WILLIAM PATERSON UNIVERSITY OF NEW JERSEY

Freezing of Gait and Balance in a Person with Parkinson's After 6 Weeks of Virtual Reality

A THESIS

Submitted in partial fulfillment of the requirements

for the degree of

MASTER OF SCIENCE

in Exercise and Sport Studies

by

Ivana Massa

December 2023

WILLIAM PATERSON UNIVERSITY OF NEW JERSEY

Freezing of Gait and Balance in a Person with Parkinson's After 6 Weeks of Virtual Reality

A THESIS

By

Ivana Massa

A Master's Thesis Submitted to the Faculty of

William Paterson University of New Jersey

For the Degree of

MASTER OF SCIENCE

in Exercise and Sport Studies: Exercise Physiology

December 2023

College/School: Science and Health

Department: Kinesiology

Thesis Supervisor:

____

Michael Figueroa, Ed.D.

Chairperson:

____

Kathy Gill, Ph.D.

ABSTRACT

Freezing of Gait and Balance in a Person with Parkinson's After 6 Weeks of Virtual Reality

By

Ivana Massa

This case study investigated whether reminiscence therapy (RT) could potentially mitigate freezing of gait (FOG) in an older person with Parkinson's Disease (PD). RT and VR separately have been shown to help with anxiety and depression, potentially impacting movement issues tied to mental state. During this study, one person engaged in a 6-week program, spending 30 minutes navigating a virtual map of New York City from the 1950s. Before and after the intervention, the participant's walking patterns were evaluated using the Gait and Falls Questionnaire (GFQ), the Dynamic Parkinson Gait Scale (DPGS), video recordings, and the notes from the participant's Occupational Therapist's observation to assess whether the therapy effectively reduced the occurrence of FOG. Improvements were observed in various aspects related to FOG, such as the duration of FOG episodes, start hesitation, turning hesitation, destination hesitation, tight quarters hesitation, stress-induced freezing, and the feeling of being rooted to the ground. The participant also reported increased festinating gait and an additional fall during the study, possibly associated with basal ganglia dysfunction. Post-test scores on the GFQ were 14 points lower than the pre-test, and the DPGS scores showed a 3-point improvement. The Functional Reach Test, performed by the Occupational Therapist, also showed a 2-inch improvement. Video analysis demonstrated improved walking patterns characterized by more controlled steps and reduced forward lean. Results indicate a reduction in FOG in a participant with PD, showing that the combination of VR and RT may possibly help with reducing FOG symptoms.

ACKNOWLEDGEMENTS

This thesis has been a challenging and exciting experience, pushing past what I thought I could do and was only possible with the support of many people. I want to express my gratitude to the many individuals who have supported and guided me throughout the research and writing of this thesis.

First and foremost, I am deeply thankful to my advisor, Dr. Figueroa, whose invaluable guidance and intellectual insights have been instrumental in shaping this work. Your mentorship has enriched my academic journey and encouraged my personal growth. I extend my appreciation to the William Paterson University Exercise Science Department faculty members for their profound knowledge, which significantly contributed to the development of this thesis. Their willingness to engage in discussions and provide constructive feedback has been invaluable.

I am indebted to my family, my mother, father, brother Daniel, and cousin Sarai Lavendero, for their unending encouragement, guidance, assistance, and understanding during the ups and downs of this academic pursuit. Your love and belief in my abilities have motivated me constantly. My best friend, Kimberly Chimento Tichacek, deserves a special mention for her unwavering support and assistance throughout the writing of this thesis. Your belief and help in my thesis work were vital, and this paper would not be the same without it. Our countless discussions have been a large part of my academic journey. I want to thank all my work and barn friends for their unwavering encouragement and support. Without them, I would have undoubtedly felt a heavier weight of stress.

Finally, I would like to thank my participant, who generously contributed his time, energy, and insights to this study. Your participation was pivotal in the success of this research.

This thesis culminates these individuals' collective effort and support; I am profoundly grateful. Thank you so much from the bottom of my heart.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

Introduction

Parkinson’s Disease (PD) is a chronic, idiopathic, debilitating, progressive, neurodegenerative disease in which static balance, movement, and cognition are affected due to low or no dopamine levels in an area of the brain called the basal ganglia (substantia nigra) (73). Dopamine is a chemical that is responsible for sending messages across nerve pathways, and a shortage of dopamine is associated with issues with involuntary movement and coordination. It is due to these low or nonexistent levels of dopamine that patients with PD experience issues in both static balance and movement. Genetically, PD is associated with specific genes such as SNCA, located on chromosome 4, and parkin, located on chromosome 6. Static balance and movement require the coordination of the nervous and musculoskeletal systems and are significantly impaired with the progression of the disease. Unfortunately, there is currently no known cure for PD. The exact cause of PD remains unclear; many scientists speculate that it results from a combination of genetic and environmental factors. Although PD is typically diagnosed in individuals in their 50's or 60's, it can also occur before the age of 50.

Each individual's experience with PD is unique, as no two cases are identical. PD manifests differently with a wide range of symptoms, intensities, and progressions. The progression of PD varies significantly among individuals; some living with PD may see changes develop slowly over 20 years or more, while others experience a more rapid progression. Therefore, accurately predicting the course of the disease is challenging. There is a period between the onset of neuron loss and the appearance of noticeable movement symptoms in PD patients. Thus, by the time most people receive a PD diagnosis, around 80 percent of their dopamine-producing neurons have been lost (19). Also, after a PD diagnosis, many individuals may respond well to medications such as Levodopa. Although the duration varies from person to person, this positive response can last for many years. However, as the disease advances, patients often need to collaborate with their healthcare providers to adjust Levodopa dosages. During this time, they may encounter new or worsening movement symptoms, Levodopa-induced dyskinesia, swallowing difficulties, gait problems, falls, and balance issues. Young-onset PD patients are more susceptible to Levodopa-induced dyskinesia and motor fluctuations, while those diagnosed later in life may experience cognitive changes and non-movement symptoms. Motor fluctuations typically become problematic about five to ten years after diagnosis, while postural instability, affecting balance and leading to falls, typically arises after about ten years. Those living with Parkinson's often exhibit similar shared stages and symptoms. Additionally, they also face an elevated risk of developing certain related conditions.

PD extends beyond physical symptoms, impacting emotions such as anxiety and depression, which can significantly affect one’s overall health. The changes in brain chemistry during PD are connected to the changes that cause anxiety and depression. Individuals with PD often exhibit low levels of a neurotransmitter called Gamma-aminobutyric acid, which is linked to anxiety and depression. This makes anxiety and depression more likely to occur in people with PD. Anxiety can affect up to 40% of individuals with PD and can be triggered by dependence or embarrassment. Symptoms include fear, intrusive thoughts, sudden terror, sweating, and dizziness, and treatments often involve medications such as Clonazepam (5). Additionally, depression affects about 50% of people with PD and is caused by changes to neurotransmitters norepinephrine and serotonin, which produce dopamine. Depression symptoms include overwhelming feelings of sadness, loss, and hopelessness, often intensifying movement and cognitive symptoms. People who experience motor issues, such as freezing of gait, are more prone to depression. Medications, such as ones to manage PD's motor symptoms and Venlafaxine, are frequently prescribed to treat depression (14). Although medications are often used, exercise is another method to manage symptoms of anxiety and depression while also improving the physical challenges of PD (4, 5, 14).

Parkinsonism

Parkinsonism refers to a set of symptoms and movement issues found in conditions like PD, where people experience slowness, stiffness, and resting tremors (68). Some other disorders can show similar symptoms to PD. Therefore, making an accurate diagnosis is essential for treatment. Neurologists evaluate these symptoms to diagnose the underlying condition. There are two main categories of Parkinsonism: primary and secondary. Both can be categorized based on how the person responds to Levodopa. Primary parkinsonian disorders include PD and atypical parkinsonian disorders. PD is usually called either idiopathic, typical, or classic PD, and it is categorized by having movement and non-movement issues that get worse over time. Symptoms typically progress slowly, and movement issues usually improve with Levodopa medication. Atypical Parkinsonism disorders are sometimes referred to as Parkinson's plus syndromes and include multiple system atrophy, corticobasal degeneration, progressive supranuclear palsy, dementia with Lewy bodies, and others. Even though the symptoms are the same as those seen in classic PD, progression usually occurs faster (advanced symptoms tend to occur within 1-3 years). Furthermore, symptoms are less likely to improve with Levodopa therapy. Both types of primary Parkinsonian conditions can sometimes be wrongly diagnosed, which is why it is crucial for a neurologist who specializes in movement disorders to make a precise diagnosis. Secondary Parkinsonism includes neurological disorders usually caused by brain tumors, toxins, or medications. Symptoms resembling those of PD can be observed in certain conditions, and their response to treatment varies depending on the specific disorder. Notably, unlike PD, the symptoms do not improve with the medication Levodopa.

Hoehn and Yahr Rating Scales

PD is also broken down into different stages based on specific recognizable symptoms. PD is also broken down into different stages. Doctors typically utilize Hoehn and Yahr rating scales. However, they can choose from several rating scales. The Hoehn & Yahr Scale defines five stages of PD based on the level of clinical disability, providing clinicians with a way to describe the progression of motor symptoms. In this scale, stages 1 and 2 indicate early-stage PD, stages 2 and 3 indicate mid-stage PD, and stages 4 and 5 indicate advanced-stage PD. In stage 1, the person has mild symptoms that typically do not disrupt their daily routine. These symptoms, which may include tremors and movement issues, are usually limited to one side of the body and are accompanied by alterations in posture, gait, and facial expressions. Movement symptoms start to affect both sides of the body or trunk in stage 2. At this stage, tasks of daily living are more difficult and take more time. Stage 3 consists of a significant decline in balance, leading to instability when turning or encountering external forces while standing. Patients experience a higher risk of falling during this stage. PD patients' motor symptoms continue to worsen, and individuals may face limitations in their daily activities. Nevertheless, patients typically maintain the physical capability to live independently. The patient’s disability during this stage typically ranges from mild to moderate. By stage 4, symptoms are fully developed, and the person is unable to live alone. The individual can still walk and stand independently but might require a cane or walker for added safety. Furthermore, they rely heavily on assistance for everyday activities. Lastly, during stage 5, the legs can become stiff, making it impossible to walk or stand, and the person is usually confined to a wheelchair or bed. The person also needs constant care for all daily living activities (63).

Medications

Customizing and finding the right combinations of Parkinson's treatments, doses, supplements, and foods to target each person's symptoms and specific health is essential for managing PD complications. In the first stages of PD, doctors first rely on medications to manage symptoms before more advanced treatments are even considered. Common medications used for the treatment of PD, called dopaminergic medications, try to temporarily replenish or mimic dopamine to reduce muscle rigidity, improve movements, and lessen tremors. Other common medications include a form of Levodopa, dopamine agonists, monoamine oxidase inhibitors, or an anticholinergic. Levodopa is one of the most effective and widely used medications for PD. Levodopa and Carbidopa, which can be delivered in many forms, are typically used in combination to alleviate symptoms associated with PD or Parkinson-like symptoms, such as tremors, rigidity, and difficulty with movement. Levodopa is converted into dopamine in the brain, assisting in regulating motor symptoms. Levodopa has many side effects, including nausea, vomiting, loss of appetite, lightheadedness, lowered blood pressure, confusion, dyskinesia, and hallucinations. Carbidopa, which is almost always combined with Levodopa, serves to prevent the breakdown of Levodopa in the bloodstream, allowing more Levodopa to reach the brain, enhancing the effectiveness of Levodopa, and reducing nausea that Levodopa can cause (11, 40). One form of the Carbidopa-Levodopa combination is the medication Rytary, an extended-release capsule containing beads that are dissolved and absorbed at different rates (40).

Surgical Treatments

Surgical possibilities may be an option and can be discussed with one´s PD specialist since it can be an effective way to treat specific PD symptoms, especially those that initially improved with Levodopa. Surgery is considered for individuals who have tried all medication options or those who experience severe motor fluctuations. Two primary surgical treatments are available: deep brain stimulation (DBS) and Duopa. DBS is a standard and low-risk procedure used to treat PD involving the implantation of electrodes in specific brain regions that generate controlled electrical impulses to regulate abnormal brain activity or target particular cells and chemicals. The stimulation level is managed by a pacemaker-like device positioned beneath the skin in the upper chest. A wire, running underneath the skin, connects this device to the brain electrodes (13). Another specialized PD treatment is Duopa therapy, which employs Carbidopa-Levodopa in a gel form delivered directly into the intestine to enhance drug absorption and minimize times of reduced effectiveness. First, a surgical procedure is required to create a small opening in the abdominal area, allowing the placement of a tube into the intestine. Then, a pump is employed to administer Duopa (16). Other surgical options, including focused ultrasound, thalamotomy, subthalamotomy, and pallidotomy, are less common yet possible depending on one's symptoms. Focused Ultrasound is a procedure that uses magnetic resonance imaging (MRI) as a guide to direct high-intensity, inaudible sound waves into the brain without surgical incisions. When these waves intersect, they target and eliminate a precise area in the brain associated with tremors. Thalamotomy is a surgical procedure where the thalamus is cut on a specific side to help ease tremors on the opposite side of the body. This procedure can cause speech and cognition issues if both sides of the brain are cut. Subthalamotomy is similar to thalamotomy; however, the subthalamus is the section that is cut. Pallidotomy is a surgical procedure where the globus pallidus is cut to reduce brain activity to a specific area. Pallidotomy is considered if the person with advanced PD has severe motor fluctuations caused by long-term Levodopa treatment and disabling tremors, rigidity, or bradykinesia that does not improve with medication (52).

Exercise

Even though medications and surgical interventions are commonly used, they are not the only interventions. Exercise-type therapies are equally effective and essential for one’s treatment strategy because they help to maintain balance mobility, increase synaptic efficiency (22, 62), and stimulate the proliferation of new neurons (35). Exercise and motor activities, in response to this neuron damage, cause the brain to change/rewire to compensate for the dopamine loss, a phenomenon referred to as "exercise-dependent neuroplasticity." Neuroplasticity is the nervous system’s and brain's ability to adapt and rewire/reorganize itself in response to changing circumstances and stimuli (18, 19, 22, 57). The spinal cord, for example, undergoes activity-dependent plasticity influenced by input from both the peripheral nervous system and the brain. This type of plasticity is vital for learning and retaining motor skills. Additionally, induction and guidance of activity-dependent plasticity have significant implications for restoring function in individuals with central nervous system disorders like PD (75). Therefore, exercise plays a crucial role in driving neuroplasticity because it aids the brain in preserving existing connections, creating new ones, and potentially restoring some of the lost ones (19). As a result, people with PD who engage in regular exercise tend to exhibit more normal movement patterns compared to those who do not engage in regular exercise (19). Key components to incorporate in any exercise routine are aerobic exercises, strength training, flexibility, and exercises focusing on balance and multitasking. One exercise technique is called amplitude training. Amplitude training involves emphasizing the execution of a movement with maximum size and power (3). In PD, the brain often misjudges the necessary size or amplitude of movements required for tasks such as walking or standing up, resulting in multiple attempts and increased fatigue. Thus, therapists will demonstrate the actual magnitude of movements needed for these movement tasks (3). Studies have shown that exercises emphasizing amplitude training can benefit individuals with PD, ultimately improving their quality of life and mobility independence (18, 56, 66).

Cognition, Neuroplasticity, and Memories

Some people with PD experience feelings of distraction, disorganization, and difficulties in planning tasks, leading to difficulty maintaining focus. Memory lapses and word-finding challenges are common, impacting daily life activities and mental well-being. These cognitive changes are linked to reduced dopamine levels, stress, medications, or depression. In individuals with PD affected by cognitive changes, the brain tries to compensate for the loss of dopamine-producing cells in the brain. Neuroplasticity is a mechanism that creates alternative pathways to regulate motor and cognitive functions from the damage caused by PD. The intricate workings of the brain, with about 100 billion neurons, and the concept of neuroplasticity play a crucial role in shaping one’s perception and interactions with the world. In a study by Northwestern Medicine, the telephone game is used to explain how one’s memory operates (55). The study emphasizes that memories are not static but dynamic and are subject to adaptation, suggesting that even memory recall can introduce inaccuracies. The research reveals that each time an individual recalls a past event, their brain networks undergo physical and chemical changes that can influence recollections. Essentially, the act of remembering can modify the memory itself, leading to small changes that can add up over time, creating more significant distortions. As a result, each retrieval can potentially contribute to less precise or even false recollections. With a better understanding of these complexities in brain physiology and its interconnected elements, treatment options can effectively aid individuals. One study highlighted how engaging in mentally stimulating activities and cognitive exercises can facilitate neuroplastic changes in the brain, improving memory and depression in individuals with PD (57).

Freezing of Gait and Mental Health

Among the many motor and nonmotor symptoms patients can experience, the main complications that will be discussed are freezing of gait and anxiety. Freezing of gait (FOG) is a momentary and involuntary inability to initiate movement, a symptom commonly experienced by individuals with PD. During a freezing episode, individuals perceive their feet as immobilized or stuck to the ground for a few seconds, increasing their risk of falling. FOG can also affect other body movements or speech. Some PD patients are more prone to experiencing freezing episodes than others, and FOG can be linked to the timing of dopaminergic medication doses. Despite ongoing research, the precise cause of FOG remains unidentified (23). Moreover, one study mentioned that FOG may be caused by disruptions in frontal cortical regions, the basal ganglia, and the midbrain locomotor region (51). Anxiety is defined as an emotional state marked by tension, worrisome thoughts, and physiological responses like rapid heart rate caused by thinking about the future (4, 23). People who suffer from anxiety disorders frequently experience persistent intrusive thoughts that can lead them to avoid certain situations. Additionally, elevated levels of anxiety have been associated with an increased occurrence of FOG (17). Individuals who encounter FOG are vulnerable to experiencing depression due to the increasing unpredictability of freezing movements (14). Both FOG, anxiety, and depression can be significantly improved by exercise through the administration of conventional methods (practicing amplitude training or other techniques) of a Physical Therapist.

Virtual Reality

Since Parkinson's is a neurological disorder that affects different people differently, virtual reality (VR) can be used to treat each person's needs. VR means 'near-reality,' where computers generate a three-dimensional virtual environment or version of reality that one may perceive as real and may interact with (73). VR refers to a simulated experience created by electronic devices such as headsets, computers, TVs, or controllers that allow individuals to immerse themselves in a visual and auditory environment to interact with its elements. In augmented reality (AR), a transparent visor or a smartphone overlays digital images onto the real world. Immersive VR involves complete submersion, where individuals experience a dynamic visual environment, either with or without a head-mounted device, that transports them to another world while they physically remain in the real world. In this state, individuals can interact in the virtual environment as they would in reality, which influences the in-game experience (65).

The use of VR, however, is relatively new but has made recent strides as a form of treatment to help patients with many different types of disabilities. VR is an option for any individual unmotivated by conventional forms of exercise. Studies show that improvements made using a virtual environment can be transferred into real-world improvements (29, 47, 48, 74). Recent advancements in technology, especially those centered on VR, have allowed their use in the medical field to be more prevalent. Where conventional exercises once dominated the field, people are exploring new solutions to old problems. VR has provided a new method for these exercises as well as a futuristic and promising approach to rehabilitation in medicine. The development and use of VR games and equipment are increasing in popularity and affordability, making them more accessible. VR is also becoming more widely used in the medical field to physically rehabilitate patients with PD.

Reminiscence therapy

A therapy that may be used for people with PD is reminiscence therapy since PD can affect the brain. Reminiscence therapy (RT) has been used to treat people who have Alzheimer's, dementia, anxiety, depression, and Parkinson’s. RT emerged as a non-invasive and effective treatment for managing mental health conditions. RT is a treatment approach that involves the use of sensory stimuli such as music and objects to trigger memories and promote engagement to assist individuals in recollecting past events, people, and places from their earlier lives fondly. This therapy relies on patients' deep connection with familiar people and places at its foundation. Essentially, the treatment must be applicable and mindful of the individual’s experiences to foster a strong sense of connection. The therapy can range from basic activities such as conversation to more advanced clinical techniques like VR in storytelling designed to bring distant memories into the current awareness (8). RT can be provided by trained therapists, caregivers, or family members and is tailored to suit the needs and preferences of the individual.

RT aims to stimulate the individual's memory, promote social interaction, and enhance one’s sense of identity, self-esteem, and emotional well-being. Some researchers, including Zhuo Liu, Maria Reitano, Dimitrios Saredakis, and Hsin-Yen Yen, found reminiscence therapy to be effective throughout their studies. According to their research, RT helps to improve memory, cognition, reduce anxiety, and alleviate depression in people with PD (44, 59, 61, 79). So far, RT has no adverse effects as long as painful memories are monitored, heard, and redirected. Also, the effectiveness of RT depends on a few factors, namely, one's cognitive functioning, cultural background, personality, unwillingness to share, the length/structure of the treatment, and whether there are any long-term effects (44, 68, 79).

According to P. T. Wong, there are six types of RT: integrative, instrumental, transmissive, narrative, escapist, and obsessive. The primary purpose of integrative reminiscence is to help individuals achieve self-worth, coherence, and reconciliation with their past. Instrumental reminiscence contributes to a sense of competence and continuity by recalling past plans, goal-directed activities, and problem-solving experiences to resolve present issues. It is associated with problem-focused coping strategies and internal control. Transmissive reminiscence involves referencing cultural values, traditional wisdom, and lessons learned from the past to pass on cultural ideals and enhance self-esteem. Escapist reminiscence is characterized by glorifying the past to help maintain psychological stability. Obsessive reminiscence arises from guilt over past experiences and involves persistent rumination on adverse events, leading to negative psychological effects. Lastly, narrative reminiscence focuses on recounting past events with little interpretation or evaluation (76).

Music therapy can be a form of RT, in which people recall the pleasant memories of when they heard a particular song. Music therapy is an evidence-based clinical practice that employs music interventions guided by a credentialed professional to achieve personalized therapeutic goals (2). It is used to help alleviate pain, enhance memory, manage stress, and promote physical rehabilitation. Studies suggest music therapy positively impacts neuroplasticity, improving cognition and other executive functions (35). Additionally, using music when exercising has been shown to enhance episodic memory and processing speed while reducing age-related hippocampal atrophy (18). Often, music therapy is introduced into exercise programs for people suffering from PD.

THEORETICAL FRAMEWORK

Robert N. Butler first explored the psychological phenomenon of reminiscence when he presented his “life review” theory in 1963. In his paper, Butler proposed the therapeutic potential of using reminiscence to alleviate psychological distress and promote emotional well-being in older individuals (10). Then, in 1971, Lewis conducted the first experiment in RT and suggested that reminiscing might help some older people cope with stress better (41). Since then, many studies have emerged to try to measure the effectiveness, reliability, and validity of RT. Liu’s research showed that RT had a significant positive impact on reducing depressive symptoms in older adults, including those with chronic illnesses and those on antidepressant medication, immediately after the intervention (44). Reitano’s results showed improvements in overall cognitive functions and long-term verbal memory in patients with PD. Additionally, mindfulness-based interventions were found to have positive effects on depressive symptoms (59). Saredakis’ research suggests that using VR in RT positively impacted reducing apathy levels among residents in aged care facilities. This study also shows that VR for RT could efficiently address apathy (61). Furthermore, Yen’s study highlighted various benefits of RT among older adults in Taiwan, including enhanced cognitive function, decreased anxiety and depression symptoms, improved self-esteem, heightened life satisfaction, and better interpersonal relationships (79). Although these articles claim that RT can be an effective intervention for addressing apathy, they also state that further research is needed to validate and expand upon findings.

Over the past century, VR technology has seen significant advancements in hardware and software. Notable milestones like Morton Heilig's creation of the Sensorama, one of the earliest VR machines in the 1950s, paved the way for rapid evolution and interest (31). In more recent years, VR has been used for educational purposes and even in the medical field. Aasma Basharat's review revealed notable improvements in motor functions, non-motor functions, and disease staging in PD patients after using VR therapy. Consequently, the research suggests that VR is an effective treatment option for alleviating PD's motor and non-motor symptoms (7). Kim Dockx's research evaluated multiple studies, finding that they were inconclusive but suggesting that VR training showed similar effectiveness to traditional physiotherapy (15). Brook Galna's study indicated that PD patients tolerated Kinect-based exergaming interventions and demonstrated potential improvements in balance and gait. The researchers also featured the feasibility and potential advantages of using motion-sensing technology for PD treatment (25). Luis Gómez-Jordana's experiment found that virtual doorways induced FOG just like real-life doorways did and that virtual footstep cues presented in a VR setting can significantly enhance gait performance (28, 29). Kaylena Ehgoetz Martens' study used VR to discover that anxiety can cause FOG (17). Anat Mirelman's experiment concluded that treadmill training with virtual obstacles may significantly enhance physical performance and cognitive function (48). Aram Kim's study proposes that fully immersive VR environments are safe for gait training people with PD (37). Lastly, Cheng Lei's testing suggested that VR-based rehabilitation training not only achieves similar results to traditional rehabilitation but also demonstrates superior performance in enhancing gait and balance in PD patients. They conclude that VR rehabilitation training can be considered a viable alternative when traditional methods are insufficient to improve PD patients' gait and balance (38).

STATEMENT OF THE PROBLEM

The benefits of treating the body as a whole and not as separate entities without communication may better serve the well-being of the aging and disabled community. Additionally, distracting the mind can lead to differences in movement. Past studies have looked at the impact of one's mental state on performance and social interactions (1, 45, 80). These studies show that feelings like depression can have a negative impact on one's interactions and performance. For example, one study saw that when participants felt sad due to sad music or a situation that limited movement, their muscle sensors responded differently, with increased dynamic firing (1). The researchers concluded that sad feelings prepare the body for actions like withdrawal or avoidance. Conversely, positive emotions can facilitate intrinsic motivation (45) and positive emotions can also aid in more normal movement patterns. However, the precise cause of this phenomenon remains unidentified. Research on the application of RT to address physical impairments such as FOG is lacking, and no prior research establishes a connection between VR and RT in addressing movement-related issues. Since FOG poses significant challenges, including mobility limitations, interference with daily tasks, and increased fall risks, people with PD suffer from depression and anxiety; anxiety and depression can trigger the symptoms of FOG (17). Managing FOG usually requires medications, physical therapy, assistive devices, and sometimes surgical interventions. Traditional methods to help FOG can be mundane, repetitive, and without instant gratification. This makes the treatment less appealing to patients, causing them to not adhere to the program or stop exercising entirely. As a result, their physical abilities decline rapidly. Both RT, demonstrated by Liu, Reitano, Saredakis, and Yen, and VR, as endorsed by Basharat, Galna, Gómez-Jordana's, Ehgoetz Martens', Mirelman's, Kim's, and Lei, are effective methods that people with PD can use. Therefore, combining RT and VR seems to offer the best chance of success. In this approach, a VR environment was created resembling 1950s New York City, complete with vintage cars, signs, advertisements, and other elements, aiming to blend the immersive joy of the virtual world with the familiarity and nostalgia of the past of RT.

Liu, Reitano, Saredakis, and Yen claim that RT has the potential to be an effective intervention for addressing depression (44, 59, 79), improvements in cognitive functions (59, 79), apathy (61), improved self-esteem, heightened life satisfaction, better interpersonal relationships, and improve anxiety (79). Also, Basharat's, Galna's, Gómez-Jordana’s, Mirelman’s, Kim’s, and Lei's research highlights that VR and exergaming can potentially serve as a therapeutic tool for individuals with PD to improve motor and non-motor symptoms, gait, balance, stress, and overall quality of life in individuals with PD (7, 25, 28, 29, 37, 38, 48). However, further research is needed to identify any long-term benefits and validate and expand upon findings for both RT and VR. Also, mental and physical impairments are addressed separately, medically, and in terms of therapy. Potentially, when treated together, therapy for PD patients can be more intuitive and practical. Movement therapies need to handle the psychological barriers patients face before they can see physical improvements. This is because patients sometimes think they are incapable of the exercises presented due to fear or lack of confidence. Using VR is a distraction from these thoughts since it can be used to facilitate RT; using VR to aid in RT would bring patients to a new or past world and diminish the barriers of the present world, thereby allowing therapists to approach physical issues from a different perspective.

PURPOSE OF THE STUDY

This study aimed to investigate the application of VR as an RT intervention to enhance the mobility of individuals with PD while assessing its effectiveness in mitigating FOG. The research centered on using VR to trigger meaningful memories and elicit positive emotions, as well as its potential to alleviate symptoms like depression and anxiety. Given that RT has already exhibited efficacy in addressing anxiety and depression, it holds promise in addressing other facets, notably motor function, which is significantly influenced by an individual's psychological state. Through VR, individuals are immersed in a customized virtual environment tailored to their specific needs and preferences in a way that has not been done before through traditional physical therapy methods. The fusion of RT with established physical therapy practices presents the prospect of achieving superior outcomes. Moreover, this thesis explored the potential implications of VR-based RT on a PD patient's overall quality of life and its potential integration into clinical settings and future research endeavors.

DELIMITATIONS

The following were delimitations of the study:

1. This was a single case focus, focusing on a single individual with Parkinson's disease, allowing for any findings of changes that occurred after the intervention to be attributed to the intervention.
2. This study only focused on one individual with a particular demographic. My participant was a certain age, gender, and level of disease severity.
3. Unreal Engine, the VIVE Focus 3, and the Xbox controller were chosen for their ease of use and advanced technology.

4. The study concentrated on a particular VR intervention to improve gait. This focus provides a detailed examination of the targeted area
5. This study only assesses the short-term effects of the VR intervention given within 6 weeks on the participant's symptoms and functional abilities.
6. The study has a restricted follow-up period, where the participant's progress and outcomes were assessed after the VR intervention but not over an extended period.
7. The study used specific assessment tools tailored to the symptom being addressed
8. The study took place within a controlled environment where the person was carefully monitored and allowed the use of aids.

LIMITATIONS

1. This was a single case focus, focusing on a single individual with Parkinson's disease, which may limit the generalizability of the findings to other individuals with Parkinson's since it may not represent the diverse characteristics of the entire Parkinson's population. Since my participant was a certain age, gender, and level of disease severity, this may limit the applicability of findings to other demographics.
2. The PAR-Q provides only a limited amount of information regarding the health and preparedness of an individual to participate in physical activity. It does not provide information on the diagnosis or progression of PD.
3. The number of sessions varied due to personal scheduling conflicts. The effort and repeatability were influenced by environmental, physiological, and mental status and time of week and day.
4. Environmental factors such as temperature and humidity were uncontrolled influences that may have impacted the participant's perceptual and actual exertion.

5. The validity of hardware and software was unknown to the researcher. This study potentially limits the use of certain VR systems due to cost, accessibility, or compatibility issues.
6. High-quality VR equipment can be costly, and access to such technology may not be readily available to all individuals with Parkinson's, limiting its widespread use and adoption.
7. Some individuals with Parkinson's disease may experience motion sickness or discomfort while using VR. This can be magnified by the motor symptoms of Parkinson's, which can affect their ability to navigate the virtual environment smoothly.
8. Some individuals with Parkinson's may have difficulty operating VR devices or controls due to motor impairments and/or dexterity issues.

ASSUMPTIONS OF THE STUDY

1. The hardware and software of the VIVE Focus 3 were calibrated accurately for validity.
2. Two individuals performed the pilot study of the exercise protocol and adequately graded the stimulation
3. The participant was a volunteer who had the opportunity to withdraw from the study at any time and provided his best effort for each session and test.
4. VR technology and interventions chosen for this case study are feasible and safe for individuals with Parkinson's disease.
5. The risk of any adverse effects or injuries was minimized.
6. Ethical guidelines and practices are followed throughout the case study.
7. Any improvements observed in the virtual reality environment will translate to functional improvements in the participant's daily life.

8. The chosen outcome measures are appropriate for capturing the effects of the virtual reality interventions on freezing of gait symptoms

HYPOTHESES

RT using VR will positively affect a participant with PD, allowing the person to have more controlled movements and less FOG.

The following are the null hypotheses of this study:

1. There are no significant correlations between VR and FOG occurrences; VR will not affect people with PD, and the person will not have more controlled movements and fewer FOG occurrences.
2. There are no significant correlations between RT and FOG occurrences; RT will not affect people with Parkinson's, and the person will not have more controlled movements and fewer FOG occurrences.
3. VR compromises a participant's sense of sight, so the participant's walking may be negatively affected.

DEFINITIONS OF TERMS

Parkinson's Disease *(PD)* is a progressive neurodegenerative disorder that is caused by the progressive degeneration of dopamine-producing neurons in the substantia nigra, a region of the brain involved in motor control. The loss of dopamine, a neurotransmitter responsible for transmitting signals between nerve cells, leads to the characteristics of motor and non-motor symptoms (72).

Deep brain stimulation (DBS) is a medical procedure that implants electrodes to deliver electrical impulses to specific brain regions. It is primarily used to treat certain neurological and psychiatric disorders, especially disorders that do not respond well to conventional medications or other treatments (13).

Virtual Reality (VR) is a simulated, computer-generated environment that immerses users into a three-dimensional, interactive virtual world. VR allows users to feel as if they are physically present in the artificial environment and enables them to interact with this environment in real time (73).

Reminiscence therapy (RT) is a therapeutic approach that uses memories and experiences to stimulate cognitive functions in individuals. It facilitates recalling past events, activities, and personal experiences through conversation, storytelling, or engagement with familiar objects, photographs, or music from the past. The goal is to reduce anxiety and depression by tapping into long-term memories. A person is not required to be a licensed medical practitioner to provide reminiscence therapy (68).

Freezing of gait (FOG) is a neurological phenomenon commonly associated with Parkinson's Disease. It is characterized by the temporary inability to initiate or continue walking, usually occurring when turning, moving through crowds, or under doorways (23).

Unreal Engine is a powerful and sophisticated software game engine developed by Epic Games, providing developers with the tools and resources to create high-quality video games and virtual reality experiences.

VIVE Focus 3 is a virtual reality (VR) headset manufactured by HTC.

VIVE Business Streaming is a software developed by HTC to enable virtual reality (VR) experiences

SteamVR is a virtual reality (VR) platform and software developed by Valve Corporation. SteamVR is designed to work with various virtual reality headsets, providing tools and features to enable VR experiences.

Xbox Controller is a gaming controller owned and produced by Microsoft Corporation.

CHAPTER II

LITERATURE REVIEW

Introduction

PD is a chronic neurodegenerative disorder that disrupts balance, movement, and cognition due to reduced dopamine levels in the substantia nigra. Dopamine plays a crucial role in transmitting nerve signals, and its deficiency leads to involuntary movement and coordination issues. However, PD's symptoms and progression exhibit considerable variation among individuals. Parkinsonism symptoms, such as those seen in PD, include slowness, stiffness, and resting tremors. A precise diagnosis from a specialized neurologist is essential for treatment. Treatment for PD involves a combination of medications, surgical options, and exercise therapies to alleviate specific symptoms. Exercise therapies are crucial for managing PD, promoting neuroplasticity, enhancing synaptic efficiency, and stimulating neuron growth. Exercise-dependent neuroplasticity allows the brain to adapt and rewire to compensate for dopamine loss; exercise helps preserve existing neural connections, create new ones, and potentially restore lost ones. Two significant issues in PD, FOG and anxiety, can also be improved through exercise. FOG is an involuntary inability to initiate movement, and anxiety often accompanies PD. Both conditions respond well to conventional physical therapy methods, VR, and other therapies, such as RT.

VR has emerged as an innovative treatment approach tailored to individual needs in PD management. VR creates three-dimensional virtual environments that patients can perceive as real and interact with. VR therapy can be particularly effective for individuals unmotivated by traditional exercise and has demonstrated the potential to translate improvements to the real world.

RT is a therapeutic approach designed to enhance the well-being and overall quality of life for individuals, especially older adults, grappling with cognitive impairment or dementia. This method involves engaging individuals in discussions and recollections of personal memories, life experiences, and past events, often facilitated through conversations, group sessions, or activities such as looking at old photographs or listening to music from their earlier years. RT aims to stimulate the individual's memory, promote social interaction, and enhance their sense of identity, self-esteem, and emotional well-being. Previous research found RT to be effective in reducing depression, anxiety, and agitation in older adults with dementia.

This study sought to explore the use of VR as a tool to administer RT to enhance mobility in individuals with PD while evaluating its efficacy in addressing FOG. The research focused on leveraging VR to evoke meaningful memories and elicit positive emotions, with the potential to alleviate symptoms like depression and anxiety. Building on the effectiveness of RT in managing psychological aspects and VR in assisting motor symptoms in PD from other studies, this study examined addressing motor function with established physical therapy practices, which is profoundly influenced by an individual's mental state. Given the existing knowledge gap surrounding RT and VR in assisting with motor symptoms found in PD, conducting this study is essential, as it can provide valuable insights and benefits for PD patients. The objective is to assess the participant's response to the combined application of both interventions and ascertain whether there is an improvement in their motor function. The following sections detail research pertaining to dynamic movement, FOG, and psychological factors in the context of utilizing VR and RT interventions to assist individuals with PD.

Reminiscence Therapy

Liu conducted a systematic review of *The effectiveness of reminiscence therapy on alleviating depressive symptoms in older adults: A systematic review* to evaluate the effectiveness of RT in reducing depressive symptoms among older adults. The review included 10 randomized controlled trials (RCTs) for meta-analysis, revealing high heterogeneity in the results. However, subgroup analyses indicated that RT had a significant positive effect in alleviating depressive symptoms in older adults. Interestingly, RT appeared to benefit older adults with chronic illnesses and those taking antidepressant medication. Group-based RT was found to be more effective and cost-effective than individual therapy. Also, structured therapy was considered more replicable, generalizable, and user-friendly for new therapists. While RT showed immediate positive impacts on depression remission and quality of life in older adults, the long-term effects and its influence remained unclear. The study recommended more rigorous research to address these gaps, including larger sample sizes, RCT designs, extended follow-up periods, and exploring other RT approaches (44).

In Reitano’s exploratory study, a new mindfulness-based cognitive rehabilitation protocol was compared to conventional Cognitive Rehabilitation Training in individuals with Parkinson's disease (PD) and Mild Cognitive Impairment (MCI). The results showed improvements in overall cognitive functions and long-term verbal memory in the experimental group. This aligns with previous findings that mindfulness interventions can enhance cognitive abilities, including attention, memory, and executive functions. Additionally, the study found that mindfulness-based interventions were found to have positive effects on depressive symptoms. However, certain methodological limitations and the multi-approach nature of the treatment program may influence the results. The researchers concluded that further research with larger, more controlled samples and neuroimaging assessments was needed to confirm the observed clinical improvements and their underlying neurophysiological mechanisms (59).

The study conducted by Saredakis aimed to investigate the effect of RT using VR on apathy in residential aged care settings. The researchers conducted a multisite nonrandomized controlled trial to evaluate the outcomes. Participants were divided into two groups: the intervention group, which received RT using VR, and the control group, which received standard care without VR therapy. The intervention group used YouTube VR (developed by Google LLC) to view personalized videos in VR and Wander (developed by Parkline Interactive) to observe personalized places of interest in VR. The control group used a laptop for viewing Google Street View, YouTube, and the internet in general. Then, the study assessed the apathy levels in both groups before and after the intervention. Preliminary findings from the preprint study indicated that RT using VR positively reduced apathy levels in residential aged care settings. The study suggests that VR-based RT has the potential to be an effective intervention for addressing apathy in residential aged care. However, further research is needed to validate and expand on these findings (61).

Yen’s paper, *A systematic review of reminiscence therapy for older adults in Taiwan. Journal of Nursing Research* conducted a systematic review of RT, focusing on its applications and outcomes. RT sessions typically involved 7 to 12 participants meeting weekly from 30 minutes to 2 hours for 4 to 16 weeks. Each session aimed to evoke memories from participants' youth, using folk songs, toys, photos, radio programs, newspapers, and food. Due to small sample sizes, most studies used quasi-experimental designs, often lacking random assignment or control groups—however, a few studies employed randomized controlled trials. Only a few studies conducted assessments during the pretest, posttest, and follow-up periods. The findings from these studies highlighted several benefits of RT for older adults in Taiwan, including improved cognitive function, anxiety, depressive symptoms, self-esteem, life satisfaction, personal interaction, and no negative post-intervention impacts on participants. Yen’s study deemed that RT was a noninvasive and effective therapeutic treatment for preventing and managing mental health conditions in Taiwanese older adults. The study concluded that further studies are necessary to establish the effectiveness of evidence-based protocols and systemic intervention (79).

Effects of Reminiscence Therapy on Older Adults

The studies conducted by Liu, Reitano, Saredakis, and Yen all explore different aspects of RT and RT’s effects on aging populations. These studies vary in terms of their focus, methodology, and findings. While Liu's study specifically investigates the impact of traditional RT on depressive symptoms in older adults (44), Reitano's study explores a mindfulness-based cognitive rehabilitation program for individuals with PD and MCI (59). Saredakis' VR study introduces VR into the context of RT for addressing apathy in aged care (61), while Yen's systematic review provides insights into the applications and outcomes of traditional RT in

Taiwanese older adults (79). Each study contributes to my understanding of RT and its potential benefits for older adults and different settings. Collectively, the articles suggest that RT has a positive impact on the psychological well-being of older adults by reducing depression and has the potential to be an effective intervention (44, 59, 61, 79). However, they also emphasize the need for further research and larger sample sizes to validate and better understand RT's therapeutic potential, indicating that the field of RT is still evolving and growing. Given the observed influences of RT on one's mental well-being, as highlighted by Liu, Reitano, Saredakis, and Yen, the exploration of this therapeutic approach through the integration of emerging technologies presents a promising avenue. My research endeavors to extend the existing body of knowledge within the domain of RT and innovatively apply these findings to a previously unexplored realm: the field of physical therapy.

Virtual Reality

The objective of Basharat's review was to investigate the effect of VR in the rehabilitation of PD. The study employed a quasi-experimental design and selected 30 diagnosed patients up to stage 4 of the Hoehn and Yahr scale using purposive sampling techniques. These patients played a VR game, specifically Microsoft Kinect, for 6 weeks, 4 days a week at the Railway General Hospital. Baseline measurements were taken using the Modified Unified Parkinson Disease rating scale, Modified Hoehn and Yahr rating scale, and the Schwab and England Activities of Daily Living Scale. The results indicated a significant improvement in the first three parts of the Modified Unified Parkinson's Disease rating scale, demonstrating enhancement in motor functions. Additionally, the study showed a significant improvement in non-motor aspects of daily living. The staging of modified Hoehn and Yahr disease and Schwab and England activities of daily life scale also showed a significant improvement. The study concluded that VR is an effective treatment choice for minimizing the exaggerated symptoms of Parkinson's disease, benefiting both motor and non-motor functions (7).

Dockx's article systematically reviews 8 trials involving 263 people from 4 to 12 weeks of intervention. The paper looked at the use of VR in rehabilitating PD patients. The authors explored VR's potential benefits and effectiveness as a therapeutic tool in improving motor function, balance, and quality of life for individuals with PD. The review synthesizes findings from multiple studies and evaluates the overall quality of evidence supporting the use of VR in PD rehabilitation. They discuss various VR interventions, such as virtual environments for gait training, balance exercises, and activities of daily living, and summarize the outcomes of these interventions. The authors assessed the effects of VR interventions on various motor and non-motor symptoms in PD patients, focusing on functional outcomes, quality of life, and patient satisfaction. The authors realized that the studies had small sample sizes and exhibited significant heterogeneity in study design and outcome measures. Consequently, the quality of the evidence was generally rated as low or very low because of the sample size. Most of these studies aimed to enhance motor function using commercially available VR devices and were compared to traditional physiotherapy. They concluded that compared to physiotherapy, the findings suggest that VR interventions may result in a moderate improvement in step and stride length. Additionally, VR and physiotherapy interventions appeared to have similar effects on gait, balance, and quality of life. Notably, no adverse events were reported with VR interventions, and exercise adherence was similar between the VR and other intervention groups. The review ends by expressing a need to validate these findings with high-quality, large-scale studies (15).

Lei conducted a systematic review encompassing sixteen articles to assess the efficacy of VR technology for PD patients. Their objective was to understand the effectiveness of VR technology for PD rehabilitation, focusing on improving gait and balance. The inclusion criteria were limited to randomized controlled trials published before December 30, 2018, which investigated the impact of VR interventions on PD patients. The meta-analysis suggested that VR-based rehabilitation training not only yields comparable results to conventional rehabilitation but also exhibits superior performance in improving gait and balance impairments among PD patients. Consequently, when conventional rehabilitation methods proved inadequate in addressing gait and balance issues in PD patients, the authors expressed that VR-based rehabilitation training is a viable alternative therapeutic option. Nevertheless, they concluded that further research featuring more rigorous, large-scale, and multicenter randomized controlled trials is needed to provide evidence of the potential of VR-based rehabilitation (38).

Galna's study explores the potential of using the Microsoft Kinect system for exergaming-based to rehabilitate dynamic postural control in PD patients, pilot testing the game's safety and feasibility. The researchers developed a series of games that target specific motor impairments commonly associated with PD. Through pilot testing, they found that the Kinect-based exergaming interventions were well-tolerated by PD patients and showed promise in improving functional outcomes, such as balance and gait. Seven of the nine participants enjoyed playing the game and expressed that they would continue to play it if it improved their balance. Certain participants encountered challenges distinguishing between various types and orientations of visual objects within the game. Additionally, some experienced difficulty when performing stepping tasks concurrently with reaching tasks. They concluded that there is a need for future studies with a larger sample to establish the game's safety, feasibility, and clinical efficacy to improve the postural control of people with PD (25).

Ehgoetz Martens' study used VR to provoke anxiety in patients with PD to test if the situations induced a greater occurrence of FOG. The study included 14 PD patients with FOG (Freezers) and 17 PD patients without FOG (Non-Freezers). Participants were asked to walk in two virtual environments: one with a plank at ground level and the other with a plank suspended over a deep pit. Anxiety levels were measured using self-assessment manikins. The results showed that Freezers experienced higher anxiety levels compared to Non-Freezers ($p<0.001$), reporting increased anxiety when walking on the plank suspended over a deep pit ($p<0.001$). Freezers had more FOG episodes ($p=0.013$), spent a larger portion of each trial frozen ($p=0.005$), and exhibited greater variability in step length when dealing with the plank suspended over a deep pit condition. The authors concluded that this study was the first to directly compare FOG and anxiety, indicating anxiety and the limbic system play a significant role in causing FOG in PD (17).

Mirelman's research hypothesized that VR could be a valuable tool to address the multifaceted issues related to the risk of falling in people with PD. They had twenty patients, with an average age of 67.1 years and an average disease duration of 9.8 years, who underwent 18 sessions of progressive intensive treadmill training with virtual obstacles (TT + VR). The study assessed gait under typical walking conditions, dual-task conditions, and walking while negotiating physical obstacles. They also evaluated cognitive function and functional performance. After the training, gait speed notably increased during typical walking, dual-task situations, and while navigating obstacles. Additionally, dual-task gait variability, functional performance, and performance on the Trail Making Test (parts A and B) improved. Furthermore, there seems to be a positive impact on specific aspects of cognitive function. Their results suggest that TT + VR is a feasible approach for individuals with PD and may significantly enhance physical performance, particularly during challenging conditions. The authors suggest that these findings hold significance for understanding motor learning in the presence of PD and for managing fall risk in individuals with PD, aging individuals, and others at an elevated risk of falls (48).

Gómez-Jordana's study created a VR environment featuring virtual doorways, a scenario known to trigger FOG in real-life situations, and compared the outcomes with those of a previous real-world experiment. They involved three groups: healthy controls (N = 10), idiopathic PD patients without FOG episodes (N = 6), and those with a history of freezing (PD-f, N = 4). They had patients walk in three virtual conditions: no door, a narrow doorway (100% of shoulder width), and a standard doorway (125% of shoulder width). The results closely paralleled those observed in the real-world setting. Virtual doorways led to reduced step length, velocity, and increased gait variability. The PD-f group consistently exhibited slower walking, shorter step lengths, and the most significant increases in gait variability. The narrow doorway induced FOG in 66% of the trials, while the standard doorway caused FOG in 29% of the trials, closely mirroring the outcomes seen with actual doors. The authors concluded that this methodology offers a secure, personalized, and adequately controlled approach to studying FOG in PD patients, as well as exploring potential interventions (28).

Another of Gómez-Jordana's studies looked at a VR environment that was created to provide visual cues in an immersive, interactive manner. These cues were represented as black footprints and were manipulated to convey spatial and temporal information. Step lengths (spatial cues) could be varied by adjusting the distance between the footprints. Additionally, by altering the timing when the footprints changed color to red, foot placement timing (temporal cues) was conveyed. In total, a group of healthy controls (HC; N = 10) and a group of individuals with idiopathic PD (PD, N = 12) were instructed to walk using personalized visual cues based on their gait performance. The cues included two spatial conditions and three different temporal conditions. Both groups successfully matched their step length and cadence to the provided visual cues in all conditions except for the 125% step cadence condition. The PD group exhibited reduced gait variability in all conditions. This was not observed in the HC group. Moreover, step velocity demonstrated a significant increase in both groups' temporal and spatial conditions. The coefficient of variation for step length, cadence, and velocity was consistently lower in the PD group compared to the HC group. The study highlights how virtual footstep cues presented in an immersive VR setting can significantly enhance gait performance in individuals with PD (29).

In Kim’s study, 33 participants were recruited, including 11 healthy young individuals, 11 healthy older adults, and 11 individuals with PD. They were asked to walk for 20 minutes while immersed in a virtual city scene using an Oculus Rift DK2 head-mounted display (Oculus VR, LLC, 2013). Safety was assessed through various measures, including the mini-BESTest, center of pressure excursion, and questionnaires addressing symptoms of simulator sickness, stress, and arousal levels. The results revealed that most participants completed the trials without any discomfort. There were no significant changes in symptoms of simulator sickness or measures of static and dynamic balance across the groups following exposure to the virtual environment. Interestingly, stress levels decreased in all groups, while the PD group showed increased arousal levels after exposure. The authors concluded that older adults and individuals with PD could use immersive VR during walking without experiencing adverse effects, providing systematic evidence supporting the safety of immersive VR for gait training in these populations (37).

Issues with Parkinson's Disease Related to Movement

One symptom VR has tried to tackle is the difficulty PD patients experience with walking movements. Issues in gait tend to increase after the progression of each stage of PD. Movement is defined as the act of shifting one's position to change location from one place to another (50). For many older adults, movement becomes impaired due to a lack of strength and increased rigidity with the postural muscles involved in balance and the muscles in the legs involved in walking. It has been concluded that in numerous studies involving VR, movement significantly improves in PD patients (9, 24, 38). Primarily, PD is considered a movement disorder since tremors, slow movements, and rigidity indicative of the disease interfere with the overall quality of life (72). These issues with movement also lead many to make compensations in their walking gait, such as using a shuffling gait. Badarny's study, which used AR, mentioned that medication can make these movements worse (6). Badarny conducted research that examined how visual cues given through portable transparent glasses, which responded to a patient's self-motion, impacted the walking capabilities of individuals with PD. The study assessed the immediate and lasting effects of factors like walking speed and the length of each stride. Badarny discovered that more than 20% of the patients exhibited enhancements in either their walking speed, stride length, or both, accounting for 56% of the observed cases. Following the removal of the device and a 15-minute wait period, patients were directed to walk once more, and 68% of PD patients exhibited a remarkable improvement of over 20% in either their walking speed, stride length, or both. A week later, 36% of these patients sustained a notable 20% or greater enhancement in their baseline performance compared to their initial test. The potential of combining visual feedback AR techniques, which is similar to VR, alongside conventional physical therapy may preserve gait and postural capabilities in patients suffering from PD. Hence, given the similarities between VR and AR in their functionalities, it stands to reason that the outcomes achieved through VR could potentially mirror those attained with AR, rendering VR an intriguing and viable alternative.

Virtual Reality on Freezing of Gait

A prominent symptom of PD is FOG, a condition where individuals experience a sensation of their feet being immobilized (70). This predicament intensifies as PD progresses, particularly during certain challenging circumstances. Regrettably, the etiology of FOG remains unknown, yet it is likely attributed to the altered operation of cerebral circuits governing intricate motor actions (70). PD patients often experience FOG when initiating movement, decelerating, encountering stress, changing their course, traversing different surfaces, multitasking, coming to a halt, traversing doorways, or navigating crowded environments (72). FOG can lead individuals to lose their balance and fall (70). However, interventions have exhibited the potential to mitigate the frequency of FOG episodes (28, 43, 48). This was measured by quantifying changes to one’s stride length and walking velocity before and after VR interventions (43, 48). FOG causes individuals to decrease their stride length and walking velocity. VR interventions aim to replicate real-world challenges through tailored applications, such as virtual doorways, enabling participants to become desensitized to visual stimuli and acquire strategies to manage FOG episodes. Gómez-Jordana’s study shows how the virtual environment elicits the same responses as the real world in both the control and experimental groups (PD participants with a history of FOG), with higher responses (increasing the amount of time for the trial) in the experimental group (28). Additionally, studies had participants perform different tasks at the same time (48) or with different doorway widths (28) and heights (17), which also resulted in the FOG. A reduction in FOG was demonstrated for the studies that used AR, holding promise for practical, real-world applications (6, 69). These investigations have revealed that AR cues do not result in shortened stride lengths or reduced walking velocities for participants (69). Some articles suggest that VR significantly improves the participants' walking abilities (6, 28), particularly one's movement speed, stride length, and gait variability (48). One study also found that these improvements and improvements in multitasking translated into the real world (48).

Virtual Reality on Depression and Anxiety in Parkinson's Patients

PD often manifests in symptoms that affect muscle control and movement, making everyday tasks like working, writing, and getting dressed challenging. This loss of control and increased dependence on others can leave people feeling that they are missing out on important aspects of life and relationships with loved ones. Most individuals with chronic illnesses experience a multitude of mental symptoms, such as depression and anxiety. Sometimes, the anxiety and depression faced by these individuals can be more debilitating than the actual disease. As a result, these mental symptoms can cause more and more negative effects. In a previous study on exercise and depression, exercise has been suggested to decrease the amount of negative emotions (53). Depression is defined as a medical illness where individuals have a lack of enjoyment, sadness, and decreased ability to function, impacting their actions (71). Depression is usually accompanied by anxiety, which is a fear or worry that gets worse over time (34). One of the body's responses to anxiety is stress, making one feel uneasy. This anxiety, which is experienced at different times and during different situations, can induce FOG (17). Individuals with PD are usually negatively impacted by depression, anxiety, and stress due to their bodies not physically being able to do what their minds are telling them to do (72).

However, VR has been suggested to combat these emotions in most studies of participants with PD. VR can be used to improve cognitive function in individuals with PD (61). VR can help improve attention, memory, and problem-solving skills by providing stimulating and engaging virtual environments. Overall, studies show that stress decreased and enjoyment increased (25, 37). This increased enjoyment was caused by the inclusion of extrinsic feedback like receiving higher scores and motivating participants to perform better on tests (60). This works on the reward system in our brains, increasing feelings of satisfaction and demonstrating a persistent desire for engagement. These emotions will lead to a willingness among participants to independently engage in games at home, especially when there are potential benefits for alleviating their physical symptoms (25). Studies show that stress scores, based on questionnaires after using VR, significantly decreased for the experimental (PD patients) and control groups, but larger arousal levels were seen in the experimental group (37). Another study found that using VR reduces pain intensity and improves scores in balance and gait (12). Some of the studies previously mentioned that the only difference between conventional forms of therapy and VR is the positive emotions associated with playing games.

Effects of Virtual Reality on Older Adults

Overall, these studies and reviews collectively highlight the potential of virtual reality as a therapeutic tool for individuals with PD, differing in their specific methodologies, findings, and recommendations. While Basharat's study provides the positive effects of VR in PD rehabilitation of motor and non-motor aspects, Dockx's article expresses that the results are inconclusive, highlighting the need for more rigorous research. Galna’s study saw the benefits of using the Microsoft Kinect system to rehabilitate dynamic postural control and showed the need for larger-scale validation, while Kim’s study found no balance improvements. Gómez-Jordana's research revealed that virtual doorways in a VR environment could induce FOG and that VR footstep cues can significantly improve gait performance. Mirelman's treadmill training with virtual obstacles showed promise in enhancing physical performance and cognitive function, while Lei's systematic review suggests VR as an alternative to traditional physical therapy.

VR uses techniques from physical therapy, such as integrating visual cues for walking and employing movement exercises, incorporating them into a game framework. Moreover, VR capitalizes on emulating real-world sensory feedback (43). In particular, two studies (24, 43) involved participants utilizing a balance board, engaging in back-and-forth walking on a designated track (28, 29), or employing a treadmill (37, 48) to translate their movements into the virtual realm. These investigations encompassed an extensive examination of balance alongside movement, recognizing the intrinsic connection between the two aspects. The experiments were diversely executed: two within a virtual corridor (28, 29) and five conducted within fully immersive virtual environments (17, 24, 37, 42, 48). Out of the reviewed studies, all PD participants were between stages I-IV on the Hoehn and Yahr scale and had anywhere from 9 to 36 participants. There were no significant differences between men and women. Many of these studies also lasted about 6 weeks, with 2 to 3 sessions every week.

While some studies indicate that VR improves the lives of PD patients, indicating similarities to traditional methods, some are not convinced. Many of the studies reviewed suggested that VR can help improve motor function in individuals with PD, strengthening the muscles used for movement. Additionally, they propose that immersive and interactive environments challenge individuals using VR to perform specific movements and exercises. This can lead to improvements in coordination, balance, FOG, and flexibility. Overall, the studies found improvements in movement for patients with PD, and some studies suggested that there are no adverse effects for participants using virtual environments (25, 28, 29, 37, 48). Furthermore, drawing insights from the findings, it can be asserted that the implemented interventions closely replicated real-life scenarios. This experimental design provides a robust framework, enabling researchers to control aspects of the intervention, thus facilitating the development of more effective treatment strategies. Each contributes to understanding how VR can benefit individuals with Parkinson's disease. However, further research and clinical trials are needed to fully establish the most effective approaches and VR’s long-term benefits. Considering VR offers comparable benefits to conventional physical therapy, it becomes a compelling avenue for enhancing patient engagement. Kim’s study, where patients walked through a virtual city, and Gómez-Jordana’s experiment investigating FOG inspired this current study. Given the boundless potential of VR and its adaptability for medical applications, it becomes a particularly promising option for developing immersive historical environments.

Summary

By engaging in VR, individuals effectively employ a strategy to divert their cognitive processes, creating an illusion of reduced effort and heightened motivation. VR emerges as a potent tool for enhancing motivation for therapy and exercise programs. By offering engaging and enjoyable experiences, VR promotes greater participation among individuals with PD, mitigating the perception of tedium associated with traditional exercise routines. VR opens a multitude of gaming options, each tailored to target specific areas requiring improvement and appealing to the intrinsic desire for progress. This appeal, along with extrinsic feedback, performance feedback, and intrinsic feedback, reinforces motivation driven by external performance cues to adhere to the activity. The enthusiasm to engage with these games during therapy sessions also increases the likelihood of self-directed participation (25), fostering continual personal improvement and more favorable outcomes. Also, the repetition of these activities facilitates motor skill acquisition and refinement. VR repeatedly challenges individuals to perform specific movements and exercises, potentially improving coordination, balance, FOG, and flexibility. However, no existing study precisely matches the scope of investigation attempted with this research. Specifically, a notable gap exists in examining how RT implemented through VR influences movement in individuals with PD. Amidst a wealth of both supporting and contradictory research findings, it is imperative to continue investigating to advance one's understanding of how VR can be integrated into treatment plans.

CHAPTER III

METHODS

Introduction

Physical therapists formulate tailored training protocols to improve FOG symptoms, which are contingent upon their levels of expertise, experience, and the availability of equipment resources. Various questionnaires and maneuver assessments are employed to quantify, offering many approaches. This exercise protocol was designed to replicate scenarios conducive to FOG episodes and to minimize fall risks. The primary objective was to elicit positive emotional responses from the simulated environment to improve overall well-being. The utilization of VR in assisting individuals with PD is still relatively new. Thus, there is a lack of standardized protocols and assessment measures to gauge the effectiveness of VR interventions.

Design of Study

This case study employed quantitative and qualitative methods to evaluate the effect of RT on FOG. Inclusion criteria stipulated that the participant should be capable of walking for a minimum of 30 minutes and have no other impairments or disorders besides PD. The study was a six-week intervention involving a single participant utilizing VR technology through the VIVE Focus 3. The participant's gait was assessed before and after the intervention to determine if the therapy was able to decrease the recurrence of FOG. Information was collected using the Gait and Falls Questionnaire (GFQ), the Dynamic Parkinson Gait Scale (DPGS), video recordings, and observational notes.

Subject

The participant is currently in his 80s and has lived with PD for approximately 25 years. When asked about his family medical history, he revealed a prevalence of PD in his mother and siblings. He also mentioned that his ancestral town has a high incidence of the disease. More than a decade ago, the participant underwent DBS to alleviate the tremors commonly associated with PD. The participant's medical protocol involves consultations with his PD specialist every 2 to 3 months. After consulting with his physician, the physician described the participant's condition to be in stage 3 of the Hoehn & Yahr scale. His occupational therapist consults with the participant two to three times a week. In accordance with information provided by the participant´s occupational therapist, The participant has atypical PD. This diagnosis presents notable manifestations of atypical PD, characterized by the absence of typical motor deficits common in PD.

In addition to his PD diagnosis, the participant experiences a degree of arthritic discomfort localized to his right shoulder. Throughout the experiment, the participant was actively engaged in therapeutic interventions, receiving speech therapy and occupational therapy. Despite the occasional festinating gait, the participant has retained a degree of independence. Festinating gait is described as quick, small steps to maintain one's center of gravity when the body leans forward past one's feet. He is able to walk with the assistance of a cane. There is a discernible asymmetry in motor function between his left and right side, most apparent when he is walking. His right side demonstrates unhindered motor function, moving without difficulty. His left side appears burdened in terms of motor control and initiating movements. Currently, he exhibits an absence of tremors but is experiencing dysphagia. He also has gastrointestinal issues, particularly indigestion and constipation. His pharmacological regimen includes Rytary, Tamsulosin, Clonazepam, and Venlafaxine. At the study's commencement, the implanted DBS device's battery level registered at 35%.

The participant's professional background included a managerial role for a pharmaceutical company. During the later 1950s, the participant frequently visited New York City and still has many fond memories of his experiences. For this reason, the VR world was created to replicate various features from NYC, which the participant was fond of in the 1950's. The participant also enjoys gardening and spending time with his plants.

Table 1: List of Medications Taken by the Participant

Medications	Dose	Schedule	Reason
Rytary Extended-Release Capsules	195 mg	2 in the morning, 8:30- 9 a.m. 2 in the afternoon, 1 p.m. 2 at 6 p.m. 2 at 10 p.m.	Levodopa and Carbidopa Management of PID symptoms
Tamsulosin Hydrochloride	0.4 mg	1 capsule at bedtime	To help treat an enlarged prostate gland
Clonazepam	1 mg	1 capsule at bedtime	For anxiety
Venlafaxine Hydrochloride Extended-Release Capsules	75 mg	1 capsule at bedtime	For depression

Experimental Protocol

Before each session, the participant was given a VIVE Focus 3 (HTC, 2021) headset without the use of handheld controllers. The participant was able to adjust the headset using an adjustment dial for a better fit. The headset felt balanced with weight on the front and the back of the headset.

(*VIVE Focus 3*, 2021)
Figure 1. VIVE Focus 3 (HTC, 2021) headset (front view and side view)

The headset was connected wirelessly to a custom-built NZXT gaming computer using VIVE Business Streaming (HTC, 2021) and Steam VR (Valve Corporation, 2015). Unreal Engine 5 (Epic Games, 2022) and a few prebuilt assets, the 1950s NYC Environment Megapack (Leartes Studios, 2021) and Quixel Megascans (Epic Games, 2016) were used to create a simple 1950s New York City map. The map had two straight paths and three turns: two left turns and one right turn. Movement in the map was accomplished using an Xbox (Microsoft Corporation, 2013) controller connected to the computer, moving at roughly the same pace as the participant's walking speed. Movements were recorded using a personal video recording device. After each session, the recordings were downloaded onto a computer and later analyzed.

(*Xbox*, 2013)
Figure 2. Xbox One (Microsoft Corporation, 2013) controller

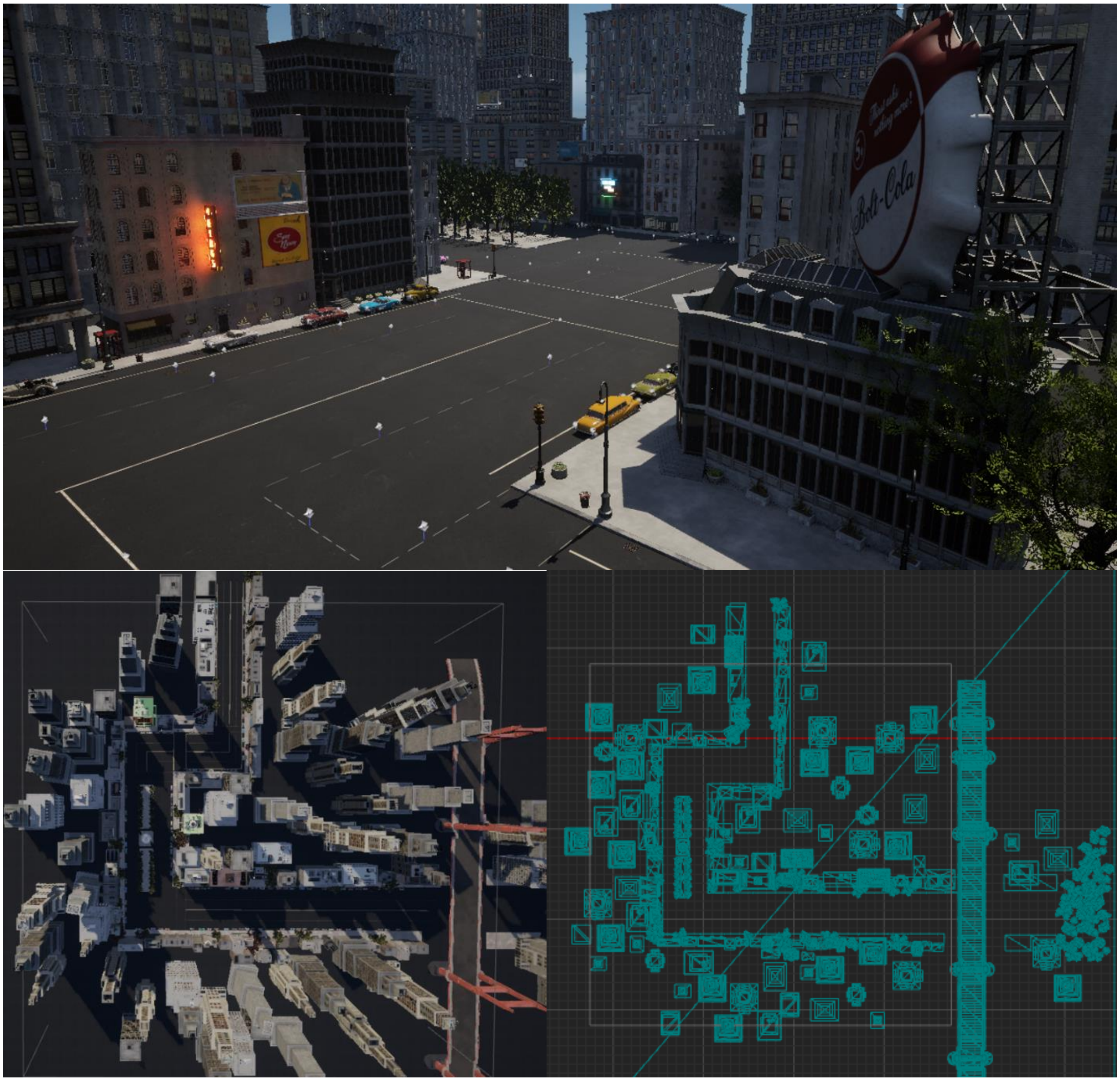

Figure 3. The 1950s New York City Map and Top Map View

Images of the VR experience taken by the researcher

Table 2: Computer Specs

Processor	Intel(R) Core (TM) i7-9700K CPU @ 3.60GHz 3.60 GHz, 3601 Mhz, 8 Core
Installed RAM	128 GB
System type	64-bit operating system, x64-based processor
Edition	Windows 10 Pro
Graphics	NVIDIA GeForce RTX 3090
Disk	Samsung SSD 970 EVO Plus 1 TB

Procedures

Prior to the commencement of the experiment, the participant was provided with a Physical Activity Readiness Questionnaire (PAR-Q) and a consent form. The participant was required to thoroughly read, comprehend, and sign both forms. The participant's PD physician was duly informed and gave permission for the study to take place. To ensure the participant's complete awareness and understanding, the participant was given a detailed briefing regarding VR features and potential side effects. Data pertaining to the participant's baseline health and mobility was collected through the GFQ, the DPGS, and the Occupational Therapist's Functional Reach Test. Before the immersion in the VR environment, the participant was asked a series of well-being questions and was engaged in preparatory exercises.

Each session commenced with a preliminary assessment of the participant's emotional well-being. Questions were evaluated using a scale ranging from 1 to 10, where 1 denoted the worst and 10 the best. The following questions were asked at the start of each session:

1. How would you rate your overall physical health today?
2. How would you rate your current emotional state?

3. How would you rate your stress right now?
4. How would you rate your satisfaction with your day?

Following these questions, the participant practiced walking with his eyes closed, without the VR headset, under the supervision of an assistant. The assistant/researcher accompanied the participant by walking backward in front of him and beside him to ascertain the most comfortable method. Then, the participant repeated the same exercises with the VIVE Focus 3 VR headset without the headset being activated to ensure continued comfort with the chosen walking method. Once this first introduction was successfully completed, the participant was given the Oculus 1 (Reality Labs, 2016) headset for a trial. The participant was encouraged to play Bogo (Meta, 2019), a free Quest experience involving the interactions of a virtual pet to become familiar with the headset and VR system. After approximately 10 minutes of engagement and familiarization with the VR features, the participant was introduced to the VIVE Focus 3 headset. While following pre-mapped pathways, he was encouraged to explore the VR world, which represented a reimagined 1950s New York City.

Following this assessment, the setup was executed for each session as follows:

- Open up Unreal Engine (Epic Games, 2022) 5.0 and 5.2
    - Assets were made by Leartes Studios and Quixel Megascans
- Open SteamVR and VIVE Business Streaming
- Turn on and link up to the VIVE Focus 3 headset
- Set the Engine Scalability Settings to Epic and Streaming Pool Size to 1800.

Figure 4. Image of Computer Set-up

Images of the system and the participant taken by the researcher

Figure 5. Image of the Participant with Headset During Week 3

Images of the participant taken by the researcher

After starting the system and setting up the virtual world, the participant walked accompanied by the researcher to lower the fall risks. This was accomplished by walking around a 25 ft x 7 ft space for 30 minutes at very light/light intensity and an effort of 2-3/10. It was determined that the participant felt the most comfortable and confident when the assistant walked backwards in front of the participant, holding onto his arms from underneath. This prevented the participant from walking more to one side, facilitating balance. The participant tended to lunge forward with the upper trunk and was reminded to keep a more upright and straight position while walking. Additionally, when walking, the participant was reminded constantly to take larger steps to prevent shuffling and was given positive reinforcement. When the participant seemed tired, he was allowed to take breaks, rest, or drink water at any given time.

At the end of the first session, the participant was asked a series of questions:

1. Do you feel like you are able to do the activity, or do you feel like it was too difficult? Were you tired, or did you have the stamina to do more exercises?
2. Did any past experiences come to mind during this exercise? Did anything look familiar/remind you of any past experiences? Why or why not?
3. Did this experience seem relevant to you?
4. Do you feel like this exercise improved your walking?
5. Did this experience simulate any other senses? What senses, if any?
6. Do you feel comfortable with VR? If not, what might make you more comfortable?

At the end of each session, the participant was asked again how he would rate his current emotional state and if he felt stressed or worried. By the end of the six weeks, data was collected again through the emotional well-being questions, the GFQ, the DPGS, the Occupational

Therapist’s Functional Reach Test, and video recordings. The results were compared with the baseline data to determine whether the intervention decreased FOG.

Data Collection

The GFQ and the DPGS scores were taken the first day before the intervention was administered. A total of 24 questions were asked, some requiring the participant’s verbal response and others requiring a physical action. Scores were recorded, and videos were taken to compare the gait before and after intervention. The outcomes of the emotional well-being questions were also compared. After 6 weeks, the participant was asked to perform and answer the same 24 questions. Another video was recorded, and the scores obtained were compared with the scores from the initial day.

Data Analysis

The results from the emotional well-being questions, the GFQ, the DPGS scores, the Occupational Therapist’s Functional Reach Test, and video recordings were compared pre- vs post-intervention. The researcher answered the questions prior to the commencement of the intervention to collect baseline data. The researcher relied on observations from initial experimental exercises to select the best response. The researcher answered the same questions at the study's conclusion. Differences in answers to numerous questions were noted.

CHAPTER IV

RESULTS

This case study involved the intervention of an 80+ male who has had Parkinson’s disease for 25 years. Out of a possible 18 sessions, a total of 17 sessions were administered.

Sessions were between 2 p.m. and 4 p.m., after the participant ate lunch, took his afternoon pills, and sometimes held a few hours after the participant had other therapy sessions that morning. The warm-up was excluded due to the light volume and intensity of the activity.

At the end of the first session, the participant answered these questions:

1. Do you feel like you are able to do the activity, or do you feel like it was too difficult? Were you tired? Or did you have the stamina to do more exercises?

   Yes, I was able to do the activity. It was not too difficult. I was not too tired and had the stamina to complete more exercises.

2. Did any past experiences come to mind during this exercise? Did anything look familiar/remind you of any past experiences? Why or why not?

   Yes, it reminded me of going to the city when I was younger. The buildings and objects did remind me of when I used to visit New York City. The cars looked familiar since they were similar in style and color to those popular in the 1950s.

3. Did this experience seem relevant to you?

   Yes, the experience seemed relevant to me.

4. Do you feel like this exercise improved your walking?

   I do not know if the experience improved my walking. It was fascinating to look at.

5. Did this experience simulate any other senses? What senses, if any?

   No, it did not simulate any other senses.

6. Do you feel comfortable with VR? If not, what might make you more comfortable?

   Yes, I feel very comfortable with the VR. It does not bother me at all.

Appendix F: Gait and Falls Questionnaire (GFQ) consists of 16 inquiries, each to a scaling system ranging from 0 to 4. In this scaling scheme, a score of 0 denoted normal movements. A score of 4 indicated severe disability, such as being unable to walk. In the pretest assessment, the participant scored 29 out of a conceivable 64 points. A score of 64 represents the most severe condition, whereas a score of 0 would indicate an absence of any motor or movement issues. Subsequent to the intervention, the participant's overall score improved to 15 points in the post-test.

Table 3: Results of the Gait and Falls Questionnaire (GFQ)

Appendix F Q#	Question	Pre answer	Post answer
1	During your best state-do you walk	3	3
2	During your worst state—do you walk	3	3
3	Are your gait difficulties affecting your daily activities and independence?	2	2
4	Do you feel that your feet get glued to the floor while walking, making a turn or when trying to initiate walking (freezing)?	1	0
5	How long is your longest freezing episode?	3	0
6	How long is your typical start hesitation episode (freezing when initiating the first step)	4	0
7	How long is your typical turning hesitation (freezing when turning)	3	0
8	How long is your typical destination hesitation (freezing when approaching the target, such as when stepping onto a scale or approaching a chair to sit down)?	2	0
9	How long is your typical tight quarters hesitation (freezing when attempting to get through narrow space such as a doorway)?	2	0
10	How long is your typical freezing episode while walking on straight?	0	0
11	How long is your typical freezing episode during stressful time-demanding situations, such as when the telephone rings, at elevators or street crossing?	2	0
12	How often do you fall?	1	2
13	How often do you fall when standing?	0	0
14	How often do you fall because of freezing episodes?	0	0
15	Do you experience festinating gait? (Festinating gait: accelerated, short steps, gait)	3	4
16	How often do you fall because of festinating gait?	0	1
Total		29/64	15/64

The questions are located in Appendix F; however, the following questions were identified as exhibiting differences between the pre-test and post-test.

- Do you feel that your feet get glued to the floor while walking, making a turn or when trying to initiate walking (freezing)?
- How long is your longest freezing episode?
- How long is your typical start hesitation episode (freezing when initiating the first step)
- How long is your typical turning hesitation (freezing when turning)
- How long is your typical destination hesitation (freezing when approaching the target, such as when stepping onto a scale or approaching a chair to sit down)?
- How long is your typical tight quarters hesitation (freezing when attempting to get through a narrow space such as a doorway)?
- How long is your typical freezing episode during stressful time-demanding situations, such as when the telephone rings, at elevators or street crossing?
- How often do you fall?
- Do you experience festinating gait? (Festinating gait ˆ accelerated, short steps, gait)
- How often do you fall because of festinating gait?

Appendix G: Dynamic Parkinson Gait Scale (DPGS) contained a set of 8 questions. Responses were graded on a scale ranging from 0 to 3, with a score of 3 signifying normal function and a score of 0 representing severe impairment. Notably, the initial four questions of this questionnaire consistently yielded the same scores in both the pretest and posttest assessments. During the pretest, the participant scored 10 out of a potential 24 points, reflecting the range from maximal functionality to minimal performance impairment. After the intervention, as evidenced by the posttest, the participant's score exhibited an improvement, reaching a total of 13 out of the possible 24 points, indicating a positive trend in gait performance following the intervention

For this questionnaire, the first four questions had the same score from pre- to post-test. Overall, his scores for the dynamic gait index pretest were 10 out of a possible 24 points. His score for the posttest was 13 out of a possible 24 points. A lower score indicates severe impairment, while a higher score reflects more typical gait patterns.

Table 4: Results of the Dynamic Parkinson Gait Scale (DPGS)

Appendix G Q#	Question	Pre answer	Post answer
1	Gait level surface-walking at average speed	1	1
2	Change in gait speed	1	1
3	Gait with horizontal head turns	1	1
4	Gait with vertical head turns	1	1
5	Gait and pivot turn	1	3
6	Step over obstacle	1	2
7	Step around obstacles	2	2
8	Steps	2	2
Total		10/24	13/24

The following questions had different responses from pre- to post-intervention:

- Gait with pivot turn
- Step over obstacle

Video recording analysis revealed that the participant made short steps in the pretest and hesitated to turn. His arms were outstretched, and his upper body stayed inclined primarily at 10 degrees to his hips. His feet were also behind his body at about 10 degrees past his hips. The participant completed a distance of 12 feet in 19.22 seconds. After the intervention, the participant’s upper body was straighter, not leaning as far forward when walking, and his legs were underneath his body. In the post-test, he made larger and more controlled steps. He also completed the same 12-foot distance test in the pre-test in 16.36 seconds.

Figure 6. Image of the Participant's Posture during Week 1 and Week 6

Images of the participant taken by the researcher (before and after intervention)

Balance assessments were made before the intervention in July and after the intervention in August using the Functional Reach Test. The average of three scores were used for both the pre- and post-tests. The participant had a baseline score of 7 inches in July and, in August, had a score of 9 inches.

Before the start of each exercise session, the participant was asked a series of well-being questions. The averages of each question were recorded by week.

Table 5: Well-Being Questions Before Each Session

Well-Being Question	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6
How would you rate your overall physical health today?	2.5	3.5	4	5	5.5	6.5
How would you rate your current emotional state?	3	3	3.5	5.5	5.5	7
How would you rate your stress right now?	5.5	5.5	6	7.5	8	9
How would you rate your satisfaction with your day?	3	3	4	4.5	4.5	5

Table 6: Well-Being Questions After Each Session

Well-Being Question	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6
How would you rate your current emotional state?	3.5	4	4	6.5	6.5	8
How would you rate your stress right now?	6	6	7.5	8	8	9.5

DISCUSSION

According to the available knowledge, this study appears to be the first to use RT through VR to help with movement symptoms. This study aimed to investigate the subjective and objective quantification methods of FOG using VR as an RT intervention to enhance the mobility of individuals with PD. Although previous studies looked at the impacts of RT on one's mental state or VR as a possible treatment for individuals with PD (7, 15, 17, 25, 28, 29, 37, 38, 44, 49, 59, 60, 61, 79), there has yet to be any studies that combined both forms of therapies. Comparisons between the GFQ, the DPGS scores, and video analysis were conducted pre- and post-intervention. The findings of this study indicated a reduction in instances of FOG and an enhancement in walking without any observed adverse effects. Thus, individuals with moderate

PD can safely use VR to help symptoms of FOG. FOG instances can increase as PD progresses, increasing the risk of falls. Although effective in alleviating symptoms and maintaining one’s walking ability, traditional methods are mundane. Occasionally, throughout the study, the participant needed reminders to adopt larger steps to avoid shuffling. These are the same cues used during physical or occupational therapy sessions. This recurrent prompt points to an essential aspect of PD, which predominantly affects the function of the brain. Regulating the steps of a patient with PD is a means to emulate a more "normal" gait pattern. It is suggested that individuals with PD need to engage in cognitive processes before initiating movements. VR can be integrated as a supplementary component to conventional physical or occupational therapy, adding to the overall efficacy of PD rehabilitation. Preliminary observations suggested that the inclusion of VR interventions has the potential to yield enhanced outcomes compared to a regimen solely composed of physical or occupational therapy. The participant may have derived additional therapeutic benefits by applying VR with traditional physical or occupational therapy protocols.

Initial assessment questions of the participant’s overall VR experience after the first session aimed to gather insights into the participant’s emotional and physical experiences. The assessment intended to acknowledge the participant's comfort, whether the VR environment triggered any reminiscences, stimulated any other senses beyond sight, and whether he perceived any impact on his walking abilities yet. Overall, the participant’s personal experiences and perceptions related to his engagement with VR technology. As the participant progressed through the study, his demeanor became more positive, and his walking improved.

Using the GFQ, the participant scored the same on several questions. This is because the participant still required the use of a cane to walk, his gait was mildly affecting his independence due to losing his balance while walking, and he has never fallen due to standing still or FOG. Consistency in certain movement aspects in PD can signify improvement despite unchanged scores. PD is a progressive condition, meaning it typically worsens over time. Thus, maintaining specific abilities is beneficial amid this progressive nature. Also, this stability shows one's ability to retain capabilities without significant deterioration, signifying effective management of the condition's progression and function. Improvements were seen in the length of freezing episodes, start hesitation, turning hesitation, destination hesitation, tight quarters hesitation, stress-induced freezing, and the extent to which the participant felt glued to the floor. The participant noticed that he no longer felt like his feet were glued to the floor while walking, making a turn, initiating movement, approaching an object, or attempting to move through a narrow space. Possible explanations exist for the increase in falls and its connection to fascinating gait. Regarding the participant's falls, he mentioned that he fell once before the study and once within the time of the study when he had a festinating gait episode and misjudged a step outside of a restaurant. Also, according to the participant, he felt he experienced festinating gait more often. Festinating gait is due to a dysfunction in the basal ganglia to cue each part of the motor plan promptly (33), and treatment focused on postural control and balance impairment is recommended (51). This increase in festinating gait often occurs on days when he walks for more extended periods and can be due to many outside factors, such as changes in medications. Nevertheless, the participant scored better overall in the post-test, scoring 14 points less than the pretest. A lower number means less FOG frequency and disturbances in gait that may increase the risk of falls. The extra practice might have helped him walk more naturally, like warming up muscles before moving.

For the DPGS, the first four questions had the same score from pre- to post-test, having moderate impairment due to his festinating gait and stage in PD. Regarding gait and pivot turn, the participant safely turned within 3 seconds and was able to stop without any loss of balance during the post-test. The researcher noticed that the participant's balance appeared to have improved at around three weeks into the experiment. For stepping over obstacles, in the post-test, he was able to step over a shoe box safely by slowing down without stopping. The participant achieved the same scores in his step mobility and ability to move over obstacles since he needed to slow down and adjust his steps to go over the cones. In addition, the participant relies on a handrail for support while navigating stairs. Recognizing the progressive nature of PD, the study expected specific scores to remain stable. The study's physical components aided in preserving the participant's current capabilities, culminating in an overall improvement of 3 points in his scores.

Wellness questions revealed a shift in the participant's emotional state during the intervention's initial phase compared to the final weeks. At the onset of the intervention, the participant reported higher levels of depression and a lower opinion of his overall health, stress, emotional well-being, and satisfaction. The participant had a diminished view of his health after having battled PD for over 20 years. Also, anticipating a new intervention and adapting to the VR exercise may have resulted in lower scores initially. By the end of the intervention, the participant's responses indicated a slight improvement in his perception of overall health, emotional state, stress, and satisfaction scores. Familiarity and confidence with the VR environment, or improvements in mobility, may have contributed to the change in his emotional and wellness perceptions. The VR experience set in the 1950s has been seen to reduce stress and enhance mood by tapping into the familiarity and discovery of different elements in that environment. The participant enjoyed the VR experience and expressed amazement at the technological advancements showcased in the experience. Anxiety has been associated with an increased occurrence of FOG (17), and lower anxiety experienced by the participant produced less FOG occurrence. Additionally, anxiety and depression can be greatly improved by exercise. The increase in exercise might have played a pivotal role in alleviating the participant's anxiety and depression. Physical activity results in the release of neurotransmitters with mood-boosting effects, thereby mitigating feelings of anxiety and depression. Moreover, exercise promotes neural growth and enhances neural connections, contributing to one's improved mental state. Additionally, there was a change in scores before each session and after each session. At the start of each session, overall health, emotional well-being, and satisfaction were slightly lower than the session's conclusion. This, again, correlates to physical activity positively affecting one's mental state.

Upon video analysis comparing before and after the intervention, the participant exhibited notable improvements in gait. There was a noticeable difference in the quality and control of his steps. Before the intervention, the participant's upper body and lower body were at a 10-degree difference to his hips. As a result, walking can become more difficult, creating a trunk-to-pelvis misalignment and changing one's center of gravity. The body needs to align to maintain balance and stability; a deviation from this disrupts the alignment and brings the center of gravity forward from the body. Typically, when walking, the center of gravity is at the umbilicus. When this happens, maintaining equilibrium and coordinated movements becomes challenging. A misalignment also increases the demand on the muscles and joints that support the movement, causing increased muscle fatigue. As a result, falls have become more common. Additionally, his steps were heavy, and he placed much of his weight on the researcher's arms. The participant stumbled and stopped often when walking in the first four weeks. By the last two weeks of the experiment, he had a reduced forward lean compared to the pre-test phase and better, more controlled steps. The participant's feet were lighter when he walked than the pre-test, and he did not place his weight on the researcher. Instead, his arms lightly rested on the researcher's arms, allowing the researcher to guide him without difficulty. Additionally, there was a notable difference in stride length and speed. Specifically, the participant made larger strides and completed a 12-foot distance faster by 2.86 seconds. These stride length and speed improvements correlate to the improved alignment of the participant's body. An aligned body positively affects gait performance and balance. It is also likely that the participant felt an increased sense of confidence walking in the virtual world by the end of the study.

Balance assessments were made in July, before the intervention, and in August after the 6-week intervention, using the Functional Reach Test. In August, slight improvements were documented. The average of three scores were used for both pre- and post-tests. The participant had a baseline score of 7 inches in the first week of the intervention, and in the last week of the intervention, his reach increased to 9 inches. This 2-inch difference is associated with an improvement in overall balance. Balance is the foundation for movements such as walking because one's body needs to shift one's weight from one foot to another. Walking involves the complex coordination of multiple muscles and joints working in unison to accomplish a task. Improved balance scores are associated with increased stability, posture, independence, maintenance of gait patterns, and reduced fall risk and strain on muscles. Additionally, increased balance allows for smoother and more controlled transitions between steps, optimizing the body's movement efficiency and precision. After the intervention, he was noted to be able to walk around more freely and perform routine tasks, including cutting his bushes. Interestingly, a trend was noticed, indicating a potential positive outcome following occupational therapy sessions. While the extent of the improvement is yet to be quantified, this observation suggests that on days when the participant engaged in more movement, this extra exercise may have benefited the participant's walking ability. This implies that the more interventions one is involved in, the better one's motor coordination is.

There is variability in symptom severity amongst individuals grappling with PD from day to day. One day, a person may be able to walk without difficulty; another day, a person may heavily rely on a cane. This variance in the presentation of symptoms is a hallmark of PD, arising from the complex interplay of multiple underlying disease factors. Additionally, as the study progressed, the participant seemed to have an increased number of better days, particularly increasing in frequency in the study's latter stages. Nevertheless, it is valuable to consider that a minimal risk of confirmation bias is inherent in any study.

The researcher noticed that the participant's steps felt less encumbered as the study progressed, allowing for easier and quicker movements by the end of the study. This subjective observation could signify an improvement in overall gait and mobility; however, it warrants careful consideration since only one participant was tested in the study. The interpretations of these findings should consider the multifaceted nature of PD. Also, understanding what contributed to this perceived improvement is essential for tailoring interventions. A plethora of variables, including medications, therapeutic interventions, environmental factors, and psychological well-being, can influence PD's course. The interpretations and possible reasons for the observed results help better understand PD and potential treatment options for PD. RT through VR allows for a holistic approach that considers both the condition's physiological and psychosocial aspects. Understanding these intricacies is pivotal for developing more tailored and effective strategies to manage movement symptoms of PD and improve the quality of life for those living with the condition.

CHAPTER V

SUMMARY

In summary, this case study aimed to determine the potential impact of RT delivered via VR on mitigating FOG in an older person afflicted with PD. PD is variable, and symptoms progress in severity without remediation. Existing research indicates that the utilization of VR can yield improvements in balance, FOG, and stress alleviation for PD patients (7, 15, 28, 29, 37, 49). The kinematic parallels between movement using a VR simulation and conventional physical therapy methods, which involve performance feedback, highlight the possible use of either therapy method. VR offers a controlled setting that can be tailored to the individual's requirements, offering targeted motor training with an emphasis on repetition and variability, which forms a foundational basis for motor learning. As technology advances, the capabilities of VR devices and other electronic devices that can be used in unison facilitate precise and efficient performance feedback, surpassing what can be achieved by human intervention alone.

Furthermore, there is an association between emotional factors, notably anxiety, and movement impairments such as FOG in people with PD (17). FOG management typically involves medication, surgery, physical therapy, and assistive devices. RT through VR holds the potential to offer PD patients a respite from the anxiety often linked to movement. By immersing patients in goal-driven VR experiences, the technology redirects patients with PD focus from anxiety towards achieving in-game objectives and strengthening the muscles associated with movement. This shift creates a more positive connotation with walking, potentially diminishing anxiety and, by extension, instances of FOG. Treating the body holistically rather than as separate components and addressing the connection between mental and physical well-being can be particularly beneficial for aging and disabled individuals. There is a lack of research on the use of RT through VR to address physical impairments, like FOG, which people with PD often experience. The case study aimed to explore whether RT, when combined with VR, can reduce FOG in elderly individuals with PD, potentially offering a more personalized and effective approach compared to traditional methods.

This case study utilized quantitative methods to investigate the impact of RT with VR. The study involved a single participant who had to meet specific criteria, including the ability to walk for 30 minutes and having no impairments other than PD that could affect their walking. Over 6 weeks, the participant's gait was evaluated before and after the therapy to assess whether the intervention reduced the occurrence of FOG. Data collection methods included the GFQ, the DPGS, video recordings, and the participant’s occupational therapist's observation notes. After the case study, the GFQ showed that the participant still required a cane to walk and experienced some balance issues, mainly when misjudging stairs. However, improvements were observed in FOG episode duration, start hesitation, turning hesitation, destination hesitation, tight quarters hesitation, stress-induced freezing, and the sensation of being glued to the floor. The participant also reported increased festinating gait, which can be related to basal ganglia dysfunction. Despite occasional falls, the overall posttest score on the GFQ was 14 points lower than the pretest, indicating reduced FOG. On the DPGS, some questions showed moderate impairment due to festinating gait and Parkinson's stage. The participant's balance improved, and he could pivot turn safely. He also adapted his gait when stepping over obstacles and relied on handrails while navigating stairs. Although some scores remained stable due to the progressive nature of PD, the study demonstrated an overall improvement of 3 points in the DPGS scores. Video analysis showed that the participant exhibited larger, more controlled steps with reduced forward lean when walking. Also, video analysis revealed that the completion of a 12-foot distance decreased by 2.86 seconds. Wellness questions showed an overall improvement in the perceived anxiety and depression felt by the end of the 6 weeks. Additionally, balance assessments using the Functional Reach Test revealed slight improvements, with the participant's reach increasing from 7 to 9 inches, leading to better overall balance and increased mobility. Due to the limited sample size, a formal statistical analysis was not conducted. However, notable improvements in scores on the specified tests suggest positive changes in an individual with PD. Consequently, it is plausible to accept the hypothesis that VR may improve motor skills and mental state in individuals with PD. However, the application of VR in the physical rehabilitation of individuals with cognitive and physical disabilities remains relatively new. Therefore, further comprehensive testing and rigorous assessments are required to validate the observed results and refine the therapeutic approach.

CONCLUSION

In the past, various technologies emerged to support individuals in managing diseases and disorders. These technologies primarily aim to mitigate the effects of secondary conditions rather than address the underlying causes. However, as society's understanding of diseases and their treatments advanced, technology has evolved accordingly. As a result, therapists can use technology to alleviate symptoms and conditions, thereby improving one’s quality of life. One such example can be the therapeutic application of VR gaming.

VR offers several advantages in the realm of PD rehabilitation. One of the great advantages of VR is that it provides enhanced sensory feedback, surpassing the precision achievable when facilitated by physical or occupational therapists. Sensory feedback is essential for integrating complex motor behaviors (69, 74). Another advantage is VR's capacity to effectively simulate diverse scenarios in a guided and validated manner, a feat often more challenging to accomplish in the physical world. VR can also include more repetition and variability compared to conventional training, fostering motor learning (47, 48). With the right technology, researchers can benefit from collecting objective data on various symptoms, especially motor function, within a controlled VR environment; VR provides a controlled setting for the examination of intervention effects, placing the person in different situations that would not be possible without VR such as from higher heights (17). Additionally, VR interventions exercise the same muscles as traditional therapy, usually having the person perform similar movements. The data gained from VR gauges the effectiveness of different interventions and treatments, ultimately contributing to a more comprehensive understanding of treating PD. Also, the data collected through VR minimizes the influence of confounding variables and heightens the accuracy and reliability of treatments. Moreover, the continued cost-effectiveness of VR technology makes it an accessible and affordable means to deliver therapy and exercise programs, offering a broader range of patients the opportunity to engage in such interventions.

VR interventions should complement conventional therapies until more research is done regarding the effects of such therapies. While conventional training plays a role in improving motor symptoms for PD patients, it has inherent limitations, such as being mundane. With the emergence of innovative equipment and accessories used for VR, including exercise bikes, treadmills, and body trackers, VR is becoming easier to afford and try. With lower costs, like those of the Meta Quest 2 for $299.99 (Reality Labs, 2020), ease of use, and convenience, there is a growing utilization of VR in diverse applications. The versatility of VR programming, coupled with recent technological advancements, such as Unreal Engine 5, is expected to expand the applications and benefits of VR interventions. Utilizing play as an integral component of our rehabilitation programs aligns with its fundamental role during the early stages of animal life. Also, as the popularity of video gaming continues to rise across different age groups, spanning from mobile gaming to advanced console and PC gaming, it is increasingly likely that virtual games will become a means of achieving physical improvements. This trend is expected to gain momentum as it aligns with an increasingly diverse demographic's evolving preferences and habits. Therefore, developing and implementing more effective therapeutic games are of greater significance as generations age and seek innovative avenues for improving their well-being.

VR interventions and their potential in rehabilitation align with the concepts of neuroplasticity, emphasizing the brain's remarkable adaptability. Exercise therapies are vital for treating conditions like PD, as they contribute to maintaining balance mobility and promoting the growth of new neurons (19, 22, 36, 62, 69). Through exercise, the brain adapts and rewires itself to compensate for dopamine loss, crucial for learning motor skills and restoring function in individuals with PD. Regular exercise and techniques like amplitude training help preserve existing brain connections, create new connections, and potentially restore lost connections, leading to more normal movement patterns in PD patients. Also, emphasizing amplitude training in exercises can significantly benefit individuals with PD, improving their quality of life and mobility independence (18, 56, 66). Experiences, whether through physical exercises in VR or the act of remembering (55, 57), can induce changes in brain networks and perceptions. These changes, the brain’s rewriting abilities to bypass damaged areas, can improve brain function and, ultimately, physical movements. This showcases the dynamic nature of neural connections and their potential for improvement, even when confronted with diseases. Ultimately, comprehending and harnessing brain plasticity enhances one's ability to improve the well-being of patients with a disease or disorder.

The interconnected nature of the body's cells denotes the importance of holistic care. There is an intricate communication network that exists among the cells within the human body, connecting all physiological processes. People with chronic diseases commonly suffer from anxiety and depression due to changes in brain chemistry and lack of movement control (4, 5, 14). Consequently, it is imperative to recognize that depression and anxiety can exert profound and far-reaching impacts on the body's overall well-being and functionality; conditions such as depression and anxiety can significantly impact the body and the course of one's illness, exacerbating the recovery process. In people with PD, anxiety can worsen symptoms, inducing FOG (17). Moreover, in anxiety and depression, stress hormones like cortisol can suppress the immune response, making individuals more susceptible to infections and illnesses and impeding organ function. A weakened immune system hinders the body's ability to recover from existing illnesses or defend against new ones. Additionally, the long-term effects of cortisol can have lasting and more severe impacts on the body, leading to an increased risk of developing chronic illnesses such as cardiovascular diseases, digestive issues, and muscle inflammation. Also, anxiety and depression can lead to sleep disturbances or insomnia, removing a crucial process for the body's ability to recover. A lack of sleep can reduce the body's ability to repair and regenerate cells, exacerbating existing health conditions. Due to the nature of anxiety and depression, changes in appetite and lack of motivation or energy may occur. VR technology can serve as a means of diversion from depression and anxiety, offering individuals respite from their worries. Furthermore, RT given through VR can be strategically utilized to mentally transport individuals to a period predating the onset of their disease, fostering a therapeutic approach that is emotionally and psychologically beneficial. Recognizing the potential for various therapies to address health's physical and psychological aspects offers a comprehensive strategy for overall well-being.

Beyond its utility to researchers, VR technology can expand our understanding of PD and its therapeutic applications. VR and related technologies can help researchers identify specific areas of dysfunction and potentially develop new targets for treatment. By highlighting its capacity to improve both motor and cognitive function and boosting motivation for therapy participation, VR can stimulate the development of innovative approaches to treating PD and other diseases. Additionally, VR can be individualized by changing some features or tasks, and VR can be used to suit the person's needs. VR also does not need the assistance of a physical or occupational therapist. Objective data collected through VR can also facilitate a deeper exploration of the underlying mechanisms of PD, such as understanding the relationship between anxiety and FOG (17). When paired with other advanced technologies, VR can provide insights into specific areas of dysfunction, offering potential new targets for treatment. This dual impact on researchers' understanding and patient outcomes solidifies VR's place in PD research and therapy. The information about the benefits of VR for PD can contribute to the broader field of rehabilitation and assistive technology, informing the development of new approaches to assistive technology for a range of neurological and musculoskeletal conditions.

While VR has many benefits, it is essential to acknowledge several challenges. The field of VR for PD is still emerging and needs standardized protocols and measures, rendering direct comparisons across studies difficult. The findings may not capture the entire spectrum of PD-related challenges. Furthermore, ensuring that VR technology is accessible and user-friendly for those with varying degrees of disability is crucial. Some individuals with PD may have difficulty operating VR devices due to motor or cognitive impairments. Individuals tend to gravitate towards and find comfort in the familiar. However, RT, if not monitored, may bring up worrisome memories. Overcoming these challenges through ongoing advancements in VR technology and research methodology will maximize the benefits of VR-based interventions for individuals with PD.

Studies showed that RT significantly reduced depressive symptoms and apathy, particularly benefiting older adults and adults with chronic illnesses (44, 59, 61, 79). RT also improves cognitive functions and long-term verbal memory (59, 79). One study even found that RT improved anxiety, self-esteem, and life satisfaction (79). Additionally, studies involving VR demonstrated significant improvement in motor functions and daily living activities in PD patients (7). There were also improvements in stride length (15), step (15), gait (25, 28, 37, 48), balance (25, 37), cognitive function (48), fall risk management (48), reduced gait variability (28), and reduced stress (37). Research indicates that VR provides a controlled method for investigating FOG (17, 28), aiding in the exploration of underlying triggers like anxiety-induced FOG (17). Despite the limited knowledge of combining RT and VR or using RT for movement challenges such as FOG, RT and VR hold promise for more significant enhancements than separately.

Regarding this study, several benefits and challenges were observed. This study tracked the participant's progress in improving FOG through various subjective and objective measures. The participant initially showed moderate impairment, and the VR intervention reduced FOG instances without adverse effects. The participant showed notable improvements post-intervention through the GFQ and the DPGS, scoring better by 14 points and 3 points, respectively. In particular, the participant experienced reduced feelings of being glued to the floor, shorter freezing episodes, and improved turn initiation. Improvements in balance, performance of dual tasks, and reduced FOG can be attributed to the exercises targeting the same muscle groups as in traditional physical therapy (6, 28, 47, 48, 74). In areas where the participant scored the same in the pre-and post-test, the participant was able to preserve his current mobility capabilities without significant deterioration. Video analysis revealed that the participant experienced refined gait quality, with improved stride length, speed, step control, and reduced forward lean. Wellness questions showed a decrease in the perceived levels of depression and anxiety as the intervention progressed. Balance assessments made by the occupational therapist reported a 2-inch improvement in the Functional Reach Test, noting the participant's increased ability to perform daily activities. Overall, the participant seemed to experience better movement and mobility, with fewer encumbered steps. These findings indicate the potential therapeutic benefits of using RT through VR when integrated into traditional therapy programs despite the progressive nature of PD. Following occupational therapy sessions, the participant's ease of movement increased. This increased ease of movement positively influenced his walking ability, suggesting that more engagement in interventions could enhance motor coordination. Some challenges included occasional festinating gait episodes, an additional fall, and the need for a cane or handrail. PD's progressive nature and many outside variables can account for these discrepancies.

The findings from this study indicate that RT through VR interventions may have the potential to positively influence a broad range of PD symptoms, including gait and cognitive function. The engaging nature of VR can address common issues related to exercise adherence, making therapy more enjoyable and motivating for patients. VR may also offer opportunities to unlock memories, create positive experiences, and improve overall well-being.

Furthermore, VR's ability to provide a balanced combination of cognitive and motor training, engaging patients and potentially reducing FOG, is promising. As technology becomes more affordable and user-friendly, VR interventions may become more accessible to a broader population, potentially contributing to improved health and well-being. In summary, VR technology holds great potential for enhancing our understanding of PD, improving patient outcomes, and advancing the field of assistive technology. While challenges persist, the potential benefits for both researchers and patients are substantial, making further exploration and development in this area highly valuable.

RECOMMENDATIONS FOR FUTURE STUDIES

Exploring potential reasons behind the observed trends in symptom severity and improvement in mobility may lead us to uncover valuable insights. Future investigations should consider a more comprehensive evaluation of participants' daily routines, medication regimens, and changes in psychological well-being over time. Examining external factors, such as seasonal changes or modifications in exercise habits, might have influenced mobility to understand the observed patterns better.

Participants with PD need to engage in cognitive processes before initiating movements. More conclusive evidence regarding this cognitive aspect and further investigations involving neurological assessments would be required to establish the connection between cognitive function and gait dynamics in PD patients. Some examples of neurological assessments that would benefit PD patients would include neuroimaging or neuropsychological tests.

One limitation of this study was the reliance on only one participant. Future research should include a larger and more diverse group of PD patients. Studies should also extend the duration, which is crucial to gathering more data, investigating, and verifying the observations experienced during this study to reduce FOG. This comprehensive understanding will help to see if RT is a possible intervention for FOG.

Another limitation was that the participant was unable to see his limbs or body in the virtual environment, which may have impacted his immersion into the VR world. Future research should provide visual feedback and assess the impact of this feedback to enhance VR interventions. It should also integrate real-time movement control and feedback mechanisms in the environment to improve the effectiveness of VR interventions. There were issues related to visual control within the VR environment. Participants in future studies should be able to maintain their desired view without unintended adjustments, such as inadvertent upward gazes, which can disrupt the immersive experience. Another recommendation is the incorporation of audio elements into the VR environment. This addition can significantly enhance the overall experience, making it more engaging and realistic. Implementing ambient sounds or era-specific music can contribute to the sense of immersion. Additionally, to further boost engagement and interactivity, future studies should include the integration of dynamic avatars within the VR environment. Since FOG can occur in crowded areas, dynamic avatars can be particularly beneficial for PD participants to practice overcoming these situations. Lastly, converting the VR environment to be more game-like can make the therapy more enjoyable and motivating, encouraging active participation and adherence to the treatment regimen.

Future studies should provide more opportunities for collaborating with additional experts in multiple fields for insight into the study design and findings, which can strengthen the research's validity and reliability. This study was one of the first to investigate the relationship between RT and VR to help with movement disabilities. Further studies can also use RT through VR to assist individuals suffering from other health conditions or better overall health. VR is highly adaptable and can be tailored to suit a wide range of needs and benefits; VR can be individualized and is very flexible for whatever one wants to test.

By implementing these recommendations, future studies can aim for more effective and engaging VR-based interventions that will contribute to a deeper understanding of the relationship between VR, the medical field, and movement disabilities.

REFERENCES

1. Ackerley R, Aimonetti J-M, Ribot-Ciscar E. Emotions alter muscle proprioceptive coding of movements in humans. *Scientific Reports* 2017;7(1):8465.
2. American Music Therapy Association [Internet]. What is music therapy? American Music Therapy Association (AMTA) [date unknown]; [cited 2023 Sep 24]. Available from: https://www.musictherapy.org/about/musictherapy/
3. Amplitude movements: Parkinson's NSW [Internet]. Parkinson's NSW; 2022; [cited 2023 Sep 24]. Available from: https://www.parkinsonsnsw.org.au/amplitude-movements/
4. Anxiety [Internet]. American Psychological Associatio*n* [date unknown]; [cited 2023 Sep 25]. Available from: https://www.apa.org/topics/anxiety
5. Anxiety [Internet]. Parkinson's Foundation [date unknown]; [cited 2023 Nov 19]. Available from: https://www.parkinson.org/understanding-parkinsons/non-movement-symptoms/anxiety
6. Badarny S, Aharon-Peretz J, Susel Z, Habib G, Baram Y. Virtual reality feedback cues for improvement of gait in patients with Parkinson's disease. *Tremor and Other Hyperkinetic Movements* 2014;4:225.
7. Basharat A, Anum A, Rashid I, Naz K, Waqar Z, Waqar Z. Effect of exer gaming on rehabilitation of patient with Parkinson's disease. *International Journal of Health Sciences* 2023;7(S1):1280–94.
8. Benefits of reminiscence therapy [Internet]. *Elder Care Alliance* 2023; [cited 2023 Sep 24]. Available from: https://eldercarealliance.org/blog/benefits-reminiscence-therapy/

9. Betker AL, Szturm T, Moussavi ZK, Nett C. Video game–based exercises for balance rehabilitation: A single-subject design. *Archives of Physical Medicine and Rehabilitation* 2006;87(8):1141–9.
10. Butler RN. The life review: An interpretation of reminiscence in the aged. *Psychiatry* 1963;26(1):65–76.
11. Carbidopa and levodopa (oral route) description and brand names [Internet]. Mayo Clinic 2023; [cited 2023 Jul 15]. Available from: https://www.mayoclinic.org/drugs-supplements/carbidopa-and-levodopa-oral-route/description/drg-20095211
12. D'Alencar MS, Ribeiro J, Cruz R, Sá K, Pinto E, Baptista AF. Exercises with and without virtual reality on pain in patients with Parkinson's disease: A randomized, controlled, single-blind trial. *Brazilian Journal of Medicine and Human Health* 2017;5(4):144–52.
13. Deep brain stimulation [Internet]. Mayo Clinic 2021; [cited 2023 Jul 15]. Available from: https://www.mayoclinic.org/tests-procedures/deep-brain-stimulation/about/pac-20384562
14. Depression [Internet]. Parkinson's Foundation [date unknown]; [cited 2023 Nov 19]. Available from: https://www.parkinson.org/understanding-parkinsons/non-movement-symptoms/depression
15. Dockx K, Bekkers EM, Van den Bergh V, et al. Virtual Reality for Rehabilitation in Parkinson's Disease [Internet]. The Cochrane database of systematic reviews 2016; [cited 2023 Jul 6]. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6463967/
16. Duopa [Internet]. Parkinson's Foundation [date unknown]; [cited 2023 Sep 24]. Available from: https://www.parkinson.org/living-with-parkinsons/treatment/surgical-treatment-options/duopa

17. Ehgoetz Martens KA, Ellard CG, Almeida QJ. Does anxiety cause freezing of gait in Parkinson’s disease? *PLoS ONE* 2014;9(9).

18. Emmady PD, Puderbaugh M. Neuroplasticity - statpearls - NCBI bookshelf [Internet]. National Library of Medicine 2023; [cited 2023 Sep 24]. Available from: https://www.ncbi.nlm.nih.gov/books/NBK557811/

19. Exercise [Internet]. Parkinson’s Foundation [date unknown]; [cited 2023 Sep 24]. Available from: https://www.parkinson.org/living-with-parkinsons/treatment/exercise

20. Farley BG, Koshland GF. Training big to move faster: The application of the speed–amplitude relation as a rehabilitation strategy for people with Parkinson’s disease. *Experimental Brain Research* 2005;167(3):462–7.

21. Fisher BE, Wu AD, Salem GJ, et al. The effect of exercise training in improving motor performance and corticomotor excitability in people with early Parkinson’s disease. *Archives of Physical Medicine and Rehabilitation* 2008;89(7):1221–9.

22. Fisher BE, Petzinger GM, Nixon K, et al. Exercise-induced behavioral recovery and neuroplasticity in the 1-methyl-4-phenyl-1,2,3,6-tetrahydropyridine-lesioned mouse basal ganglia. *Journal of Neuroscience Research* 2004;77(3):378–90.

23. Freezing [Internet]. Parkinson’s Foundation [date unknown]; [cited 2023 Sep 25]. Available from: https://www.parkinson.org/living-with-parkinsons/management/activities-daily-living/freezing

24. Galeote Livia L, Francisca Cecato J. Análisis De La Escala De Berg e Do Timed Up and Go Administrada a Personas Con Mal Parkinson: Realidad Virtual Como Método De Intervención. *Perspectivas En Psicología: Revista De Psicología y Ciencias Afines* 2018;15(1):58–64.

25. Galna B, Jackson D, Schofield G, et al. Retraining function in people with Parkinson’s disease using the Microsoft Kinect: Game design and pilot testing. *Journal of NeuroEngineering and Rehabilitation* 2014;11(1).

26. GameStop; 2013. [cited 2023 Sep 5]. Available from: https://www.gamestop.com/gaming-accessories/controllers/xbox-one?start=60&sz=20

27. Gandolfi M, Geroin C, Dimitrova E, et al. Virtual reality telerehabilitation for postural instability in Parkinson’s Disease: A multicenter, single-blind, randomized, controlled trial. *BioMed Research International* 2017;2017:1–11.

28. Gómez-Jordana LI, Stafford J, Peper C (Lieke), Craig CM. Crossing Virtual Doors: A new method to study gait impairments and freezing of gait in Parkinson’s disease. *Parkinson’s Disease* 2018;2018:1–8.

29. Gómez-Jordana LI, Stafford J, Peper C (Lieke), Craig CM. Virtual footprints can improve walking performance in people with Parkinson’s disease. *Frontiers in Neurology* 2018;9.

30. Harris DJ, Buckingham G, Wilson MR, et al. The effect of a virtual reality environment on gaze behaviour and motor skill learning. *Psychology of Sport and Exercise* 2020;50:101721.

31. History of Virtual Reality [Internet]. The Franklin Institute 2023; [cited 2023 Oct 23]. Available from: https://fi.edu/en/history-virtual-reality

32. HTC; 2021. [cited 2023 Oct 22]. Available from: https://www.vive.com/us/product/vive-focus3/overview/

33. Iansek R, Huxham F, McGinley J. The sequence effect and gait festination in Parkinson's disease: Contributors to freezing of gait? *Movement Disorders* 2006;21(9):1419–24.

34. Jovanovic T. Anxiety - What is anxiety & how to treat it [Internet]. *Anxiety Disorders and Universal Health Care* 2023; [cited 2023 Nov 26]. Available from: https://www.anxiety.org/what-is-anxiety

35. Jun E-M, Roh YH, Kim MJ. The effect of music-movement therapy on physical and psychological states of stroke patients. *Journal of Clinical Nursing* 2012;22(1–2):22–31.

36. Kempermann G, Kuhn HG, Gage FH. Experience-induced neurogenesis in the senescent dentate gyrus. *The Journal of Neuroscience* 1998;18(9):3206–12.

37. Kim A, Darakjian N, Finley JM. Walking in fully immersive virtual environments: An evaluation of potential adverse effects in older adults and individuals with Parkinson's disease. *Journal of NeuroEngineering and Rehabilitation* 2017;14(1).

38. Lei C, Sunzi K, Dai F, et al. Effects of virtual reality rehabilitation training on gait and balance in patients with Parkinson's disease: A systematic review. *PLoS ONE* 2019;14(11).

39. Lennon S, Ramdharry G, Verheyden G. In: *Physical management for neurological conditions*. S.l.: Elsevier Health Science; 2018 p. 398.

40. Levodopa [Internet]. *Parkinson's Foundation* [date unknown]; [cited 2023 Jul 15] Available from: https://www.parkinson.org/living-with-parkinsons/treatment/prescription-medications/levodopa

41. Lewis CN. Reminiscing and self-concept in old age. *Journal of Gerontology* 1971;26(2):240–3.

42. Liao Y-Y, Yang Y-R, Cheng S-J, Wu Y-R, Fuh J-L, Wang R-Y. Virtual reality–based training to improve obstacle-crossing performance and dynamic balance in patients with Parkinson's disease. *Neurorehabilitation and Neural Repair* 2014;29(7):658–67.

43. Liao Y-Y, Yang Y-R, Wu Y-R, Wang R-Y. Virtual reality-based Wii fit training in improving muscle strength, sensory integration ability, and walking abilities in patients with Parkinson's disease: A randomized control trial. *International Journal of Gerontology* 2015;9(4):190–5.

44. Liu Z, Yang F, Lou Y, Zhou W, Tong F. The effectiveness of reminiscence therapy on alleviating depressive symptoms in older adults: A systematic review. *Frontiers in Psychology* 2021;12.

45. Løvoll HS, Røysamb E, Vittersø J. Experiences matter: Positive emotions facilitate intrinsic motivation. *Cogent Psychology* 2017;4(1):1340083.

46. Mahoney JW, Gucciardi DF, Ntoumanis N, Mallet CJ. Mental toughness in sport: Motivational antecedents and associations with performance and Psychological Health. *Journal of Sport and Exercise Psychology* 2014;36(3):281–92.

47. Mendes FA, Pompeu JE, Lobo AM, et al. Motor learning, retention and transfer after virtual-reality-based training in Parkinson's disease – effect of motor and cognitive demands of games: A longitudinal, controlled clinical study. *Physiotherapy* 2012;98(3):217–23.

48. Mirelman A, Maidan I, Herman T, Deutsch JE, Giladi N, Hausdorff JM. Virtual reality for gait training: Can it induce motor learning to enhance complex walking and reduce fall risk in patients with Parkinson's disease? *The Journals of Gerontology Series A: Biological Sciences and Medical Sciences* 2010;66A(2):234–40.

49. Movement definition & meaning [Internet]*Merriam-Webster* [date unknown]; [cited 2018 Nov 26] Available from: https://www.merriam-webster.com/dictionary/movement

50. Nonnekes J, Giladi N, Guha A, Fietzek UM, Bloem BR, Růžička E. Gait festination in parkinsonism: Introduction of two phenotypes. *Journal of Neurology* 2018;266(2):426–30.

51. Nutt JG, Bloem BR, Giladi N, Hallett M, Horak FB, Nieuwboer A. Freezing of gait: Moving forward on a mysterious clinical phenomenon. *The Lancet Neurology* 2011;10(8):734–44.

52. Other surgical options [Internet]. *Parkinson's Foundation* [date unknown]; [cited 2023 Sep 25] Available from: https://www.parkinson.org/living-with-parkinsons/treatment/surgical-options/other-surgical-options

53. Paolucci EM, Loukov D, Bowdish DME, Heisz JJ. Exercise reduces depression and inflammation but intensity matters. *Biological Psychology* 2018;133:79–84.

54. Park J-H, Kang Y-J, Horak FB. What Is Wrong with Balance in Parkinson's Disease? *Journal of Movement Disorders* 2015;8(3):109–14.

55. Paul M. Your Memory is like the Telephone Game [Internet]. *Northwestern Now* 2012; [cited 2023 Nov 12] Available from: https://news.northwestern.edu/stories/2012/09/your-memory-is-like-the-telephone-game/

56. Peterka M, Odorfer T, Schwab M, Volkmann J, Zeller D. LSVT-big therapy in Parkinson's disease: Physiological evidence for proprioceptive recalibration. *BMC Neurology* 2020;20(1).

57. Petrelli A, Kaesberg S, Barbe MT, Timmermann L, Fink GR, Kessler J, Kalbe E. Effects of cognitive training in Parkinson's disease: a randomized controlled trial *PubMed* 2014; 20(11):1196-202.

58. Pompeu JE, Mendes FA, Silva KG, et al. Effect of Nintendo Wii™-based motor and cognitive training on activities of daily living in patients with Parkinson's disease: A randomised clinical trial. *Physiotherapy* 2012;98(3):196–204.

59. Reitano MR, Guidetti M, Maiorana NV, et al. The effects of a new integrated and multidisciplinary cognitive rehabilitation program based on mindfulness and reminiscence therapy in patients with Parkinson's disease and mild cognitive impairment: A pilot study. *Brain Sciences* 2023;13(2):201.

60. Ribas CG, Alves da Silva L, Corrêa MR, Teive HG, Valderramas S. Effectiveness of exergaming in improving functional balance, fatigue and quality of life in Parkinson's Disease: A pilot randomized controlled trial. *Parkinsonism & Related Disorders* 2017;38:13–8.

61. Saredakis D, Keage HA, Corlis M, Ghezzi ES, Loffler H, Loetscher T. The effect of reminiscence therapy using virtual reality on apathy in residential aged care: Multisite nonrandomized controlled trial. *Journal of Medical Internet Research* 2021;23(9), e29210.

62. Smith AD, Zigmond MJ. Can the brain be protected through exercise? Lessons from an animal model of Parkinsonism. *Experimental Neurology* 2003;184(1):31–9.

63. Stages of Parkinson's [Internet]*Parkinson's Foundation* [date unknown]; [cited 2023 Jul 15] Available from: https://www.parkinson.org/understanding-parkinsons/what-is-parkinsons/stages

64. Takakusaki K, Habaguchi T, Ohtinata-Sugimoto J, Saitoh K, Sakamoto T. Basal ganglia efferents to the brainstem centers controlling postural muscle tone and locomotion: A

new concept for understanding motor disorders in basal ganglia dysfunction. *Neuroscience* 2003;119(1):293–308.

65. The now: Understanding virtual reality and augmented reality [Internet]*GCFGlobal.org* [date unknown]; [cited 2023 Oct 3] Available from: https://edu.gcfglobal.org/en/thenow/understanding-virtual-reality-and-augmented-reality/1/
66. Turgay T, Ekmekyapar Firat Y, Soğan SS, Günel P. Impact of LSVT-big ® on functional mobility, walking, dexterity, and quality of life in Parkinson's disease. *Cukurova Medical Journal* 2022;47(4):1738–45.
67. Types of Parkinsonisms [Internet]*Parkinson's Foundation* [date unknown]; [cited 2023 Sep 12] Available from: https://www.parkinson.org/understanding-parkinsons/what-is-parkinsons/types-parkinsonisms
68. Waichler W by: I. Reminiscence therapy: What it is & how it works [Internet]. *Choosing Therapy* [date unknown]; [cited 2023 Sep 24] Available from: https://www.choosingtherapy.com/reminiscence-therapy/
69. Weghorst S. *Augmented Reality Approaches to Sensory Rehabilitation*. 2018 p. 1–5.
70. Weiss H. Dr. Howard Weiss discusses 'freezing of gait' in Parkinson's disease [Internet]. *Parkinson Foundation* 2023; [cited 2023 Oct 26] Available from: https://parkinsonfoundation.org/blog/dr-howard-weiss-discusses-freezing-gait-parkinson-disease
71. What Is Depression? [Internet] *American Psychiatric Association* [date unknown]; [cited 2018 Oct 26] Available from: https://www.psychiatry.org/patients-families/depression/what-is-depression

72. "What Is Parkinson's?" Parkinson's Foundation. (n.d.). [online] Available at: https://www.parkinson.org/understanding-parkinsons/what-is-parkinsons [Accessed 7 Dec. 2018].
73. What is virtual reality? [Internet]*Virtual Reality Society* 2017; [cited 2023 Sep 25] Available from: https://www.vrs.org.uk/virtual-reality/what-is-virtual-reality.html
74. Witte K, Droste M, Ritter Y, et al. Sports training in virtual reality to improve response behavior in karate kumite with transfer to Real World. *Frontiers in Virtual Reality* 2022;3
75. Wolpaw JR, Tennissen AM. Activity-dependent spinal cord plasticity in health and disease. *Annual Review of Neuroscience* 2001;24(1):807–43.
76. Wong PT, Watt LM. What types of reminiscence are associated with successful aging? *Psychology and Aging* 1991;6(2):272–9.
77. Yelshyna D, Gago MF, Bicho E, et al. Compensatory postural adjustments in Parkinson's disease were assessed via a virtual reality environment. *Behavioural Brain Research* 2016;296:384–92.
78. Yen C-Y, Lin K-H, Hu M-H, Wu R-M, Lu T-W, Lin C-H. Effects of virtual reality–augmented balance training on sensory organization and attentional demand for postural control in people with Parkinson disease: A randomized controlled trial. *Physical Therapy* 2011;91(6):862–74.
79. Yen H-Y, Lin L-J. A systematic review of reminiscence therapy for older adults in Taiwan. *Journal of Nursing Research* 2018;26(2):138–50.
80. Young KS, Parsons CE, Stein A, Kringelbach ML. Motion and emotion: Depression reduces psychomotor performance and alters affective movements in caregiving interactions. *Frontiers in Behavioral Neuroscience* 2015;9

APPENDIX A

PAR-Q

2022 PAR-Q+

The Physical Activity Readiness Questionnaire for Everyone

The health benefits of regular physical activity are clear; more people should engage in physical activity every day of the week. Participating in physical activity is very safe for MOST people. This questionnaire will tell you whether it is necessary for you to seek further advice from your doctor OR a qualified exercise professional before becoming more physically active.

GENERAL HEALTH QUESTIONS

Please read the 7 questions below carefully and answer each one honestly: check YES or NO.	YES	NO
1) Has your doctor ever said that you have a heart condition ☐ **OR** high blood pressure ☐?	☐	☐
2) Do you feel pain in your chest at rest, during your daily activities of living, **OR** when you do physical activity?	☐	☐
3) Do you lose balance because of dizziness **OR** have you lost consciousness in the last 12 months? Please answer **NO** if your dizziness was associated with over-breathing (including during vigorous exercise).	☐	☐
4) Have you ever been diagnosed with another chronic medical condition (other than heart disease or high blood pressure)? **PLEASE LIST CONDITION(S) HERE:** ____________	☐	☐
5) Are you currently taking prescribed medications for a chronic medical condition? **PLEASE LIST CONDITION(S) AND MEDICATIONS HERE:** ____________	☐	☐
6) Do you currently have (or have had within the past 12 months) a bone, joint, or soft tissue (muscle, ligament, or tendon) problem that could be made worse by becoming more physically active? Please answer **NO** if you had a problem in the past, but it **does not limit your current ability** to be physically active. **PLEASE LIST CONDITION(S) HERE:** ____________	☐	☐
7) Has your doctor ever said that you should only do medically supervised physical activity?	☐	☐

If you answered NO to all of the questions above, you are cleared for physical activity.
Please sign the PARTICIPANT DECLARATION. You do not need to complete Pages 2 and 3.

- Start becoming much more physically active – start slowly and build up gradually.
- Follow Global Physical Activity Guidelines for your age (https://www.who.int/publications/i/item/9789240015128).
- You may take part in a health and fitness appraisal.
- If you are over the age of 45 yr and NOT accustomed to regular vigorous to maximal effort exercise, consult a qualified exercise professional before engaging in this intensity of exercise.
- If you have any further questions, contact a qualified exercise professional.

PARTICIPANT DECLARATION
If you are less than the legal age required for consent or require the assent of a care provider, your parent, guardian or care provider must also sign this form.

I, the undersigned, have read, understood to my full satisfaction and completed this questionnaire. I acknowledge that this physical activity clearance is valid for a maximum of 12 months from the date it is completed and becomes invalid if my condition changes. I also acknowledge that the community/fitness center may retain a copy of this form for its records. In these instances, it will maintain the confidentiality of the same, complying with applicable law.

NAME ____________________ DATE ____________

SIGNATURE ____________________ WITNESS ____________

SIGNATURE OF PARENT/GUARDIAN/CARE PROVIDER ____________________

If you answered YES to one or more of the questions above, COMPLETE PAGES 2 AND 3.

Delay becoming more active if:

- You have a temporary illness such as a cold or fever; it is best to wait until you feel better.
- You are pregnant - talk to your health care practitioner, your physician, a qualified exercise professional, and/or complete the ePARmed-X+ at www.eparmedx.com before becoming more physically active.
- Your health changes - answer the questions on Pages 2 and 3 of this document and/or talk to your doctor or a qualified exercise professional before continuing with any physical activity program.

01-11-2021

2022 PAR-Q+

FOLLOW-UP QUESTIONS ABOUT YOUR MEDICAL CONDITION(S)

1. Do you have Arthritis, Osteoporosis, or Back Problems?
If the above condition(s) is/are present, answer questions 1a-1c — If **NO** ☐ go to question 2

1a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	YES ☐ NO ☐
1b.	Do you have joint problems causing pain, a recent fracture or fracture caused by osteoporosis or cancer, displaced vertebra (e.g., spondylolisthesis), and/or spondylolysis/pars defect (a crack in the bony ring on the back of the spinal column)?	YES ☐ NO ☐
1c.	Have you had steroid injections or taken steroid tablets regularly for more than 3 months?	YES ☐ NO ☐

2. Do you currently have Cancer of any kind?
If the above condition(s) is/are present, answer questions 2a-2b — If **NO** ☐ go to question 3

2a.	Does your cancer diagnosis include any of the following types: lung/bronchogenic, multiple myeloma (cancer of plasma cells), head, and/or neck?	YES ☐ NO ☐
2b.	Are you currently receiving cancer therapy (such as chemotheraphy or radiotherapy)?	YES ☐ NO ☐

3. Do you have a Heart or Cardiovascular Condition? This includes Coronary Artery Disease, Heart Failure, Diagnosed Abnormality of Heart Rhythm
If the above condition(s) is/are present, answer questions 3a-3d — If **NO** ☐ go to question 4

3a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	YES ☐ NO ☐
3b.	Do you have an irregular heart beat that requires medical management? (e.g., atrial fibrillation, premature ventricular contraction)	YES ☐ NO ☐
3c.	Do you have chronic heart failure?	YES ☐ NO ☐
3d.	Do you have diagnosed coronary artery (cardiovascular) disease and have not participated in regular physical activity in the last 2 months?	YES ☐ NO ☐

4. Do you currently have High Blood Pressure?
If the above condition(s) is/are present, answer questions 4a-4b — If **NO** ☐ go to question 5

4a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	YES ☐ NO ☐
4b.	Do you have a resting blood pressure equal to or greater than 160/90 mmHg with or without medication? (Answer **YES** if you do not know your resting blood pressure)	YES ☐ NO ☐

5. Do you have any Metabolic Conditions? This includes Type 1 Diabetes, Type 2 Diabetes, Pre-Diabetes
If the above condition(s) is/are present, answer questions 5a-5e — If **NO** ☐ go to question 6

5a.	Do you often have difficulty controlling your blood sugar levels with foods, medications, or other physician-prescribed therapies?	YES ☐ NO ☐
5b.	Do you often suffer from signs and symptoms of low blood sugar (hypoglycemia) following exercise and/or during activities of daily living? Signs of hypoglycemia may include shakiness, nervousness, unusual irritability, abnormal sweating, dizziness or light-headedness, mental confusion, difficulty speaking, weakness, or sleepiness.	YES ☐ NO ☐
5c.	Do you have any signs or symptoms of diabetes complications such as heart or vascular disease and/or complications affecting your eyes, kidneys, **OR** the sensation in your toes and feet?	YES ☐ NO ☐
5d.	Do you have other metabolic conditions (such as current pregnancy-related diabetes, chronic kidney disease, or liver problems)?	YES ☐ NO ☐
5e.	Are you planning to engage in what for you is unusually high (or vigorous) intensity exercise in the near future?	YES ☐ NO ☐

2022 PAR-Q+

6. Do you have any Mental Health Problems or Learning Difficulties? This includes Alzheimer's, Dementia, Depression, Anxiety Disorder, Eating Disorder, Psychotic Disorder, Intellectual Disability, Down Syndrome

If the above condition(s) is/are present, answer questions 6a-6b — If **NO** ☐ go to question 7

6a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	YES ☐ NO ☐
6b.	Do you have Down Syndrome **AND** back problems affecting nerves or muscles?	YES ☐ NO ☐

7. Do you have a Respiratory Disease? *This includes Chronic Obstructive Pulmonary Disease, Asthma, Pulmonary High Blood Pressure*

If the above condition(s) is/are present, answer questions 7a-7d — If **NO** ☐ go to question 8

7a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	YES ☐ NO ☐
7b.	Has your doctor ever said your blood oxygen level is low at rest or during exercise and/or that you require supplemental oxygen therapy?	YES ☐ NO ☐
7c.	If asthmatic, do you currently have symptoms of chest tightness, wheezing, laboured breathing, consistent cough (more than 2 days/week), or have you used your rescue medication more than twice in the last week?	YES ☐ NO ☐
7d.	Has your doctor ever said you have high blood pressure in the blood vessels of your lungs?	YES ☐ NO ☐

8. Do you have a Spinal Cord Injury? *This includes Tetraplegia and Paraplegia*

If the above condition(s) is/are present, answer questions 8a-8c — If **NO** ☐ go to question 9

8a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	YES ☐ NO ☐
8b.	Do you commonly exhibit low resting blood pressure significant enough to cause dizziness, light-headedness, and/or fainting?	YES ☐ NO ☐
8c.	Has your physician indicated that you exhibit sudden bouts of high blood pressure (known as Autonomic Dysreflexia)?	YES ☐ NO ☐

9. Have you had a Stroke? *This includes Transient Ischemic Attack (TIA) or Cerebrovascular Event*

If the above condition(s) is/are present, answer questions 9a-9c — If **NO** ☐ go to question 10

9a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer **NO** if you are not currently taking medications or other treatments)	YES ☐ NO ☐
9b.	Do you have any impairment in walking or mobility?	YES ☐ NO ☐
9c.	Have you experienced a stroke or impairment in nerves or muscles in the past 6 months?	YES ☐ NO ☐

10. Do you have any other medical condition not listed above or do you have two or more medical conditions?

If you have other medical conditions, answer questions 10a-10c — If **NO** ☐ read the Page 4 recommendations

10a.	Have you experienced a blackout, fainted, or lost consciousness as a result of a head injury within the last 12 months **OR** have you had a diagnosed concussion within the last 12 months?	YES ☐ NO ☐
10b.	Do you have a medical condition that is not listed (such as epilepsy, neurological conditions, kidney problems)?	YES ☐ NO ☐
10c.	Do you currently live with two or more medical conditions?	YES ☐ NO ☐

PLEASE LIST YOUR MEDICAL CONDITION(S) AND ANY RELATED MEDICATIONS HERE: ______________________

GO to Page 4 for recommendations about your current medical condition(s) and sign the PARTICIPANT DECLARATION.

2022 PAR-Q+

If you answered NO to all of the FOLLOW-UP questions (pgs. 2-3) about your medical condition, you are ready to become more physically active - sign the PARTICIPANT DECLARATION below:

- It is advised that you consult a qualified exercise professional to help you develop a safe and effective physical activity plan to meet your health needs.
- You are encouraged to start slowly and build up gradually - 20 to 60 minutes of low to moderate intensity exercise, 3-5 days per week including aerobic and muscle strengthening exercises.
- As you progress, you should aim to accumulate 150 minutes or more of moderate intensity physical activity per week.
- If you are over the age of 45 yr and **NOT** accustomed to regular vigorous to maximal effort exercise, consult a qualified exercise professional before engaging in this intensity of exercise.

If you answered **YES** to **one or more of the follow-up questions** about your medical condition:

You should seek further information before becoming more physically active or engaging in a fitness appraisal. You should complete the specially designed online screening and exercise recommendations program - the **ePARmed-X+ at www.eparmedx.com** and/or visit a qualified exercise professional to work through the ePARmed-X+ and for further information.

Delay becoming more active if:

- You have a temporary illness such as a cold or fever; it is best to wait until you feel better.
- You are pregnant - talk to your health care practitioner, your physician, a qualified exercise professional, and/or complete the ePARmed-X+ **at www.eparmedx.com** before becoming more physically active.
- Your health changes - talk to your doctor or qualified exercise professional before continuing with any physical activity program.

- You are encouraged to photocopy the PAR-Q+. You must use the entire questionnaire and NO changes are permitted.
- The authors, the PAR-Q+ Collaboration, partner organizations, and their agents assume no liability for persons who undertake physical activity and/or make use of the PAR-Q+ or ePARmed-X+. If in doubt after completing the questionnaire, consult your doctor prior to physical activity.

PARTICIPANT DECLARATION

- All persons who have completed the PAR-Q+ please read and sign the declaration below.
- If you are less than the legal age required for consent or require the assent of a care provider, your parent, guardian or care provider must also sign this form.

I, the undersigned, have read, understood to my full satisfaction and completed this questionnaire. I acknowledge that this physical activity clearance is valid for a maximum of 12 months from the date it is completed and becomes invalid if my condition changes. I also acknowledge that the community/fitness center may retain a copy of this form for records. In these instances, it will maintain the confidentiality of the same, complying with applicable law.

NAME ______________________________ DATE ______________________________

SIGNATURE ______________________________ WITNESS ______________________________

SIGNATURE OF PARENT/GUARDIAN/CARE PROVIDER ______________________________

For more information, please contact
www.eparmedx.com
Email: eparmedx@gmail.com

Citation for PAR-Q+
Warburton DER, Jamnik VK, Bredin SSD, and Gledhill N on behalf of the PAR-Q+ Collaboration. The Physical Activity Readiness Questionnaire for Everyone (PAR-Q+) and Electronic Physical Activity Readiness Medical Examination (ePARmed-X+). Health & Fitness Journal of Canada 4(2):3-23, 2011.

The PAR-Q+ was created using the evidence-based AGREE process (1) by the PAR-Q+ Collaboration chaired by Dr. Darren E. R. Warburton with Dr. Norman Gledhill, Dr. Veronica Jamnik, and Dr. Donald C. McKenzie (2). Production of this document has been made possible through financial contributions from the Public Health Agency of Canada and the BC Ministry of Health Services. The views expressed herein do not necessarily represent the views of the Public Health Agency of Canada or the BC Ministry of Health Services.

Key References

1. Jamnik VK, Warburton DER, Makarski J, McKenzie DC, Shephard RJ, Stone J, and Gledhill N. Enhancing the effectiveness of clearance for physical activity participation; background and overall process. APNM 36(S1):S3-S13, 2011.
2. Warburton DER, Gledhill N, Jamnik VK, Bredin SSD, McKenzie DC, Stone J, Charlesworth S, and Shephard RJ. Evidence-based risk assessment and recommendations for physical activity clearance; Consensus Document. APNM 36(S1):S266-s298, 2011.
3. Chisholm DM, Collis ML, Kulak LL, Davenport W, and Gruber N. Physical activity readiness. British Columbia Medical Journal. 1975;17:375-378.
4. Thomas S, Reading J, and Shephard RJ. Revision of the Physical Activity Readiness Questionnaire (PAR-Q). Canadian Journal of Sport Science 1992;17:4 338-345.

APPENDIX B

PARTICIPANT RECRUITMENT EMAIL

5/1/2023

Re: Freezing of Gait and Balance in a Person with Parkinson's After 6 Weeks of Virtual Reality

Dear:

I invite you to participate in a research study aimed at decreasing freezing of gait through the use of virtual reality technology. The study will investigate the effects of reminiscence therapy on freezing of gait and will be conducted in the comfort of our residence.

If you are experiencing difficulties with your freezing of gait symptoms, you may be eligible to participate in this study. Your voluntary involvement will entail wearing a virtual reality headset and engaging in physical walking exercises for at least 30 minutes three times per week. While physical risks are possible, such as feeling dizzy or hurt, I will guide you in an open space without obstacles to minimize potential injuries. There is also a slight possibility of psychological or emotional risks, such as feeling connected to scenery or bringing up unpleasant memories, although these risks are minimal.

Participating in this study has many potential benefits, including improved motor and cognitive function and increased motivation to engage in therapy and exercise programs, leading to a better quality of life.

All electronic files used for this research project will be stored in my personal school account's Google Drive and personal computer, while paper files will be securely locked in my personal filing cabinet. The data will be stored for seven years, then deleted or shredded, and used to complete my graduate thesis and any future publications or presentations.

If you require additional information about this study, do not hesitate to contact me at massai@student.wpunj.edu. Thank you for your time and consideration. Please do not hesitate to contact me if you want to learn more about this Institutional Review Board-approved project.

Ivana Massa
Principal Investigator
College of Science and Health, William Paterson University
IRB Protocol number 2023-096

APPENDIX C

HEALTH CLEARANCE FORM

WILLIAM PATERSON UNIVERSITY

Participant: Print clearly in ink before the appointment

First and Last Name

____

Health Provider Instructions: Forms without signatures and required information will be considered incomplete and will be returned.

TO THE PHYSICIAN/HEALTHCARE PROFESSIONAL
Please fill out this form to confirm that the participant is in good health and medically cleared to participate in the "Freezing of Gait and Balance in a Person with Parkinson's After 6 Weeks of Virtual Reality Study." The Health Clearance form must be completed, signed, and returned to the researcher before the participant can participate in the study. Both the healthcare professional and the participant should retain copies of the Medical History and Health Clearance forms as confidential medical records. Please review the participant's health thoroughly and discuss it with the participant, referencing their medical records on file.

GENERAL REQUIREMENTS FOR STUDY PARTICIPATION:
In addition to fulfilling the specific requirements of this study, the participant must meet the following general criteria:

1. Physical and mental well-being: The participants must possess the necessary physical and mental health to walk for 30-minute periods with assistance.
2. Flexibility and adaptability: The participant should demonstrate flexibility and the ability to function effectively in potentially uncertain environments and devices he is not used to.
3. Healthcare needs: The participant must be able to manage his healthcare needs like medications and physical therapy

PHYSICIAN STATEMENT:
After conducting a comprehensive review of the participant's health, referencing the participant's medical records on file, and having been informed of the details of this study in person by the researcher, I have thoroughly evaluated the participant's condition. Based on the information

obtained from the participant's medical records, as well as the information provided to me directly by the participant, and taking into account my current observation of the participant, I can confidently state that, to the best of my knowledge, the participant is:

☐ The participant is CLEARED. There are no medical or mental health contraindications to participation in the "Freezing of Gait and Balance in a Person with Parkinson's After 6 Weeks of Virtual Reality Study."

☐ The participant is CLEARED and (Check all that apply below):

☐ The participant requires an accommodation to participate in the research program
(e.g., specialized walker, side walker, wheelchair access, etc.). Please provide care recommendations:

____

____

____

☐ The participant is NOT CLEARED: There are medical or psychological health contraindications to participation in the "Freezing of Gait and Balance in a Person with Parkinson's After 6 Weeks of Virtual Reality Study."

Licensed Physician / Health Provider* (Please print legibly) License Number

_______________________________________ __________________

Signature: ________________________________

Date: ________________

Contact Information in case of a medical emergency:

Phone: ____

Email (if applicable): ________________________________

Address: ____

*Physician or Health Provider must be licensed in the U.S. & cannot be an immediate family member of the participant.

APPENDIX D

INFORMED CONSENT FORM

William Paterson University
Project Title: Freezing of Gait and Balance in a Person with Parkinson's After 6 Weeks of Virtual Reality
Principal Investigator: Ivana Massa
Faculty Sponsor: Michael Figueroa
Faculty Sponsor Phone Number: 973-720-3950
Department: Kinesiology
Course Name and Number: EXSC 7800 Thesis in Exercise Science
Protocol Approval Date: 6/8/2023

I have been asked to participate in a research study on freezing of gait and balance. The purpose of this study will be to determine if the use of reminiscence therapy in a virtual world decreases freezing of gait in older adults with Parkinson's Disease. I understand that I will be trained in how to use the virtual reality device prior to participating in this research study. I understand that I will be asked to perform light walking in two different virtual worlds three times a week for about 30 minutes to an hour each session for 18 sessions. I understand that one virtual world will be used to explore, and the other will be in a 1950s cityscape, requiring me to walk in a straight line and turn. I understand there are risks to using a virtual reality device, such as physical discomfort, fatigue, eye strain, headaches, dizziness, VR/motion sickness, tripping, impact on vision, eye dryness, musculoskeletal strain/ injuries, or stress when exposed to certain VR content. I understand that training will occur in the researcher's personal residence and/or my residence. I understand that my personal healthcare provider will be contacted and will determine medical clearance. I understand that my participation is entirely voluntary, and I may end my participation in this research at any time.

I understand that data will be collected in the researcher´s or my personal residence and that any data and recordings collected as part of this study will be stored in a safe and secure location. I understand that this data will be anonymized for long-term storage and will be used for up to seven years when this research is completed. I understand that I will be video recorded and that these recordings will be destroyed after seven years.

I understand that my identity will be protected at all times and that neither my name nor my images will be used without my separate written permission. I understand that the results of this study will not be reported in a way that would identify me. This may also include digitally altering any identifiable facial features.

I understand that by providing consent for this study, I am also providing consent for my anonymized responses to be included in datasets that may be used in the future by the investigator of this study for research related to the purpose of this research study.

If I have questions about this study, I may call the investigator, Ivana Massa, listed in the heading of this document. If I have any questions or concerns about this research, my participation, the conduct of the investigator, or my rights as a research subject, I may contact the Institutional Review Board (IRB) at 973-720-2852 or by email to IRBAdministrator@wpuunj.edu.

By signing this consent form, I am agreeing to participate in this research study.

Name of Participant____
Signature of Participant____Date:______________
Name of Investigator____
Signature of Investigator____Date:___________

APPENDIX E

INSTITUTIONAL REVIEW BOARD APPROVAL

THE WILLIAM PATERSON UNIVERSITY OF NEW JERSEY

INSTITUTIONAL REVIEW BOARD FOR HUMAN SUBJECT RESEARCH

c/o Office of Sponsored Programs
1800 Valley Road, Room 222
973-720-2852 (Phone)
973-720-3573 (Fax)
http://www.wpunj.edu/osp/irb/

Chair: Elizabeth Victor (VictorE@wpunj.edu)
College of Arts, Humanities and Social Sciences
Contact: Kate Boschert (BoschertK1@wpunj.edu)
Office of Sponsored Programs

June 8, 2023

To: Ivana Massa

From: Elizabeth Victor

RE: Protocol #2023-096: *Freezing of Gait and Balance in a Person with Parkinson's After 6 Weeks of Virtual Reality*

The IRB has APPROVED the above study involving humans as research subjects. This study was approved as: Category: Expedited 45 CFR 46.101(b)(2) and (3); special class of subjects: A patient with Parkinson's disease (80 years old).

Please note the following extra conditions or requirements that must be met before you may initiate your research:

- *None*

General Conditions and Requirements:

1. The Institutional Review Board expects that your research will be carried out in accordance with your protocol request.
2. Any IRB directed extra conditions or requirements listed above must be approved by your faculty advisor prior to beginning your research.
3. Modifications to the research plan, subject pool, informed consent, survey instruments, or other critical components of your project, must be submitted to the IRB for approval before those changes are implemented.
4. You are required to immediately report any problems that you encounter while using human subjects to your faculty sponsor who will help you report these problems to the Institutional Review Board.
5. This approval of your research is effective for one year from the date of this approval. If your research extends more than one year you must submit an electronic Continuing Review Form to provide an Annual Update to the IRB regarding the progress on your research and to obtain a new approval notice.

Good luck with your research, please contact IRBAdministrator@wpunj.edu if you have any questions.

C: Dr. Figueroa

APPENDIX F

GAIT AND FALLS QUESTIONNAIRE (GFQ)

1. During your best state—do you walk:

0 Normally
1 Almost normally—somewhat slow
2 Slow but fully independent
3 Need assistance or walking aid
4 Unable to walk

2. During your worst state—do you walk

0 Normally
1 Almost normally—somewhat slow
2 Slow but fully independent
3 Need assistance or walking aid
4 Unable to walk

3. Are your gait difficulties affecting your daily activities and independence?

0 Not at all
1 Mildly
2 Moderately
3 Severely
4 Unable to walk

4. Do you feel that your feet get glued to the floor while walking, making a turn or when trying to initiate walking (freezing)?

0 Never
1 Very rarely—about once a month
2 Rarely—about once a week
3 Often—about once a day
4 Always—whenever walking

5. How long is your longest freezing episode?

0 Never happened
1 1–2 s
2 3–10 s
3 11–30 s
4 Unable to walk for more than 30 s

6. How long is your typical start hesitation episode (freezing when initiating the first step)?[1]

0 None
1 Takes longer than 1 s to start walking
2 Takes longer than 3 s to start walking
3 Takes longer than 10 s to start walking

4 Takes longer than 30 s to start walking

7. How long is your typical turning hesitation (freezing when turning)[1]

0 None
1 Resume turning in 1–2 s
2 Resume turning in 3–10 s
3 Resume turning in 11–30 s
4 Unable to resume turning for more than 30 s

8. How long is your typical destination hesitation (freezing when approaching the target, such as when stepping onto a scale or approaching a chair to sit down)?

0 None
1 Resume walking in 1–2 s
2 Resume walking in 3–10 s
3 Resume walking in 11–30 s
4 Unable to resume walking for more than 30 s

9. How long is your typical tight quarters hesitation (freezing when attempting to get through narrow space such as a doorway)?

0 None
1 Resume walking in 1–2 s
2 Resume walking in 3–10 s
3 Resume walking in 11–30 s
4 Unable to resume walking for more than 30 s

10. How long is your typical freezing episode while walking on straight?

0 None
1 Resume walking in 1–2 s
2 Resume walking in 3–10 s
3 Resume walking in 11–30 s
4 Unable to resume walking for more than 30 s

11. How long is your typical freezing episode during stressful time-demanding situations, such as when the telephone rings, at elevators or street crossing?

0 None
1 Resume walking in 1–2 s
2 Resume walking in 3–10 s
3 Resume walking in 11–30 s
4 Unable to resume walking for more than 30 s

12. How often do you fall?

0 Never
1 Very rarely—about once a year
2 Rarely—about once a month
3 Often—about once a week
4 Very often—once a day or more

13. How often do you fall when standing?

0 Never
1 It happened once or twice
2 It happened 3–12 times in the last 6 months
3 More than once a week
4 Whenever trying to walk unassisted

14. How often do you fall because of freezing episodes?

0 Never
1 It happened once or twice
2 It happened 3–12 times in the last 6 months
3 More than once a week
4 Whenever trying to walk unassisted

15. Do you experience festinating gait? (Festinating gait ˆ accelerated, short steps, gait)

0 Never
1 Very rarely—about once a month
2 Rarely—about once a week
3 Often—about once a day
4 Whenever walking

16. How often do you fall because of festinating gait?

0 Never
1 It happened once or twice
2 It happened 3–12 times in the last 6 months
3 More than once a week
4 Whenever trying to walk unassisted

APPENDIX G

DYNAMIC PARKINSON GAIT SCALE (DPGS)

1. Gait level surface-walking at normal speed

3 Normal: Walks 20’, no assistive devices, good speed, no evidence for imbalance, normal gait pattern.
2 Mild impairment: Walks 20’, uses assistive devices, slower speed, mild gait deviations
1 Moderate impairment: Walks 20’, slow speed, abnormal gait patterns, evidence for imbalance
0 Severe impairment: Cannot walk 20’ without assistance, slow speed, severe gait deviations or imbalance

2. Change in gait speed

3 Normal: Able to smoothly change walking speed without loss of balance or gait deviation. Shows significant difference in walking speeds between normal, fast and slow paces.
2 Mild impairment: Is able to change speed but demonstrates mild gait deviations, or no gait deviations but unable to achieve a significant change in velocity, or uses an assistive device.
1 Moderate impairment: Makes only minor adjustments to walking speed, or accomplishes a change in speed with significant gait deviations, or changes in speed but loses balance but is able to recover and continue walking.
0 Severe impairment: Cannot change speeds, or loss balance and has to reach for a wall or be caught.

3. Gait with horizontal head turns

3 Normal: Performs head turns smoothly with no change in gait.
2 Mild impairment: Performs head turns smoothly with slight change in gait velocity, i.e. minor disruption to smooth gait path or uses walking aid.
1 Moderate impairment: Performs head turns with moderate change in gait velocity, slows down, staggers, but recovers, can continue to walk.
0 Severe impairment: Performs task with severe disruption of gait, i.e. staggers outside 15” path, loses balance, stops, reaches for wall.

4. Gait with vertical head turns

3 Normal: Performs head turns smoothly with no change in gait.
2 Mild impairment: Performs head turns smoothly with slight change in gait velocity, i.e. minor disruption to smooth gait path or uses walking aid.
1 Moderate impairment: Performs head turns with moderate change in gait velocity, slows down, staggers, but recovers, can continue to walk.
0 Severe impairment: Performs task with severe disruption of gait, i.e. staggers outside 15” path, loses balance, stops, reaches for wall.

5. Gait and pivot turn

3 Normal: Pivot turns safely within 3 seconds and stops quickly with no loss of balance.
2 Mild impairment: Pivot turns safely in >3 seconds and stops with no loss of balance.
1 Moderate impairment: Turns slowly, requires verbal cueing, requires several small steps to catch balance following turn and stop.
0 Severe impairment: Cannot turn safely, requires assistance to turn and stop.

6. Step over obstacle

3 Normal: Is able to step over box without changing gait speed; no evidence for imbalance.
2 Mild impairment: Is able to step over shoe box, but must slow down and adjust steps to clear box safely.
1 Moderate impairment: Is able to step over box but must stop, then step over. May require verbal cueing.
0 Severe impairment: Cannot perform without assistance

7. Step around obstacles

3 Normal: Is able to walk safely around cones safely without changing gait speed; no evidence of imbalance.
2 Mild impairment: Is able to step around both cones, but must slow down and adjust steps to clear cones.
1 Moderate impairment: Is able to clear cones but must significantly slow speed to accomplish task, or requires verbal cueing.
0 Severe impairment: Unable to clear cones, walks into one or both cones, or requires physical assistance

8. Steps

3 Normal: Alternating feet, no rail.
2 Mild impairment: Alternating feet, must use rail.
1 Moderate impairment: Two feet to a stair, must use rail.
0 Severe impairment: Cannot do safely.