must pick it up and proceed to the next level.

2.1.4 Objectives: The primary objective of this game is to motivate patients to engage in rehabilitation exercises.

2.1.5 Play Flow:



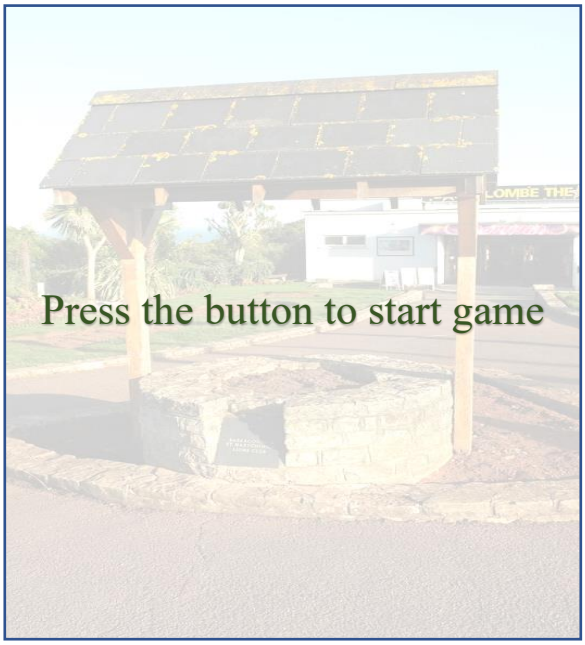
2.2 Mechanics:

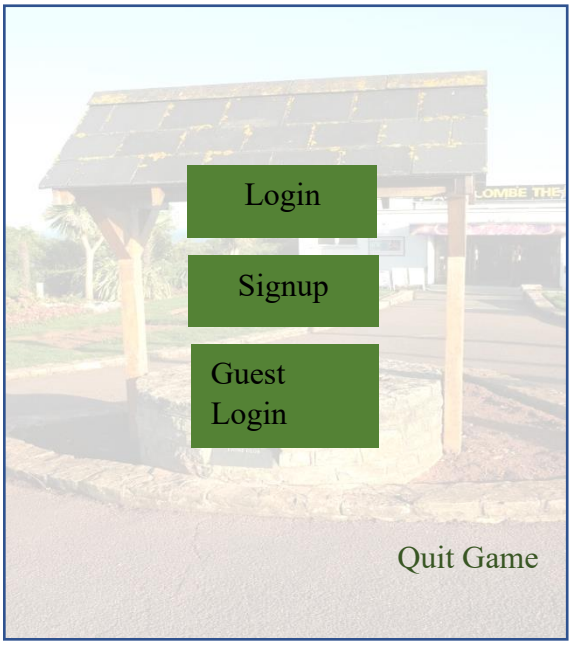
2.2.1 Rules: In the game, the player has to reach the wishing well. In that respect, there are some implicit and explicit rules to be followed:

- explicit rule: to move to the next level, the player must collect the key; to collect the ball, the player has to get the key.
- Implicit rules: To get the keys, a player must follow the same method shown on the screen. If they deviate from those moves, then they will not be able to collect the keys. After collecting keys, the player will look for the ball, and the path will be guided accordingly. After picking up the ball and throwing it to the well, the player will automatically advance to the next level, and the ball will be saved in the player's progress.

2.2.2 Physics: This game will be built using Unreal Engine, and physics will be utilised for player movement, key collection, interaction with tree branches, and movement due to air and water flow.

2.2.3 Screen Flow:

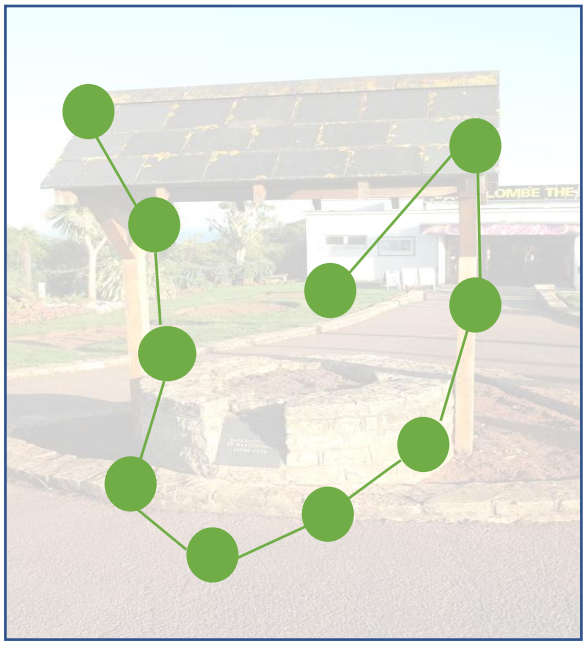




Level

Credit

Optio



Credit/Achievement

Keys:

Levels:

Options

Volume

Difficulty

Control

Training

Help

2.2.4 Replaying and Saving: The player's action will be saved for the physiotherapist, and replaying the last action will be done on completion of the level.

3. Story, Setting, and Levels

The story will follow a nodal plot (as the game is based on a linear structure) in which the player will go to the next stage after completing one stage.

The back story of this game is that a wizard put a healing spell on this wishing well. A player needs to reach this wishing well with all the keys hidden in each level to get this healing spell effective on them.

The game begins with the player's portal quest journey. A player is sitting in the doctor's room and sees a picture of an old door there. The patient went to that door and suddenly turned to the other side of it.

In this game, there are nine levels. In the preliminary testing, only two levels will be executed. The base for keeping the nine levels is that the patient's therapy time is ninety days, and the player will play each level for ten days. After playing one level for ten days, the player's body will become accustomed to exercising, and according to the physiotherapist, the exercise time will be increased. In the preliminary study, levels one and level nine will be made.

In this game, the Portal Quest fantasy will be utilised. The reason for using Portal Quest is that players need to escape from the pain, and diversion can be the best method to provide escapism to patients. The next factor for using Portal Quest is to keep players engaged in the game. the player will be engaged in the game till the time their interest is kept in the game. Many traditional fantasy stories, such as The Chronicles of Narnia and The Lord of the Rings, provide clear indications of how portal quest fantasy can engage the audience.

4. Levels

4.2 Level 1: The patient dropped into a garden (butterfly garden). In the centre of the garden, there is a significant monument, a butterfly fountain from which water of rainbow colours is flowing out. The garden is filled with lush grass and beautiful flower beds on the sides and in the middle, and a multitude of butterflies are gliding through the air, flying from one flower to another. On the fence of the park, there are some trees, and the rest are small plants. The player will move to the grass area and do the exercises after getting the required key. The player will be led to the park fence, where they will find the key to access the next level. The sun is shining like a morning sun. Here, the player will engage in exercises for the next 10 days. On each day, the player will receive keys upon completing the exercise. After ten days, a player will have 90 keys.

(In this place, butterflies, water, flower beds, and morning time sunlight are all being used as curative factors.)
After completing this level, the player will move toward the river. The second level will be on the path to the river. The third level will be located along the riverside. In the fourth level, the player will be in a boat on the river. In the fifth level, the player will disembark from the ship, and all exercises will be conducted on the other side of the river. In the sixth level, the player will be moving on the pathway toward the castle, in the seventh level, the player will be passing the countryside to reach the castle, in the eighth level, the player will be close to the castle and can see the castle, which will again be the countryside. In the ninth level, the player will be in the castle.
Last level: The player will be near the wishing well. A player will go to the wishing well. The wishing well will be a well, made of old times, and the player will drop the keys into the well. And in the end, the healing spell of the wizard will come out with fireworks of the rainbow colour, written with a wish well on that.

4.2 Training Level/ Help

There will be a button for help, on which players will find information on how to play the game, how points are collected, and how keys can be used to obtain the ball.

5. Interface

5.1 Visual System: In the main HUD UI, the key collection and time bar will be shown. An Unreal Engine virtual reality template will be used. Several exercises will be completed, and upon each exercise's completion, a key will be displayed.
5.2 Control System: The Oculus controller will be used. In the Unreal Engine VR template, all the control system commands are already built in for new commands; minor changes in a blueprint will be required.
5.3 Audio, music, and sound effects: At the start of the game, light music will be played in the background. The sound effect will be played when collecting each key and upon earning the key. The music will be played after the game is won. Audio will be played while providing instructions for gameplay.

6. Technical

6.1 Target Hardware: Hardware required for gameplay will be Oculus Quest 2

6.2 Development of hardware and software, including Game Engine:
Workstation detail

- Processor: Intel(R) Core(TM) i7-1065G7 or greater
- Ram: 16 GB or greater
- Graphic Card: RTX 2080 or greater

Software: Unreal Engine
Device: Oculus Quest
6.3 Network requirements: None

Reference images:

Image removed due to copyright restrictions	Image removed due to copyright restrictions
Image removed due to copyright restrictions	Image removed due to copyright restrictions
Image removed due to copyright restrictions	Image removed due to copyright restrictions

GDD of Healing Well: only the environment will change; all the rest of the GDD will be the same as wishing well.