FELSBERG, DANIELLE TOMECK. Ph.D. Investigating the Gap Between Evidence and Practice in the use of Virtual Reality for Physical Rehabilitation – Is VR Just a Fancy Toy? (2021) Directed by Dr. Christopher K Rhea 179. pp.

Physical rehabilitation aims to address functional deficits, restore healthy movement patterns, and optimize independence following dysfunction caused by aging, injury, or disease. Virtual reality (VR) has been shown to be a promising tool to create interventions to improve motor outcomes, however, there appears to be a gap between scientific evidence and clinical practice. The purpose of this dissertation was to three-fold: (1) to identify the degree to which VR research for physical rehabilitation is being translated out of laboratories through studies performed in clinical settings; (2) to identify the acceptance, adoption, and perceived barriers to use of VR in rehabilitation by those practicing physical therapy across the profession spectrum (physical therapists (PTs), physical therapist assistants (PTAs), and students of both programs); and (3) to identify the perceptions and intention to use VR in rehabilitation by patients who have or are currently receiving physical rehabilitation.

Aim 1 used a systematic review to investigate the current state of VR research for physical rehabilitation from 2010 to present. The review included 88 articles. The findings of this review indicated that most VR research for physical rehabilitation is being performed in clinical settings; primarily inpatient settings such as hospitals and outpatient clinics. Additionally, most studies reported significant improvements in their outcome variables following VR intervention. Aims 2 and 3 investigated the views of clinical use of VR by physical rehabilitation professionals/students (Aim 2) and patients (Aim 3) via the (ADOPT-VR2) survey. For Aim 2, A total of 626 clinicians and 91 students completed all portions of the survey. As expected, a small percentage of respondents reported using VR in clinical practice. All ADOPT-VR2 constructs are significant predictors of behavioral intention to use VR. Interestingly, students have significantly higher

positive attitudes toward use of VR than clinicians, including behavioral intentions to use VR in clinical practice. For Aim 3, a total of 38 current or former patients completed all portions of the survey. None of the participants reported receiving interventions that included VR during their PT experience, however 60.5% of respondents reported they would request VR interventions if available and 71.1% of respondents reported they would prefer providers that utilize VR interventions. Only the ADOPT-VR constructs of attitudes, perceived usefulness, perceived ease of use, and compatibility were found to be predictive of intention. Additionally, patients' behavioral intention to use VR appears to be independent of external factors including age, socioeconomic status, experience with VR, and educational level, as these were not found to be significant predictors of intention in this population. Thus, clinics should be cautious when determining if their clients would be interested or appropriate for VR interventions based on one of these factors.

These findings illuminate the current state of the research and clinical use of VR interventions to improve motor outcomes. VR research has evolved out of labs and into clinical settings, and the results continue to support the efficacy of VR as an intervention. However, a gap does exist as clinicians are largely not utilizing VR as a treatment modality despite patients' acceptance and positive intentions to participate in VR interventions. Findings regarding student's positive attitudes and intentions toward VR use are promising, as this suggests that there is potential for a shift in clinical VR usage patterns as these students become autonomous, licensed clinicians.

# INVESTIGATING THE GAP BETWEEN EVIDENCE AND PRACTICE IN THE USE OF VIRTUAL REALITY FOR PHYSICAL REHABILITATION – IS VR JUST A FANCY TOY?

by

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A Dissertation

Submitted to

the Faculty of The Graduate School at

The University of North Carolina at Greensboro

in Partial Fulfillment

of the Requirements for the Degree

Doctor of Philosophy

Greensboro

2021

Approved by

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Dr. Christopher K Rhea
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# DEDICATION

*Perseverance matters so much more than brilliance.*

-W. Geoffrey Wright, Ph.D.

This dissertation is dedicated to all the people who have helped me persevere to get to this point, especially to my mentor, my husband, and my children. To Chris, I appreciate you and your mentorship. As one of only a select few that did not think pursuing a PhD while commuting from Charlotte with three, then four, then five children was a completely insane endeavor – you have always seen me and my potential, even when I didn't, and pushed me to succeed against all odds. To my husband, Jordan, if it wasn't for your unwavering support none of this would have been possible. I appreciate all the sacrifices you've made over the last four years to allow me to pursue this dream and keep our family thriving. And, above all, to my children – Lily, Charleston and Fiona who have been on this ride from the beginning, and Shepherd and Willow who joined our brood along the way – you inspired me to keep going, even when I didn't want to. I hope I've made you proud, and that I've shown you that you can do hard things.

APPROVAL PAGE

This dissertation written by Danielle Tomeck Felsberg has been approved by the following committee of the Faculty of The Graduate School at The University of North Carolina at Greensboro.

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Date of Final Oral Examination

ACKNOWLEDGEMENTS

I would like thank Stephanie Glegg, OT, PhD who kindly shared the Assessing Determinants of Prospective Take-up of Virtual Reality Survey (version 2) questions for use in this dissertation.

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# CHAPTER I: INTRODUCTION

Interest in understanding human movement can be seen as far back as the cave drawings of the Paleolithic Era (Andriacchi & Alexander, 2000). Human motor development is phylogenetically unique from other mammals in that children require more time to develop upright stability and independent gait (Garwicz et al., 2009; Iosa et al., 2014). In the first year of life, children develop the motor skills required for postural control and coordinated upright mobility which is further refined throughout childhood to the mature movement patterns of adulthood (Forssberg, 1999; Thelen 1995). Healthy human movement patterns are characterized by an optimal level of consistency to provide stability for the system and variability to allow the system flexibility to adapt to the environment (Stergiou & Decker, 2011). Aging, injury, or disease can have profound effects on mobility and overall function. Physical rehabilitation aims to address functional deficits, restore healthy movement patterns, and optimize independence.

The primary role of a Physical Therapist (PT) or Physical Therapist Assistant (PTA) is to address motor deficits and improve functional independence to optimize overall quality of life. Physical rehabilitation professionals utilize a variety of therapeutic modalities in conjunction with motor assessments and knowledge of motor learning principles to create effective treatment protocols to meet a patient's functional goals. Virtual reality (VR) has been identified as a uniquely promising treatment modality to provide effective interventions for improving motor outcomes (Felsberg et al., 2019; Howard, 2017; Porras et al., 2018). However, current adoption and use of VR in clinical settings for physical rehabilitation appears to be low. To address this gap in the literature, theoretically driven, survey-based research regarding technology acceptance of both clinicians and patients may help explain why adoption of VR is low in clinical settings despite the evidence in support of its use.

There are several theories and models developed in the social sciences that help explain behavior, which are useful in the current context. These are the Technology Acceptance Model (TAM), Diffusion of Innovation Theory, and Decomposed Theory of Planned Behavior (DTPB). The TAM suggests that predictors of technology acceptance rely on perceived usefulness (PU) and perceived ease of use (PEOU) as determinants of an intention to use technology and technology usage (Davis, 1985; Lee et al., 2003). The Diffusion of Innovation Theory seeks to explain technology adoption through factors such as the relative advantage of adopting the new technology, how well it fits into the user's life, how difficult it is to use, how much it can be trialed before fully adopting, and the extent to which it provides measurable change (Rogers, 2004). Finally, the DTPB shares some of the same relationships present in the TAM, however, builds on some of the weakness of the TAM by including factors of social influence and behavioral control (Taylor & Todd, 1995). The TAM and Diffusion of Innovation Theory provide strong foundational information regarding technology acceptance and adoption (Davis, 1985; Davis et al., 1989; Rogers, 2004). However, the additional of factors regarding attitudes toward technology, influence of peers, and perceived resource and technology constraints also included in the DTPB seems to lend it well to the application of VR acceptance in clinical settings. Currently, there is a small amount of research in the area of VR acceptance by clinicians in physical rehabilitation. One research group has adapted the DTPB to VR use in clinical settings, called the Assessing Determinants of Prospective Take-up of Virtual Reality (ADOPT-VR) survey (Glegg et al., 2013). Understanding the technology acceptance of both clinicians and patients can illustrate a better understanding of why VR interventions may not be widely used in clinical practice for physical rehabilitation.

Despite empirical evidence supporting the use of VR as a therapeutic intervention to improve motor outcomes, the adoption of VR in clinical settings remains low (Glegg & Levac, 2018). Currently, it's unclear why there is a gap that exists between evidence and practice. Understanding this gap between research supporting VR use for physical rehabilitation interventions and the current VR acceptance and usage in clinical practice will help address the questions regarding if VR really is meant to serve a role as a useful therapeutic modality or, conversely, is just a fancy a toy.

To address this gap, a systematic review and series of surveys are presented in three manuscripts. The aims and associated hypotheses for each manuscript are presented as follows:

## Manuscript 1

### Systematic Review

Aim 1: Systematically review current literature investigating the use of virtual reality (VR) in clinical settings for physical rehabilitation.

## Manuscript II

### Survey 1

Aim 2: Identify the acceptance, adoption, and perceived barriers to use of VR in rehabilitation by physical therapy professionals across the spectrum; Physical Therapists, Physical Therapist Assistants, and students of both programs.

Hypotheses:

1a: A small quantity of PT and PTAs will be currently using VR in their clinical practice.

1b: The majority of PT and PTAs using VR in their clinical practice will be using of-the-shelf products, like Nintendo Wii, and associated games.

1c: Students will have more positive intentions to use VR in clinical practice than licensed clinicians.

1d: Recreational use of VR will be predictive of positive intention to use VR in clinical practice

1e: Affiliation with a teaching or research institution will be predictive of positive intention to use VR in clinical practice.

1f: Years of clinical experience will be predictive of intention to use VR in clinical practice such that those with more years of clinical experience will be lower intention to use VR.

1g: Higher overall technology acceptance as demonstrated by higher composite scores on the ADOPT-VR2 will be predictive of positive intention to use VR in clinical practice.

1h: A majority of participants will demonstrate a positive intention to use VR following presentation of an informational video regarding the use of VR in clinical practice.

## Manuscript III

**Survey 2**

Aim 3: Identify patient perspectives and behavioral intention to the use of VR in rehabilitation.

Hypothesis:

1a: Experience with VR in their rehabilitation treatment will be predictive of positive desired intention to use VR in future PT treatments.

1b: Participants' age will be predictive of desired intention to use VR in future PT treatments such that increased age with demonstrate less intention to use VR.

1c: Participants' education level will be predictive of positive desired intention to use VR in future PT treatments.

1d: Participants' socioeconomic status will be predictive of positive desired intention to use VR in future PT treatments.

1e: Time since rehabilitation experience will be predictive of negative intention to use VR in PT treatments such that more time since participation in PT would predict less intention to use VR in any future PT treatment.

1f: Higher overall technology acceptance as demonstrated by higher composite scores on the ADOPT-VR2 will be predictive of positive desired intention to use VR in PT treatments.

1g: Participants will demonstrate an increased intention to use VR following presentation of an informational video regarding the use of VR in clinical practice.

# CHAPTER II: REVIEW OF THE LITERATURE

## Overview

Physical therapy (PT) aims to improve quality of life through addressing movement dysfunction, restoring function, and optimizing independence. As technology has developed, virtual reality (VR) has emerged as a tool to produce effective rehabilitation intervention to improve motor outcomes. Previous research investigating the use of VR in rehabilitation has demonstrated significant improvements in gross motor outcomes, however most of this research has been conducted in controlled laboratory environments and the translation to clinical practice appears to be limited. This literature review will discuss the development of upright mobility in humans followed by the effects of injury, aging and disease on motor function. Next, this literature review will discuss the role of VR as a rehabilitation intervention to improve upright mobility. From there, literature will be outlined discussing the acceptance of technology globally, followed by the acceptance of technology in healthcare. Finally, gaps in previous research and current clinical practice in regard to the use of VR will be identified as it relates to the specific aims of this dissertation.

## Development of Upright Mobility in Humans

The development of the skills required for upright mobility in humans are seen in the early primitive movements of the neonate. This is demonstrated by the flexion and extension movements performed by a fetus (Prechtl, 1984) and the innate ability of newborns to perform stepping when held erect (Forssberg, 1985; McGraw, 1940). Infants are born with a set of motor behaviors such as sucking, rooting, righting reactions and stepping which allow the infant to survive and thrive through the newborn period (Forssberg, 1999). These innate motor behaviors exist alongside spontaneous rhythmic motor behaviors in the first year of an infant's life and, together, lay the ground work for future motor development (Thelen, 1995).

Human motor development is phylogenetically unique from other mammals in that children require more time to develop upright stability and independent gait (Garwicz et al., 2009; Iosa et al., 2014). Soon after birth, neonates demonstrate stepping activity, however these steps are not similar in pattern to adult plantigrade stepping (Forssberg, 1985; McGraw, 1940). Infant steps lack a true heel strike, and the lower limbs are maintained in a hyper-flexed position similar to patterns seen in quadrupeds (Forssberg, 1985). As the infant progresses through the first year of life, the development of independent gait is established with similar patterns to infant stepping (Forssberg, 1985). The average onset of independent walking is around 14 months of age (Bosch et al., 2007). Once able to produce independent steps, through a cycle of repetitive exploration, the development of locomotor patterns more closely related to adult gait begin to form and mature until around age seven at which time gait patterns are grossly similar to that of adulthood (Forssberg, 1985; Iosa et al., 2014; Thelen, 1995).

Gait is a foundational element for functional independence across the lifespan. A child's first independent steps are, arguably, the most thrilling milestone of early development. Establishing optimal gait dynamics are related to the adaptability and overall health of the system throughout life (Stergiou & Decker, 2011). However, as bipeds, humans are inherently unstable with the majority of body mass located above the hips, similar to an inverted pendulum (Winter, 1995). Locomotion in humans is essentially about controlling a series of forward falls. Thus, balance and postural control are required to successfully stabilize the system for upright mobility (Andriacchi & Alexander, 2000; Assaiante, 1998; Massion, 1994; Winter, 1995).

To acquire and maintain upright positioning, humans must establish balance and postural control. The visual, somatosensory, and vestibular systems work together to control these tasks (Massion, 1994; Winter, 1995). Vision provides information regarding the environment. The somatosensory system provides information regarding the body's position and movement. The vestibular system provides information regarding linear and angular acceleration. Together these systems provide information needed to produce successful upright mobility and stability. However, The contribution of each system changes with development, aging, disease or injury.

As previously stated, successful locomotor ability in gait requires balance and postural control; where posture is the body's orientation to vertical and balance refers to the postural changes performed to prevent falling. In quiet stance, the system must maintain the body's center of mass (COM) within the support surface (Assaiante, 1998; Mittelstaedt, 1983). Initial postural responses develop first with head control, then trunk control, followed by control of the lower extremities. This cephalocaudal progression of control allows for stability in standing which is a prerequisite for upright mobility. Once children acquire the strength and coordination for upright positioning within the first year of life, mastery of coordination between the upper and lower extremities continues to develop through the age of seven where postural control and balance resembles that of adult patterns (Assaiante, 1998).

The inverted pendulum model applies to balance, posture, and locomotion. In double limb supported, static standing the body's COM must remain within the base of support (BOS) to maintain equilibrium with respect to both the anteroposterior (A/P) and mediolateral (M/L) directions (Horak & Nashner, 1986; Massion, 1994; Winter, 1995). This is accomplished through a combination of ankle and hip strategies. These postural actions are automatic and are influenced by environmental factors as well as prior experience (Horak & Nashner, 1986). Maintaining equilibrium of the inverted pendulum becomes even more challenging in progression from quiet stance to locomotion at which time balance must be maintained in single-limb support (Assaiante, 1998; Brenière et al., 1989).

In the case of locomotion, pelvis stabilization is necessary to initiate and control excursions of COM (Assaiante, 1998). Each step of the gait cycle is an initiation of a forward fall. Hip-centered balance control provides a reference frame to stabilize posture and control this forward momentum before termination of the gait cycle at which time the forward the fall is stopped by successful foot placement of the swing limb (Assaiante, 1998; Winter, 1995). About 80% of the gait cycle is comprised of two instances of single-limb support (approximately 40% for each limb) separated by two much shorter instances of double-limb support (Winter, 2009). A full gait cycle is the defined as the time between heel strike of one limb and the subsequent heel strike of that same limb (Houglum & Bertoti, 2011). Different from the parameters of static standing which require COM to remain within the defined limits of stability, gait requires dynamic balance where during single-limb stance the COM is actually outside the base of support and balance is maintained by the swing limb on the next stance phase (Winter, 1995). Development of postural control, balance and gait begins with the first motor milestones of infancy through approximately the first seven years of life during which time children explore their environment and refine mastery of fundamental motor abilities.

As previously described, quiet standing is maintained by keeping the COM within the support surface in both the A/P and M/L directions with a combination of ankle and hip strategies (Horak & Nashner, 1986; Massion, 1994; Winter, 1995). However, to initiate locomotion, the system must move the COM forward, outside the base of support to begin the forward momentum of gait. To accomplish this, the muscles that assist with maintaining quiet standing, the ankle plantar- and dorsiflexors (A/P control muscles) and the hip abductors and adductors (M/L control muscles), must coordinate to shift from quiet stance to the rhythmic, reciprocal motions of gait (Winter, 2009). To move from the stable conditions of quiet standing to the dynamic movement of gait, COM must be shifted forward. To allow this to happen, the center of pressure (COP) is shifted toward the swing limb by increased activation of the swing limb hip abductors, which momentarily unloads the stance limb. The posterolateral shift in COP produces the forward movement of the COM toward the stance limb, which is followed by increased hip abductor activity and a COP shift toward the stance limb. This is accompanied by unweighting of the swing limb to be propelled up and forward through the swing phase via the hip flexors and knee extensors. The COM then maintains forward movement controlled by the activity of the ankle plantarflexors of the stance limb. The body is now in a forward fall with the COP moving forward under the stance limb and toward the final position of the swing limb as it makes heel contact, and this cycle continues reciprocally until gait is terminated (Brenière et al., 1989; Winter, 1995; Winter, 2009). Terminating gait and transitioning back to quiet stance requires deceleration of the COM upon heel contact of the stance limb via a forward shift of the COP controlled by the plantarflexors. Then the COP accelerates toward the final stance limb at a midpoint between the two feet which is an estimation by the system of the future endpoint of the COM (Winter, 1995).

Mastery of a motor skill may be demonstrated by having consistent performance with little variation, however at the same time development of sophisticated movement may demonstrate increased variation as the behavioral repertoire evolves. Biological systems are naturally variable, and although consistent motor performance is desirable, this variation can also indicate a healthy system (Cavanaugh et al., 2005; Stergiou & Decker, 2011). Movement variability can be assessed through two lenses: magnitude and complexity. The magnitude of variability relates to how close repeated motions are to a central point. From this perspective, mastery of locomotion may be demonstrated by having consistent gait mechanics (i.e., stride time) with little deviation. Yet, this only gives one view of the current state of the motor system. Looking at the complexity, or the structured pattern, of the variations in performance of a motor skill over time can give a different view of motor behavior.

Initially, variations in motor output were viewed as random error. However, when looking at the structure (complexity) of these variations across a series of time a pattern emerges, which in a healthy system is not random (Dingwell & Cusumano, 2000). From this perspective, gait behavior that initially seems consistent in average performance may demonstrate patterns of fluctuating variations that are predictable over time (Lipsitz & Goldberger, 1992). The structure of the pattern that emerges, how statistically persistent or random these patterns are over time, can be indicative of the overall health and adaptability of the system (Cavanaugh et al., 2005; Stergiou & Decker, 2011).

## Motor Changes with Aging, Injury, or Disease

In healthy, typically developing motor systems balance and postural control can be maintained in upright stance, and gait occurs in a stable and adaptable manner. Aging, injury, or disease can negatively impact gait, balance, and postural control. These changes can lead to impaired movement, increased falls, and loss of functional independence. Maintaining balance and postural control during both static and dynamic tasks is required to execute activities of daily living without falling (Alexander, 1994; Berg et al., 1989).

Aging is often associated with frailty, decreased independence, and falls. Falls are a major public health concern, especially in older adults over the age of 65 (Ambrose et al., 2013). Falls in the older adult are a major contributor to injury and death in this population (Ambrose et al., 2013;

Tinetti, 2003). Those who fall demonstrate increased postural sway in quiet standing, unsteadiness during dynamic tasks, and are less able to stand on one leg which is crucial for gait ("Fall Risk Index for Elderly Patients Based on Number of Chronic Disabilities," 1986; Fernie et al., 1982; Lipsitz et al., 1991; Lord et al., 1991; Ring et al., 1988; Studenski et al., 1991). Postural control requires maintaining the COM within the limits of stability (Assaiante, 1998; Horak, 1987; Mittelstaedt, 1983). To do this, the visual, somatosensory, and vestibular systems must work together (Massion, 1994; Winter, 1995). Changes in function of one or more of these sensory systems, which is common in aging, can create inaccurate perceptions of body position, tasks demands, or the available limits of stability and lead to an inappropriate balance response (Alexander, 1994; Shumway-Cook & Horak, 1990). Age-related changes in vision, vestibular, and somatosensory systems as well as changes in the musculoskeletal system and cognition can influence how older adults maintain postural control and balance in upright mobility (Alexander, 1994).

Age-related changes in physical functioning contribute to changes seen in gait and balance in elderly population. Similarly, injury and disease-related changes to the visual, vestibular, and (or) somatosensory systems, effects on integration of these systems, as well as physiological changes to the associated body systems can influence gait and balance in variety of ways. For example, Parkinson's Disease (PD) is a common chronic, neurodegenerative disorder characterized by hypokinesia (small movements), bradykinesia (slow movements), tremor, and increased muscle tone contributing to gait and balance disturbances (Hausdorff, 2009). These characteristic features of PD are associated with a loss of dopamine production in the basal ganglia, a major movement center of the brain. The disruption in dopamine production is thought to influence automatic movements, leading to changes in gait and balance reactions (Morris et al., 1994). Some of these changes are visible and assessable by typical clinical outcome measures such as decreased stride length and slower gait speed (Hausdorff, 2009; Morris et al., 1994). Conversely, changes in gait variability also are noted in this population but are not easily discernable visually. Likely due to the impaired automaticity of movement seen in PD, there is a loss of consistency in the rhythmic nature of ambulation which leads to increased gait variability (Hausdorff, 2009). Together, these changes in the mechanics and dynamics of gait and balance lead to increased risk for falls and decreased functional independence in those with PD.

Similar changes in gait, balance and postural control can be seen in in those who have suffered traumatic brain injury (TBI). These changes may be somewhat intuitive given the requirement of coordination and integration of sensory information between visual, vestibular and somatosensory systems in movement control. Under healthy conditions, afferent information is taken in by these systems, integrated, then used to select and generate an appropriate movement response. Following TBI, an over-reliance on visual input and decreased use of the vestibular system to appropriately resolve differences between somatosensory and visual input (Basford et al., 2003; Geurts et al., n.d.; Wade et al., 1997). These impairments lead to postural instability in static and dynamic tasks, which may even be present in those who have otherwise seemingly recovered well from their (Basford et al., 2003).

Aging, injury, or disease can negatively impact gait, balance, and postural control. These changes can lead to impaired movement, increased falls, and loss of functional independence. To address these impairments, those with movement deficits may require physical rehabilitation to promote motor recover and optimize function.

## Physical Rehabilitation to Improve Motor Behavior

Physical rehabilitation aims to improve quality of life through assessing movement dysfunction, restoring function, and optimizing independence. Physical Therapists (PTs) and Physical Therapist Assistants (PTAs) are primary members of a multidisciplinary team focused on supporting those with deficits related to aging, injury or disease. PTs and PTAs focus on assessing motor impairments, addressing functional deficits, and improving quality of life across a variety of patient populations and clinical care settings with the goal to learn or relearn motor skills and return as close to prior level function as possible. To learn or relearn motor skills, physical rehabilitation interventions are created with principles of motor control and motor learning in mind. These interventions can include traditional rehabilitation methods such as strengthening or stretching exercises, manual therapy, and gait training or other functional training activities, among others, to address motor deficits and optimize independence. Increasingly over the last decade, virtual reality (VR) has presented itself as a promising tool for physical rehabilitation due to its functional, motivating, and modifiable nature. A growing body of literature demonstrates that VR can produce both effective assessment for impairments as well as provide meaningful interventions for the rehabilitation of motor tasks (Felsberg et al., 2019; Howard, 2017; Porras et al., 2018; Teel & Slobounov, 2015; Wright et al., 2017)

## Virtual Reality

Virtual reality (VR) can be defined as a computer-generated environment which contains sensory information that may be interacted with, visualized, and (or) manipulated to allow natural behaviors to emerge as if the environment were real (Jerald, 2016; Rizzo & Koenig, 2017; Steinicke et al., 2013). Technology has greatly progressed from the stereoscopes of the 1800s to the advanced systems seen today. VR can take many forms and continues to evolve as technology advances.

The 1990s marks a boom in the development of personal computers, internet connectivity, and use of information systems by the general public (Rizzo & Koenig, 2017). This time is marked by a large increase in the interest to use technology for both productivity and entertainment. Early uses of clinical VR are seen in the area of psychology in the mid-1990s where the technology was used for exposure therapy (Lamson, 1994; Rizzo & Koenig, 2017). Since that time, VR has been applied to a variety of clinical fields such a pain management (Hoffman et al., 2011), cognition (Brown et al., 1998), and motor rehabilitation (Felsberg et al., 2019; Howard, 2017). Clinicians across different disciplines all acknowledge the engaging, interactive, and modifiable nature of VR as a useful tool to produce meaningful interventions in clinical practice.

The 2000s really marks the modern evolution of VR. The early 2010s is the beginning of low-cost, commercially-available VR hardware with the presentation of the Oculus, a HMD (Jerald, 2016). Since then, several HMDs have developed such as Samsung Gear VR, Oculus Rift, Play Station VR, HTC Vive, and Google Cardboard. Around the same time, consumer technology companies produced commercially available video game hardware commonly used in VR research today such as the Wii Fit and Xbox Kinect. As technology developed and became more widely available, the use of VR was applied to a variety of context including clinical settings.

The presentation of VR exists on a continuum from non-immersive to fully immersive experiences. Immersion itself is defined as the level of display fidelity, or how true to reality the sensory experience is produced by that system (Jerald, 2016). Several factors contribute to the level of immersion of a VR. These factors include the extensiveness (how rich is the sensory experience), matching (how congruent the sensory cues are to the interaction), surroundedness (how encompassing is the experience), vividness (related to the graphic and audio quality), interactivity (the degree to which the user can modify and respond to the experience), and plot (consistency of the theme of the experience) (Slater & Wilbur, 1997). Immersion should not be confused with level of presence, which is the subjective feeling of the user in response to the environment (Jerald, 2016). Both immersion and presence are affected by the quality of the hardware and software used to present the virtual environment to the user. Thus, it is easy to see how the potential to create highly immersive and present VR has become more of a reality as technology has improved over time. As computing power, graphics quality, screen size and resolution, audio quality, and other related technologies have evolved from the dawn of VR to present day even systems viewed as less immersive, such as computer and projection screens, can provide engaging user experiences.

VR can provide seemingly endless possibilities at creating multisensory experiences for a variety of desired outcomes. Early research in this area demonstrated that postural adjustments could be induced through simulated movement via graphic projections (Lestienne et al., 1977; van Asten et al., 1988). These early works demonstrated motor behavior can be elicited through the manipulation of visual information and provided support for the use of VR in motor behavior research. Since that time, current research indicates that VR interventions for improving gait and balance are effective at improving motor outcomes, in some case more so than traditional therapeutic interventions (Felsberg et al., 2019; Howard, 2017; Porras et al., 2018). This area of research has developed rapidly since about 2010, which aligns with the development of technology available beginning around that time (Porras et al., 2018). Through the use of VR, users can have experiences that may be difficulty to create or engage with in the physical world. For this reason, VR provides a safe, functional and motivating context for physical rehabilitation. Technology has made great advances from the early Sensorama and flight simulators of the mid-1900s to the VR technology available today. Virtual reality provides a safe, functional and motivating context for use in many fields. A growing body of research exists to demonstrate the role of VR as a useful tool for assessment and rehabilitation of motor behavior. The engaging and modifiable features of VR uniquely position this technology for use in physical rehabilitation.

### Virtual Reality in Physical Rehabilitation

Physical rehabilitation aims to address movement impairments, restore function, and improve quality of life following aging, injury, or disease. VR has presented itself as a promising tool for physical rehabilitation due to its functional, motivating, and modifiable nature. A growing body of literature demonstrates that VR can produce both effective assessment for impairments as well as provide meaningful interventions for the rehabilitation of motor tasks (Felsberg et al., 2019; Howard, 2017; Porras et al., 2018; Teel & Slobounov, 2015; Wright et al., 2017).

To learn or relearn motor skills, physical rehabilitation interventions are created with principles of motor control and motor learning in mind. The unique features of VR may provide the desirable environment to promote motor learning, retention, and transfer of motor skills in a way that cannot be accomplished through traditional therapeutic methods. These features that align with motor learning principles include observational learning, a standardized environment for practice, feedback, and motivation (Levac & Sveistrup, 2014). VR can provide the environment necessary to perform repetitive, intensive, and engaging practice of motor skills to promote neuroplasticity and improve motor outcomes (Levin, 2011)

Observational learning refers to the activation of the mirror neuron system of the primary motor cortex which happens when watching the performance of a task (Brihmat et al., 2018). In VR, observation learning can occur if the VR either projects the user’s image into the environment, uses an interactive avatar which matches the user’s movements, or employs a visual representation of the skill (Eng et al., 2007; Flynn et al., 2007; Weiss & Katz, 2004). Tunik and colleagues (2011) also demonstrated that participants with stroke had increased activation of the sensorimotor cortex associated with their paretic limb when observing a virtual hand perform a task. Thus, research suggests that a VR that allows the user to see the skill performance, either of themselves or a virtual representation, may be a useful clinical tool to activate neural circuitry and promote reorganization. Observational learning can be incorporated in the physical world through the use of mirrors or the therapist demonstrating the desired skill, however this cannot always be easily accomplished due to clinic setup, constraints of the mirror to fit the size of the skill, and availability of the therapist to demonstrate the skill. VR may address some of these limitations by containing the visualization of the users' movements to their field of view and not relying on the availability of a therapist to demonstrate the skill throughout the treatment session.

Practice is a key feature of rehabilitation interventions. To learn or relearn a motor skill, practice must be abundant, specific to the desired tasks, and motivating to the learner (Levac & Sveistrup, 2014; Levin, 2011). It has been proposed that VR can provide an environment that is optimally engaging for patients to participate in multiple repetitions of practicing a motor task (Adamovich et al., 2009; Levac & Sveistrup, 2014). Take gait training, for example, in the physical environment the mass practice of stepping may quickly become mundane to the patient and they may become disengaged from the task which could impact motor learning. However, in virtual reality, the environment could include interesting graphics, sound, gamification, interactivity, and (or) be graded in real-time to create the ideal level of engagement in a way that the physical world cannot be customized (Adamovich et al., 2009; Levac & Sveistrup, 2014; Zimmerli et al., 2013). Research supports this, demonstrating that patients engage in a treatment task longer or performed better quality movements when coupled with VR than when performing the intervention alone (Mirelman et al., 2010; Bryanton et al., 2006). Additionally, VR can recreate realistic, task-specific environments that may be difficulty or dangerous to practice in the real world such as crossing the street, walking on a balance beam, or obstacle avoidance (Rizzo & Kim, 2005). Therefore, VR has the potential to be used in clinical practice to create optimally engaging environments for repetitive task-specific practice.

It is common to for clinicians to give feedback to patients to improve motor performance and support motor learning (Schmidt et al., 2019). This feedback can either provide knowledge regarding how the task is being performed (knowledge of performance) or regarding the success of the task (knowledge of results), and can be given at set frequencies and timepoints of an intervention (Schmidt et al., 2019). Feedback can be readily provided by clinicians, however VR has the potential to provide multisensory feedback in real-time, and more objectively than may be possible in the physical world (Subramanian et al., 2010). For example, knowledge of performance can be provided regarding lower limb joint movements in real-time, and in a way that is easily visualized by the user to understand if they are performing the desired amount of joint flexion or extension for the task (van Gelder et al., 2017). This level of precision and visualization could not be provided by a clinician in the physical world. In this way, VR could be a very useful tool in clinical settings to enhance interventions for motor rehabilitation.

A hallmark of rehabilitation interventions is repetition which can lead to disengagement of the performer. Motivation is needed to fully engage in an intervention to optimize motor learning and output (Schmidt et al., 2019). Motivation is often cited as a likely reason VR interventions are successful in improving motor outcomes, however this is not typically directly measured in current research (Felsberg et al., 2019; Porras et al., 2018; Schmidt et al., 2019). VR applications could improve motivation if they provide rewards, feedback, plot, or other game-like features. VR also can be modified in real-time to provide the ideal level of task complexity which can improve motivation (Felsberg et al., 2019; Porras et al., 2018; Rizzo & Koenig, 2017). For example, a VR could be set to a specific level of performance such that if the performer exceeds that performance level, the task becomes harder, or if the performer does not meet that level of performance the task is simplified. This could create an optimally motivating environment avoiding boredom from simple tasks or frustration from tasks that are too challenging. This aspect could be used in clinical settings to improve motivation and participation in intervention as this level of grading task-complexity is challenging for clinicians to perform with the same timing and precision as VR.

Physical rehabilitation aims to address movement impairments to improved functional independence and quality of life following aging, injury or disease. The safe, multisensory, modifiable, and interactive nature of VR make it a promising tool for use in clinical rehabilitation settings to improve motor outcomes. VR can produce interventions that incorporate elements of observational learning, practice, feedback, and motivation in ways that align with the mission of physical rehabilitation. Additionally, given the technology and attributes of VR hardware and software, these key motor learning features typically employed in rehabilitation interventions can be executed in precise, timely, and customizable way that is difficult to achieve in the physical environment even further supporting the potential incorporation of VR in clinical settings.

Physical rehabilitation is provided in a variety of settings including inpatient, home-based, and outpatient settings. Also, given the coronavirus pandemic, there has been a growing demand for telerehabilitation. Regardless of setting, creating any rehabilitation protocol requires consideration of what is known about current motor learning techniques, biomechanics, physiology, neuroplasticity, and motor control to select appropriate interventions and modalities to optimize outcomes (Spiess et al., 2018). Therefore, VR use in clinical settings should not be viewed as a sole therapy, but as a tool in the treatment modality toolbox. We do not live in a virtual world; therefore, physical rehabilitation intervention cannot only be comprised of virtual interventions but must exhibit transfer to the physical world.

The overall goal of integrating VR into clinical settings should be to consider the advantages of all intervention types whether it be traditional equipment use, hands-on techniques, or VR and combine these in a supporting fashion to create a well-rounded treatment protocol (Spiess et al., 2018). Commercial devices like the Nintendo Wii, Xbox Kinect, and HMDs could be incorporate in acute and sub-acute inpatient settings where treatment spaces are typically limited, treatment session times are shorter, and treatments often occur at bedside. Currently, HMDs have been used in acute burn centers for management of pain during wound care and physical therapy treatments (Hoffman et al., 2011). The low cost, mobile, and relatively easy setup of these devices lend nicely to the needs of these settings. These features also make these technologies potentially well suited for home-health and telerehabilitation settings. A recent systematic review regarding the feasibility of using VR in telerehabilitation found support for the use of VR in this capacity, however evidence is limited (Schröder et al., 2019). Commercial VR technologies, as well as medical-grade VR technologies such as the Motek GRAIL and CAREN systems, and Gesturetek IREX system may be a good fit for acute inpatient and outpatient rehabilitation settings as these settings typically have larger treatment spaces, longer treatment times, as well as patient populations requiring higher level of intensity in their rehabilitation protocols. The Motek systems and Gesturetek IREX have been created for use in rehabilitation settings, but are more costly than the HMDs, Wii and Kinect mentioned previously. The Motek systems are also rather cumbersome. However, these systems also allow for a high degree of customization, are more immersive, and have the potential to provide high-quality feedback as well as data collection. Despite cost and space concerns (in the case of the Motek GRAIL and

CAREN systems), research does support the use of these medical-grade devices to improve motor outcomes and the potential for their use in medical facilities (Biffi et al., 2017; Brien & Sveistrup, 2011; Sessoms et al., 2015).

A variety of VR technologies exist on the market at a range of price points, available features, and levels of immersion to fit the specific needs of various clinical settings. However, the research supporting VR use for motor rehabilitation is largely performed in laboratory settings. Future research should focus on translation of VR to clinical practice to allow clinicians to become more familiar with how these technologies could fit into their clinical practice and make informed choices for patient.

## Technology Acceptance

As technology has infiltrated most parts of everyday life, technology developers have attempted to refine their methods for creation of new technology to involve the end-user more in the development process (Gabbard et al., 1999; Schuler & Namioka, 1993). With user-centered designs, the user's needs are in the center of development. Throughout the design process, users are involved to test versions of the product and participate in the optimization process (Gabbard et al., 1999; Marsden et al., 2008). Research in this area has shown user-centered designs as a success in the technology development process (Gabbard et al., 1999). However, this process is predicated by the experiences and thoughts of the users involved in the development process, and this may not be generalizable to the larger population for which the product is targeted (Marsden et al., 2008). Therefore, a disconnect may still exist between the technology developer and the end-user. Additionally, the acceptance of technology is not dictated by how unique or useful the creator believes the technology to be. Instead, technology acceptance is determined by the end-user's feelings toward technology.

There are several models that seek to explain the relationship between an individual's views toward technology and adoption of technology. One such model is the Technology Acceptance Model (TAM) (Davis, 1985). The TAM proposes that technology acceptance is determined by a person's perceived usefulness (PU) and perceived ease of use (PEOU) of technology. That said, if a technology does not seem to be useful to someone because it does not solve a problem or serve their needs in some way, or if the technology does not seem easy to use and incorporate into daily life, then technology acceptance will likely be low. This information regarding user acceptance of technology paired with weak user representation in technology design can create a problem for the acceptance of a technology that may otherwise seem useful to the creator.

It is important to identify that technology acceptance and adoption are different. Technology acceptance is the overall feeling toward technology, while technology adoption is the actual usage (Lee et al., 2003; Venkatesh et al., 2003). However, technology acceptance is predicative of technology adoption (King & He, 2006; Lee et al., 2003; Marangunic & Granic, 2015). There are several theories and models that help explain behavior. There are three that relate well specifically to the use of technology. These are the Technology Acceptance Model (TAM), Diffusion of Innovation Theory, and Decomposed Theory of Planned Behavior (DTPB). The TAM and DTPB explain influences on the acceptance of technology and usage, while the Diffusion of Innovation Theory explains how innovations are viewed and adopted.

The TAM is one of the most influential and commonly cited models for describing technology acceptance (Lee et al., 2003). The TAM was originally proposed in 1985 as an adaptation of the Theory of Reasoned Action (TRA) and Theory of Planned Behavior (TPB) (Davis, 1985; Marangunic & Granic, 2015). The basis of TRA is that behavioral intentions are the main predictor of behaviors rather than an individual's attitude (Ajzen et al., 1980). However, one limitation identified regarding TRA is that it does not take into account and individual's power of control their behaviors or intentions (Marangunic & Granic, 2015). The TPB was created to address the limitation of perceived behavioral control that exists in TRA, and looks at attitude toward the behavior, subjective norms around the behavior, and perceptions of success with the behavior (Ajzen, 1985). To create a model that could predict technology use, the TAM was proposed as an adaptation of both the TRA and TPB that specifically applied to the use of technology (Marangunic & Granic, 2015).

The TAM suggests that predictors of technology acceptance rely on perceived usefulness (PU) and perceived ease of use (PEOU) as determinants of an intention to use technology and technology usage (Davis, 1985; Lee et al., 2003). PU is the extent to which someone believes using a technology will enhance their performance while PEOU is the extent to which someone believes using a technology with be effortless (Davis, 1985). In this model, technology usage is determined by intent to use technology, which in turn is determined by attitudes toward usage and PU (Taylor & Todd, 1995). Additionally, attitude toward usage is influenced by both PU and PEOU, and PEOU directly affects PU. A significant amount of research has been conducted using the TAM to predict technology acceptance across a variety of technologies and situations (Adams et al., 1992). However, the strength of the relationships between these variables have not held up in all cases. The strongest evidence seems to be for the significant role of PU as a direct effect on intention to use technology as well as the influence of PU on attitudes toward using technology (Taylor & Todd, 1995). Additionally, the TAM does not include the potential of social influence or power of perceived control that could affect behavior (Taylor & Todd, 1995). Despite these limitations, The TAM continues to be widely used in research and has been found to be a valid and robust predictive model for technology acceptance and usage (King & He, 2006).

A theory related to technology adoption is the Diffusion of Innovation Theory. This theory explains how an innovation spreads and is adopted across a social system. It seeks to explain technology adoption through factors such as the relative advantage of adopting the new technology, how well it fits into the user's life, how difficult it is to use, how much it can be trialed before fully adopting, and the extent to which it provides measurable change (Rogers, 2004). These factors influence a user to perceive the technology as innovative which is related to adoption of that technology. This theory has some similarities to the TAM in that the factor of relative advantage of an innovation is similar to the factor PU in the TAM and complexity factor, how hard it is to use, is the antithesis of PEOU (Davis et al., 1989).

Finally, the Decomposed Theory of Planned Behavior (DTPB) is another adaptation of TPB which decomposes the structures of beliefs. As previously described, The TPB was created to address the limitation of perceived behavioral control that exists in TRA, and looks at attitude toward the behavior, subjective norms around the behavior, and perceptions of success with the behavior (Ajzen, 1985). The thought is that a general belief construct cannot explain the variety of beliefs that may influence intention in any number of situations, thus decomposing to more specific belief factors may make the model more adaptable to various cases of adoption (Taylor & Todd, 1995). The DTPB shares some of the same relationships present in the TAM, however, builds on some of the weaknesses of the TAM by including factors of social influence and behavioral control. The DTPB also adds components of Diffusion of Innovation Theory, suggesting that attitudes toward technology could be influenced by the characteristics that one perceives as innovative (Taylor & Todd, 1995). Given the redundant nature of PU and relative advantage and

PEOU and complexity, PU and PEOU from the TAM and compatibility from the Diffusion of Innovation Theory were added as factors influencing attitude in the DPTB. The DTPB also broke social norms into influences from peer groups both above and below the user, and perceived control into the factors of self-efficacy, resource facilitating conditions (i.e. funding), and technology facilitating conditions (i.e. technology compatibility) (Taylor & Todd, 1995). In a study investigating the predictive nature of the DTPB constructs on behavioral intention to use as well as actual usage of a business school's computing resource center (CRC), Taylor and Todd (1995) found the constructs of the DTPB to predict actual usage of the CRC better than the TAM or TPB (path coefficient from behavioral intention to actual usage: DTPB = 1.28, TAM = 0.38, and TPB = 1.20). Research on comparison between the TAM and the DTPB show they are comparable in explaining technology acceptance, however the DTPB provides a richer explanation of behavior intention with detail regarding attitudes, social influences, and the influence of perceived control (Taylor & Todd, 1995).

**Technology Acceptance of Virtual Reality in Physical Rehabilitation**

As technology has developed, and VR has become more widely available, clinicians and researchers alike have identified VR as a potentially useful tool in providing rehabilitation interventions to improve motor function. Current research in this area of VR for rehabilitation has largely demonstrated that VR interventions can produce clinically meaningful change in motor outcomes (Felsberg et al., 2019; Howard, 2017). Despite evidence to support the use of VR in clinical settings, adoption and use of VR by clinicians has been low (Glegg & Levac, 2018; Levac et al., 2017, 2018). There appears to be a gap between evidence and practice in that the evidence supports the use of VR for rehabilitation but that does not seem to translate to actual VR use by practicing clinicians. For VR to prove itself as being more than just a fancy toy, it is important to first identify the potential barriers and facilitators of VR use in clinical settings to understand more about why this gap between evidence and practice exists.

To identify barriers and facilitators of VR use by clinicians more investigation into their acceptance of technology, and perceived barriers and facilitators to use would be valuable. Several theories and models exist to identify the determinants of technology adoption. The most widely used and applicable theories have been identified and explained in the previous section. These are the TAM, Diffusion of Innovation Theory, and Decomposed Theory of Planned Behavior. The TAM and Diffusion of Innovation Theory provide strong foundational information regarding technology acceptance and adoption (Davis, 1985; Davis et al., 1989; Rogers, 2004). However, the additional of factors regarding attitudes toward technology, influence of peers, and perceived resource and technology constraints also included in the DTPB seems to lend it well to the application of VR acceptance in clinical settings. Currently, there has only been a small amount of research begun in the area of VR acceptance by clinicians. One group has adapted the DTPB to VR use in clinical settings creating a survey called the Assessing Determinants of Prospective Take-up of Virtual Reality (ADOPT-VR) survey (Glegg et al., 2013). Through field testing, the ADOPT-VR survey has proven face and content validity, and good internal consistency (Cronbach's alpha = 0.876) (Glegg et al., 2013). Following development of the ADOPT-VR survey, a second version was created, the ADOPT-VR2, which adds items to further describe the previously identify constructs of ADOPT-VR as well as add the construct of client influence (Levac et al., 2017). Psychometric testing has been performed on the ADOPT-VR 2, but have not yet been published (Levac et al., 2017). Overall, the DTPB seems to provide the fullest explanation regarding technology acceptance in clinical settings. The adaptation of the DTPB to the established

ADOPT-VR and ADOPT-VR2 surveys is a logical next-step to applying this theoretical framework to understand adoption and usage behavior of VR by both clinicians and patients.

Previous research using the ADOPT-VR2 survey, although limited, has provided a foundation to begin to understand the landscape of VR use in physical rehabilitation. Two studies have surveyed groups of both PTs and OTs (occupational therapists) in Canada and the United States (US) (Levac et al., 2017, 2019). These studies showed that a moderate amount of therapists have had experience with using VR in their clinical practice (46% in Canada and 64% in the US), but the number of clinicians using VR in their current practice is considerably lower (12% in Canada and 31% in the US) (Levac et al., 2019). In both Canada and the US, the ADOPT-VR2 constructs of attitudes toward VR, the perceived ease of use (PEOU) as well as the perceived usefulness (PU) of VR, the compatibility of VR to the therapist's clinical practice, social norms, peer influence, client influence, therapist self-efficacy, and facilitating conditions were all predictive of intention to use VR (Levac et al., 2017, 2019). Some of the most commonly cited barriers in both countries were problems with funding, available space for the technology, time to include the intervention in treatment, support staff to setup or run the VR, and appropriate patients (Levac et al., 2019). Conversely, some of the facilitators to use of VR in both countries include client motivation and management support (Levac et al., 2017, 2019). Interestingly, when comparing mean responses regarding facilitators and barriers to VR, US clinicians rated facilitators more positively and barriers less negatively than did their Canadian counterparts (Levac et al., 2019).

One limitation of these studies is timing. The Canadian survey was conducted between 2014-2015 (Levac et al., 2017) and the US survey was conducted between 2017-2018 (Levac et al., 2019). It's possible that the differences seen between respondents in both countries could be contributed to the two to three-year difference between surveys and the development and integration of VR technology in that time. Another limitation is that these surveys included both OTs and PTs. Although both disciplines share similar common goals in wanting to improve functional independence and quality of life in their patients, often the primary goals and interventions are different between the professions. Also, both professions have assistant-level disciplines providing treatment to patients. Certified Occupational Therapy Assistants (COTAs) and Physical Therapist Assistants (PTAs) are not responsible for creating the plan of care of patients but are involved in executing treatment plans to meet the goals set by the treating therapist which could include the use of VR. Additionally, these studies don't investigate additional factors that could be influencing clinician decisions to use VR such as insurance coverage.

## Current Gaps in the Research as it Relates to this Dissertation

Physical rehabilitation aims to address movement impairments, restore function, and improve quality of life following aging, injury, or disease. VR has presented itself as a promising tool for physical rehabilitation due to its functional, motivating, and modifiable nature. A growing body of literature demonstrates that VR can produce both effective assessment for impairments as well as provide meaningful interventions for the rehabilitation of motor tasks (Felsberg et al., 2019; Howard, 2017; Porras et al., 2018; Teel & Slobounov, 2015; Wright et al., 2017). However, these studies mostly occur in controlled laboratory settings (Felsberg et al., 2019). It is currently unclear the current degree to which VR research for physical rehabilitation interventions has been translated to more ecologically valid, clinical settings. Additionally, the adoption of VR for use in physical rehabilitation appears to be low (Glegg et al., 2013; Glegg & Levac, 2018; Levac et al., 2017). There appears to be a gap between the evidence supporting the use of VR for physical rehabilitation and actual use in clinical practice. It's currently unclear exactly why this gap exists.

Current research in this area is limited and either investigates VR acceptance and usage by clinicians in one specific practice area (Banerjee-Guénette et al., 2020; Glegg et al., 2013) or combine clinicians from different disciplines (Levac et al., 2017, 2019).

To further understand the gap between evidence and practice in the use of VR for physical rehabilitation, it would be best to survey the clinicians whose primary role is to address and restore gross motor dysfunction, PTs and PTAs. Also, the views regarding use of VR in clinical practice by the students of both of these professions may provide information regarding the intention to use VR by future clinicians. Additionally, factors related to patient influences are cited as both a barrier (client appropriateness) and a facilitator (client motivation) to VR use in clinical practice (Levac et al., 2017, 2019). Investigating patient acceptance and perceived barriers to use of VR in their physical rehabilitation treatment programs could give insight into client influences on clinician use of VR.

# CHAPTER III: OUTLINE OF PROCEDURES

## Procedures Aim 1

Aim 1 is investigating the current landscape of VR research for physical rehabilitation. The purpose of this systematic review was to investigate how VR is being used in physical rehabilitation to date, and how much research is currently being conducted in clinical settings. The systematic review followed the protocol set by the Preferred Reporting Items for Systematic Reviews and Meta-analysis (PRISMA) guidelines (Moher et al., 2015). A keyword search was performed in between July and August 2021 using the following databases: PubMed, Scopus, and EBSCOhost. Searches were further refined by selections for English-language texts and publication years of 2010-2021. The keyword searches included all possible combinations of (1) “virtual reality” (2) “physical therapy”, “Physiotherapy”, or “rehabilitation” (3) “gait”, “ambulation”, “balance”, “mobility”, “function” or “motor performance”. The keyword search algorithm can be found in Figure 1. Following the keyword search, duplicate articles were removed. Through screening of titles and abstracts, articles were excluded if they were a systematic review, scoping review or meta-analysis, a non-research text, a study protocol, or case study. Additionally, studies were excluded if they investigated an upper extremity tasks, cognitive or psychological domains, pain management, included an adjunct modality (i.e., robotic-assisted gait training (RAGT), functional electric stimulation (FES), etc.), did not use VR or used augmented reality (AR), did not use a gross motor task or outcomes, or were not testing a VR intervention. Following this initial screening process, all full text articles were further accessed for inclusion. Studies were selected for inclusion if they investigated the role of VR in improving motor behavior related to balance, ambulation, or upright mobility. Studies were excluded following full text assessment if they did not use VR, were not investigate the direct role of a VR intervention on motor outcomes or used an adjunct modality (i.e., transcranial magnetic stimulation). All remaining studies were included for data extraction and synthesis. The primary goal of Aim 1 is to investigate the current state of VR research for physical rehabilitation including the extent to which research is between conducted outside controlled laboratory environments. Thus, studies selected for inclusion were categorized by the following factors: publication year, patient population, publication location and setting, study protocols, sample size, VR hardware and software, and intervention outcomes.

**Figure 1: Database Search Algorithm**

| Database | Search Algorithm |
|---|---|
| PubMed | (virtual reality) AND (physical therapy or physiotherapy or rehabilitation) AND (gait or ambulation or balance or mobility or function or motor performance)<br>Refined by: English, Publication years 2010-2021 |
| Scopus | (virtual reality) AND (physical therapy or physiotherapy or rehabilitation) AND (gait or ambulation or balance or mobility or function or motor performance)<br>Refined by: English, Publication years 2010-2021 |
| EBSCOhost | (virtual reality) AND (physical therapy or physiotherapy or rehabilitation) AND (gait or ambulation or balance or mobility or function or motor performance)<br>Refined by: English, Publication years 2010-2021 |

## Procedures Aim 2

**Participants:** To identify the technology acceptance, adoption, and perceived barriers to use of VR in rehabilitation by physical therapy professionals across the professional spectrum, an electronic survey was circulated to PTs, PTAs, and students of both disciplines. PTs and PTAs practicing in the United States were recruited to participate in this survey. Recruitment consisted of e-mail contact through both state licensing boards and specialty sections of the American Physical Therapy Association (APTA). Students in PT and PTA programs were also recruited by circulating the survey via email to respective programs listed on the APTA website. All professional participants (PTs, PTAs, and students) were also recruited via convenience and snowball sampling using social media and other digital outlets.

**Survey Methods:** The survey sent to professional participants consisted of demographic information followed by the ADOPT-VR2 survey (Levac et al., 2017). The demographic information included questions regarding age, professional status, education level, clinical experience, experience with using VR in clinical practice, and questions regarding insurance coverage of their clients. The ADOPT-VR2 survey, which was adapted for use in this dissertation, has not yet been published, however the original ADOPT-VR survey can be seen in Appendix A. The ADOPT-VR survey has previously established face and content validity, as well as good internal consistency (Glegg et al., 2013). The ADOPT-VR2 survey uses the same constructs as the ADOPT-VR survey with the addition of items to the social norms, perceived behavior control, self-efficacy, and facilitating conditions constructs as well as adding a new construct to the social norms composite called client influence (Levac et al., 2017). Following the initial survey (demographics and ADOPT-VR2), participates were presented with an informational video providing examples of VR use in physical rehabilitation (Appendix F). After viewing the short videos, participants were asked a few short follow-up questions regarding their intention to use VR in the future.

The complete survey experience was presented to participants using REDCap. Students and clinicians were present with slightly different versions of the demographic portion of the survey with questions more relevant to each group, followed by the ADOPT-VR2. An outline of the demographic portion of the survey can be found in Appendix B (student version) and Appendix C (clinician version). An outline of the ADOPT-VR2, which was presented following the demographic questions, as well as the follow-up questions which were presented after the VR informational videos to both students and clinicians can be seen in Appendix D. The survey was first disseminated on July 12, 2021, monitored for responses, and recirculated as needed through September 9, 2021.

**Statistical Analysis**: Data gathered from the demographic portion of the survey were analyzed using descriptive statistical methods as appropriate. Descriptive statistical methods were also used to address hypothesis 1a, 1b, and, 1h. To address hypotheses 1c, a two-tailed t-test was run to determine difference between groups. Hypotheses 1e-1f were investigated using linear regression methods.

## Procedures Aim 3

**Participants:** To identify the technology acceptance, perceptions, and perceived barriers to use of VR in rehabilitation by patients an electronic survey was circulated to participants who have either previously participated in physical therapy or are currently participating in physical therapy to improve motor outcomes. Participants were recruited via convenience and snowball sampling through social media and other digital outlets. Participants' responses were included for analysis if they are either currently participating in physical therapy or have previously participated in physical therapy.

**Survey Methods:** The survey sent to patients consisted of demographic information followed by and adaptation of the ADOPT-VR2 survey (Levac at al., 2017). The demographic information included questions regarding age, gender, race, education level, household income, insurance coverage, whether they have participated in VR interventions in physical therapy, as well as frequency and duration of physical therapy received. The ADOPT-VR2 survey, which was adapted for use in this dissertation, has not yet been published, however the original ADOPT-VR survey can be seen in Appendix A. The ADOPT-VR survey has previously established face and content validity, as well as good internal consistency (Glegg et al., 2013). The ADOPT-VR2 survey uses the same constructs as the ADOPT-VR survey with the addition of items to the social norms, perceived behavior control, self-efficacy, and facilitating conditions constructs as well as adding a new construct to the social norms composite called client influence (Levac et al., 2017). Following the initial survey (demographics and ADOPT-VR2), participates were presented with an informational video providing examples of VR use in physical rehabilitation (Appendix F). After viewing the short videos, participants were asked 3 short follow-up questions regarding their perceptions of VR and intention to use VR in the future.

The complete survey experience was presented to participants using REDCap. An outline of the complete survey presented to patients can be found in Appendix E. The survey was first disseminated on July 12, 2021, monitored for responses, and recirculated as needed through September 16, 2021.

**Statistical Analysis**: Data gathered from the demographic portion of the survey were analyzed using descriptive statistical methods as appropriate. To address hypotheses 1a-1f, multiple linear regression methods were used. To address hypotheses 1g descriptive statistical methods were used.

CHAPTER IV: MANUSCRIPT I

## The Current Landscape of Virtual Reality use in Physical Rehabilitation: A Systematic Review

### Introduction

Gait is a foundational element for functional independence across the lifespan. However, humans are inherently unstable since the majority of body mass located above the hips, similar to an inverted pendulum (Winter, 1995). Therefore, postural control is required to successfully stabilize the system for upright mobility (Andriacchi & Alexander, 2000; Assaiante, 1998; Massion, 1994; Winter, 1995). These motor skills and overall physical functioning can be profoundly affected by aging, injury, or disease. Physical rehabilitation provided by a Physical Therapist (PT) or Physical Therapist Assistant (PTA) aims to address these functional deficits, restore healthy movements, and optimize independence. These physical rehabilitation professionals create evidence-based treatment protocols to meet a patient's functional goals by utilizing a variety of therapeutic modalities. One such modality is virtual reality (VR), which has been identified as a uniquely promising treatment tool to provide effective and meaningful interventions for improving motor outcomes (Felsberg et al., 2019; Howard, 2017; Porras et al., 2018). Moreover, VR helps meet a clinical need by providing a training modality that can be challenging or impossible to recreate in the real world (Adamovich et al., 2009; Levin, 2011, p. 20), as well as having been shown to enhance psychological motivation to continue and/or complete the prescribed treatment (Levac & Sveistrup, 2014; Zimmerli et al., 2013).

VR can be defined as a computer-generated environment which contains sensory information that may be interacted with, visualized, and (or) manipulated to allow natural behaviors to emerge as if the environment were real (Jerald, 2016; Rizzo & Koenig, 2017; Steinicke et al., 2013). The early 2010s marks the beginning of low-cost, commercially-available

VR hardware with the presentation of the Oculus, a head-mounted display (HMD) (Jerald, 2016). As technology has continued to develop since this time, virtual reality has emerged as a tool to produce effective rehabilitation intervention to improve motor outcomes due to its increased accessibility to clinical researchers. Previous research investigating the use of VR in rehabilitation has demonstrated significant improvements in gross motor outcomes, however most of this research has been conducted in controlled laboratory environments and the translation to clinical practice appears to be limited (Felsberg et al., 2019; Howard, 2017; Porras et al., 2018).

Research interest in the use of VR as a rehabilitation modality has increased since the introduction of low-cost, commercially available VR hardware around 2010 and has continued as technology has further evolved over the last decade (Rizzo & Koenig, 2017). To better understand the current landscape of VR, use for physical rehabilitation, this review systematically surveyed the literature, starting in 2010 to present, regarding the use of VR for physical rehabilitation interventions to improve gait, balance, or upright mobility. The purpose of this paper is to better understand the research-to-practice landscape in VR for physical rehabilitation. Specifically, we aimed to investigate how VR is being used in physical rehabilitation research to-date including which clinical populations are being included in study designs, in what settings and locations, and the types of VR hardware and software being used as a therapeutic tool to improve gait, balance, and upright mobility.

**Methods**

This systematic review followed the protocol set by the Preferred Reporting Items for Systematic Reviews and Meta-analysis (PRISMA) guidelines (Moher et al., 2015). Additionally, to guide the inclusion criteria, a participant, intervention, comparison, outcomes and study design (PICOS) model was used (Liberati et al., 2009).

**Data Sources & Searches:** A keyword search was performed between July and August 2021 using the following databases: PubMed, Scopus, and EBSCOhost. Searches were further refined by selections for English-language texts and publication years of 2010-2021. The keyword searches included all possible combinations of (1) "virtual reality" (2) "physical therapy", "Physiotherapy", or "rehabilitation" (3) "gait", "ambulation", "balance", "mobility", "function" or "motor performance". The keyword search algorithm can be found in Table 1.

**Table 1: Database search algorithm**

| **Database** | **Search Algorithm** |
|---|---|
| PubMed | (virtual reality) AND (physical therapy or physiotherapy or rehabilitation) AND (gait or ambulation or balance or mobility or function or motor performance)<br>Refined by: English, Publication years 2010-2021 |
| Scopus | (virtual reality) AND (physical therapy or physiotherapy or rehabilitation) AND (gait or ambulation or balance or mobility or function or motor performance)<br>Refined by: English, Publication years 2010-2021 |
| EBSCOhost | (virtual reality) AND (physical therapy or physiotherapy or rehabilitation) AND (gait or ambulation or balance or mobility or function or motor performance)<br>Refined by: English, Publication years 2010-2021 |

**Eligibility Criteria:** Study selection was guided by a participant, intervention, comparison, outcomes and study design (PICOS) model which can be seen in Table 2. The PICOS model was set according the primary aim of this review, which was to investigate the use of VR as an intervention to improve gait, standing balance, or upright mobility.

**Table 2: PICOS inclusion criteria**

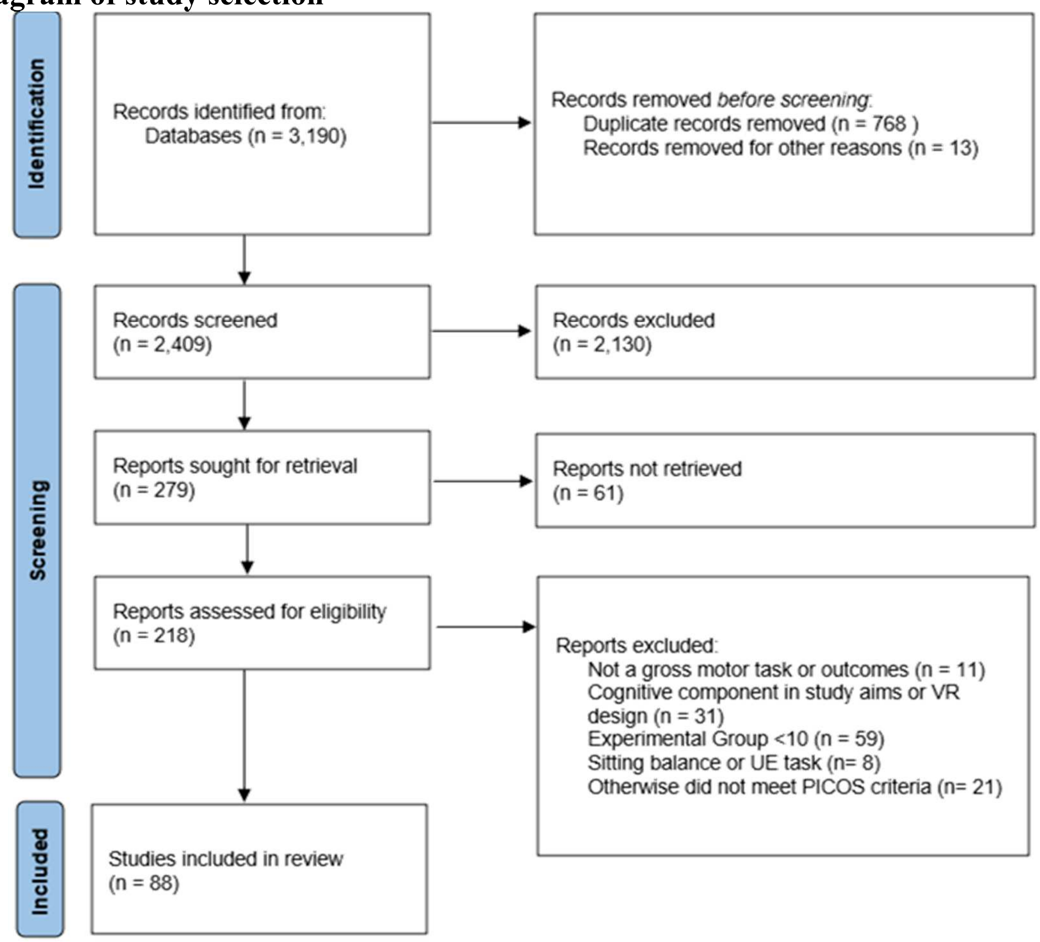
| | |
|---|---|
| **Participants** | Any population |
| **Interventions** | Treatment interventions using VR aimed to improve gait, standing balance and/or upright mobility. Not including interventions using adjunct therapeutic modalities simultaneously with the VR intervention (robot-assisted gait training, transcranial magnetic stimulation, etc). |
| **Comparisons** | Pre- and Post-treatment assessments and/or comparisons between VR and conventional treatment (i.e. balance training, etc) |
| **Outcomes** | Functional or clinical outcome measures of gross motor abilities, or biomechanical measures related to gait, balance or upright mobility |
| **Study Design** | Study designs which employ baseline and post-treatment assessments excluding case studies or studies with less than 10 participants in the experimental group. |

**Data Extraction:** Following database searches and study selection, data extraction was performed. Data regarding publication year, patient population, publication location and setting, study protocols, sample size, VR hardware and software used, and intervention outcomes were extracted. Information regarding each intervention was also extracted, such as VR hardware and software, intervention protocol, objectives, and outcomes.

**Results**

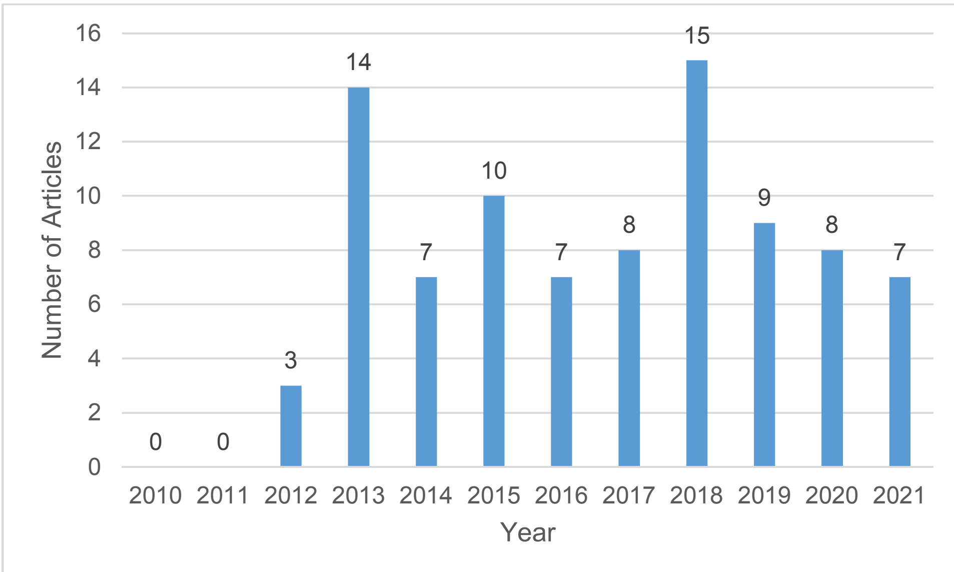
**Study Selection:** Figure 2 illustrates the article selection process. The initial database searches led to a total of 3,190 articles for initial screening derived from PubMed (n=1,960), Scopus (n=362), and EBSCOhost (n=862). Of these 3,190 articles, 768 were found to be duplicates and 13 were removed because they either did not have associated text or were only abstracts. Following removal of these articles, 2,409 articles were screened for inclusion through title and abstract. Of these articles screened, 2,130 articles were excluded for not meeting the PICOS criteria due to being a systematic review, meta-analysis, study protocol, case study or commentary, used an adjunct modality, studied cognitive or psychological factors, did not investigate a gross motor task or did not use gross motor outcomes, was not a VR intervention, or used an upper extremity task. Following the screening process 279 full-text articles were sought for retrieval for full-text review, 61 articles were unable to be retrieved as full-text versions were not available at the time of review. This left 218 articles to assess for full-text review. Of these 218 full-text articles, 130 were excluded because they did not meet the PICOS eligibility criteria. The 88 remaining articles were included in this review. A summary of the demographics from all included studies are presented in Appendix G, followed by a summary of their findings in Appendix H.

**Figure 2: Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flow diagram of study selection**



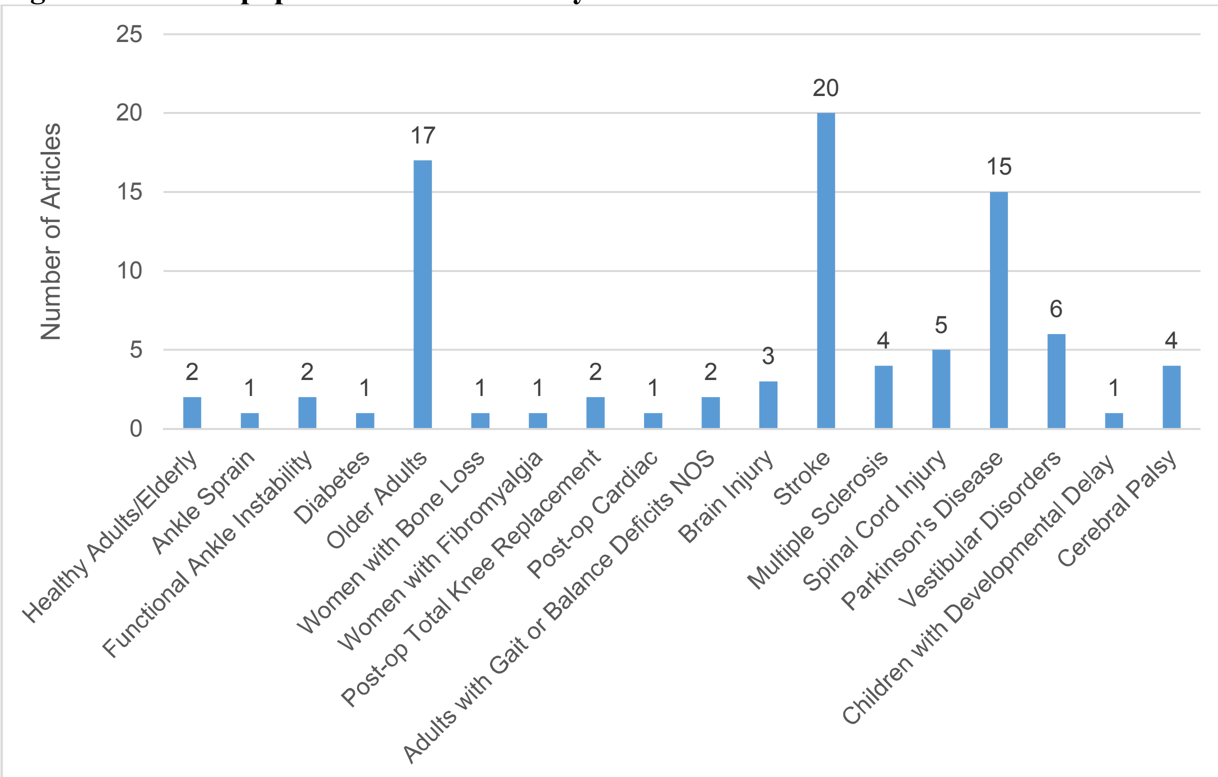

**Publication Year:** This review included articles published between the years of 2010 and 2021. Of the included articles, none were published in 2010 or 2011. All 88 articles were published within the 10-year range of 2012-2021. Over half (n=47; 53.4%) of the 88 included articles were published in the second half of this decade between 2017 and 2021. A table of the distribution of publications between 2010 and 2021 can be seen in Figure 3.

**Figure 3: Publications per year**




**Patient Population:** The primary patient population studied was stroke (22.7%), followed by older adults (19.3%) and Parkinson's Disease (17%). Figure 4 shows the distribution of studied patient populations.

**Figure 4: Patient populations of each study**

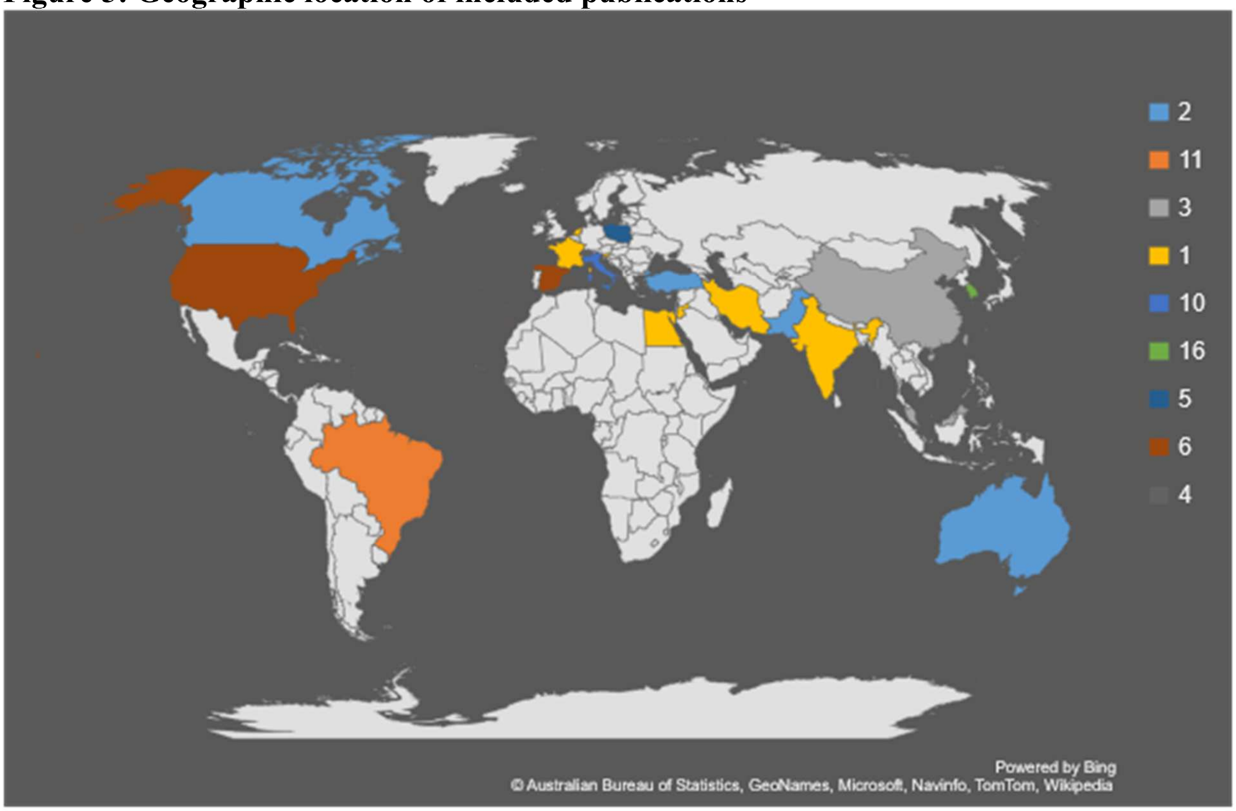



The majority of studies (n=83; 94.3%) used adult populations with six studies (6.8%) using pediatric participants. The average age of subjects participating in studies with adult populations ranged from 21 to 84.5 years of age (overall mean: 60.9 ± 13.3 years). The average range of subjects in pediatric studies ranged 4 to 16 years of age (overall mean: 10.1 ± 3.9 years).

**Publication Location and Setting:** The largest number of studies have been conducted and published in South Korea (n= 16; 18.2%). This is followed by Brazil (n= 11) and Italy (n= 10) producing 12.5% and 11.4% of the included publications, respectively. Research conducted in the United States (n=6) and Spain (n=6) each contributed 6.8% of the included publications. Five publications came from research conducted in Poland (5.7%), four from Switzerland (4.5%), three from Israel (3.4%), three from Taiwan (3.4%), three from China (3.4%), and three from Malaysia

(3.4%). Australia (n=2), Canada (n=2), Pakistan (n=2) and Turkey (n=2) each contributed 2.2% of the include publications. The remaining countries each produced 1.1% (n=1, each) of the articles included in this review: Egypt, France, India, Iran, Jordan, Singapore, Slovenia, and The Netherlands. Two articles (2.2%) did not provide explicit information regarding the geographic location of their research. The locations of the research conducted for each publication included in this review can be viewed in Figure 5.

**Figure 5: Geographic location of included publications**

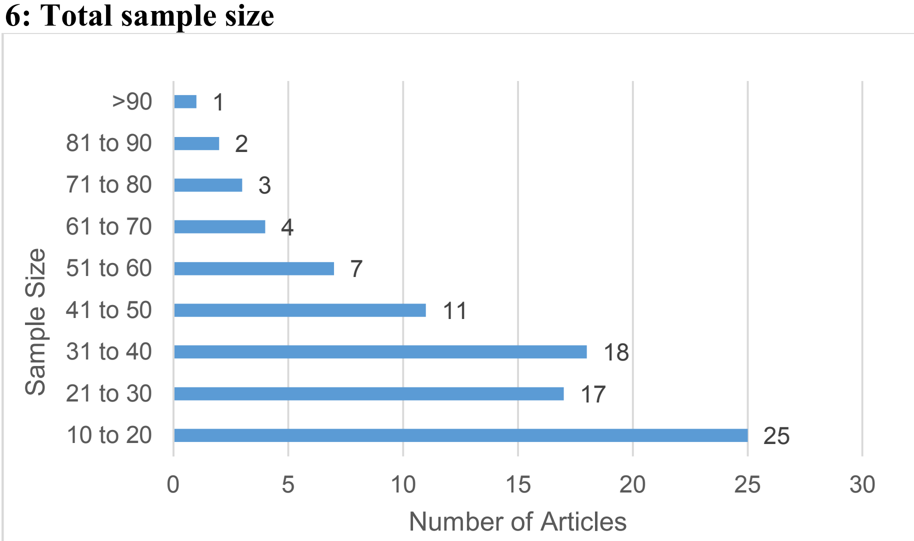



The largest percentage of studies were conducted in inpatient settings of clinical facilities (n=27; 30.7%) such as acute rehabilitation centers, hospitals, subacute rehabilitation facilities, and nursing homes. This is followed by outpatient clinical facilities (n=13; 14.8%), research settings (n=10; 11.4%), community centers (n=9; 10.2%), home-based settings (n=6; 6.8%), telerehabilitation (n=4; 4.5%), and school-systems (n=3; 3.4%). Notably, 16 studies, or 18% of the included publications, did not explicitly state the setting in which research was conducted.

**Study Protocols**: To be included in this review, studies had to investigate the use of VR in interventions to improve gait, balance, or upright mobility. Forty-eight (54.5%) of studies used interventions with the primary aim to improve balance. This is followed in descending order by studies with interventions targeting gait and balance (n=18; 20.5%), upright mobility (n= 9; 10.2%), gait (n=8; 9.1%), balance and upright mobility (n=3; 3.4%), and a combination of the gait, balance, and upright mobility (n=2; 2.3%).

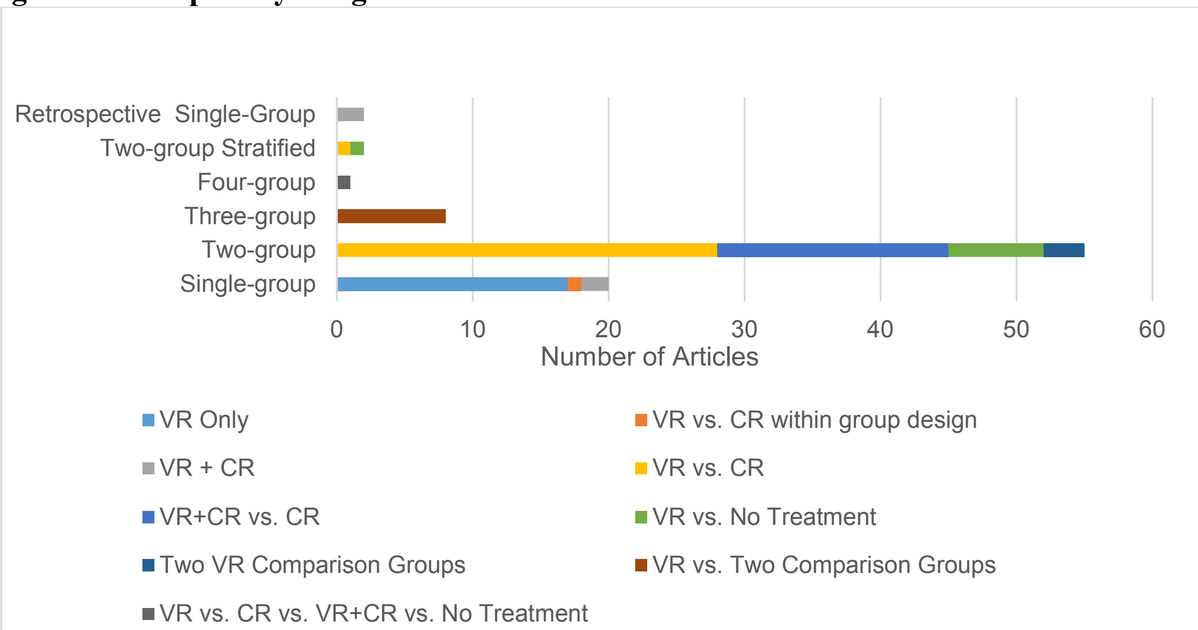
The total sample size for each study ranged widely from 10 to 195 subjects. The average number of subjects used was 37 (±25.7 participants). The majority of studies (n=71; 80.7%) had total samples sizes of 50 or less. The distribution of sample sizes of the included studies can be seen in Figure 6.

**Figure 6: Total sample size**




Most studies (n=29; 32.95%) utilized a two-group study design comparing VR to an active control performing some form of conventional rehabilitation (CR). This is followed by studies with a single, VR-only group (n=17; 19.3%) or two-group design comparing VR plus CR versus CR alone (n=17; 19.3%). Distribution of study design groups can be viewed in Figure 7.

**Figure 7: Group study design**




Sixty-four studies (72.7%) used study designs with a control group. Of these studies, 48 studies used a randomized method for allocating their participants while 16 did not randomize group allocation.

Studies employed study designs with various dosages of their VR interventions. Intervention length varied from 1 to 12 weeks, with most studies using 6 weeks (n=23; 26.1%) closely followed by 4-weeks (n=21; 23.9%). Intervention frequency ranged from once per week to two-times per day; total session number ranging from 5 to 60 sessions. Intervention durations ranged from 15 to 60 minutes per session. Of note, 23.9% of studies provided a rationale for the design of their VR intervention with empirical support while 76.1% did not provide evidence-based rationale for their intervention.

**Virtual Reality Hardware and Software:** The majority of studies used less-immersive (n=74; 84.1%), commercially available (n= 48; 54.5%) VR hardware such as Nintendo Wii and Xbox Kinect. Eight studies (9.1%) used semi-immersive hardware including the Computer Assisted Rehabilitation Environment (CAREN) system (n= 2), Gait Real-time Interactive Lab (GRAIL) system (n= 3), Rhetoric VR system (n= 1) and multi-screen interactive setups (n=2) which provide increased surroundedness and interactivity over less-immersive VR technologies. Of the eight semi-immersive setups, six were medical grade hardware (CAREN, GRAIL, Rhetoric) and two were custom setups which are not off-the-shelf products. Four studies (4.5%) used immersive technologies with head-mounted displays (HMD) providing higher level of immersion due to the full-surroundedness of the display. These immersive VR hardware include the Balance Rehabilitation Unit (BRU, n= 2), Oculus Rift (n= 1), and Revelation HMD (n= 1). Figures 8 and 9 show the distribution of level of immersion (Figure 8) and grade (Medical, commercial, custom-created, Figure 9) of all VR hardware used in the included publications. Two studies did not report details of the VR hardware used for their intervention.

**Figure 8: Level of immersion of VR**

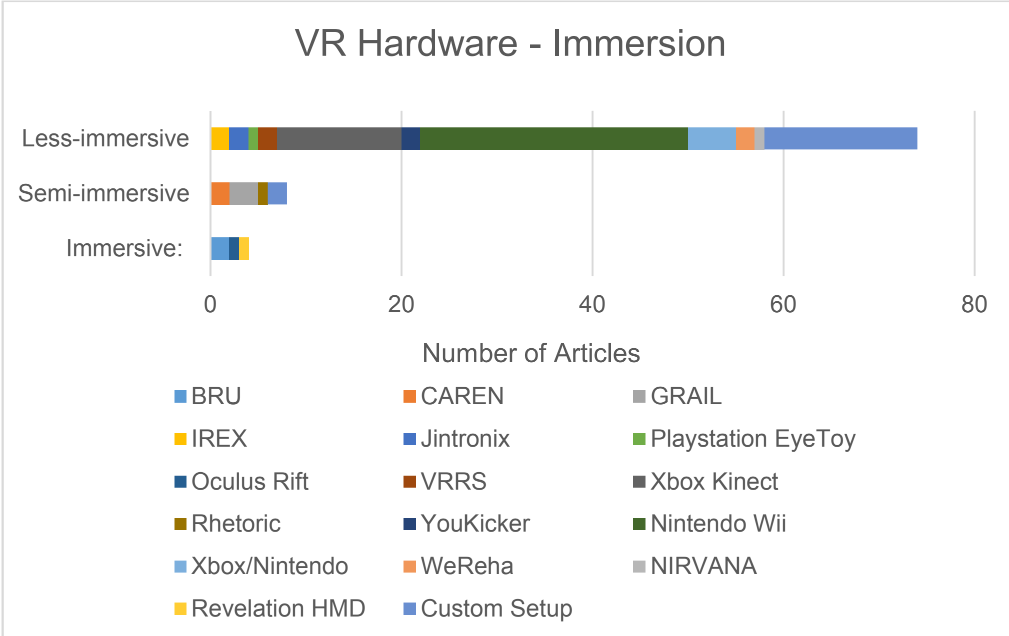
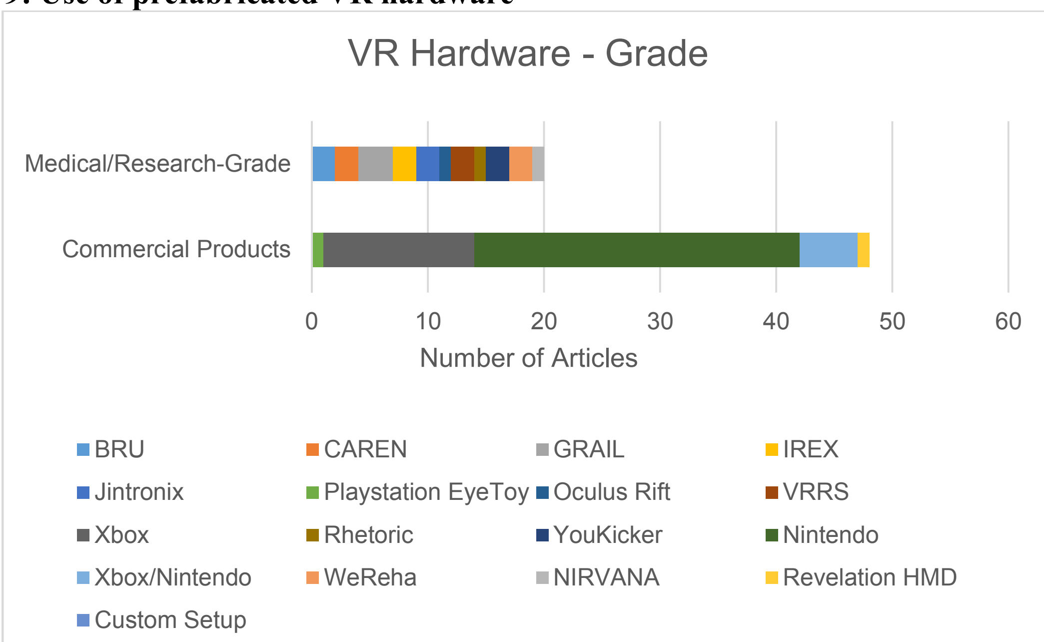
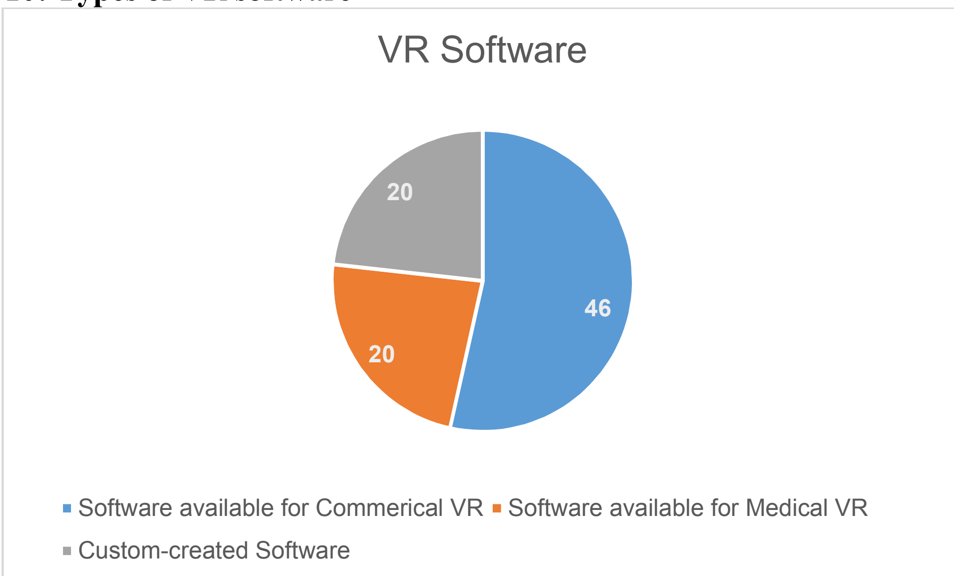



**Figure 9: Use of prefabricated VR hardware**




The majority of studies (n= 46; 52.3%) used software available for commercial VR products such as Wii Fit Plus and Kinect Adventures. Twenty studies (27.7%) used software available for medical-grade VR products such as programs for the CAREN or GRAIL systems. Twenty studies (27.7%) used custom programs for their VR interventions created with programs such as 3D Studio Max. Figure 10 illustrates the breakdown of types of VR software used. Two studies did not report details regarding the software used for their VR intervention.

**Figure 10: Types of VR software**




**Intervention Outcomes:** The majority of studies (n= 85; 96.6%) reported significant improvements in outcomes related to gait, balance, and upright mobility following their VR intervention. Thirty (34.1%) of these studies found a significant improvement in gait, balance, or upright mobility in their VR treatment group over the comparison group following VR intervention. Twelve studies that reported between-group differences in favor of the VR group employed study designs in which the VR group also participated in conventional rehabilitation programs. Three studies (3.4%) reported improvements in the VR group, however this improvement was not statistically significant. None of the studies included reported no change or a decline in function related to gait, balance or upright mobility following their VR intervention.

## Discussion

The aim of this systematic review was to investigate how VR is being used in physical rehabilitation research from 2010 to present, including which clinical populations are being included in study designs, in what settings and locations, and the types of VR hardware and software being used as a therapeutic tool to improve gait, balance, and upright mobility. All studies reported improvements in these motor domains following VR intervention. Statistically significant improvements were found in 96.6% of studies, and 34.1% of these studies found VR interventions produced better outcomes than comparison groups. This is consistent with previous systematic reviews of this nature which have also found VR interventions provide effective therapeutic outcomes which can even be superior to standard care (Felsberg et al., 2019; Howard, 2017; Porras et al., 2018). Despite repeated findings to support the effectiveness of VR interventions to improve motor outcomes, it is important to point out the known publication bias toward easily interpreted, statistically significant results over those that accept the null hypothesis (Greenwald, 1975). That is to say that studies finding a degradation, or at the least no change, in motor skills following VR intervention may not always be published, which should be taken into consideration when interpreting the results of this review that found 96.6% of studies had statistically significant improvements in the functional outcomes of the VR group. However, to this point, 3.4% (n= 3) of studies in this review did publish non-significant results, reporting the VR group did exhibit improvements in the functional outcomes of their study, but these improvements were not statistically significant.

Prior systematic reviews and meta-analyses regarding VR for rehabilitation have found that studies have limited methodological validity due to small sample sizes, lack of control groups, or the absence of a clear, a priori, rationale for the development of their VR intervention (Felsberg et al., 2019; Porras et al., 2018). In this review, the average sample size was 37 participants (±25.7) with 80.7% (n=71) of studies having total sample sizes of 50 participants or less. Of these 71 studies, most of them (n= 25) had sample sizes between 10 and 20. Additionally, of the 46 studies with sample sizes between 20 and 50, 40 studies used a two- or more group design, creating an average number of participants in the VR group of 16.6 participants (±4.4).This is important to consider when interpreting the findings of VR intervention studies, as small sample sizes can lead to low statistical power and an overestimation of the significance of the effects from interventions (Lohse et al., 2016). It should also be noted that an exclusion criterion for this review was studies with less than ten subjects in the experimental group. Of the 218 articles included for full-text review, 27.1% (n = 59) were excluded due to having an experimental group smaller than 10.

Previous systematic reviews have cited the lack of a comparison group, use of only no treatment or waitlist control groups, and/or lack of randomization as methodological shortcomings in this area of research (Cheng et al., 2019; Felsberg et al., 2019; Howard, 2017). Regarding the study design for articles included in this review, the majority of studies (60.2%) used two-group designs with primarily active control groups performing CR interventions. The use of a two-group design is the cleanest way to not only test the efficacy of an intervention, but to also provide a performance comparison to a group not performing the intervention (Charness et al., 2012). Further, including an active control groups performing a rehabilitation program considered to be standard care provides a more rigorous comparison than a no-treatment control group (Howard, 2017). Additionally, the use of active control groups helps to circumvent any ethical dilemmas related to providing no treatment to clinical populations (Schwartz et al., 1997). Regarding group allocation, 54.5% of studies used randomization methods for allocating subjects to their study groups. As previously mentioned, small samples size is a common limitation in this area of research, and small sample sizes can reduce statistical power. However, randomization techniques can help boost statistical power that may be effected by both small sample sizes and between-group analyses (Lohse et al., 2016; Schwartz et al., 1997). The findings of this review suggest that VR researchers adhered to this methodological quality in their study designs, as most studies had an active comparison group and random allocation of participants to each group. However, research continues to lack clear rationale regarding the development of their interventions. Only 23.9% of studies in this review provided a rationale for at least part of the design of their VR intervention with empirical support.

In regarding to patient populations and settings, studies continue to focus primarily on adults and largely neurological populations. Eighty studies had adult participants while only six researched pediatric populations. This disparity between adult and pediatric populations could be due to the general composition of the United States which is projected to see considerable growth in the aging population over 65 years of age (Ortman & Velkoff, 2014). Additionally, the relative ease of recruiting adult subjects compared to obtaining the parental consent for minors could also be a contributing factor. More than half (58%) of studies investigated the role of VR interventions to improve gait, balance, or upright mobility in neurologic populations including brain injury, stroke, multiple sclerosis, spinal cord injury, Parkinson's disease, or cerebral palsy. This is possibly due to the extent to which neurological deficits impact a person's overall functional independence and quality of life make investigating effective treatment interventions of high priority. Injuries to the nervous system can result in a range of deficits including changes in motor planning and execution, sensation, strength, and coordination—all of which can profoundly impact a person's ability to ambulate, balance, or perform everyday activities of daily living (Basford et al., 2003; Murray et al., 2007). Thus, the primary aims of physical rehabilitation interventions for this population align with the primary aim of this review, which was to investigate VR interventions for gait, balance and upright mobility. Additionally, physical rehabilitation to improve motor deficits following neurological impairment involves therapy protocols that use high levels of repetition which can quickly become disengaging for participants (Levin, 2011; Murray et al., 2007). To address this barrier, VR has been shown to have psychological benefits for patients in PT, including reducing tension, increasing calmness, easing fatigue, reducing depression, improving motivation, and enhancing quality of life (Araújo et al., 2019; Chen et al., 2009; Qian et al., 2020). Aside from neurologic populations, older adults are the next most prominently studied group comprising 19.3% of the included publications in this review. As mentioned earlier, this could be due to the increase in the aging population (Ortman & Velkoff, 2014). Additionally, aging is associated with frailty, decreased independence, and falls especially in older adults over the age of 65 (Ambrose et al., 2013). Age-related changes in vision, vestibular, and somatosensory systems as well as changes in the musculoskeletal system can influence how older adults maintain balance during gait and upright mobility, again, making typical physical rehabilitation treatment plans for this population aligned with the primary outcomes of this review (Alexander, 1994). This is also in line with other reviews which have found VR to be effective in mobility, balance, and overall physical functioning in older adults (Dermody et al., 2020; Molina et al., 2014; Neri et al., 2017)

Surprisingly, 45.5% of studies were conducted in either inpatient or outpatient clinical-based settings. Additionally, 25% of studies were performed in community-based settings, school-systems, via telerehabilitation or in home-based settings. Thus, most studies included in this review were conducted in more ecologically valid settings than the 11.4% of studies performed in sterile, research laboratory environments. It should be noted that 16 publications did not explicitly report the setting of their research. Despite this, the findings of this review show that a majority of VR research for physical rehabilitations interventions of gait, balance, and upright mobility are being conducted in clinical environments, which is in contrast to a previous review which found VR research in this area to be primarily performed in laboratory settings (Felsberg et al., 2019). This could be due to the fact that the previous review was only investigating VR interventions for upright mobility in neurological populations, creating a narrower review of the literature. Additionally, article searches for the previous review were performed in 2017 to 2018. In the currently review, of the articles performed in non-laboratory settings (n= 62), 30.6% of them were published in 2019 or later.

Most of the studies included in this review were conducted outside of the United States, with just 6.8% of included studies were conducted in the US. The most research in this area is performed in South Korea (18.1%) followed by Brazil (12.5%) and Italy (11.4%). Regardless of location, studies primarily used less immersive (84.1%) and commercially available (54.5%) VR hardware. Additionally, 52.3% of studies used off-the-shelf software such as Wii Fit or Kinect Adventures. Only 22.7% of studies used a custom-designed software like 3D Studio Max to produce a VR environment tailored to their intervention. This is consistent with previous reviews which have found that most VR interventions utilize hardware that has associated prefabricated environments, and typically these are off-the-shelf programs such as Wii Fit (Felsberg et al., 2019; Molina et al., 2014; Porras et al., 2018). Moreover, this speaks to the criticism that research in this area grossly lacks theory-driven VR intervention development (Felsberg et al., 2019; Porras et al., 2018). A majority of research is being conducted to answer efficacy-level question of VR at large and thus use low-cost or time-efficient ways to execute this by using ready-to-run programs. This is favorably in some sense, as clinicians may be more likely to use VR technology and games that are easier to access. However, in the case of commercially available VR products, these technologies were created for entertainment without a priori use of theory-based principles in mind to address the desired motor learning principle, motor deficits, or component of exercise prescription to achieve the specific outcome of the intervention.

As previously discussed, a limited number of studies provided a rationale for the development of their intervention including study design, VR hardware and software, as well as the intervention dosage. Interventions ranged from one to 12 weeks with the two most common intervention lengths being four (n=21) or six (n= 23) weeks. Additionally, intervention frequency and duration ranged from five to 60 session lasting between 15 to 60 minutes each. The most common intervention dosage used was a duration of 6 weeks (n=23), 3 visits per week (n=32), for 30 minutes each session (n=28). This is consistent with a previous review which found the most common VR intervention implemented 3 sessions per week for 20-40 minutes over 4-6 weeks (Porras et al., 2018). Of the studies that cited evidence-based rationale for their VR intervention development, 11 of them provided support for either the frequency, intensity or duration. However, only two articles cited evidence to support their intervention prescription that were specifically related to VR interventions (Kiper et al., 2020; Phu et al., 2019). The other nine articles cited support based on empirical evidence related to intervention prescription for specific patient populations such as Multiple Sclerosis (Kalron et al., 2016) or by recommendations for general physical activity prescription from national organizations such as the American College of Sports Medicine (ACSM) (Lima Rebêlo et al., 2021). Thus, VR research seems to be applying more systematic and theory-driven approach to the development of VR interventions, however more work needs to be done to identify VR-specific recommendations regarding dosage. As has been supported in by other systematic reviews of VR interventions to improve motor outcomes, currently a wide range of intervention protocols are being employed and not always with a priori justification that is specific to VR training (Darekar et al., 2015; Felsberg et al., 2019; Porras et al., 2018).

VR can be defined as an artificial environment containing sensory information that can be interacted with, visualized, or manipulated to allow natural behaviors to emerge as if the environment were real (Jerald, 2016; Rizzo & Koenig, 2017; Steinicke et al., 2013). In the case of VR for rehabilitation in the context of the articles included in this review, the natural behaviors elicited are gross motor functions of gait, balance, and upright mobility. The variety in functionality and customization of VR makes it a promising tool to provide functional and meaningful interventions to improve motor outcomes.

VR can take many forms and continues to evolve as technology advances. With the development of off-the-shelf, commercially available products VR has been more widely researched for use in a variety of domains including physical rehabilitation. As can be seen in the publications included in this review, the majority of studies utilize commercially available VR hardware and software for gait, balance, and upright mobility interventions. This is consistent with prior systematic reviews which also have found the majority of research is conducted using low-cost VR technologies. This is likely due to the low-cost and easy setup being more conducive to use in clinical or home settings. However, as suggest by Porras et al (2018), as the merit of VR interventions has continued to be supported research in this area should move beyond purely efficacy-based questions and, perhaps, begin to answer questions regarding efficacy of different VR hardware compared to each other, the benefits of using particular VR in specific clinical settings or with particular populations, as well as investigating more deliberate designs of the VR intervention.

It should be noted that some limitations to this review exist. First, this review was limited to outcomes of gait, balance, and upright mobility. Other domains of gross motor function such as upper extremity rehabilitation, or adjacent domains such as pain management and cognitive function were not included in this review. Similarly, research that used an adjunctive modality such as transcranial magnetic stimulation, functional electric stimulation, or robot assisted gait training were also not included in this review. These domains, as they related to VR research, may be most appropriate to review separately as they have their own critical mass and may reveal interesting insights into the use of VR in these areas or in combination with adjunct modalities. Last, articles were limited to three database searches and do not account for eligible studies that could be acquired through additional databases or grey literature. Despite these limitations, this review included a large sample of research (n=88) covering a wide range of patient populations, research locations, and research settings giving a diverse understanding of how VR is being research for use as an intervention to improve gait, balance and upright mobility.

In conclusion, it is encouraging to see that 70.5% of studies in this review were conducted outside of a research laboratory. This demonstrates that research in this area is moving beyond proof-of-concept and toward better translation to clinical application. Beyond demonstrating that VR can provide significant improvement in gait, balance and upright mobility this also supports that VR can be used successfully in clinical, community or home environments. What still remains unclear is how this empirical evidence is being utilized by clinical providers. Future research may benefit from assessing the usability from the prospective of the clinical providers assisting with the data collection as many studies reported that PTs supervised their VR interventions. Additionally, as studies find significant improvement in their desired outcomes with their VR intervention, studies regarding knowledge translation or sustainability of that intervention in that particular clinical setting could be useful for implementing actual use of the VR intervention beyond the boundaries of the study protocol.

CHAPTER V: MANUSCRIPT II

**Current Perspectives on Virtual Reality use in Physical Therapy Education and Practice**

**Introduction**

The primary goal of physical rehabilitation is to assess movement impairments and restore function in order to improve quality of life following aging, injury, or disease. A growing body of literature demonstrates that virtual reality (VR) can produce effective assessment of impairments, as well as provide meaningful interventions for the rehabilitation of motr skills (Felsberg et al., 2019; Howard, 2017; Porras et al., 2018; Teel & Slobounov, 2015; Wright et al., 2017). VR affords the ability to create safe, multisensory, modifiable, and/or interactive interventions in ways that are difficult or impossible in the physical environment. These unique features of VR may provide the optimal environment to promote motor learning, retention, and transfer of motor skills in a way that is difficulty to accomplished through traditional therapeutic methods. For example, it has been shown that VR can be used to modify fractal gait patterns (i.e., low-level biological variability associated with functional mobility) over a period of 10 minutes of training (Rhea et al., 2014). An intervention of that nature with visual stimuli would be nearly impossible to create in the real world. Moreover, VR can be used to produce interventions that incorporate elements of observational learning, practice, feedback, and motivation in ways that align with the mission of physical rehabilitation. Additionally, given the technology and attributes of VR hardware and software, these key motor learning features typically employed in rehabilitation interventions can be executed in a precise, timely, and customizable way that is difficult to achieve in the physical environment, which even further supports the potential incorporation of VR in clinical settings.

A variety of VR technologies exist on the market at a range of price points, available features, and levels of immersion to fit the specific needs of various clinical settings. VR can be defined as an artificial, computer-generated environment which contains sensory information that users can interact with, visualize, and (or) manipulate to allow natural behaviors to emerge as though the environment were real (Jerald, 2016; Rizzo & Koenig, 2017; Steinicke et al., 2013). As technology has developed, and VR has become more widely available, clinicians and researchers alike have identified VR as a potentially useful tool in providing rehabilitation interventions to improve motor function. Current research in this area of VR for rehabilitation has largely demonstrated that VR interventions can produce clinically meaningful change in motor outcomes (Felsberg et al., 2019; Howard, 2017). Although the research in this area has increasingly been moving out of controlled-laboratory settings and into clinical settings, adoption and use of VR by clinicians has been moderate at best (Glegg & Levac, 2018; Levac et al., 2017, 2018).

Even it has been shown that VR interventions can enhance motor outcomes, there appears to be a gap between evidence and practice. The current evidence supports the use of VR for rehabilitation, but that does not seem to translate to actual VR use by practicing clinicians (Levac et al., 2017, 2019; Porras et al., 2018; Felsberg et al., in progress). For VR to be shown as more than just a fancy toy, it is important to first gage the current use of VR in clinical practice, and then identify the potential barriers and facilitators of VR use in clinical settings to understand more about why this apparent gap between evidence and practice may exists. Moreover, grounding these observations in theoretical models can help guide the research questions and data interpretation.

Accordingly, there are several theories and models that exist to identify the determinants of technology adoption. These include the Technology Acceptance Model (TAM) (Davis, 1985), Diffusion of Innovation Theory (Rogers, 2004), and Decomposed Theory of Planned Behavior (DTPB) (Taylor & Todd, 1995). The TAM and DPTB explain behavioral influences on the acceptance of technology and usage. They both suggest that and individual's attitudes toward technology, including perceived usefulness (PU) and perceived ease of use (PEOU), are determinants of intention to use technology. The Diffusion of Innovation Theory explains how innovations are viewed and adopted. The DTPB shares some of the same relationships present in the TAM, however, it builds on some of the weaknesses of the TAM by including factors of social influence and behavioral control. Taylor and Todd (1995) tested the predictive nature of behavioral intention to use a business school's computing resource center (CRC) on actual usage of the CRC via both the DTPB and TAM. The DTPB was found to predict actual usage of the CRC better than the TAM (path coefficient from behavioral intention to actual usage: DTPB = 1.28 and TAM = 0.38) suggesting that the DTPB is a more descriptive model to predict actual technology usage (Taylor & Todd, 1995). The DTPB also adds components of Diffusion of Innovation Theory, suggesting that attitudes toward technology could be influenced by the characteristics that one perceives as innovative, useful, and compatible with their lifestyle (Taylor & Todd, 1995). The TAM and Diffusion of Innovation Theory provide strong foundational information regarding technology acceptance and adoption (Davis, 1985; Davis et al., 1989; Rogers, 2004). However, the additional of factors regarding attitudes toward technology, influence of peers, and perceived resource and technology constraints also included in the DTPB seems to lend it well to the application of VR acceptance in clinical settings.

Currently, there has only been a small amount of research in the area of VR acceptance by physical rehabilitation clinicians. One group has adapted the DTPB to VR use in clinical settings by creating a survey called the Assessing Determinants of Prospective Take-up of Virtual Reality (ADOPT-VR) survey (Glegg et al., 2013). Through field testing, the ADOPT-VR survey has strong face and content validity, and good internal consistency (Cronbach's alpha = 0.876) (Glegg et al., 2013). Following development of the ADOPT-VR survey, a second version was created, the

ADOPT-VR2, which adds items to further describe the previously identify constructs of ADOPT-VR, as well as add the construct of client influence (Levac et al., 2017). Psychometric testing has been performed on the ADOPT-VR 2, but have not yet been published (Levac et al., 2017). Using DTPB to situate the ADOPT-VR and ADOPT-VR2 surveys was a logical next-step to applying a theoretical framework to understand adoption and usage behavior of VR by clinicians.

Previous research using the ADOPT-VR2 survey, although limited, has provided a foundation to begin to understand the use of VR in physical rehabilitation. Two studies have surveyed groups of both PTs and OTs (occupational therapists) in Canada and the United States (US) (Levac et al., 2017, 2019). These studies showed that a moderate amount of therapists have had experience with using VR in their clinical practice (Canada=46%; US=64%), but the number of clinicians using VR in their current practice is considerably lower (Canada=12%;US=31%) (Levac et al., 2019). In both Canada and the US, the ADOPT-VR2 constructs of attitudes toward VR, the perceived ease of use (PEOU), the perceived usefulness (PU), the compatibility of VR to the therapist's clinical practice, social norms, peer influence, client influence, therapist self-efficacy, and facilitating conditions were all predictive of intention to use VR (Levac et al., 2017, 2019). Some of the most commonly cited barriers in both countries were problems with funding, available space for the technology, time to include the intervention in treatment, support staff to setup or run the VR, and appropriate patients (Levac et al., 2019). Conversely, some of the facilitators to use of VR in both countries included client motivation and management support (Levac et al., 2017, 2019). Interestingly, when comparing mean responses regarding facilitators and barriers to VR, US clinicians rated facilitators more positively and barriers less negatively than did their Canadian counterparts (Levac et al., 2019).

One limitation of these studies is timing. The Canadian survey was conducted between 2014-2015 (Levac et al., 2017) and the US survey was conducted between 2017-2018 (Levac et al., 2019). It's possible that the differences seen between respondents in both countries could be contributed to the two to three-year difference between surveys and the development and integration of VR technology in that time. Another limitation is that these surveys included both OTs and PTs. Although both disciplines share similar common goals in wanting to improve functional independence and quality of life in their patients, often the primary goals and interventions are different between the professions. For example, OTs commonly focus on fine motor skills, upper extremity tasks, and performing activities of daily living such as dressing. However, PTs commonly focus on gross motor skills, motor performance, and functional tasks such as ambulation. Also, both professions have assistant-level disciplines providing treatment to patients. For PTs, Physical Therapist Assistants (PTAs) are not responsible for creating the plan of care of patients but play a critical role in executing treatment plans to meet the goals set by the treating therapist which could include the use of VR. Thus, understanding PTA perspectives would provide valuable insight into adoption of VR and barriers to use. Additionally, these studies didn't investigate technology acceptance or perspectives on the use of VR by the future clinicians—in this case PT and PTA students—as this could give insight into the potential evolution of VR use in clinician practice.

Current adoption and use of VR in clinical settings for physical rehabilitation appears to be limited, highlighting a gap between evidence supporting the use of VR and actual clinical use. At present, it is unknown the extent to which VR is being used in clinical settings for physical rehabilitation specifically by PTs and PTAs. Additionally, it is unclear the extent to which PT and PTA students are exposed to VR in their clinical education and clinical fieldwork experiences. To address this gap in the literature, theoretically driven survey-based research regarding technology acceptance of both licensed clinicians and student clinicians could help explain why adoption of VR is low in clinical settings despite the evidence in support of its use. Thus, the purpose of this study was to identify the acceptance, adoption, and perceived barriers of use of VR in rehabilitation by physical therapy professionals across the spectrum of PTs, PTAs, and students of both programs. It was hypothesized that

1: A small quantity of PT and PTAs will be currently using VR in their clinical practice.

2: The majority of PT and PTAs using VR in their clinical practice will be using of-the-shelf products, like Nintendo Wii, and associated games.

3: Students will have more positive intentions to use VR in clinical practice than licensed clinicians.

4: Recreational use of VR will be predictive of positive intention to use VR in clinical practice

5: Affiliation with a teaching or research institution will be predictive of positive intention to use VR in clinical practice.

6: Years of clinical experience will be predictive of intention to use VR in clinical practice such that those with more years of clinical experience will be less likely to have intent to use VR.

7: Higher overall technology acceptance as demonstrated by higher composite scores on the ADOPT-VR2 will be predictive of positive intention to use VR in clinical practice.

8: A majority of participants will demonstrate a positive intention to use VR following presentation of an informational video regarding the use of VR in clinical practice.

**Methods**

**Participants:** PTs and PTAs and students in both programs in the United States were recruited to participate in this study. Recruitment was a convenience sample consisting of e-mail contact through both state licensing boards and specialty sections of the American Physical Therapy Association (APTA). Students in PT and PTA programs were also recruited via convenience sampling by circulating the survey via email to respective programs listed on the APTA website. All professional participants (PTs, PTAs, and students) were also recruited via convenience and snowball sampling using social media and other digital outlets. All participants completed an online, IRB-approved informed consent process, including the estimated time to complete the survey and information regarding the anonymity of their responses.

**Survey Methods:** The survey sent to professional participants consisted of demographic information followed by the ADOPT-VR2 survey (Levac et al., 2017) (Appendix D). The demographic information included questions regarding age, professional status, education level, clinical experience, experience with using VR in clinical practice, and questions regarding insurance coverage of their clients (Appendix C). The survey sent to students included demographic information related to their age, educational level, program, and exposure to VR in their education or clinical experiences (Appendix B). As with the licensed clinicians, the ADOPT-VR2 survey followed the demographic portion of the survey sent to students.

The ADOPT-VR2 survey, which was adapted for use in this study, has not yet been published; however, the original ADOPT-VR survey can be seen in Appendix A. The ADOPT-VR survey has previously established face and content validity, as well as good internal consistency (Cronbach's alpha ranging from 0.71 to 0.94) (Glegg et al., 2013). The ADOPT-VR2 survey uses the same constructs as the ADOPT-VR survey with the addition of items to the social norms, perceived behavior control, self-efficacy, and facilitating conditions constructs as well as adding a new construct to the social norms composite called client influence (Levac et al., 2017). The ADOPT-VR2 consists of questions falling under each of the constructs found to be predictive of VR adoption (Glegg et al., 2013). These ten constructs are then further grouped under three larger composites: 1 – Attitudes (A): Perceived Usefulness (PU), Perceived Ease of Use (PEOU), and Compatibility (CO); 2 – Social Norms (SN): Peer Influence and Superior Influence; and 3 – Perceived Behavioral Control (PBC): Self-Efficacy, Facilitating Conditions and Barriers. Following the initial survey (demographics and ADOPT-VR2), participants were presented with an informational video providing examples of VR use in physical rehabilitation (Appendix F). After viewing the short video (3 minutes, 56 seconds), participants were asked a few short follow-up questions regarding their perceptions of VR and intention to use VR in the future.

The complete survey experience was presented to participants using REDCap. Students and clinicians were presented with slightly different versions of the demographic portion of the survey with questions more relevant to each group, followed by the ADOPT-VR2. An outline of the ADOPT-VR2 which was presented following the demographic questions, as well as the follow-up questions which were presented after the VR informational videos to both students and clinicians can be seen in Appendix D. The survey was first disseminated on July 12, 2021, monitored for responses, and recirculated as needed through September 10, 2021.

**Statistical Analysis**: Data gathered from the demographic portion of the survey were analyzed using descriptive statistical methods as appropriate and to address hypotheses 1, 2 and 8. To address hypotheses 3, two-tailed t-tests were run to investigate the differences between groups. To investigate the predictive nature of the external factors of recreational use of VR, employer affiliation with a research or medical institutions, and years of clinical experience (hypotheses 4, 5 and 6), linear regression methods were used with each factor tested separately as an independent variable predicting the dependent variable of behavioral intention to use VR. To test the predictive nature of the three DTPB composites on intention to use VR, linear regression methods were used with the mean scores of each composite from the ADOPT-VR2 survey inserted in the model as independent variables predicting the depending variable of behavioral intention to use VR. The three overarching composites from the DTPB being tested as predictive variables in this model include: composite 1 (attitudes, perceived usefulness, perceived ease of use, and compatibility), composite 2 (social norms, superior influence, peer influence, and client influence), and composite 3 (perceived behavioral control, self-efficacy, facilitating conditions and barriers). Results were considered significant for $P < 0.05$.

**Results**

A total of 626 clinicians (PTs = 528; PTAs = 98) and 91 student clinicians (PT students = 58; PTA students = 33) completed the survey. The completion rate for PT and PTA licensed clinicians was 65.4% and 58.3% for PT and PTA students. Demographic information for all participants is shown in Table 3.

Information regarding VR use in clinical practice can be found in Table 4. Questions regarding patient population, patient age, and purpose of VR interventions allowed respondents to select multiple responses that applied to them. Most participants reported using VR in outpatient settings (n=29) followed by sub-acute rehabilitation (n=11) and acute rehabilitation (n=6) settings. The four most common patient populations respondents reportedly used VR interventions with are Neurologic (n=37), Orthopedic (n=31), Sports (n=14), and Cardiopulmonary (n=11). Participants reported using VR the most with adults (ages 19-64 years; n=68) and older adults (ages >65 years; n=66).

## Table 3: Participant demographics

| Participant Demographics | | Total Sample (n=717) n(%) | PTs (n=528) n(%) | PTAs (n=98) n(%) | PT Students (n=58) n(%) | PTA Students (n=33) n(%) |
|---|---|---|---|---|---|---|
| *Age* | 20-29 | 135 (18.8) | 56 (10.6) | 6 (6.1) | 55 (84.5) | 18 (54.5) |
| | 30-39 | 162 (22.6) | 125 (23.7) | 24 (24.5) | 2 (3.4) | 11 (33.3) |
| | 40-49 | 149 (20.8) | 123 (23.3)) | 21 (21.5) | 1 (1.7) | 4 (12.1) |
| | 50-59 | 179 (25.0) | 148 (28.0)) | 31 (31.6) | - | - |
| | 60-69 | 87 (12.1) | 71 (13.4) | 16 (16.3) | - | - |
| | >70 | 5 (0.70) | 5 (0.95) | - | - | - |
| *Geographic Region* | Northeast | 52 (7.3) | 41 (7.8) | 5 (5.1) | 4 (6.9) | 2 (3.4) |
| | Southeast | 350 (48.8) | 262 (49.6) | 34 (34.7) | 42 (72.4) | 12 (20.7) |
| | Midwest | 174 (24.3) | 113 (21.4) | 38 (38.8) | 10 (17.2) | 13 (22.4) |
| | Southwest | 121 (16.9) | 98 (18.6) | 18 (18.4) | 1 (1.7) | 4 (6.9) |
| | West | 20 (2.8) | 14 (2.7) | 3 (3.1) | 1 (1.7) | 2 (3.4) |
| *Education Level (highest completed)* | High School | 5 (0.70) | - | - | - | 5 (15.2) |
| | Associate’s | 65 (9.1) | 2 (0.38) | 49 (50.0) | - | 14 (42.4) |
| | Bachelor’s | 205 (28.6) | 97 (18.4) | 40 (40.8) | 54 (93.1) | 14 (42.4) |
| | Master’s | 132 (18.4) | 122 (23.1) | 7 (7.1) | 3 (12.1) | - |
| | Clinical Doctorate | 285 (39.7) | 284 (53.8) | 1 (1.0) | - | - |
| | Terminal Doctorate | 25 (3.5) | 23 (4.4) | 1 (1.0) | 1 (1.7) | - |
| *Recreational Use of VR* | Yes | 60 (8.4) | 33 (6.3) | 15 (15.3) | 8 (13,8) | 4 (12.1) |
| | No | 657 (91.6) | 495 (93.8) | 83 (84.7) | 50 (86.2) | 29 (87.9) |
| *Explored VR at Work* | Yes | 101 (14.1) | 73 (13.8) | 16 (16.3) | 10 (17.2) | 2 (6.1) |
| | No | 616 (85.9). | 455 (86.1) | 82 (83.7) | 48 (82.8) | 31 (93.9) |
| *Clinical Use of VR* | Yes | 54 (7.5) | 36 (6.8) | 9 (9.2) | 6 (10.3) | 3 (9.1) |
| | No | 663 (92.5) | 492 (93.2) | 89 (90.8) | 52 (89.7) | 30 (90.9) |
| *Employer Affiliation with Research Institution, University or Teaching Hospital* | Yes | 182 (29.1) | 162 (30.7) | 20 (20.4) | - | - |
| | No | 444 (70.9) | 366 (69.1) | 78 (79.6) | - | - |

***Northeast**: ME, NH, VT, MA, CT, RI, NY, PA, NJ **Southeast**: MD, DE, VA, WV, KY, TN, NC, SC, GA, AL MS, FL, AR, LA **Midwest:** ND, SD, NE, KS, MN, IA, MO, WI, IL, MI, IN, OH **Southwest**: AZ, NM, OK, TX **West:** HI, AK, WA, OR, CA, NV, ID, MT, WY, UT, CO*

**Table 4: Details of VR use in clinical practice**

| | | Total Sample (n=54) n(%) | PTs/PTAs (n=45) n(%) | PT/PTA Students (n=9) n(%) |
|---|---|---|---|---|
| *Setting* | Acute Care | 3 (5.6) | 2 (4.4) | -1 (11.1) |
| | Acute Rehab | 6 (11.1) | 2( 4.4) | 4 (44.4) |
| | Sub-acute Rehab | 11 (20.4) | 10 (22.2) | 1 (11.1) |
| | Outpatient | 29 (53.7) | 26 (57.8) | 3 (33.3) |
| | Home Health | 2 (3.7) | 2 (4.4) | - |
| | Long-term Care | 2 (3.7) | 2 (4.4) | - |
| | Academic | 1 (1.9) | 1 (2.2) | - |
| *Patient Population* | Orthopedic | 31 | 29 | 2 |
| | Neurologic | 37 | 30 | 7 |
| | Cardiopulmonary | 11 | 11 | - |
| | Sports | 14 | 14 | - |
| | Pelvic Health | 2 | 2 | - |
| | Pediatrics | 2 | 2 | - |
| | Geriatrics | 2 | 2 | - |
| | Chronic Pain | 1 | 1 | - |
| | Vestibular | 2 | 2 | - |
| *Patient Age* | <2 years | - | - | - |
| | 2-5 years | 1 | 1 | - |
| | 6-12 years | 15 | 14 | 1 |
| | 13-18 years | 19 | 18 | 1 |
| | 19-44 years | 32 | 29 | 3 |
| | 45-64 years | 36 | 33 | 3 |
| | 65-79 years | 37 | 32 | 5 |
| | >80 | 29 | 27 | 2 |
| *Purpose* | Balance | 35 | 30 | 5 |
| | Strength | 14 | 13 | 1 |
| | Range of Motion | 14 | 13 | 1 |
| | Gait | 18 | 17 | 1 |
| | Neuromuscular Re-ed | 37 | 31 | 6 |
| | Motivation/Reward | 22 | 21 | 1 |
| | Other: Education | 1 | 1 | - |
| | Pain mgmt. | 4 | 4 | - |
| | External Focus cuing | 1 | 1 | - |
| | Engagement | 1 | 1 | - |
| | Endurance | 2 | 2 | - |
| | Vestibular Stimulaiton | 1 | 1 | - |
| | Relaxation | 1 | 1 | - |
| | Coordination | 2 | 1 | 1 |
| | Cognition | 1 | - | 1 |

**Hypothesis 1: A small quantity of PT and PTAs will be currently using VR in their clinical practice:** The majority of respondents reported not using VR recreationally (n=657; 91.6%) or in clinical practice (n=663; 92.5%). Forty-five licensed clinicians (PTs and PTAs =7.2%) reported currently using VR in their clinical practice. However, 89 clinicians (14.2%)

reported exploring VR during their work hours without clients present. Nine student clinicians (9.9%) reported using VR in their clinical education experiences. Most clinicians, both PTs and PTAs, had greater than 20 years of clinical experience (n=295; 47.3%). Similarly, most clinicians using VR in clinical practice also reported greater than 20 years of experience (n=23; 51.1%). Years of clinical experience reported by both PTs and PTAs, as well as a breakdown of years of experience of those reporting current VR use in clinical practice can be seen in Table 5.

**Table 5: Clinician work experience and VR use in clinical practice**

| | | All Clinicians | | | Clinicians using VR in Practice | | |
|---|---|---|---|---|---|---|---|
| | | **Total Sample (n=626) n(%)** | **PTs (n=528) n(%)** | **PTAs (n=98) n(%)** | **Total Clinician Sample (n=45) n(%)** | **PTs (n=36)** | **PTA (n=9)s** |
| *Years of Experience* | <1 year | 12 (1.9) | 11 (2.1) | 1 (1.0) | - | - | - |
| | 1-5 years | 91 (14.5) | 76 (14.4) | 15 (15.3) | 7 (15.6) | 7 (19.4) | - |
| | 6 -10 years | 87 (13.9) | 70 (13.3) | 17 (17.3) | 5 (11.1) | 4 (11.1) | 1 (11.1) |
| | 11-15 years | 68 (10.9) | 51 (9.7) | 17 (17.3) | 7 (15.6) | 4 (11.1) | 3 (33.3) |
| | 16-20 years | 73 (11.7) | 60 (11.4) | 13 (13.3) | 3 (6.7) | 1 (2.8) | 2 (22.2) |
| | >20 years | 295 (47.3) | 260 (49.2) | 35 (35.7) | 23 (51.1) | 20 (55.6) | 3 (33.3) |

**Hypothesis 2: The majority of PT and PTAs using VR in their clinical practice will be using of-the-shelf products, like Nintendo Wii, and associated game**: Figure 11 shows the reported VR hardware used in clinical practice. As expected, the most commonly used VR was the Nintendo Wii system (n=19), followed by the Oculus Head Mounted Display (HMD) (n=17). Off-the-shelf, commercially available VR reportedly used by the participants in this survey include Nintendo Wii (n=19), Xbox Kinect (n=3), Oculus (n=17), Pico (n=2), Razer (n=1), and a smartphone-HMD

combination (n=2). Commercially available VR (n=44) were more commonly used than VR systems created for medical use (medical grade; n=12) (Figure 12).

**Figure 11: Reported VR hardware used in clinical practice**

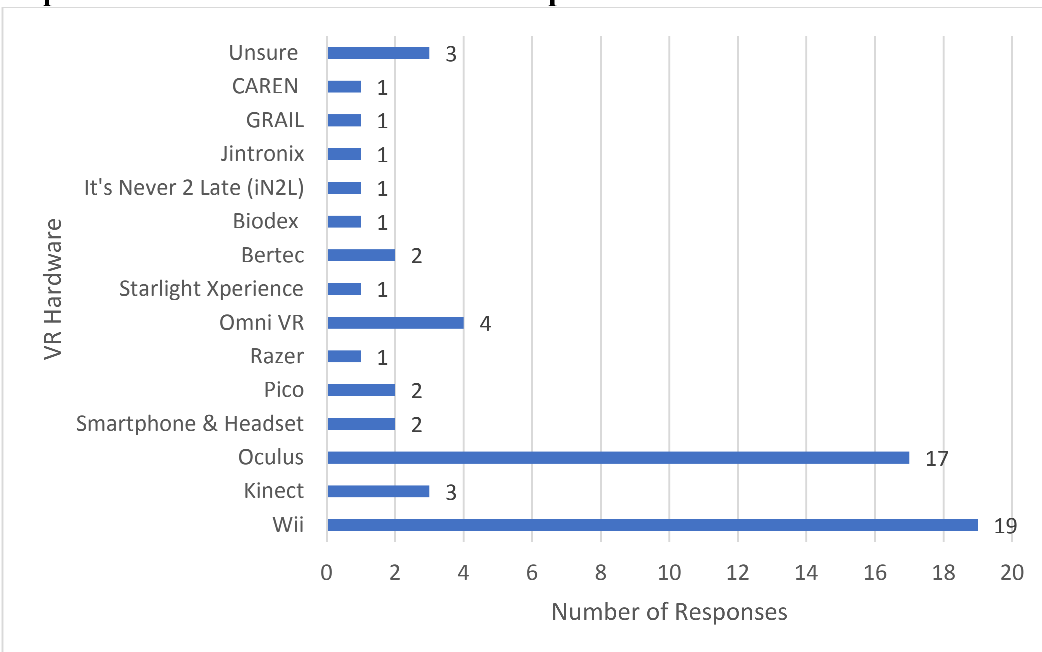
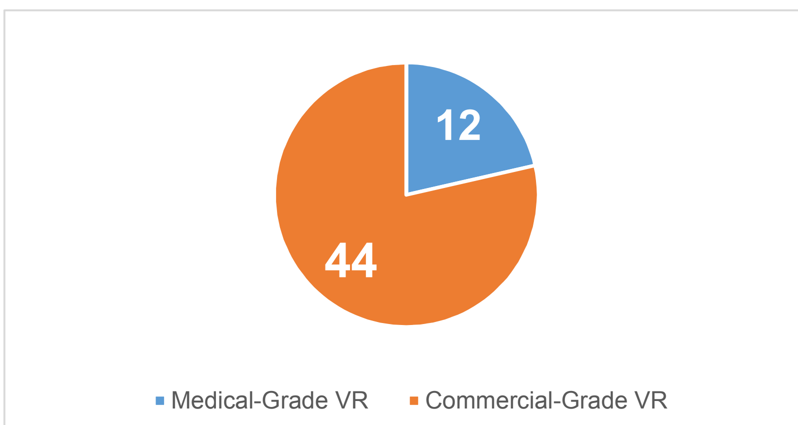



**Figure 12: Medical vs. commercial VR system use in clinical practice**




***Medical Grade VR**: CAREN, GRAIL, Jintronix, iN2L, Biodex, Bertec, OmniVR, Starlight Xperience;* ***Commercial VR:*** *Nintendo Wii, Xbox Kinect, Oculus, Pico, Razer, and smartphone-HMD combinations*

**Hypothesis 3: Students will have more positive intentions to use VR in clinical practice than licensed clinicians:** Figure 13 shows the means of each construct of the ADOPT-VR2 separated by students and clinicians. The ADOPT-VR2 responses are on a Likert scale (1 to 9) anchored at extremes, where one is an extremely negative response and nine is an extremely positive response. Students had higher means for each construct, as well as behavioral intention to use VR than clinicians. Two-tailed independent t-tests showed students had significantly higher means than clinicians for all constructs except facilitating conditions and barriers ($t(715)= .766$; $p= .444$). Students also demonstrated significantly higher behavioral intention to use VR than clinicians ($t(125.119)= 7.641$; $p=<.001$). Table 6 shows t-test results comparing the mean for each ADOPT-VR2 construct between clinician and student groups.

**Figure 13: Mean values for each ADOPT-VR2 construct comparing students to clinicians**

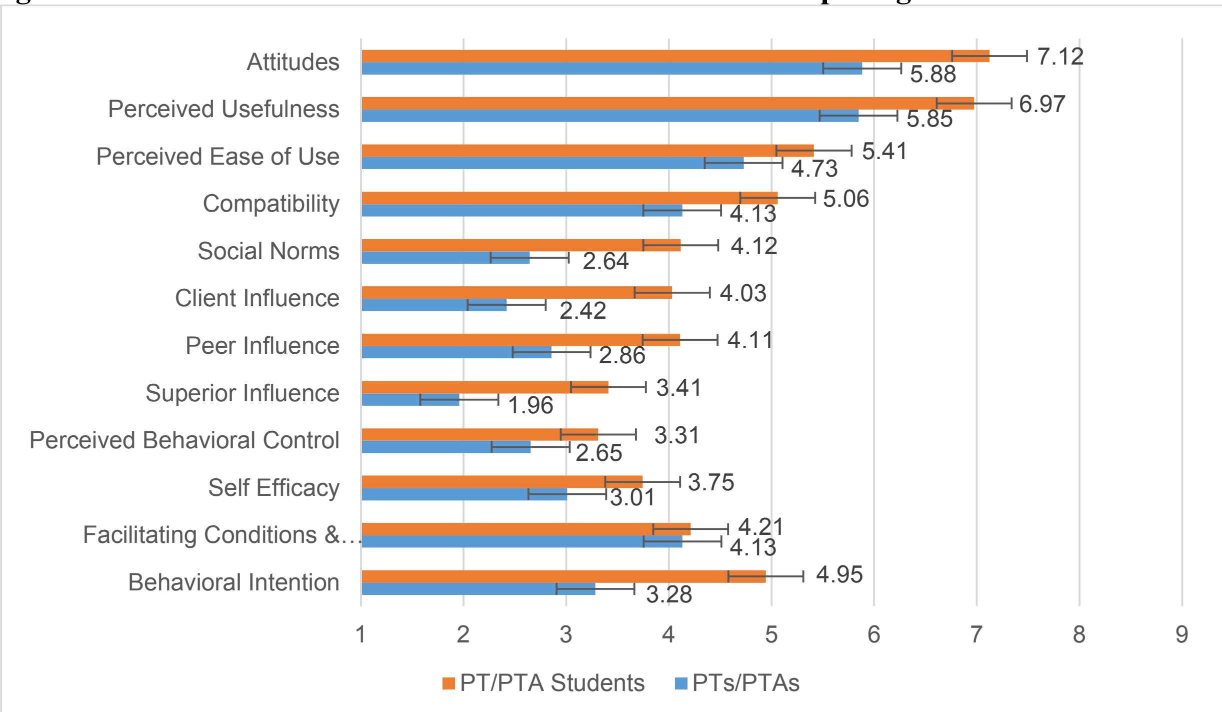



**Table 6: Comparison of group means for each ADOPT-VR2 construct**

| *Construct* | Group | Mean | SD | t | df | p |
|---|---|---|---|---|---|---|
| *Attitude* | Students | 7.12 | 1.59 | 6.612 | 143.569 | <.001* |
| | Clinicians | 5.88 | 2.17 | | | |
| *Perceived Usefulness* | Students | 6.97 | 1.44 | 6.514 | 152.503 | <.001* |
| | Clinicians | 5.85 | 2.11 | | | |
| *Perceived Ease of Use* | Students | 5.41 | 1.61 | 3.701 | 129.514 | <.001* |
| | Clinicians | 4.73 | 1.90 | | | |
| *Compatibility* | Students | 5.06 | 1.92 | 4.210 | 128.998 | <.001* |
| | Clinicians | 4.13 | 2.26 | | | |
| *Social Norms* | Students | 4.12 | 1.68 | 7.739 | 121.103 | <.001* |
| | Clinicians | 2.64 | 1.78 | | | |
| *Client Influence* | Students | 4.03 | 1.64 | 8.632 | 124.166 | <.001* |
| | Clinicians | 2.42 | 1.81 | | | |
| *Peer Influence* | Students | 4.11 | 1.69 | 6.342 | 715 | <.001* |
| | Clinicians | 2.86 | 1.77 | | | |
| *Social Influence* | Students | 3.41 | 1.80 | 7.349 | 107.782 | <.001* |
| | Clinicians | 1.96 | 1.46 | | | |
| *Perceived Behavioral Control* | Students | 3.31 | 1.89 | 3.006 | 715 | .003* |
| | Clinicians | 2.65 | 1.96 | | | |
| *Self-Efficacy* | Students | 3.75 | 2.13 | 3.143 | 715 | .002* |
| | Clinicians | 3.01 | 2.08 | | | |
| *Facilitating Conditions & Behaviors* | Students | 4.21 | 0.996 | .766 | 715 | .444 |
| | Clinicians | 4.13 | 0.930 | | | |
| *Behavioral Intention* | Students | 4.95 | 1.91 | 7.641 | 125.119 | <.001* |
| | Clinicians | 3.28 | 2.13 | | | |

Regarding facilitators and barriers to use of VR. Clinicians tended to report facilitators less positively and barriers more negatively than did students. Figures 14 and 15 show the means reported for facilitators and barriers on the ADOPT-VR2 separated by clinicians and students. The three highest rated facilitators for both clinicians and students was patient motivation, having access to resources, and time to use VR in treatment sesisons. The three main barriers as reported by clinicians and students included lack of funding to purchase equipment or software, space limitations or lack of a dedicated space for equipment, and lack of interest to use VR with patients.

**Figure 14: Mean reported facilitators on ADOPT-VR2 comparing clinicians and students**

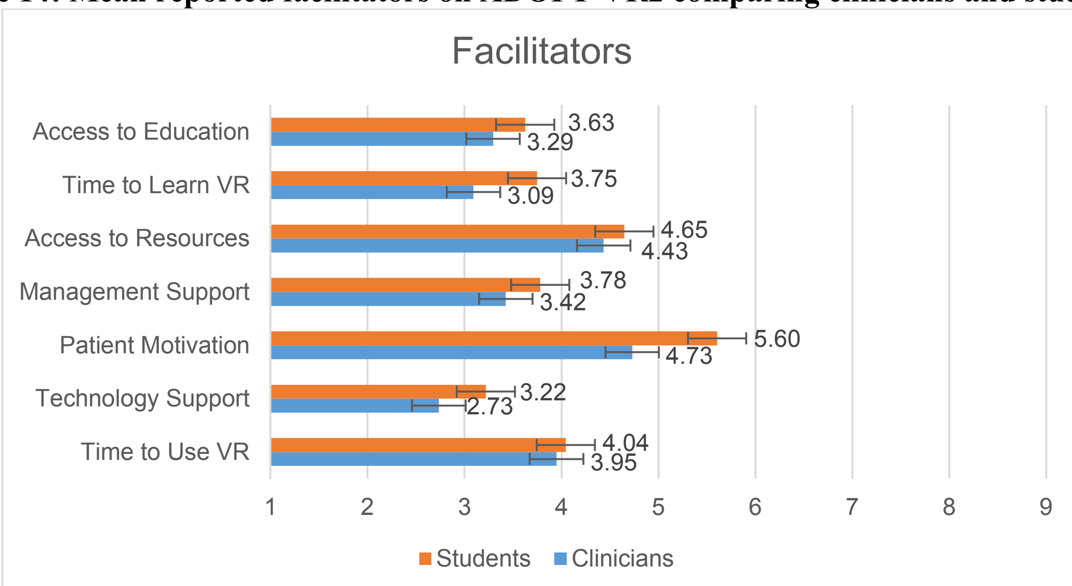
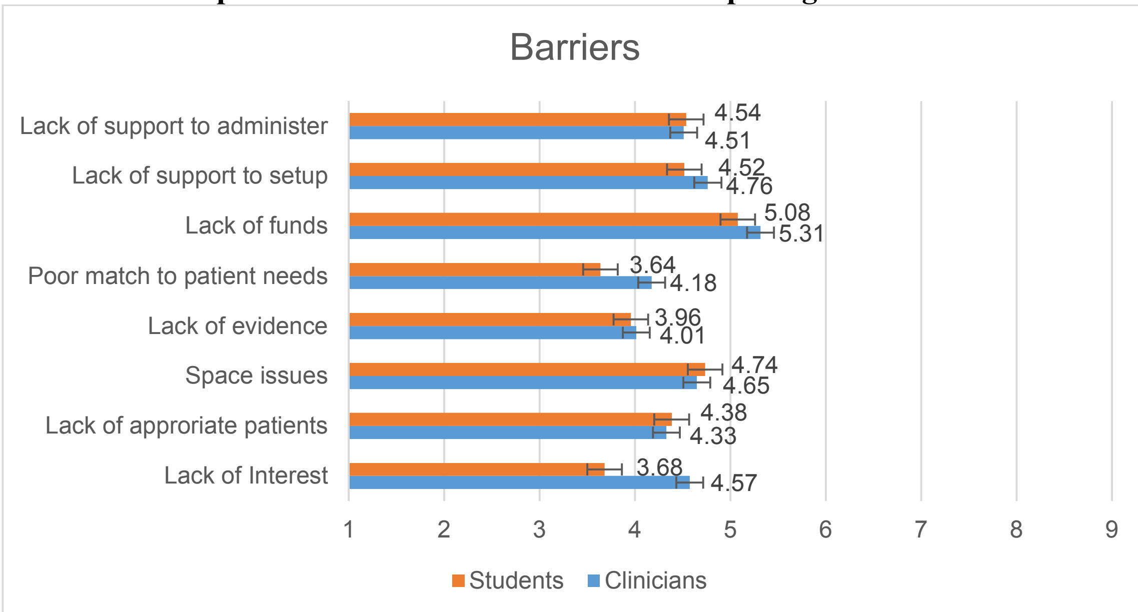


**Figure 15: Mean reported barriers on ADOPT-VR2 comparing clinicians and students**




**Hypotheses 4 -6: Recreational use of VR (hypothesis 4), affiliation with a teaching or research institution (hypothesis 5), and years of clinical experience will be predictive of behavioral intention to use VR:** To investigate the predictive nature of the external factors of recreational use of VR (both students and clinicians), affiliation of the clinicians' employer with a research and (or) medical institution, and clinicians' years of clinical experience, separate simple linear regressions were performed. Recreational use of VR was found to be a significant predictor of behavioral intention to use VR, however the correlation is weak ($R^2$= .038, $F_{1,715}$= 28.097, p = <.001). Only 3.8% of the variance in behavioral intention is explained by recreational use of VR. Employer affiliation with a teaching, research and (or) medical institution is not predictive of behavioral intention to use VR ($R^2$= .003, $F_{1,624}$= 1.619, p = .204). The linear regression with years of experience as a predictor for behavior intention was significant overall, however the correlation between years of experience and behavioral intention seems to be weakly related ($R^2$= .016, $F_{1,624}$=

10.283, p = .001). Therefore, 1.6% of the variance in behavioral intention is explained by years of experience. The predictive value for these external factors can be found in Table 7.

**Table 7: Predictive value of external factors on behavioral intention to use VR**

| ***External Factor*** | **Unstandardized Coefficients Beta** | **p** |
|---|---|---|
| *Recreational Use of VR[1]* | 4.580 | <.001* |
| *Employer Affiliation with Research/Medical Institution[2]* | .716 | .204 |
| *Years of Clinical Experience[3]* | -.067 | .001* |

*Notes: 1: $R^2$ = .038 (p <.05); 2: $R^2$ = .003 (p <.05); 3: $R^2$ = .016 (p <.05)*

**Hypothesis 7: Higher overall technology acceptance as demonstrated by higher composite scores on the ADOPT-VR2 will be predictive of positive intention to use VR in clinical practice.:** To determine the predictive value of the ADOPT-VR2 constructs on behavioral intention to use VR, a multiple linear regression was performed. The summative composite scores (composites 1, 2 and 3) were used as predictive variables. The three composites group the ADOPT-VR2 constructs as follows: Composite 1 – Attitudes (A), Perceived Usefulness (PU), Perceived Ease of Use (PEOU), and Compatibility (CO); Composite 2 – Social Norms (SN), Peer Influence, Superior Influence; and Composite 3 – Perceived Behavioral Control (PBC), Self-Efficacy, Facilitating Conditions and Barriers. The overall regression model was significant with all three composite scores in the model ($R^2$= .562, $F_{3,713}$= 304.45, p = <.001). All three composites significantly predicted behavioral intention (Table 8).

**Table 8: Predictive value of each ADOPT-VR2 Composite Score on behavioral intention**

| ***Composite*** | **Unstandardized Coefficients Beta** | **p** |
|---|---|---|
| *1 (Attitudes)* | .050 | <.001* |
| *2 (Social Norms)* | .033 | <.001* |
| *3 (Perceived Behavioral Control)* | .012 | <.001* |

*Note:: $R^2$= .562 (p<.05)*
*Composite 1: attitudes, perceived ease of use, perceived usefulness and compatibility; Composite 2: social norms and superior influence; Composite 3: perceived behavioral control, self-efficacy, facilitating conditions and barriers*

**Hypothesis 8: A majority of participants will demonstrate a positive intention to use VR following presentation of an informational video regarding the use of VR in clinical practice**: Following presentation of the informational video regarding VR use in clinical practice the majority of clinician respondents reported that despite the information they received regarding VR use, they would not plan to use VR in their future clinical practice (n= 362; 57.8%). However, following viewing the information video, 27.3% (n=99) of the 362 clinicians who reported they did not plan to use VR in the future reported they intended to seek more continuing education regarding using VR in clinical practice. In contrast, 81.3% of students reported they intended to use VR in the future following viewing the informational video. Clinician and student responses regarding behavioral intention to use VR following viewing the informational video can be seen in Figure 16 and Figure 17.

**Figure 16: Clinician intentions regarding VR following viewing informational video**

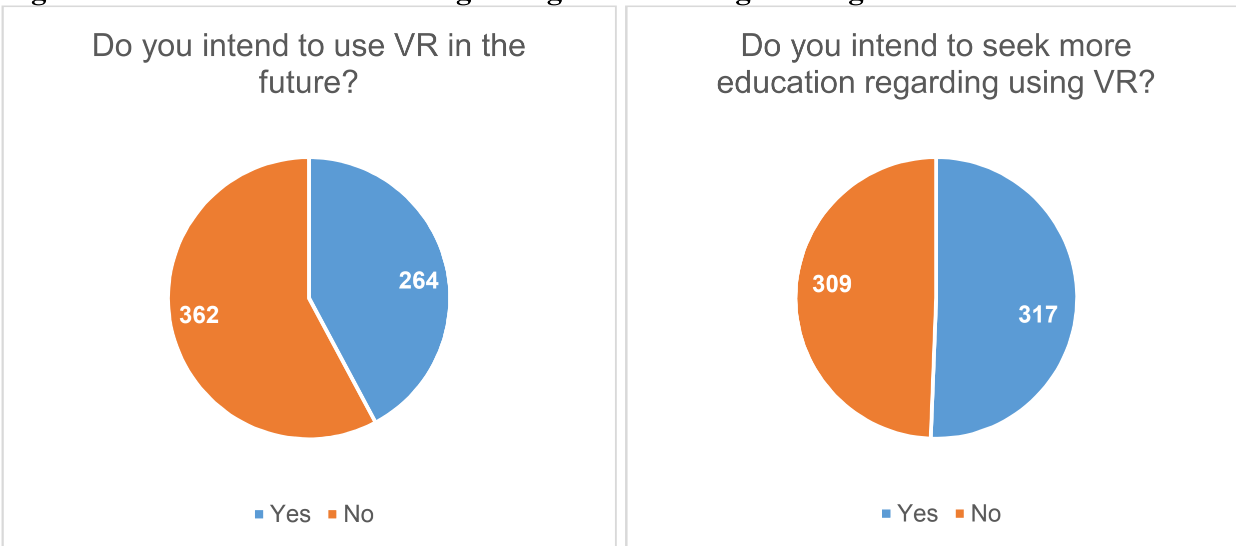
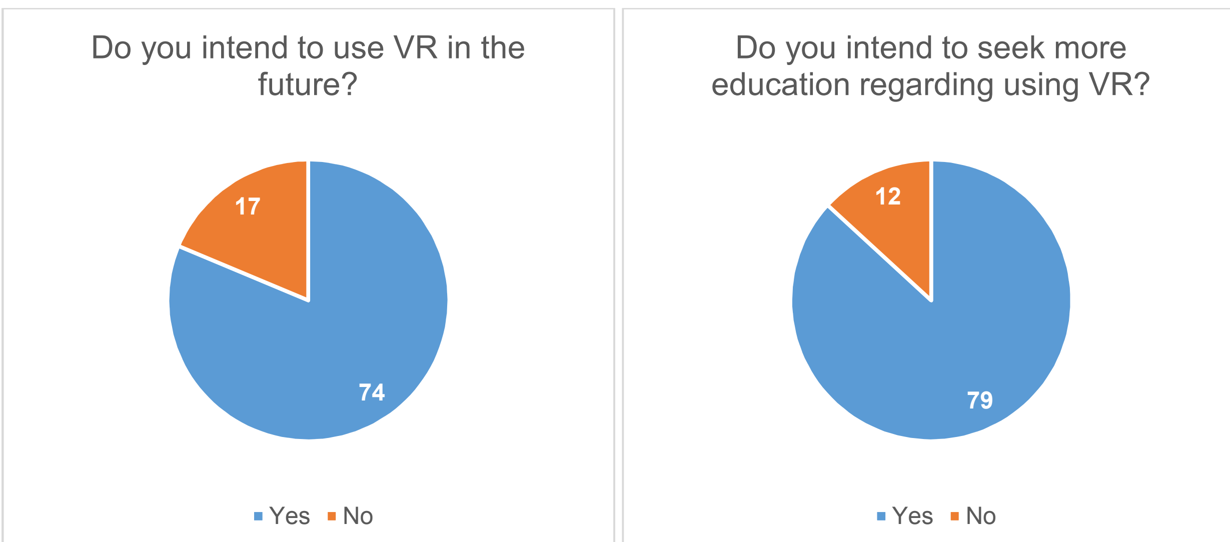



**Figure 17: Student intentions regarding VR following viewing informational video**




## Discussion

The purpose of this study was to identify the acceptance, adoption, and perceived barriers of use of VR in rehabilitation by physical therapy professionals across the spectrum of PTs, PTAs, and students of both programs. In general, we observed mixed support for our hypotheses. The findings of this survey illustrate the current acceptance, adoption, and perceived barriers of use of

VR in rehabilitation by physical therapy professionals across the spectrum of PTs, PTAs, and students of both programs. Our results are discussed below in the context of previous findings and the associated theoretical framework.

As expected, only a small percentage of respondents reported currently using VR in their clinical practice. On the ADOPT-VR2, 14.2% (n=89) of licensed clinicians and 13.2% (n=12) of student clinicians reported exploring VR in their clinical workplace. However, only 7.2% (n=45) of licensed clinicians and 9.9% (n=9) of student clinicians reported currently using VR in their clinical practice or clinical education experiences (PT/PTA students). This is lower than previously reported, as 12% of Canadian clinicians and 31% of US clinicians reported using VR in their clinical practice (Levac et al., 2017, 2019). This 23.8% decrease in reported VR usage by clinicians in the US could be due to sample differences. First, this previous research surveyed both PTs and OTs, and the total sample for the survey previously conducted in the US was 552 respondents versus the total sample of 626 in the current survey. The authors also cited that their sampling strategy relied heavily on personal contacts and social media, which could have possibly skewed the respondent pool toward those with more experience using VR. The anonymous nature of our survey along with our sampling strategy does not afford us the knowledge of the number of total potential participants reached, however the largest number of direct email contacts (51,370) came via email lists received by the licensing boards of Ohio (20,396), North Carolina (13,984), Arizona (7,896), Louisiana (5,054), Maine (2,993), and Wyoming (1,047). Our method may have allowed for recruitment of a sample with less bias toward current VR use, resulting in lower reported percentages of experience with VR and current VR usage than previous reported (Levac et al., 2017, 2019).

As expected, lower cost, commercially available VR was more commonly used compared to medical-grade products. This is consistent with previous research in which respondents reported using primarily the Wii Fit or Xbox Kinect, as well as systematic reviews of VR research which also demonstrate commercial-grade products are more commonly used by to perform VR interventions (Felsberg et al., 2019; Howard, 2017; Levac et al., 2017, 2019; Porras et al., 2018). The low-cost, low profile, and easy setup of commercial product like Nintendo Wii are qualities often cited as favorable factors over medical-grade VR systems (Levac et al., 2018; Rizzo & Koenig, 2017). However, a drawback of commercial products is that the programs associated with the system are primarily created for entertainment and recreational purposes, which requires clinicians to adapt the use of these programs to fit the desired outcome of their physical rehabilitation intervention (Deutsch & McCoy, 2017; Porras et al., 2018).

As expected, all three DTPB composites represented on the ADOPT-VR2 (1 – Attitudes; 2 – Social Norms; 3 – Perceived Behavioral Control) were predictive of behavioral intention to use VR. This is consistent with previous research which reported that all 11 constructs making of the ADOPT-VR2 were predictive of behavior intention (Levac et al., 2017, 2019). In agreement with previous research, these findings suggest acceptance of VR and subsequent intention to use VR relies on the complex relationship between multiple factors. This may complicate efforts to improve intention to use VR in clinical practice. However, regarding intentions to use VR, PT and PTA students did report more positive intentions to use VR than licensed clinicians, and this difference was statistically significant. These findings suggest that student clinicians may be more likely to use VR as an intervention. This difference between clinician and student perspectives on the use of VR interventions could be attributed to differences in clinical decision making between students, novice clinicians, and expert clinicians. Expert clinicians are more likely to rely on their prior clinical experiences when making clinical decisions (Wainwright et al., 2011). This could make them less likely to deviate from their established practice preferences. This finding is promising for future use of VR in clinical settings as these students become licensed clinicians.

We sought to explore factors that may predict behavioral intention with respect to VR use in clinical settings. We used the DTPB theory to inform our decisions on which factors to include in our analysis. Based on this, we elected to explore the factors of recreational use of VR, an affiliation of clinicians' employer with medical and/or research institution, and years of experience were selected as external factors with possible predictive value of behavioral intention.

Recreational use of VR would imply that participants are accepting of the technology in their personal life and therefore may be more like to positive attitudes toward VR, resulting in a higher technology acceptance and thus higher behavioral intention in clinical practice. Although it was found to be a significant factor, it only explained 3.8% of the variance in a respondent's intention to use VR. This may not be that surprising, given the ubiquitous nature of technology such that recreational use of VR may not be that telling of a person's overall technology acceptance (Rizzo & Koenig, 2017). Affiliation of the clinicians' employer with a medical and/or research institutions was thought to have possible predictive value as these affiliations may alleviate some of the previously cited resource barriers including lack of funding or space limitations (Levac et al., 2019). This factor was found to not be a significant predictor, highlighting that an affiliation to a medical or research institution does not automatically ease the challenge and/or increase the motivation to use VR in rehabilitation. Years of clinical experience was expected to be inversely related to behavior intention, as more seasoned clinicians may be less likely to deviate from their typical treatment protocols (Levac et al., 2017; Wainwright et al., 2011). Although significant, this factor was found to be a weak predictor of intention, explaining only 1.6% of the variance in intention to use VR. However, this is not completely surprising given that in the current sample, the majority of clinicians reporting VR use had greater than 20 years of experience, leading to a skew in the age distribution.

We were also interested in the extent to which participants reported their intention to use VR after watching a short information video on the use of VR in clinical practice at the end of the survey. This was motivated by theoretical framework of Behavior Change Techniques (BCT) that can be described as the smallest active ingredient(s) that can change behavior in an intervention (Michie et al., 2008). Such a framework has been used previously to explore VR rehabilitation in neurologic populations (Felsberg et al., 2019). Although our video would not be considered an "intervention", it did provide information that participants could have used to make a decision about their future intentions. Respondents were asked two 'yes/no' questions regarding intention to use VR in the future and desire to seek more education regarding use of VR in clinical practice. We expected that most respondents would report intention to use VR following information given in the VR video. However, most clinicians (57.8%) reported that, despite the additional information regarding the use of VR in clinical practice, they still did not intend to use VR in their future clinical practice. This is observation may dovetail with our previously stated assumption that more seasoned clinicians may be less liked to deviate from their typical treatment protocols. Interestingly, 50.7% of clinicians reported they would like to seek more education regarding the use of VR in clinical practice. This suggests that even though the majority of clinicians may currently not intend to use VR, a large percentage are open to learning more about VR and how to incorporate it into their clinical practice which may have positive implications for future use. Not surprisingly, 74% of students reported the intention to use VR in their future clinical practice and 79% reported intention to seek educational opportunities to improve their knowledge regarding clinical VR use. This makes sense given the overall higher positive intention of students to use VR in comparison to licensed clinicians. Again, this is a promising finding for the future of VR use as a physical rehabilitation intervention as these students enter the profession as licensed clinicians.

To our knowledge, this survey is one of only a few surveys of this nature and scale investigating the use of VR by rehabilitation professionals, and the first to incorporate PTAs as well as both PT and PTA students. The views of both licensed clinicians and clinical students provide important insight into current and future usage of VR in clinical practice. This survey supports previous findings that behavioral intention to use VR is based on a complex relationship of multiple factors, as all three composite scores (comprised of the 11 ADOPT-VR2 constructs) were found to be predictive of intention to use VR. Future investigation into which factors may play the most important role in behavioral intention would be useful to further address the gap between evidence and clinical practice in the use of VR for physical rehabilitation interventions.

A limitation of this survey is the large discrepancy in sample size between clinicians and students. However, the current results suggest that students have higher positive intention to use VR in clinical practice. This could be promising for the gap between evidence and practice as it suggests that these students may be more likely to use VR in their future clinical practice as they become licensed clinicians. Continued research into the usage patterns of VR by PTs and PTAs or longitudinal studies could provide insight into whether the intention of students to use VR translates into their clinical practice as licensed professionals.

In conclusion, most PT and PTA respondents reported they did not intend to use VR in the future. However, half of these participants reported they would be interested in learning more about VR and how to incorporate VR into their clinical practice. This could also be promising finding to address the gap between evidence and practice as it suggests that although the majority of surveyed clinicians don't intend to use VR given their current knowledge base, they are interested in learning more which could address barriers and facilitators related to access to evidence, resources, and education and potential change intention to use VR in the future. Future research should focus on address these learning needs to help bridge this gap and potentially improve VR usage in clinical practice for physical rehabilitation.

CHAPTER VI: MANUSCRIPT III

**Patient Perspectives Regarding use of Virtual Reality in Physical Therapy Treatment**

**Introduction**

Physical functioning can be greatly affected with aging, disease, or injury. Physical therapy (PT) aims to address these functional deficits and improve quality of life. Virtual reality (VR) has presented itself as a promising tool for physical rehabilitation due to its functional, motivating, and modifiable nature. The literature regarding the use of VR for physical rehabilitation interventions demonstrates that VR can produce both effective assessment for impairments, as well as provide meaningful interventions to improve physical function (Felsberg et al., 2019; Howard, 2017; Porras et al., 2018; Teel & Slobounov, 2015; Wright et al., 2017).

Physical Therapists (PTs) and Physical Therapist Assistants (PTAs) are the ultimate gatekeepers in PT treatment protocols, as they are the ones that decide on a plan of care and what interventions to use to address the patient's specific goals. However, patient perceptions of their PT treatment and overall satisfaction play an important role in participation, adherence to therapy protocols, and overall outcomes (Del Baño-Aledo et al., 2014). Patient-centered care places importance on patient's preferences and goals for treatment which requires the clinician to find what matters to patients to provide meaningful treatment protocols and, ultimately, the most optimal care (Del Baño-Aledo et al., 2014; Kidd et al., 2011). Therefore, although clinicians are the final gatekeeper over whether a treatment modality such as VR is used in PT treatment, the patient's perceptions and behavioral intention to use such modalities also plays a role in whether or not VR is incorporated in their care. Similarly, patient motivations to use VR is a facilitator for clinician use of VR in clinical practice (Levac et al., 2017). Thus, investigating the perceptions of those with current or previous experience in PT could help illuminate patients' desires to include

VR in their treatment and better understand clinical usage of VR. To accomplish this, a theory-driven survey targeting technology acceptance and adoption would be useful.

There are three models that help explain the relationship that exists between one's views toward technology and adoption of technology. These are the Technology Acceptance Model (TAM) (Davis, 1985), Diffusion of Innovation Theory (Rogers, 2004), and Decomposed Theory of Planned Behavior (DTPB) (Taylor & Todd, 1995). The TAM explains how certain behavioral constructs influence acceptance of technology and usage. The Diffusion of Innovation Theory explains how new technologies are viewed as innovated and diffusely adopted. The DTPB combines the TAM and Diffusion of Innovation Theory into one model to predict technology usage. In a study investigating the predictive nature of the DTPB constructs on behavioral intention to use as well as actual usage of a business school's computing resource center (CRC), Taylor and Todd (1995) found the constructs of the DTPB to predict actual usage of the CRC better than the TAM (path coefficient from behavioral intention to actual usage: DTPB = 1.28 and TAM = 0.38) suggesting that the DTPB is a more descriptive model to predict actual technology usage.

Previous research conducted regarding the acceptance and adoption of VR by PT clinicians created a survey called the Assessing Determinants of Prospective Take-up of Virtual Reality (ADOPT-VR) survey using the DTPB model as a guide (Glegg et al., 2013). Through field testing, the ADOPT-VR survey has strong face and content validity, and good internal consistency (Cronbach's alpha = 0.876) (Glegg et al., 2013). Following development of the ADOPT-VR survey, a second version was created (ADOPT-VR2) which added items to provide more depth to the previously identify constructs (Levac et al., 2017). Psychometric testing has been performed on the ADOPT-VR 2, but have not yet been published (Levac et al., 2017).

Patient-centered care is important to patient satisfaction and overall quality of care. Additionally, factors related to patient influences are cited as both a barrier (client appropriateness) and a facilitator (client motivation) to VR use in clinical practice (Levac et al., 2017, 2019). The aim of this study was to investigate patient acceptance and intention to use of VR in their physical rehabilitation treatment programs to give insight into client influences on clinician use of VR. It was hypothesized that

1: Experience with VR in their rehabilitation treatment will be predictive of positive desired intention to use VR in future PT treatments.

2: Participants' age will be predictive of desired intention to use VR in future PT treatments such that increased age with demonstrate less intention to use VR.

3: Participants' education level will be predictive of positive desired intention to use VR in future PT treatments.

4; Participants' socioeconomic status will be predictive of positive desired intention to use VR in future PT treatments.

5: Time since rehabilitation experience will be predictive of negative intention to use VR in PT treatments such that more time since participation in PT would predict less intention to use VR in any future PT treatment.

6: Higher overall technology acceptance as demonstrated by higher composite scores on the ADOPT-VR2 will be predictive of positive desired intention to use VR in PT treatments.

7. A majority of respondents will report positive desired intention to use VR in PT treatments following presentation of an informational video regarding the use of VR in PT treatment

## Methods

**Participants:** To identify patient technology acceptance, perceptions, and perceived barriers to use of VR in rehabilitation, an electronic survey was circulated to participants who have either previously participated in physical therapy or are currently participating in physical therapy. Participants were recruited via convenience and snowball sampling through social media and other digital outlets.

**Survey Methods:** The survey sent to patients consisted of demographic information followed by and an adaptation of the ADOPT-VR2 survey (Levac at al., 2017) (Appendix E). The demographic information included questions regarding age, education level, household income, if they are currently receiving PT or how long it has been since their last PT session. The ADOPT-VR2 survey, which was adapted for use in this study, has not yet been published, however the original ADOPT-VR survey can be seen in Appendix A. The ADOPT-VR survey has previously established face and content validity, as well as good internal consistency (Cronbach's alpha ranging from 0.71 to 0.94) (Glegg et al., 2013). The ADOPT-VR2 survey uses the same constructs as the ADOPT-VR survey with the addition of items to the social norms, perceived behavior control, self-efficacy, and facilitating conditions constructs as well as adding a new construct to the social norms composite called client influence (Levac et al., 2017). The ADOPT-VR2 has previously been used to survey clinicians regarding perceptions of VR, however to our knowledge has not been used to survey patients. The survey items were adapted to produce ADOPT-VR2 questions more relevant to the patient, and the previously added construct of client influence was removed as, in this case, the patient is the client. Following the initial survey (demographics and ADOPT-VR2), participants were presented with an informational video providing examples of VR use in physical rehabilitation (Appendix F). After viewing the short video (3 minutes, 56 seconds), participants were asked a few short follow-up questions regarding their perceptions of VR and intention to use VR in the future.

The complete survey experience was presented to participants using REDCap. An outline of the complete survey presented to patients can be found in Appendix E. The survey was first disseminated on July 12, 2021, monitored for responses, and recirculated as needed through September 16, 2021.

**Statistical Analysis**: Data gathered from the demographic portion of the survey were analyzed using descriptive statistical methods as appropriate, and also to address hypothesis 7. To address hypotheses 1-6, a stepwise linear regression method was used in which variables were entered into the model with the Probability-of-F-to-enter the model was ≤0.05, and Probability-of-F-to-remove was ≥0.10. Participants' experience with VR in their PT treatment, age, education level, socioeconomic status, and time since rehabilitation experience, as well as the mean scores of each composite from the ADOPT-VR2 survey inserted in the model as independent variables predicting the depending variable of behavioral intention to use VR. The three overarching composites from the DTPB being tested as predictive variables in this model include: composite 1 (attitudes, perceived usefulness, perceived ease of use, and compatibility), composite 2 (social norms, superior influence, peer influence, and client influence), and composite 3 (perceived behavioral control, self-efficacy, facilitating conditions and barriers). Results were considered significant for $P < 0.05$.

**Results**

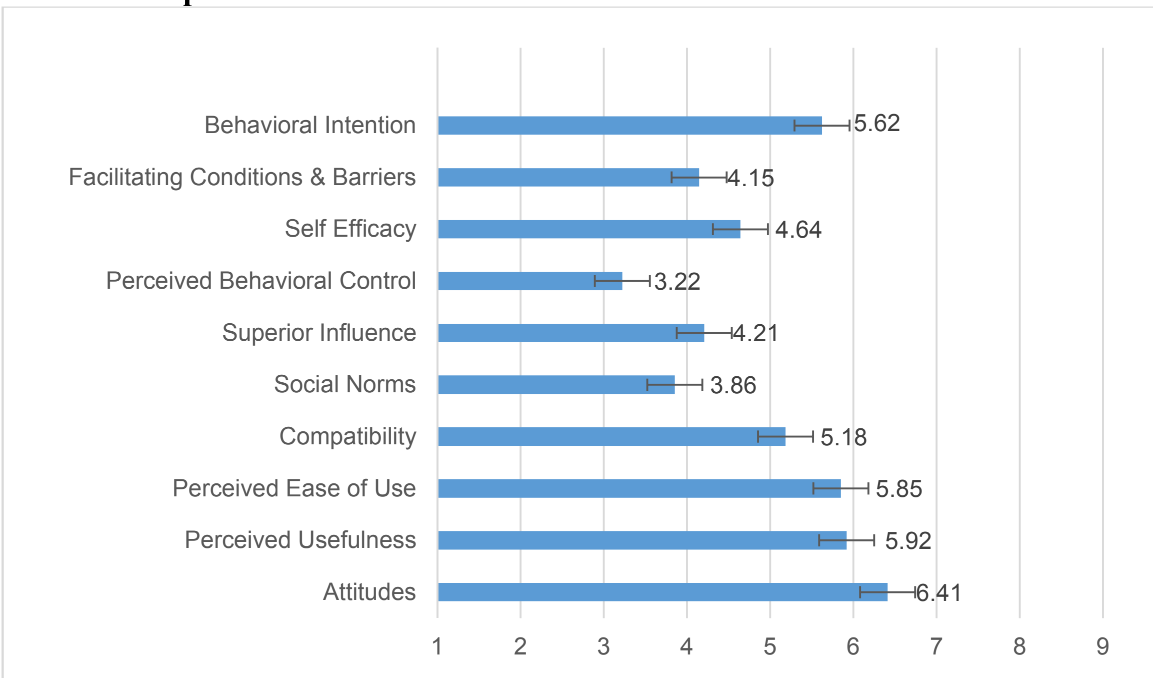
Demographic information for respondents of this survey can be found in Table 9. Most participants in this survey were in their twenties (n=11; 28.9%) or thirties (n=12; 31.65) and from the southeastern region of the US (n=21; 55.3%). Respondents reported being highly educated with 38.5% (n=15) having a bachelor's degree, 23.7% (n=9) having a Master's degree, and 31.6% (n=12) having a Doctorate-level degree. Additionally, most participants reported a household income above $150,000 (n=9; 23.7%), closely followed by $50,000-$74,999 (n=8; 21.1%) and $75,000-$99,999 (n=8; 21.1%). Twelve participants (31.6%) are currently receiving PT treatment while 26 (68.4%) have previously received PT treatment. Of the participants who reported having previously received PT intervention, the majority (n=23; 60.5%) reporting being over 1 year out from their last PT session. One respondent (2.6%) previously received PT in the acute care setting. One respondent (2.6%) is currently receiving PT from a cash-based private PT clinic. The remaining respondents (n=36; 94.7%) either received or are receiving PT in an outpatient clinical setting. One respondent (2.6%) reported using VR in their free time. None of the participants reported using VR in their PT treatments.

**Table 9: Patient demographic information**

| *Participant Demographics* | | *Total Sample (n=38) n(%)* |
|---|---|---|
| *Age* | 20-29 | 11 (28.9) |
| | 30-39 | 12 (31.6) |
| | 40-49 | 7 (18.4) |
| | 50-59 | - |
| | 60-69 | 6 (10.3) |
| | >70 | 2 (3.4) |
| *Geographic Region* | Northeast | 11 (28.9) |
| | Southeast | 21 (55.3) |
| | Midwest | 4 (10.5) |
| | Southwest | 2 (5.26) |
| | West | - |
| *Education Level (highest completed)* | Associate's | 1 (2.6) |
| | Bachelor's | 15 (39.5) |
| | Master's | 9 (23.7) |
| | Doctorate | 12 (31.6) |
| | Trade/ vocational training | 1 (2.6) |
| *Household Income* | Less than $10,000 | 2 (5.3) |
| | $10,000-$24,999 | - |
| | $25,000-49,999 | 1 (2.6) |
| | $50,000-$74,999 | 8 (21.1) |
| | $75,000-$99,999 | 8 (21.1) |
| | $100,000-$149,999 | 6 (15.8) |
| | $150,000 and greater | 9 (23.7) |
| | Prefer not to say | 4 (10.5) |
| *Recreational Use of VR* | Yes | 1 (2.6) |
| | No | 37 (97.4) |
| *Currently Receiving PT* | Yes | 12 (31.6). |
| | No | 26 (68.4) |
| *VR in PT treatments* | Yes | - |
| | No | 38 (100) |
| *PT Setting* | Acute Care | 1 (2.6) |
| | Inpatient Acute Rehab | - |
| | Skilled Nursing Facility | - |
| | Home Health | - |
| | Outpatient Clinic | 36 (94.7) |
| | Cash-Based Private Clinic | 1 (2.6) |
| *Time Since Last PT Treatment* | Current | 12 (31.6). |
| | <1 month | - |
| | 1-3 month | 2 (5.3) |
| | 3-6 months | 1 (2.6) |
| | 6-12 months | - |
| | 1-5 years | 13 (34.2) |
| | 6-10 years | 7 (18.4) |
| | >10 years | 2 (5.3) |

Figure 18 shows the mean values for each ADOPT-VR2 construct, as well as behavioral intention. The traditional ADOPT-VR2 consists of 11 constructs, however for the purposes of this survey the constructs of client and peer influence were removed as these questions were not relevant to patient respondents. Responses to ADOPT-VR2 questions are on a one to nine Likert scale anchored at extremes with a response of five being approximately neutral. Respondents reported moderately positive attitudes toward VR use in PT treatment (mean=6.41).

**Figure 18: Mean responses for ADOPT-V2 constructs:**




**Hypothesis 1: Experience with VR in their rehabilitation treatment will be predictive of positive desired intention to use VR in future PT treatments:** None of the participants reported using VR in their PT treatments. Table 10 shows the predictive value of the ADOPT-VR2 composites, as well as the external factors of age, educational status, socioeconomic status (SES), and time since last PT session. Since this external factor of VR experience in PT treatment was found to be constant, as no respondents reported receiving a VR intervention during their PT treatment, it was removed from multiple regression analysis.

**Table 10: Predictive value of ADOPT-VR2 composites and external factors on behavioral intention**

| | Unstandardized Coefficients Beta | p |
|---|---|---|
| *Composite 1: Attitudes* | 1.095 | <.001* |
| | **Beta In** | **p** |
| *Composite 2: Social Norms* | .182 | .594 |
| *Composite 3: Perceived Behavioral Control* | .018 | .732 |
| *Age* | .113 | .960 |
| *Education Level* | -.118 | .973 |
| *SES* | -.085 | .993 |
| *Time since last PT session* | .009 | .991 |

*Notes: 1: $R^2$ = .690 (p <.05); Predictors: (constant), composite 1*
*Composite 1: attitudes, perceived ease of use, perceived usefulness and compatibility; Composite 2: social norms and superior influence; Composite 3: perceived behavioral control, self-efficacy, facilitating conditions and barriers*

**Hypothesis 2: Participants' age will be predictive of desired intention to use VR in future PT treatments such that increased age with demonstrate less intention to use VR:** Through stepwise multiple regression analysis, this factor was found to not be predictive of desired intention to use VR in PT treatment sessions (*B in*= .113, t(36) = 1.196 , p = .240) (Table 10).

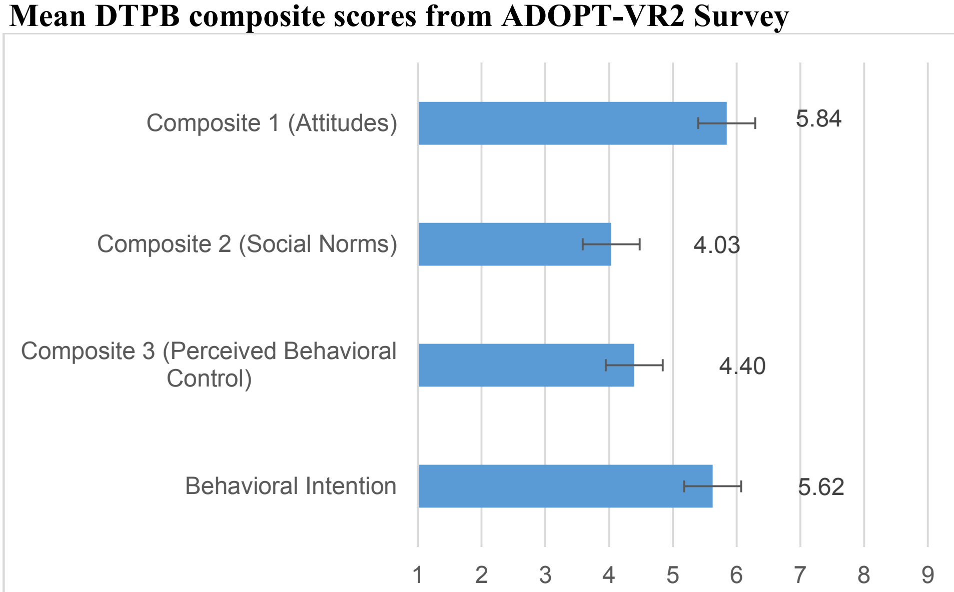
**Hypothesis 3: Participants' education level will be predictive of positive desired intention to use VR in future PT treatments:** As seen in Table 10, stepwise multiple regression analysis demonstrated that a participant's education level was not predictive of desired intention to use VR in PT treatment (*B in*= -.118, t (36) = -1.262, p = -.209).

**Hypothesis 4; Participants' socioeconomic status (SES) will be predictive of positive desired intention to use VR in future PT treatments:** Stepwise multiple regression analysis (Table 10) demonstrated that SES was not predictive of intention to use VR in PT treatment (*B in*= -.085, t (36) = -.910, p = -.152).

**Hypothesis 5: Time since rehabilitation experience will be predictive of negative intention to use VR in PT treatments such that more time since participation in PT would predict less intention to use VR in any future PT treatment**: This factor was also found to not be predictive of a participant's desired intention to use VR in PT treatment through stepwise multiple regression analysis (*B in*= .009, t (36) = -.093, p = .927). (Table 10).

**Hypothesis 6: Higher overall technology acceptance as demonstrated by higher composite scores on the ADOPT-VR2 will be predictive of positive desired intention to use VR in PT treatments:** Figure 19 shows the mean scores for each composite. Through stepwise multiple regression methods. only composite 1 was entered into the model. The model with composite 1 predicting behavioral intention was found to be significant ($R^2$= .690, $F_{1,36}$= 126.555, p = <.001), explaining 69% of the variance in intention to use VR.

**Figure 19: Mean DTPB composite scores from ADOPT-VR2 Survey**




Composite 1: attitudes, perceived ease of use, perceived usefulness and compatibility; Composite 2: social norms and superior influence; Composite 3: perceived behavioral control, self-efficacy, facilitating conditions and barriers

**Hypothesis 7. A majority of respondents will report positive desired intention to use VR in PT treatments following presentation of an informational video regarding the use of VR in PT treatment:** Following a short informational video regarding the use of VR in PT the majority of respondents reported they would request VR to be used in their PT treatment if available (n=23; 60.5%) (Figure 20) and would prefer PT providers and/or clinics that utilized VR (n=27; 71.1%) (Figure 21).

**Figure 20: Number of respondents that would request VR for future PT treatment**

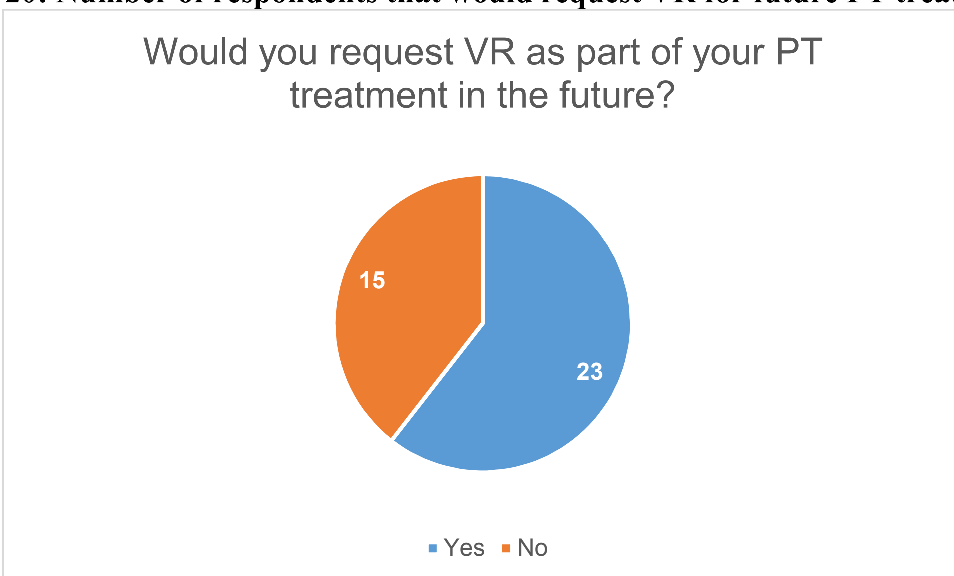
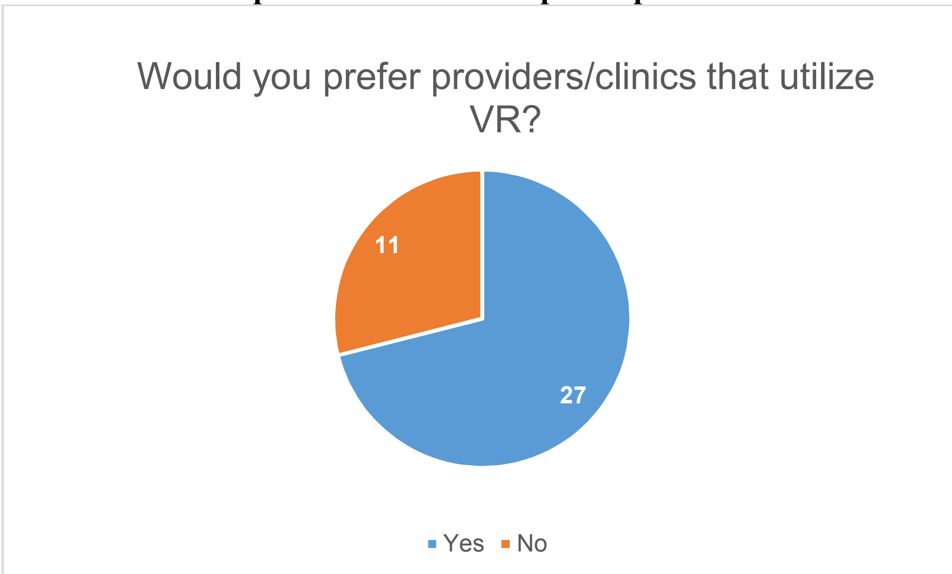


**Figure 21: Number of respondents that would prefer providers or clinics using VR**




**Discussion**

The purpose of this study was to investigate patient acceptance and intention to use of VR in their physical rehabilitation treatment programs to give insight into client influences on clinician use of VR. None of the participants reported receiving interventions that included VR during their PT experience, however 60.5% of respondents reported they would request VR interventions if available and 71.1% of respondents reported they would prefer providers that utilize VR interventions. Only the ADOPT-VR constructs of attitudes, perceived usefulness, perceived ease of use, and compatibility were found to be predictive of intention. Additionally, patients' behavioral intention to use VR appears to be independent of external factors including age, socioeconomic status, experience with VR, and educational level, as these were not found to be significant predictors of intention in this population.

The findings of this survey illuminate the perceptions and behavioral intention of patients to use VR in PT treatment. Research on the "digital divide" suggests that external factors of age, educational status, and socioeconomic status (SES) are related to an individual's access to technology and could likely be predictive of an individual's intention to use such technology (Gorski, 2005; McDonough, 2016), which motivation the formulation of our hypotheses. For example, time since last PT session was thought to have potential influence on an individual's attitudes toward VR, as proximity to the latest PT session was thought to afford the ability to envision using VR in their rehabilitation. However, our findings did not support that hypothesis. Moreover, seeing the modality as being more useful, easy to use, and compatible with PT intervention was postulated to be related to positive intentions to us VR. However, these factors were not found to be significant predictors of behavioral intention, as multiple regression methods demonstrated that a smaller number of more specific variables provide the most predictive value in determining a patient's behavioral intention to use VR in their PT treatment.

Previous research regarding acceptance and adoption of VR by PT providers has demonstrated that all 11 constructs of the ADOPT-VR2 are predictive of behavioral intention of providers to use VR in their clinical practice (Levac et al., 2017, 2019). These constructs can be grouped into three overarching composites found in the DTPB including: 1 – Attitudes (A): Perceived Usefulness (PU), Perceived Ease of Use (PEOU), and Compatibility (CO); 2 – Social Norms (SN): Peer Influence and Superior Influence; and 3 – Perceived Behavioral Control (PBC): Self-Efficacy, Facilitating Conditions and Barriers (Levac et al., 2017; Taylor & Todd, 1995). However, according to the stepwise regression methods performed in this study, composite 1 provided the best model to predict behavioral intention of patients to use VR in their PT treatment. This makes sense, as composite 1 is related to an individual's attitudes toward VR which were identified by the TAM as being the primary factors in predicting an individual's technology acceptance and adoption (Davis, 1985). It's possible that the DTPB, which adds constructs of social norms and perceived behavioral control, is required to help explain the more complex nature of a clinician's adoption of VR use, but that a patient's acceptance and adoption of VR is less complex. Patient attitudes, perceived usefulness, perceived ease of use, and feelings of compatibility of VR in their PT treatment also seem to be most related to the patient's overall healthcare experience. Conversely, Composites 2 and 3 contain constructs related to self-efficacy of using VR, social factors, barriers, and facilitators to VR use that are more relevant to the clinicians' experience of VR use as the ultimate gatekeepers of treatment protocols.

Unfortunately, none of the respondents had experience receiving PT treatment that included VR interventions. This isn't entirely surprising, as previous research has identified that only a small to moderate percentage of PT providers are currently using VR in their clinical practice (Levac et al., 2017, 2019; Felsberg et al., in progress). Additionally, only one respondent reported using VR recreationally. However, despite not having experience with VR, a majority of respondents reported they would request VR to be used in their PT treatment if it was available as a modality and would prefer PT providers and/or clinical environments which utilized VR. This is promising given that current adoption of VR interventions by PT providers is limited resulting in limited exposure of clients to VR as a modality, suggesting that, despite limited to no experience, patients would still be open to the use of VR in their treatment protocols should their PT provider decide to implement a VR intervention. This further emphasizes clinicians' critical role as the ultimate gatekeepers in VR use in rehabilitation and suggests that the current gap that exists between empirical evidence supporting VR interventions and clinical use of VR is primarily related to a clinician's behavioral intention.

Physical therapy aims to improve quality of life in individuals with functional deficits related to aging, injury or disease. Physical Therapists (PTs) and Physical Therapist Assistants

(PTAs) are the ultimate decisions-makers in PT treatment, however patient perceptions of their PT treatment and overall satisfaction play an important role in participation, adherence to therapy protocols, and overall outcomes (Del Baño-Aledo et al., 2014). Patient-centered care places importance on patient's preferences and goals for treatment which requires the clinician to find what matters to patients to provide meaningful treatment protocols and, ultimately, the most optimal care (Del Baño-Aledo et al., 2014; Kidd et al., 2011). The findings of this survey suggest that patients have positive attitudes and behavioral intentions regarding the use of VR in their PT treatment. Patient motivation is a potential facilitator in PT provider's intention to use VR which seems to be present given the responses to the current survey (Levac et al., 2017, 2019; Felsberg et al., in progress). Also, lack of appropriate patients has been cited as a barrier to the use of VR by PT providers (Levac et al., 2017, 2019). However, the current findings suggest that patient desire to use VR is present, and these positive attitudes and intentions seem to be independent of external factors such as age, education level, and SES. PT providers should also consider this when determining if a patient may be interested or appropriate for VR interventions as more patients may be motivated and appropriate for VR interventions that initially thought. PT providers may deem a patient inappropriate for VR intervention due to particular diagnoses or clinical presentation, however a patient's age, education, prior experience with VR, or their SES should not play a role in determining appropriateness for the incorporation of VR interventions into a treatment protocol.

Limitations of this study include the small sample size as well as the recruitment methods. The small sample size limits the statistical power and generalizability of these findings. Additionally, participants were primarily recruited through snowball sampling of personal contacts which may bias respondents toward positive perceptions of VR. Despite these limitations, the current findings suggest that patients who have received or are receiving PT treatment have overall positive views and behavioral intentions regarding the use of VR in their PT treatment.

Although clinicians are the final gatekeepers over the selection of treatment modalities such as VR is used in PT treatment, patients' perceptions and intentions to use such modalities should also play a part in whether VR is incorporated in their care. Future research could expand on the current study by recruiting surveying a larger population with more diverse PT and VR experiences. Additionally, the current survey suggests that only composite 1 of the ADOPT-VR2 is predictive of behavioral intention for patients. Future research could expand on the development of a theory-driven survey more tailored to the patients' experience.

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APPENDIX A: ADOPT VR SURVEY

# Appendix 1. ADOPT-VR Survey

Code: Date:

**Virtual Reality—GestureTek Health's Vivid GX/IREX Software**
This survey relates specifically to the GestureTek virtual reality system developed by GestureTek Health. This system has been used as a rehabilitation tool by therapists for a range of client populations. The system consists of a computer, a viewing screen, a camera, a green background screen, and the Vivid GX/IREX software. Please answer the survey questions with this virtual reality system in mind. The first three questions ask about your general feelings toward the GestureTek virtual reality system.

1. Using virtual reality in treatment sessions with my clients is a good idea.
   1 2 3 4 5 6 7 8 9
   Strongly Disagree Strongly Agree
2. I would have fun using virtual reality in my practice.
   1 2 3 4 5 6 7 8 9
   Strongly Disagree Strongly Agree
3. I like the idea of using virtual reality with my clients.
   1 2 3 4 5 6 7 8 9
   Strongly Disagree Strongly Agree

**Perceived Usefulness**
The next questions ask you about the usefulness of the GestureTek virtual reality system as a treatment tool.

4. Using virtual reality will result in improved functional outcomes for my clients.
   1 2 3 4 5 6 7 8 9
   Strongly Disagree Strongly Agree
5. Virtual reality provides variety for my clients in working towards their therapy goals.
   1 2 3 4 5 6 7 8 9
   Strongly Disagree Strongly Agree
6. Virtual reality adds something beyond what my conventional treatment approach could offer my clients.
   1 2 3 4 5 6 7 8 9
   Strongly Disagree Strongly Agree

**Perceived Ease of Use**
The following questions relate to how easy you feel the GestureTek virtual reality system is to use.

7. Using virtual reality with my clients requires minimal mental effort on my part.
   1 2 3 4 5 6 7 8 9
   Strongly Disagree Strongly Agree
8. It is easy for me to become skillful in using virtual reality.
   1 2 3 4 5 6 7 8 9
   Strongly Disagree Strongly Agree
9. I would find virtual reality easy to use.
   1 2 3 4 5 6 7 8 9
   Strongly Disagree Strongly Agree

**Compatibility**
The next two questions are about the virtual reality system and how compatible it is with your typical treatment approaches when working with clients.

10. Using virtual reality fits with the way I work.
    1 2 3 4 5 6 7 8 9
    Strongly Disagree Strongly Agree
11. Using virtual reality fits with my practice preferences.
    1 2 3 4 5 6 7 8 9
    Strongly Disagree Strongly Agree

**Experience**
Please answer the following questions about your experience using virtual reality to date.

12. I have explored the GestureTek IREX/Vivid GX software during work hours.
    ☐ Yes ☐ No

    12a. If Yes, please estimate the number of hours spent exploring, in total, without clients present: ________________
13. How long have you been using the GestureTek VR system with your clients? ________________________
14. There are typically over 30 games in the Vivid GX software package. The number of these games with which I feel I am familiar enough to use in therapy sessions is: ___________
15. I have provided mentoring to others who are using/wanting to use virtual reality with their clients.
    ☐ Yes ☐ No ☐ Unsure

**Social Norms**
The following questions ask about social influences related to your work.

16. Those whose opinions I value would prefer that I use virtual reality with my clients.
    1 2 3 4 5 6 7 8 9
    Strongly Disagree Strongly Agree
17. My colleagues think I should use virtual reality with my clients.
    1 2 3 4 5 6 7 8 9
    Strongly Disagree Strongly Agree
18. I feel I am keeping up with my colleagues in my use of virtual reality with clients.
    1 2 3 4 5 6 7 8 9
    Strongly Disagree Strongly Agree
19. My supervisor thinks I should use virtual reality with my clients.
    1 2 3 4 5 6 7 8 9
    Strongly Disagree Strongly Agree
20. I will have to use virtual reality in my practice because my supervisor requires it.
    1 2 3 4 5 6 7 8 9
    Strongly Disagree Strongly Agree

**Perceived Behavioral Control**
The next few questions ask you about your beliefs about both internal (e.g., knowledge, skills) and external factors (e.g., supports) that may or may not affect your ability to use virtual reality with your clients.

21. I have the knowledge to make use of virtual reality in my therapy sessions.
    1 2 3 4 5 6 7 8 9
    Strongly Disagree Strongly Agree
22. I have access to the resources and opportunities I need to use virtual reality.
    1 2 3 4 5 6 7 8 9
    Strongly Disagree Strongly Agree

**Self-Efficacy**
This section asks you to think about your confidence in using the virtual reality system with your clients to address their rehabilitation goals.

23. I feel confident in my ability to create client programs using virtual reality.
1 2 3 4 5 6 7 8 9
Strongly Disagree Strongly Agree

24. Please describe any areas in which you may be lacking confidence with respect to using virtual reality with your clients: ______

**Facilitating Conditions or Barriers**
The next set of questions asks about external factors that may or may not affect your use of virtual reality.

25. I have the time to use virtual reality.
1 2 3 4 5 6 7 8 9
Strongly Disagree Strongly Agree

26. I feel that I have the technology support I need to use virtual reality in my practice.
1 2 3 4 5 6 7 8 9
Strongly Disagree Strongly Agree

27. I see the following as barriers to my use of virtual reality in my practice **(check all that apply)**:
- ☐ Lack of time to learn how to use the virtual reality system
- ☐ The time required to use virtual reality in a treatment session
- ☐ Lack of access to evidence on virtual reality's effectiveness
- ☐ Poor quality of evidence to support the use of virtual reality
- ☐ Lack of educational opportunities related to virtual reality
- ☐ Lack of appropriate clients with which to use virtual reality
- ☐ Treatment space issues (e.g., lack of dedicated space for virtual reality equipment, room scheduling conflicts)
- ☐ Poor motivation of clients to participate
- ☐ Other: ______

28. The most significant barrier to my use of virtual reality is: ______

29. What has helped you to incorporate virtual reality into your practice? ______

**Intention to Use Virtual Reality**
The next questions relate to your motivation to use virtual reality in your daily practice in the future.

30. I intend to use virtual reality for therapy as often as needed.
1 2 3 4 5 6 7 8 9
Strongly Disagree Strongly Agree

31. To the extent possible, I would use virtual reality in therapy frequently.
1 2 3 4 5 6 7 8 9
Strongly Disagree Strongly Agree

32. I plan to increase the amount that I use virtual reality in my practice.
1 2 3 4 5 6 7 8 9
Strongly Disagree Strongly Agree

33. What are the reasons behind your intention to use/not use virtual reality in the future? ______

**Demographic Information**
The next questions ask for information about you and your clinical experience.
**Please check the appropriate box(es) for each question.**

34. Gender: ☐ M ☐ F

35. Profession:
- ☐ Occupational Therapist
- ☐ Physiotherapist
- ☐ Behavioral Therapist
- ☐ Speech-Language Pathologist
- ☐ Recreation Therapist
- ☐ Rehabilitation Therapist, OT or PT Aide, or Rehabilitation Assistant
- ☐ Other: ____________________

36. My highest academic degree or diploma is:
- ☐ Certificate/Diploma
- ☐ Bachelor's Degree (e.g., BSc)
- ☐ Research Masters (e.g., MSc)
- ☐ Clinical Masters (e.g., MOT, MPT, MRSC)
- ☐ PhD
- ☐ Other: ____________________

37. # years of experience as a therapist/aide/RA: ____________

38. My clients range in age from (**check all that apply**):
- ☐ Birth to 2 years
- ☐ 2–5 years
- ☐ 5–13 years
- ☐ 13–19 years
- ☐ 19–65 years
- ☐ 65+ years

39. # clients on my caseload per year with acquired brain injury: _____________

40. # years of experience working with clients with acquired brain injury: ____________

Thank you for your time and participation!

**Please return your completed survey to the study coordinator.**

APPENDIX B: SURVEY FOR STUDENTS

**PT/PTA Student Demographic Information**

1. How old are you?
2. What is your gender?
   - Female
   - Male
   - Prefer not to identify
   - Other: (if other, how do you identify?)
3. How would you describe yourself?
   - Black, African American
   - American Indian or Alaska Native
   - Asian
   - Native Hawaiian or Other Pacific Islander
   - White
   - Prefer not to identify
   - Other: (if other, how do you prefer to describe yourself?)
4. Where do you live? [Select State]
5. What is your highest level of education completed? (select the highest degree earned)
   - High School Diploma or GED
   - Associate degree
   - Bachelor's Degree
   - Master's Degree
   - Terminal Doctorate (i.e. PhD, EdD, etc.)
6. Are you PT student or PTA student?
   - PT Student
   - PTA Student
7. Where do you attend PT/PTA School? (Name of program you attend)
8. What year are you in your program? (ex. $2^{nd}$ of 3 years or 2/3)
9. Do you use virtual reality (VR) in your free time?
   - Yes
   - No

10. If yes, what device(s) do you use? (select all that apply)
    - Nintendo Wii
    - Xbox Kinetic
    - Playstation VR
    - Oculus
    - HTC Vive
    - Motek GRAIL system
    - Motek CAREN system
    - Gesturetek Health IREX system
    - Other: (if other, what VR system(s) do you use in your free time?)
11. Do you have any courses that incorporate VR?
    - Yes
    - No
12. If so, what device(s) are available? (select all that apply)
    - Nintendo Wii
    - Xbox Kinetic
    - Playstation VR
    - Oculus
    - HTC Vive
    - Motek GRAIL system
    - Motek CAREN system
    - Gesturetek Health IREX system
    - Other: (if other, what VR device(s) are available in your coursework/program?)
13. Have you had any clinical experiences using VR as an intervention?
    - Yes
    - No
14. If so, what clinical setting(s) was the experience? (select all that apply)
    - Acute Care
    - Acute Rehabilitation
    - Sub-acute Rehabilitation
    - Outpatient Clinic
    - Home Health
    - Other: (if other, in what clinical settings(s) was your VR experience?)
15. Describe the patient population(s) you worked with using VR? (select all that apply)
    - Orthopedic

Neurologic
Cardiopulmonary
Sports
Pelvic Health
Other: (If other, please describe the patient population(s) you worked with using VR)

16. What was the purpose(s) of the VR intervention? (select all that apply)
    Improve Balance
    Improve Strength
    Improve Range of Motion
    Improve Gait
    Neuromuscular Re-education
    Motivation or Reward
    Other: (if other, what was the purpose(s) of the use of VR in your clinical practice?

17. What is the age group(s) of the patient population you work with? (select all that apply)
    Birth to 1 month
    1 to 23 months
    2-5 years
    6-12 years
    13-18 years
    19-44 years
    45-64 years
    65-79 years
    ≥ 80 years

APPENDIX C: SURVEY FOR CLINICIANS

**PT/PTA Demographic Information**

1. How old are you?
2. What is your gender?
   - Female
   - Male
   - Prefer not to identify
   - Other: (if other, how do you identify?)
3. How would you describe yourself?
   - Black, African American
   - American Indian or Alaska Native
   - Asian
   - Native Hawaiian or Other Pacific Islander
   - White
   - Prefer not to identify
   - Other: (if other, how do you identify?)
4. Where do you live? [Select State]
5. Are you a PT or PTA?
   - PT
   - PTA
6. What is your highest level of education completed?
   - Associate degree
   - Bachelor's degree
   - Master's degree
   - Clinical Doctorate (i.e DPT)
   - Terminal Doctorate (i.e. PhD, EdD, etc)
7. How many years have you been practicing?
8. What is your current job status?
   - Full-time
   - Part-time
   - PRN
   - Retired

9. In what clinical setting do you work? (select the setting you work in most often)
   - Acute Care
   - Acute Rehabilitation
   - Sub-acute Rehabilitation
   - Outpatient Clinic
   - Home Health
   - Other: (if other, in what setting do you work?)
10. What patient population(s) do you work with? (Select all that apply)
   - Orthopedic
   - Neurologic
   - Cardiopulmonary
   - Sports
   - Pelvic Health
   - Pediatrics
   - Geriatrics
   - Other: (if other, what patient population(s) do you work with?)
11. What is the age group(s) of the patient population you work with? (select all that apply)
   - Birth to 1 month
   - 1 to 23 months
   - 2-5 years
   - 6-12 years
   - 13-18 years
   - 19-44 years
   - 45-64 years
   - 65-79 years
   - ≥ 80 years
12. Is your employer affiliated with a teaching hospital, research institution, or university?
   - Yes
   - No
13. Do you use virtual reality (VR) in your free time?
   - Yes
   - No

14. If so, what device(s) do you use? (select all that apply)
    - Nintendo Wii
    - Xbox Kinetic
    - Playstation VR
    - Oculus
    - HTC Vive
    - Motek GRAIL system
    - Motek CAREN system
    - Gesturetek Health IREX system
    - Other: (if other, what VR system(s) do you use in your free time?)
15. Do you use VR in your clinical practice?
    - Yes
    - No
16. If so, what device(s) to you use (select all that apply)?
    - Nintendo Wii
    - Xbox Kinect
    - Playstation VR
    - Oculus
    - HTC Vive
    - Motek GRAIL system
    - Motek CAREN system
    - Gesturetek Health IREX system
    - Other: (if other, what VR system(s) do you use in your clinical practice?)
17. What was the purpose of the use of VR in your clinical practice (select all that apply)?
    - Improve Balance
    - Improve Strength
    - Improve Range of Motion
    - Improve Gait
    - Neuromuscular Re-education
    - Motivation or Reward
    - Other: (if other, what was the purpose(s) of the use of VR in your clinical practice?)

18. What is the primary insurance coverage of the patient population you work with? (select all that apply)

    Private Insurance
    VA or Tricare
    Medicare
    Medicaid
    Self-pay

19. Does insurance coverage play a role in your decision to use VR as an intervention with your patients?

    Yes
    No

## APPENDIX D: ADOPT-VR2

**ADOPT-VR2 For Clinicians and Students**

The first three questions ask about your general feelings toward the use of VR. Please answer the degree to which you agree with the following statements on the scale of: (1) – strongly disagree to (9) – strongly agree

1. Using virtual reality in treatment sessions with my clients is a good idea
   1 2 3 4 5 6 7 8 9
   Strongly Disagree Strongly Agree

2. I would have fun using virtual reality in my practice
   1 2 3 4 5 6 7 8 9
   Strongly Disagree Strongly Agree

3. I like the idea of using virtual reality with my clients
   1 2 3 4 5 6 7 8 9
   Strongly Disagree Strongly Agree

---

The next questions ask you about the usefulness of VR as a treatment tool. Please answer the degree to which you agree with the following statements on the scale of: (1) – strongly disagree to (9) – strongly agree

4. Using VR will result in improved functional outcomes for my clients
   1 2 3 4 5 6 7 8 9
   Strongly Disagree Strongly Agree

5. VR provides variety for my clients in working towards their therapy goals
   1 2 3 4 5 6 7 8 9
   Strongly Disagree Strongly Agree

6. VR adds something beyond what my conventional treatment approach could offer my clients
   1 2 3 4 5 6 7 8 9
   Strongly Disagree Strongly Agree

---

The following questions relate to how easy you feel VR is to use. Please answer the degree to which you agree with the following statements on the scale of: (1) – strongly disagree to (9) – strongly agree

7. Using VR with my clients requires minimal mental effort on my part
   1 2 3 4 5 6 7 8 9
   Strongly Disagree Strongly Agree

8. It is easy for me to become skillful in using VR
   1 2 3 4 5 6 7 8 9
   Strongly Disagree Strongly Agree

9. I would find VR games easy to use
   1 2 3 4 5 6 7 8 9
   Strongly Disagree Strongly Agree

---

The next two questions are about VR and how compatible it is with your typical treatment approaches when working with clients. Please answer the degree to which you agree with the following statements on the scale of: (1) – strongly disagree to (9) – strongly agree

10. Using VR fits with the way I work
    1 2 3 4 5 6 7 8 9
    Strongly Disagree Strongly Agree

11. Using VR fits with my practice preferences
    1 2 3 4 5 6 7 8 9
    Strongly Disagree Strongly Agree

---

Please Answer the following questions about your experience using VR to date

12. I have explored VR during work hours
    Yes
    No

    If yes, please estimate the number of hours spent exploring, in total, without clients present:

13. How long have you been using VR with your clients?

14. The number of VR games with which I feel I am familiar enough to use in therapy sessions are:
15. I have provided mentoring to others who are using/wanting to use VR with their clients

    Yes

    No

    Unsure

---

The following questions ask about social influences related to your work. Please answer the degree to which you agree with the following statements on the scale of: (1) – strongly disagree to (9) – strongly agree

16. Those whose opinions I value would prefer that I use VRwith my clients

    1 2 3 4 5 6 7 8 9

    Strongly Disagree Strongly Agree

17. It is important to others that I use VRin my practice

    1 2 3 4 5 6 7 8 9

    Strongly Disagree Strongly Agree

18. My clients think I should include VR in their treatment programs

    1 2 3 4 5 6 7 8 9

    Strongly Disagree Strongly Agree

19. My colleagues think I should include VR games with my clients

    1 2 3 4 5 6 7 8 9

    Strongly Disagree Strongly Agree

20. I feel I am keeping up with my colleagues in my use of VR with clients

    1 2 3 4 5 6 7 8 9

    Strongly Disagree Strongly Agree

21. My supervisor thinks I should use VR with my clients

    1 2 3 4 5 6 7 8 9

    Strongly Disagree Strongly Agree

22. I will have to use VR in my practice because my supervisor requires it

    1 2 3 4 5 6 7 8 9

    Strongly Disagree Strongly Agree

---

The next few questions ask you about your beliefs about both internal (i.e. knowledge, skills) and external factors (i.e. supports) that may or may not affect your ability to use virtual reality with your clients. Please answer the degree to which you agree with the following statements on the scale of: (1) – strongly disagree to (9) – strongly agree

23. I have the knowledge to make use of virtual reality in my therapy sessions
    1 2 3 4 5 6 7 8 9
    Strongly Disagree Strongly Agree

24. I have access to the resources I need to use virtual reality
    1 2 3 4 5 6 7 8 9
    Strongly Disagree Strongly Agree

25. I am familiar with the current evidence on the use of virtual reality in my area of practice
    1 2 3 4 5 6 7 8 9
    Strongly Disagree Strongly Agree

26. I am familiar with the virtual reality games available to me
    1 2 3 4 5 6 7 8 9
    Strongly Disagree Strongly Agree

---

This section asks you to think about your confidence in using virtual reality with your clients to address their rehabilitation goals. Please answer the degree to which you agree with the following statements on the scale of: (1) – least confident to (9) – most confident.

27. Selecting an appropriate virtual reality system to meet my clients' goals
    1 2 3 4 5 6 7 8 9
    Least Confident Most Confident

28. Selecting an appropriate virtual reality system to meet my clients' abilities
    1 2 3 4 5 6 7 8 9
    Strongly Disagree Strongly Agree

29. Selecting an appropriate virtual reality system to meet my clients' stage of recovery
    1 2 3 4 5 6 7 8 9
    Strongly Disagree Strongly Agree

30. Setting up virtual reality equipment
1 2 3 4 5 6 7 8 9
Strongly Disagree Strongly Agree

31. Matching games to clients' needs
1 2 3 4 5 6 7 8 9
Strongly Disagree Strongly Agree

32. Selecting appropriate clients
1 2 3 4 5 6 7 8 9
Strongly Disagree Strongly Agree

33. Creating client programs using virtual reality games
1 2 3 4 5 6 7 8 9
Strongly Disagree Strongly Agree

34. Grading games to make them easier or harder
1 2 3 4 5 6 7 8 9
Strongly Disagree Strongly Agree

35. Progressing virtual reality-based treatment
1 2 3 4 5 6 7 8 9
Strongly Disagree Strongly Agree

36. Evaluating client outcomes
1 2 3 4 5 6 7 8 9
Strongly Disagree Strongly Agree

37. Evaluating my own virtual reality-based therapy practice
1 2 3 4 5 6 7 8 9
Strongly Disagree Strongly Agree

38. Managing technical issues/troubleshooting
1 2 3 4 5 6 7 8 9
Strongly Disagree Strongly Agree

39. Accessing additional information or resources on the system
1 2 3 4 5 6 7 8 9
Strongly Disagree Strongly Agree

40. Please describe any other specific areas in which you may be lacking confidence with respect to using virtual reality with your clients:

The next set of questions ask about external factors that may or may not affect your use of virtual reality. Please answer the degree to which you agree with the following statements on the scale of: (1) – strongly disagree to (9) – strongly agree

41. I have enough time to use virtual reality in my treatment sessions

    1 2 3 4 5 6 7 8 9

    Strongly Disagree Strongly Agree

42. I have the technology support I need to use virtual reality in my practice

    1 2 3 4 5 6 7 8 9

    Strongly Disagree Strongly Agree

43. I am not interested in using virtual reality with my clients

    1 2 3 4 5 6 7 8 9

    Strongly Disagree Strongly Agree

44. I do not have appropriate clients for the virtual reality system(s) available

    1 2 3 4 5 6 7 8 9

    Strongly Disagree Strongly Agree

45. My clients are/would be motivated to participate in virtual reality games

    1 2 3 4 5 6 7 8 9

    Strongly Disagree Strongly Agree

46. I have the support I need from management to use virtual reality games

    1 2 3 4 5 6 7 8 9

    Strongly Disagree Strongly Agree

47. Treatment space issues limit my use of virtual reality (i.e. lack of dedicated space for equipment, room scheduling conflicts, etc.)

    1 2 3 4 5 6 7 8 9

    Strongly Disagree Strongly Agree

48. There is poor quality evidence to support my use of virtual reality games

    1 2 3 4 5 6 7 8 9

    Strongly Disagree Strongly Agree

49. I have access to the evidence on the effectiveness of virtual reality for therapy

    1 2 3 4 5 6 7 8 9

    Strongly Disagree Strongly Agree

50. I have enough time during my workday to learn how to use virtual reality
    1 2 3 4 5 6 7 8 9
    Strongly Disagree Strongly Agree

51. I have access to enough educational opportunities about using virtual reality in clinical practice
    1 2 3 4 5 6 7 8 9
    Strongly Disagree Strongly Agree

52. Virtual reality would not effectively target my clients' needs/goals
    1 2 3 4 5 6 7 8 9
    Strongly Disagree Strongly Agree

53. A lack of funds limits my/our purchase of virtual reality equipment/software
    1 2 3 4 5 6 7 8 9
    Strongly Disagree Strongly Agree

54. I require more support staff assistance with setup/takedown of virtual reality equipment
    1 2 3 4 5 6 7 8 9
    Strongly Disagree Strongly Agree

55. I require more support staff assistance to administer virtual reality treatment programs to clients
    1 2 3 4 5 6 7 8 9
    Strongly Disagree Strongly Agree

56. Are there any other barriers to your virtual reality use that are not listed above? Please describe:
57. The most significant barrier to my use of virtual reality is:
58. What has helped you to incorporate virtual reality into your practice?

---

The next questions relate to your motivation to use virtual reality in your daily practice in the future. Please answer the degree to which you agree with the following statements on the scale of: (1) – strongly disagree to (9) – strongly agree

59. I intend to use virtual reality for therapy as often as needed
    1 2 3 4 5 6 7 8 9
    Strongly Disagree Strongly Agree

60. To the extent possible, I would use virtual reality in therapy frequently

1 2 3 4 5 6 7 8 9

Strongly Disagree Strongly Agree

61. I plan to increase the amount that I use virtual reality in my practice

1 2 3 4 5 6 7 8 9

Strongly Disagree Strongly Agree

62. If you plan to use virtual reality in the future, why?
63. If you do not plan to use virtual reality in the future, why not?

**[Presentation of VR informational primer will be inserted here including 4-5 minute video with examples of VR being used in physical therapy.]**

1. Now knowing more about virtual reality for physical therapy, do you plan to use virtual reality in the future?

   Yes

   No
2. If you plan to use VR in the future, why?
3. If you do not plan to use VR in the future, why not?

APPENDIX E: SURVEY FOR PATIENTS

**Patient Demographic Information**

1. How old are you?
2. What is your gender?
   - Female
   - Male
   - Prefer not to identify
   - Other: (if other, how do you identify?)
3. Where do you live? [Select State]
4. How would you describe yourself?
   - Black, African American
   - American Indian or Alaska Native
   - Asian
   - Native Hawaiian or Other Pacific Islander
   - White
   - Prefer not to identify
   - Other: (if other, how do you identify?)
5. What is your highest level of education you have completed? If currently enrolled, what is the highest degree received?
   - No schooling completed
   - Elementary school to middle school
   - Some High school, no diploma
   - High School or GED
   - Some college, no diploma
   - Trade/technical/vocational training
   - Associate degree
   - Bachelor’s degree
   - Master’s degree
   - Professional Degree (i.e DPT, MD, PA, DDS)
   - Terminal Doctorate (i.e. PhD, EdD, etc)

6. What is your total household income?
   - Less than $10,000
   - $10,000 - $24,999
   - $25,000 - $49,999
   - $50,000 - $74,999
   - $75,000 - $99,999
   - $100,000 - $149,999
   - $150,000 and greater
   - Prefer not to say
7. Do you have medical insurance?
   - Yes
   - No
8. If so, what type of medical insurance do you have?
   - Private Insurance (i.e. United Healthcare, BCBS, etc)
   - VA or Tricare
   - Medicare
   - Medicaid
   - Other: (if other, what type of insurance do you have?)
9. Are you currently receiving physical therapy?
   - Yes
   - No
10. If so, how long have you been receiving physical therapy?
    - Less than 1 month
    - 1 – 6 months
    - 6 months – 1 year
    - Greater than 1 year
11. If greater than 1 year, how long have you been receiving physical therapy? [enter amount of time]
12. If not, how long has it been since your last therapy session?
    - Less than 1 month
    - 1-3 months
    - 3-6 months
    - 6 months – 1 year
    - Greater than 1 year
13. If greater than 1 year, how long has it been since your last therapy session? [enter amount of time]

14. Why did you stop physical therapy?
    Stopped making progress
    Met all my goals
    Insurance coverage ran out or cost was too expensive
    Felt it was not needed
    Issues with transportation
    Other: (if other, why did you stop physical therapy?)
15. On average, how many sessions of physical therapy did you attend per week?
    1 time per week
    2-3 times per week
    3-5 times per week
    6-7 times per week
16. In what setting(s) have you received physical therapy (select all that apply)?
    Acute Care Hospital
    Inpatient Rehabilitation
    Skilled Nursing Facility
    Outpatient Clinic
    Home Health
    Other: ___________________________________
17. What was the purpose of receiving physical therapy (select all that apply)?
    To improve your balance
    To improve your strength
    To improve the range of motion of one or more of your joints
    To improve your walking
    To improve your wheelchair skills
    To improve your independence with everyday tasks
    To improve your endurance to participate in activities
    Other: _________________________________________________
    I don't know
18. Do you use VR in your free time?
    Yes
    No

19. If so, what device(s) do you use?
    - Nintendo Wii
    - Xbox Kinetic
    - Playstation VR
    - Oculus
    - HTC Vive
    - Motek GRAIL system
    - Motek CAREN system
    - Gesturetek Health IREX system
    - Other: (if other, what VR system(s) have you used in your free time?)
20. Did you participate in any activities in virtual reality during physical therapy?
    - Yes
    - No
21. If so, what type of device was used (select all that apply)
    - Nintendo Wii
    - Xbox Kinect
    - Playstation VR
    - Oculus
    - HTC Vive
    - Motek GRAIL system
    - Motek CAREN system
    - Gesturetek Health IREX System
    - Other: (if other, what type of VR device(s) were used in your physical therapy treatment?)
    - I don't know
22. To the best of your knowledge, what was the purpose of using virtual reality during your physical therapy session (select all that apply)?
    - To improve your balance
    - To improve your strength
    - To improve the range of motion of one or more of your joints
    - To improve your walking
    - To improve your wheelchair skills
    - To improve your independence with everyday tasks
    - To improve your endurance to participate in activities
    - Other: (if other, what was the purpose of using VR in your physical therapy treatment?)
    - I don't know

**ADOPT-VR2 For Patients**

The first three questions ask about your general feelings toward the use of VR. Please answer the degree to which you agree with the following statements on the scale of: (1) – strongly disagree to (9) – strongly agree

1. Using virtual reality in my treatment sessions is a good idea

   1 2 3 4 5 6 7 8 9

   Strongly Disagree Strongly Agree

2. I would have fun using virtual reality in my treatment sessions

   1 2 3 4 5 6 7 8 9

   Strongly Disagree Strongly Agree

3. I like the idea of using virtual reality in my treatment sessions

   1 2 3 4 5 6 7 8 9

   Strongly Disagree Strongly Agree

---

The next questions ask you about the usefulness of VR as a treatment tool. Please answer the degree to which you agree with the following statements on the scale of: (1) – strongly disagree to (9) – strongly agree

4. Using VR will result in improved functional outcomes for me

   1 2 3 4 5 6 7 8 9

   Strongly Disagree Strongly Agree

5. VR provides variety for me s in working towards my therapy goals

   1 2 3 4 5 6 7 8 9

   Strongly Disagree Strongly Agree

6. VR adds something beyond what my conventional treatment could offer me

   1 2 3 4 5 6 7 8 9

   Strongly Disagree Strongly Agree

---

The following questions relate to how easy you feel VR is to use. Please answer the degree to which you agree with the following statements on the scale of: (1) – strongly disagree to (9) – strongly agree

7. Using VR in my treatment sessions requires minimal mental effort on my part

   1 2 3 4 5 6 7 8 9

   Strongly Disagree Strongly Agree

8. It is easy for me to become skillful in using VR

   1 2 3 4 5 6 7 8 9

   Strongly Disagree Strongly Agree

9. I would find VR games easy to use

   1 2 3 4 5 6 7 8 9

   Strongly Disagree Strongly Agree

---

The next two questions are about VR and how compatible it is with your typical treatment session with your physical therapist/physical therapy assistant. Please answer the degree to which you agree with the following statements on the scale of: (1) – strongly disagree to (9) – strongly agree

10. Using VR fits with the way I engage in my therapy session

    1 2 3 4 5 6 7 8 9

    Strongly Disagree Strongly Agree

11. Using VR fits with my physical therapy treatment preferences

    1 2 3 4 5 6 7 8 9

    Strongly Disagree Strongly Agree

---

Please Answer the following questions about your experience using VR to date

12. How long have you been using VR in your therapy sessions?
13. The number of VR games with which I feel I am familiar with using my therapy treatment: _____

---

The following questions ask about social influences related to your physical therapy treatment. Please answer the degree to which you agree with the following statements on the scale of: (1) – strongly disagree to (9) – strongly agree

14. Those whose opinions I value would prefer that I use virtual reality in my treatment

1 2 3 4 5 6 7 8 9

Strongly Disagree Strongly Agree

15. It is important to others that I use virtual reality in my treatment

1 2 3 4 5 6 7 8 9

Strongly Disagree Strongly Agree

16. My therapist thinks I should include virtual reality in my treatment programs

1 2 3 4 5 6 7 8 9

Strongly Disagree Strongly Agree

17. I am likely to use virtual reality in my treatment because my therapist suggests it

1 2 3 4 5 6 7 8 9

Strongly Disagree Strongly Agree

---

The next few questions ask you about your beliefs about both internal (i.e. knowledge, skills) and external factors (i.e. supports) that may or may not affect your ability to use virtual reality in your therapy session. Please answer the degree to which you agree with the following statements on the scale of: (1) – strongly disagree to (9) – strongly agree

18. I have the knowledge to make use of virtual reality in my therapy sessions

1 2 3 4 5 6 7 8 9

Strongly Disagree Strongly Agree

19. I have access to the resources I need to use virtual reality

1 2 3 4 5 6 7 8 9

Strongly Disagree Strongly Agree

20. I am familiar with the current evidence on the use of virtual reality in my therapy sessions

1 2 3 4 5 6 7 8 9

Strongly Disagree Strongly Agree

21. I am familiar with the virtual reality games available to me

1 2 3 4 5 6 7 8 9

Strongly Disagree Strongly Agree

---

This section asks you to think about your confidence in using virtual reality to address your rehabilitation goals. Please answer the degree to which you agree with the following statements on the scale of: (1) – least confident to (9) – most confident.

22. Please rate your overall confidence in using virtual reality in your treatment sessions

1 2 3 4 5 6 7 8 9

Least Confident Most Confident

23. If you use VR independently in your therapy session or as part of your home exercise program, please rate how confident you are in setting up virtual reality equipment

1 2 3 4 5 6 7 8 9

Least Confident Most Confident

24. If you use VR independently in your therapy session or as part of your home exercise program, please rate how confident you are in managing technical issues/troubleshooting

1 2 3 4 5 6 7 8 9

Least Confident Most Confident

25. Please rate how confident you are at evaluating the outcome of your intervention

1 2 3 4 5 6 7 8 9

Least Confident Most Confident

26. Please describe any other specific areas in which you may be lacking confidence with respect to using virtual reality with your clients:

__________________________________________________________

---

The next set of questions ask about external factors that may or may not affect your use of virtual reality. Please answer the degree to which you agree with the following statements on the scale of: (1) – strongly disagree to (9) – strongly agree

27. I have enough time to use virtual reality in my treatment sessions

1 2 3 4 5 6 7 8 9

Strongly Disagree Strongly Agree

28. I have the technology support I need to use virtual reality in my treatment sessions

1 2 3 4 5 6 7 8 9

Strongly Disagree Strongly Agree

29. I am not interested in using virtual reality in my treatment sessions

1 2 3 4 5 6 7 8 9

Strongly Disagree Strongly Agree

30. I am not motivated to participate in virtual reality games

1 2 3 4 5 6 7 8 9

Strongly Disagree Strongly Agree

31. I have the support I need from my therapist to use virtual reality games

1 2 3 4 5 6 7 8 9

Strongly Disagree Strongly Agree

32. Treatment space issues limit my use of virtual reality (i.e. lack of dedicated space for equipment, room scheduling conflicts, etc.)

1 2 3 4 5 6 7 8 9

Strongly Disagree Strongly Agree

33. Virtual reality would not effectively target my needs/goals

1 2 3 4 5 6 7 8 9

Strongly Disagree Strongly Agree

34. Are there any other barriers to your virtual reality use that are not listed above? Please describe:
35. The most significant barrier to my use of virtual reality is:
36. What has helped to incorporate virtual reality into your treatment sessions?

The next questions relate to your motivation to use virtual reality in your treatment in the future. Please answer the degree to which you agree with the following statements on the scale of: (1) – strongly disagree to (9) – strongly agree

37. If offered, I intend to use virtual reality for therapy as often as needed

    1 2 3 4 5 6 7 8 9

    Strongly Disagree Strongly Agree

38. To the extent possible, I would use virtual reality in therapy frequently

    1 2 3 4 5 6 7 8 9

    Strongly Disagree Strongly Agree

39. If offered, I plan to request to increase the amount that I use virtual reality in my treatment

    1 2 3 4 5 6 7 8 9

    Strongly Disagree Strongly Agree

40. If you plan to use virtual reality in the future, why?
41. If you do not plan to use virtual reality in the future, why not?

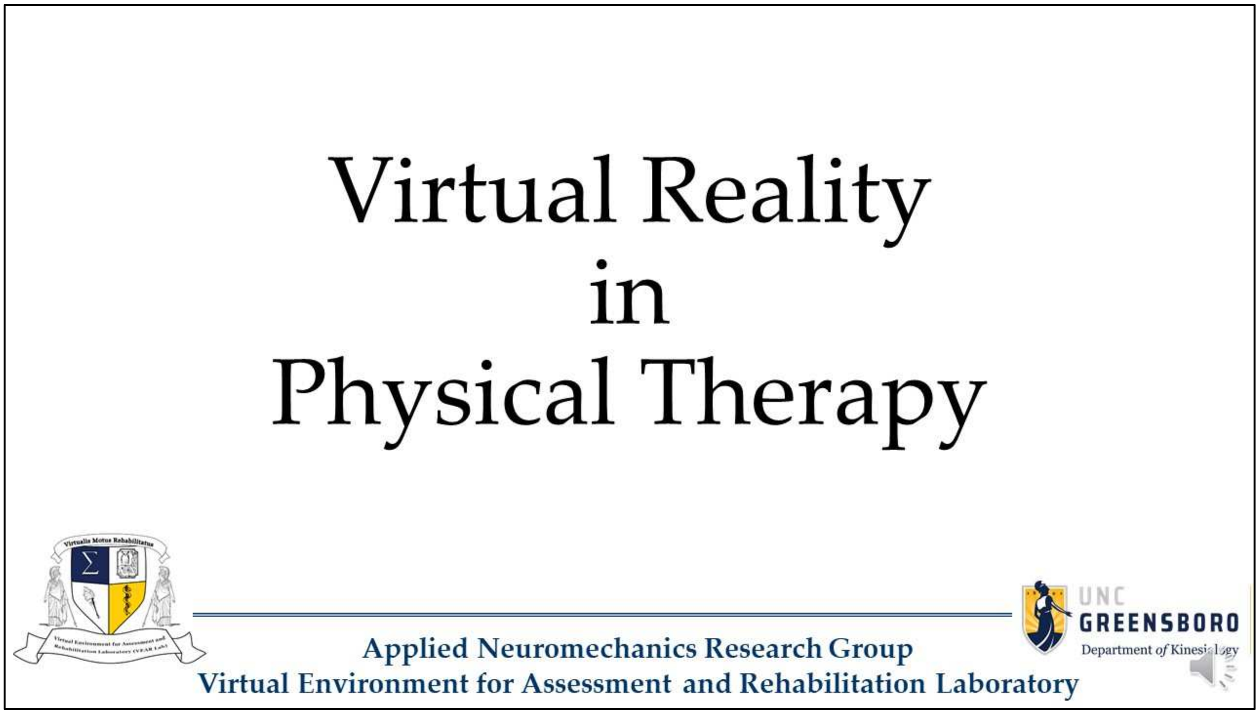
**[Presentation of VR informational primer will be inserted here including 4-5 minute video with examples of VR being used in physical therapy.]**

1. Now knowing more about virtual reality for physical therapy, do you plan to request to use virtual reality for future physical therapy treatment?

    Yes

    No
2. If you plan to use VR in the future, why?
3. If you do not plan to use VR in the future, why not?

APPENDIX F: VR INFORMATIONAL VIDEO




[HTTPS://YOUTU.BE/PX5KRM_EUQY](https://youtu.be/PX5KRM_EUQY)

## APPENDIX G: DEMOGRAPHIC INFORMATION OF INCLUDED STUDIES

| First Author | Pub year | Title | Population | N | Age (Mean) | Setting | Country | Intervention Aim | Intervention Type |
|---|---|---|---|---|---|---|---|---|---|
| **Afridi** | 2018 | Effect of balance training in older adults using Wii fit plus | Older Adults | 16 | 67.56 | Private Clinic | Pakistan | Balance | single-group, pre-post- |
| **Alahmari** | 2014 | Comparison of virtual reality based therapy with customized vestibular physical therapy for the treatment of vestibular disorders | peripheral, central or mixed vesitibular disorders | 38 CR: 18; VR: 20 | CR: 61 ± 3 VR: 53 ± 2 | Medical research facility | US | Balance | two-group, pre-post- and 6-month f/u |
| **An** | 2018 | The effects of semi-immersive virtual reality therapy on standing balance and upright mobility function in individuals with chronic incomplete spinal cord injury: A preliminary study | Chronic incomplete spinal cord injury | 10 | 44.2 ± 8.66 | Neuro Rehab Center | Korea | Balance, Upright Mobility | single-group, pre-post- |
| **Anson** | 2018 | Trunk motion visual feedback during walking improves dynamic balance in older adults: Assessor blinded randomized controlled trial | Adults with self-reported balance impairment | 40 TT: 20; VRTT: 20 | TT: 75.8 ± 6.5 VRTT: 75.7 ± 5.3 | University & Retirement Community | US | Balance | two-group, pre-post- and 4-week f/u RCT |
| **Bang** | 2016 | Effects of virtual reality training using Nintendo Wii and treadmill walking exercise on balance and walking for stroke patients | Stroke | 40 TT: 20; VR: 20 | TT: 63.2 ± 5.4 VR: 62.2 ± 7.2 | Not Reported | Korea | Balance & Gait | two-group, pre-post- |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Bellomo** | 2020 | The WeReha Project for an Innovative Home-Based Exercise Training in Chronic Stroke Patients: A Clinical Study | Stroke | 22 | 55.36 ± 8.6 | Telerehab | Italy | Balance | single-group, pre-post- and 12-week f/u |
| **Brachman** | 2021 | The Effects of Exergaming Training on Balance in Healthy Elderly Women-A Pilot Study | Elderly Women | 13 | 70.2 | Research Lab | Poland | Balance | single-group pre-, mid-training, post- |
| **Brachman** | 2021b | Biomechanical measures of balance after balance-based exergaming training dedicated for patients with Parkinson's disease | Parkinson's Disease | 24 CR: 12; VR: 12 | CR: 65.3.8 ± 9.2 VR: 69.5 ± 7.2 | Research Lab | Poland | Balance | two-group, pre-post- |
| **Cacau** | 2013 | The use of the virtual reality as intervention tool in the postoperative of cardiac surgery | Post-operative Cardiac Surgery | 60 CR: 30; VR: 30 | CR: 52 ± 2.4 VR: 49.2 ± 2.6 | Hospital | Brazil | Gait | two-group pre-, 2 mid-training, post-RCT |
| **Calabrò** | 2020 | Improving motor performance in Parkinson's disease: a preliminary study on the promising use of the computer assisted virtual reality environment (CAREN) | Parkinson's Disease | 22 | 66 ± 4 | Medical Research Lab | Italy | Balance & Gait | single group, pre-post- and 3-month f/u, within-subjects |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Cannell** | 2018 | The efficacy of interactive, motion capture-based rehabilitation on functional outcomes in an inpatient stroke population: a randomized controlled trial | Stroke | 73<br>CR: 40; VR: 39 | CR: 74.8 ± 11.9<br>VR: 72.8 ± 10.4 | Two Subacute Rehab Hospitals | Australia | Balance & Gait | Two-group, pre-post- RCT |
| **Cho** | 2014 | The Effects of Virtual Reality-based Balance Training on Balance of the Elderly | Healthy Elderly | 32<br>CG: 15; VR:17 | CG: 71.7 ± 1.2<br>VR: 73.1 ± 1.1 | Not Reported | Korea | Balance | Two-group, pre-post- RCT |
| **Cho** | 2012 | Virtual-reality balance training with a video-game system improves dynamic balance in chronic stroke patients | Chronic Stroke | 22<br>CR: 11; VR: 11 | CR: 63.13 ± 6.87<br>VR: 65.26 ± 8.35 | Stroke Rehab Unit | Korea | Balance | Two-group, pre-post- RCT |
| **Cikajlo** | 2020 | Multi-Exergames to Set Targets and Supplement the Intensified Conventional Balance Training in Patients With Stroke: A Randomized Pilot Trial | Stroke | 20<br>CR: 10; VR: 10 | CR: 51.8 ± 15.48<br>VR: 50.3 ± 7.9 | Rehab facility | Slovenia | Balance | Two-group, pre-post- RCT |
| **Collado-Mateo** | 2017 | Exergames for women with fibromyalgia: a randomised controlled trial to evaluate the effects on mobility skills, balance and fear of falling | Women with Fibromyalgia | 76<br>CG: 35; VR: 41 | CG: 52.58 ± 9.42<br>VR: 52.43 ± 9.83 | University Lab | Spain | Balance & Upright Mobility | Two-group, pre-post- RCT |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **de Melo** | 2018 | Effect of virtual reality training on walking distance and physical fitness in individuals with Parkinson's disease | Parkinson's Disease | 37 CR: 12; TT: 13; VR: 12 | CR: 65.58 ± 13.04 TT: 61 ± 10.72 VR: 60.25 ± 9.28 | Parkison's Association | Brazil | Gait | Three-group, pre-, 2 mid-training, post- RCT |
| **Feng** | 2019 | Virtual Reality Rehabilitation Versus Conventional Physical Therapy for Improving Balance and Gait in Parkinson's Disease Patients: A Randomized Controlled Trial | Parkinson's Disease | 28 CR: 14; VR: 14 | CR: 66.93 ± 4.64 VR: 67.47 ± 4.79 | Rehab Clinic | China | Balance & Gait | Two-group, pre-post- RCT |
| **Ferraz** | 2018 | The Effects of Functional Training, Bicycle Exercise, and Exergaming on Walking Capacity of Elderly Patients With Parkinson Disease: A Pilot Randomized Controlled Single-blinded Trial | Parkinson's Disease | 37 CR: 22; Cycling: 20; VR: 20 | CR: 71; Cycling: 67; VR: 67 | Public Outpatient Clinic for Elderly | Brazil | Gait | Three-group, pre-, post- RCT |
| **Gagliardi** | 2018 | Immersive Virtual Reality to Improve Walking Abilities in Cerebral Palsy: A Pilot Study | Cerebral Palsy | 16 | 11 ± 2.4 | Medical research lab | Italy | Gait | single-group, pre-post- |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Gandolfi** | 2017 | Virtual Reality Telerehabilitation for Postural Instability in Parkinson's Disease: A Multicenter, Single-Blind, Randomized, Controlled Trial | Parkinson's Disease | 70<br>CR: 34; VR: 36 | CR: 69.84 ± 9.41<br>VR: 67.45 ± 7.18 | Telerehab | Italy | Gait & Balance | two-group, pre-post- and 1-month f/u RCT |
| **Garcia** | 2013 | Vestibular rehabilitation with virtual reality in Ménière's disease | Meniere's Disease Vestibular Disorder | 44<br>CG: 21; VR: 23 | CG: 47.9 VR: 47.65 | Vestibular Clinic | Brazil | Balance | two-group, pre-post- RCT |
| **Gianola** | 2020 | Effects of early virtual reality-based rehabilitation in patients with total knee arthroplasty: A randomized controlled trial | Post-Total Knee Replacement | 85<br>CR: 41; VR: 44 | CR: 66.6 ± 8.7<br>VR: 70.7 ± 8.5 | Inaptient Rehab Facility | Italy | Upright Mobility | Two-group, pre-post- RCT |
| **Gonçalves** | 2014 | Effects of using the nintendo wii fit plus platform in the sensorimotor training of gait disorders in Parkinson's disease | Parkinson's Disease | 15 | 68.7 ± 10.2 | Movement Disorder Clinic | Brazil | Gait | single-group, pre-post- |
| **Gutiérrez** | 2013 | A telerehabilitation program by virtual reality-video games improves balance and postural control in multiple sclerosis patients | Multiple Sclerosis | 47<br>CR: 23; VR: 24 | CR: 42.78 ± 7.38<br>VR: 39.69 ± 8.13 | Telerehab | Spain | Balance | Two-group, pre-post- |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Hadamus** | 2021 | Assessment of the Effectiveness of Rehabilitation after Total Knee Replacement Surgery Using Sample Entropy and Classical Measures of Body Balance | Post-Total Knee Replacement | 42 CR: 21; VR: 21 | CR: 68 ±7.73 VR: 69 ±4.76 | Rehab facility | Poland | Balance | Two-group, pre- post- RCT |
| **Holmes** | 2013 | The Effects of a Home-Based Virtual Reality Rehabilitation Program on Balance Among Individuals with Parkinson's Disease | Parkinson's Disease | 11 | 66.64 | Home | Canada | Balance | single group, pre-, training, post- |
| **Ibrahim** | 2016 | Efficacy of virtual reality-based balance training versus the Biodex balance system training on the body balance of adults | Healthy Adults | 30 BBSG: 15; VR: 15 | BBSG: 44.4 ±7.3 VR: 39.1 ± 6.4 | University Research Center | Egypt | Balance | Two-group, pre- post- RCT |
| **Jelsma** | 2013 | The effect of the Nintendo Wii Fit on balance control and gross motor function of children with spastic hemiplegic cerebral palsy | Cerebral Palsy | 14 | 11.36 ± 1.82 | School System | - | Balance | Multiple-subjects, repeated mesaures with multiple baselines |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **dos Santos Junior** | 2019 | Combining Proprioceptive Neuromuscular Facilitation and Virtual Reality for Improving Sensorimotor Function in Stroke Survivors: A Randomized Clinical Trial | Stroke | 40<br>PNF: 15;<br>PNF/VR: 14<br>VR: 11 | PNF: 58.2 ±7.7<br>PNF/VR: 52.7 ± 13.3<br>VR: 55.5 ± 9.6 | Outpatient Clinic | Brazil | Gait & Balance | Three-group, pre-post- RCT |
| **Kalron** | 2016 | The effect of balance training on postural control in people with multiple sclerosis using the CAREN virtual reality system: a pilot randomized controlled trial | Multiple Sclerosis | 30<br>CR: 15; VR: 15 | CR: 43.9 ± 10.6<br>VR: 47.3 ± 9.6 | Multiple Sclerosis Center | Israel | Balance | two-group, pre-post- RCT |
| **Kaminska** | 2018 | The effectiveness of virtual reality training in reducing the risk of falls among elderly people | Elderly | 23 | 75.74 ± 8.09 | Social welfare institution | Poland | Upright Mobility | single-group, pre-post- |
| **Karasu** | 2018 | Effectiveness of Wii-based rehabilitation in stroke: A randomized controlled study | Stroke | 23<br>CR: 11; VR: 12 | CR: 64.1 ± 12.2<br>VR: 62.3 ± 11.79 | Rehab facility | Turkey | Balance | two-group, pre-post- and 1-month f/u RCT |
| **Khalil** | 2018 | The development and pilot evaluation of virtual reality balance scenarios in people with multiple sclerosis (MS): A feasibility study | Multiple Sclerosis | 32<br>CR: 16; VR: 16 | CR: 34.87 ± 8.98<br>VR: 39.88 ± 12.75 | Research Lab | Jordan | Balance | two-group, pre-post- RCT |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Kim** | 2013 | Unsupervised virtual reality-based exercise program improves hip muscle strength and balance control in older adults: a pilot study | Older Adults | 32<br>CG: 14; VR: 18 | CG: 68.28 ± 3.74<br>VR: 66.21 ± 3.87 | Research Lab | Korea | Balance | two-group, pre-post- RCT |
| **Kim** | 2015 | Effects of virtual reality programs on balance in functional ankle instability | Functional Ankle Instability | 20<br>VR1: 10; VR2: 10 | 23.3 ± 2.4 | Not Reported | Korea | Balance | two-group, pre-post RCT |
| **Kim** | 2019 | Comparison of virtual reality exercise versus conventional exercise on balance in patients with functional ankle instability: A randomized controlled trial | Functional Ankle Instability | 21<br>CR: 11; VR: 10 | 21.0 ± 1.2 | Not Reported | Korea | Balance | two-group, pre-post RCT |
| **Kim** | 2015b | Effects of community-based virtual reality treadmill training on balance ability in patients with chronic stroke | Chronic stroke | 17<br>CR: 7; VR: 10 | Not Reported | Not Reported | Korea | Balance | two-group, pre-post- |
| **Kiper** | 2020 | Functional changes in the lower extremity after non-immersive virtual reality and physiotherapy following stroke | Stroke | 59<br>Subacute: 31<br>Chronic: 28 | Sub: 60.02 ± 17.58<br>Chronic: 60.59 ± 11.14 | Neuro Rehab Center | Italy | Gait & Balance | two-group, pre-post- |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Lee** | 2015 | Effects of virtual reality-based training and task-oriented training on balance performance in stroke patients | Stroke | 24<br>TO: 12; VR: 12 | TO: 49.16 ± 12.85<br>VR: 45.91 ± 12.28 | Hospital | Korea | Balance | two-groups, pre-post- |
| **Lee** | 2019 | Speed-Interactive Pedaling Training Using Smartphone Virtual Reality Application for Stroke Patients: Single-Blinded, Randomized Clinical Trial | Stroke | 42<br>CG: 21; VR: 21 | CG: 64.24 ± 10.83<br>VR: 61.67 ± 8.42 | Hospital | Korea | Gait | two-groups, pre-post- RCT |
| **Lee** | 2020 | Virtual Reality Gait Training to Promote Balance and Gait Among Older People: A Randomized Clinical Trial | Elderly Fallers | 56<br>TT: 28; VRTT: 28 | TT: 79.47 ± 6.15<br>VRTT: 81.01 ± 6.89 | Senior Welfare Center | Korea | Gait & Balance | two-groups, pre-post- RCT |
| **Lee** | 2015b | Effect of virtual reality dance exercise on the balance, activities of daily living, and depressive disorder status of Parkinson's disease patients | Parkinson's Disease | 20<br>CR: 10; VR: 10 | CR: 70.1 ± 3.3<br>VR: 68.4 ± 2.9 | Not Reported | Korea | Balance | two-groups, pre-post- RCT |
| **Lee** | 2013 | Effectiveness of virtual reality using video gaming technology in elderly adults with diabetes mellitus | Diabetes Mellitus | 55<br>CG: 28; VR: 27 | CG: 74.29 ± 5.20<br>VR: 73.78 ± 4.77 | Senior Welfare Center | Korea | Gait & Balance | two-groups, pre-post- RCT |

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| **Liao** | 2015 | Virtual Reality-Based Training to Improve Obstacle-Crossing Performance and Dynamic Balance in Patients With Parkinson's Disease | Parkinson's Disease | 36 CG: 12; TE: 12; VR: 12 | CG: 64.6 ± 8.6 TE: 65.1 ± 6.7 VR: 67.3 ± 7.1 | Not Reported | Taiwan | Balance | Three-group, pre-post- RCT |
| **Lima Rebêlo** | 2021 | Immersive virtual reality is effective in the rehabilitation of older adults with balance disorders: A randomized clinical trial | Older Adults w/ balance disorders | 37 CR: 17; VR: 20 | CR: 71.41 ± 5.94 VR: 69.25 ± 5.67 | Rehab Clinic | Brazil | Balance | two-groups, pre-post- and 2-month f/u RCT |
| **Lloréns** | 2013 | BioTrak virtual reality system: effectiveness and satisfaction analysis for balance rehabilitation in patients with brain injury | Brain Injury | 10 | 41.6 ± 15 | Gymnasium | Spain | Balance | single-group, pre-post- and 1 month f/u |
| **Lloréns** | 2015 | Improvement in balance using a virtual reality-based stepping exercise: a randomized controlled trial involving individuals with chronic stroke | Chronic Stroke | 20 CR: 10; VR: 10 | CR: 55.0 ± 11.6 VR: 58.3 ± 11.6 | Outpatient Neurorehabilitation unit | Spain | Balance | Two-group, pre-post- RCT |

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| **Luna-Oliva** | 2013 | Kinect Xbox 360 as a therapeutic modality for children with cerebral palsy in a school environment: a preliminary study | Cerebral Palsy | 11 | 7.91 ± 2.77 | School System | Spain | Gait & Balance | single-group, pre- post- and 2 month f/u |
| **Malik** | 2017 | Effects of virtual reality training on mobility and physical function in stroke | Stroke | 10 | 50.2 ± 7.67 | Hospital | Pakistan | Upright Mobility | single-group, pre- post- |
| **McEwen** | 2014 | Virtual reality exercise improves mobility after stroke: an inpatient randomized controlled trial | Stroke | 59<br>CR: 29; VR: 30 | CR: 66.0 ± 15.8<br>VR: 62.2 ± 14.1 | Stroke Rehab Unit | Canada | Upright Mobility | Two-group, pre- post- and 1-month f/u RCT |
| **Meldrum** | 2015 | Effectiveness of conventional versus virtual reality-based balance exercises in vestibular rehabilitation for unilateral peripheral vestibular loss: results of a randomized controlled trial | UVL Vestibular Disorder | 71<br>CR: 36; VR: 35 | CR: 50.47 ± 15.53<br>VR: 57.83 ± 13.6 | Hospital | - | Balance | Two-group, pre-, 8-week and 6-month f/u RCT |
| **Micarelli** | 2019 | Vestibular rehabilitation in older adults with and without mild cognitive impairment: Effects of virtual reality using a head-mounted display | UVH Vestibular Disorder Older Adults vs. MCI | 47<br>CR Older Adults: 12; CR MCI: 12; VR Older Adults: 11; VR MCI: 12 | CR Older Adults: 74.3 ± 4.7<br>CR MCI: 72.5 ± 3.6<br>VR Older Adults: 76.9 ± 4.7<br>VR MCI: 76.3 ± 5.5 | Clinic & Home | Italy | Balance | Two-group, stratified pre- post- |

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| **Morone** | 2016 | Wii Fit is effective in women with bone loss condition associated with balance disorders: a randomized controlled trial | Women with Bone Loss | 38<br>CR: 19; VR: 19 | CR: 70.05 ± 4.93<br>VR:67.8 ± 2.98 | Hospital | Italy | Balance | Two-group, pre-post-, 3-month f/u RCT |
| **Nuic** | 2018 | The feasibility and positive effects of a customised videogame rehabilitation programme for freezing of gait and falls in Parkinson's disease patients: a pilot study | Parkinson's Disease | 10 | 64.2 ± 6.1 | Rehab facility | France | Gait | single-group pre-, training, post- and 3 month f/u |
| **Ortiz-Gutiérrez** | 2013 | A telerehabilitation program improves postural control in multiple sclerosis patients: a Spanish preliminary study | Multiple Sclerosis | 47<br>CR: 23; VR: 24 | CR: 42.78 ± 7.38<br>VR:39.69 ± 8.13 | Telerehab | Spain | Balance | two-group, pre-post- RCT |
| **Park** | 2015 | The effects of virtual reality game exercise on balance and gait of the elderly | Elderly | 24<br>CR: 12; VR: 12 | CR: 65.2 ± 7.9<br>VR: 66.5 ± 8.1 | Not Reported | Korea | Balance | two-group, pre-post- RCT |
| **Pazzaglia** | 2020 | Comparison of virtual reality rehabilitation and conventional rehabilitation in Parkinson's disease: a randomised controlled trial | Parkinson's Disease | 51<br>CR: 26; VR: 25 | CR: 70 ± 10<br>R:72 ± 7 | Parkinson's Disease Centers | Italy | Gait & Balance | two-group, pre-post- RCT |

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| **Pedreira da Fonseca** | 2017 | Therapeutic Effect of Virtual Reality on Post-Stroke Patients: Randomized Clinical Trial | Stroke | 30<br>CR: 15; VR: 15 | CR: 50.9 ± 10.9<br>VR: 53.8 ± 6.3 | Empty Room | Brazil | Gait & Balance | two-group, pre-post- RCT |
| **Peri** | 2019 | Motor Improvement in Adolescents Affected by Ataxia Secondary to Acquired Brain Injury: A Pilot Study | Brain Injury-induced Ataxia | 11 | 16 ± 5 | Not Reported | Italy | Gait & Balance | single-group, pre post- |
| **Phu** | 2019 | Balance training using virtual reality improves balance and physical performance in older adults at high risk of falls | Older Adults w/ Fall Risk | 195<br>CG: 50; CR: 82; VR: 63 | CG: 79; CR: 76; VR: 63 | Short-term Rehab | Australia | Balance | Three-group, pre post- |
| **Punt** | 2017 | Effect of Wii Fit™ exercise therapy on gait parameters in ankle sprain patients: A randomized controlled trial | Ankle Sprains | 90<br>CG: 30; CR: 30; VR: 30 | CG: 33..5 ± 9.5<br>CR: 34.7 ± 11.3<br>VR: 34.7 ± 10.7 | Home | Switzerland | Balance | Three-group, pre-post- and 6-montl f/u RCT |
| **Rajaratnam** | 2013 | Does the Inclusion of Virtual Reality Games within Conventional Rehabilitation Enhance Balance Retraining after a Recent Episode of Stroke? | Stroke | 19<br>CR: 9; VR: 10 | CR: 65.33 ± 9.59<br>VR: 58.67 ± 8.62 | Inaptient Rehab Facility | Singapore | Balance | Two-group, pre-post- RCT |
| **Rendon** | 2012 | The effect of virtual reality gaming on dynamic balance in older adults | Older Adults | 40<br>CG: 20; VR: 20 | CG: 83.3 ± 6.2<br>VR: 85.7 ± 4.3 | Outpatient Clinic | US | Balance | Two-group, pre-post- RCT |

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| **Rodrigues** | 2018 | Effects of Dance Exergaming on Depressive Symptoms, Fear of Falling, and Musculoskeletal Function in Fallers and Nonfallers Community-Dwelling Older Women | Older Women Fallers and Non-Fallers | 47 VR fallers: 10 VR Non-fallers: 12 CG fallers: 12 CG non-fallers: 13 | VR Fall: 69.8 ± 4.3 VR Nofall: 68.9 ± 3.3 CG Fall: 73.6 ± 5.4 CG Nofall: 68.7 ± 4.8 | Not Reported | Brazil | Upright Mobility | Two-group, stratified pre- post- |
| **Rosiak** | 2018 | Evaluation of the effectiveness of a Virtual Reality-based exercise program for Unilateral Peripheral Vestibular Deficit | Peripheral Vestibular Disorders | 50 CR: 25; VR: 25 | CR: 45.2 ± 11.07 VR: 46.48 ± 10.6 | Balance Disorders Unit | Poland | Balance | two-group, pre- post- |
| **Sadeghi** | 2021 | Effects of 8 Weeks of Balance Training, Virtual Reality Training, and Combined Exercise on Lower Limb Muscle Strength, Balance, and Functional Mobility Among Older Men: A Randomized Controlled Trial | Older Men | 64 CR: 14; VR: 15; Mix: 14; CG: 15 | CR: 70.4 ± 4.3 VR: 74.1 ± 7.0 Mix: 70.5 ± 5.1 CG: 72.2 ± 7.2 | Not Reported | Malaysia | Balance & Upright Mobility | Four-group, pre- post- RCT |
| **Salem** | 2012 | Effectiveness of a low-cost virtual reality system for children with developmental delay: a preliminary randomised single-blind controlled trial | Children with Developmental Delay | 40 CR: 20; VR: 20 | (months) CR: 48.0 ± 5.8 VR: 49.3 ± 5.6 | Preschool | US | Upright Mobility | Two-group, pre- post- RCT |

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| **Santos** | 2019 | Efficacy of the Nintendo Wii combination with Conventional Exercises in the rehabilitation of individuals with Parkinson's disease: A randomized clinical trial | Parkinson's Disease | 41 CR: 14; VR: 13; CR+VR:14 | CR: 61.7 ± 9.8 VR: 61.7 ± 7.3 CR+VR: 66.6 ± 8.2 | Neuro Department of Medical Facility | Brazil | Gait, Balance, Upright Mobility | Three-group, pre-post- RCT |
| **Sengupta** | 2020 | Role of Virtual Reality in Balance Training in Patients with Spinal Cord Injury: A Prospective Comparative Pre-Post Study | Spinal Cord Injury | 33 CR: 12; CR+VR:21 | CR: 30.5; VR: 28 | Hospital | India | Balance | Two-group, pre-post- |
| **Severiano** | 2018 | Effect of virtual reality in Parkinson's disease: a prospective observational study | Parkinson's Disease | 16 | 57.5 ± 18.7 | Not Reported | Brazil | Balance | Single-group, pre-post- |
| **Shema** | 2017 | Improved mobility and reduced fall risk in older adults after five weeks of virtual reality training | Older adults | 34 | 74.51 ± 10.51 | VR Clinic | Israel | Gait & Balance | Retrospective |
| **Shema** | 2014 | Clinical experience using a 5-week treadmill training program with virtual reality to enhance gait in an ambulatory physical therapy service | Adults who attended the Gait rehabilitation clinic as referred by their physician | 60 | 72.18 ± 10.39 | VR Clinic | Israel | Gait & Balance | Retrospective |

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| **Singh** | 2013 | Effects of balance-focused interactive games compared to therapeutic balance classes for older women | Stroke | 28 CR: 13; CR+VR:15 | CR: 67.0 ± 8.4 CR+VR: 65.4 ± 9.8 | Two Stroke Rehab Center | Malaysia | Upright Mobility | two-group, pre-post- |
| **Singh** | 2013b | Effects of substituting a portion of standard physiotherapy time with virtual reality games among community-dwelling stroke survivors | Older Women | 36 CR: 18; VR:18 | CR: 64 ± 5.88 VR: 61.12 ± 3.72 | Senior Citizens' Club | Malaysia | Balance | two-group, pre-post- |
| **Song** | 2015 | Effect of virtual reality games on stroke patients' balance, gait, depression, and interpersonal relationships | Stroke | 40 Ergometer: 20; VR:20 | Erg: 50.1 ± 7.83 VR: 51.37 ± 40.6 | Not Reported | Korea | Gait & Balance | two-group, pre-post- RCT |
| **Tarakci** | 2016 | Effects of Nintendo Wii-Fit® video games on balance in children with mild cerebral palsy | Cerebral Palsy | 30 CR: 15; VR:15 | CR: 10.53 ± 2.79 VR: 10.46 ± 2.69 | Pediatric Outpatient Clinic | Turkey | Balance | two-group, pre-post- RCT |
| **Tefertiller** | 2019 | Results From a Randomized Controlled Trial to Address Balance Deficits After Traumatic Brain Injury | Brain Injury | 63 CR: 32; VR:31 | CR: 49.5 ± 12.4 VR: 48.1 ± 12.4 | Home | US | Balance | two-group, pre-training post- and 3-month f/u RCT |
| **Tsang** | 2016 | Virtual reality exercise to improve balance control in older adults at risk of falling | Older Adults | 79 CR: 40; VR:39 | CR: 82 ± 4.3 VR: 82.3 ± 3.8 | Nursing Home | China | Balance | two-group, pre-post- RCT |

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| **Valiani** | 2017 | A New Adaptive Home-based Exercise Technology among Older Adults Living in Nursing Home: A Pilot Study on Feasibility, Acceptability and Physical Performance | Older Adults | 12 | 80.5 ± 4.2 | Nursing Home | US | Upright Mobility | single-group, pre-post- and 3-month f/u |
| **van Dijsseldonk** | 2018 | Gait Stability Training in a Virtual Environment Improves Gait and Dynamic Balance Capacity in Incomplete Spinal Cord Injury Patients | Incomplete Spinal Cord Injury | 10 | 59 ± 12 | Medical Clinic | The Netherlands | Gait & Balance | single-group, assessment at 2nd, 3rd, 12th session and 6-month f/u |
| **Villiger** | 2013 | Virtual reality-augmented neurorehabilitation improves motor function and reduces neuropathic pain in patients with incomplete spinal cord injury | Spinal Cord Injury | 14 | 52.7 | Not Reported | Switzerland | Upright Mobility | Single-group, pre-baseline, baseline, post- and 12-16 week f/u |
| **Villiger** | 2017 | Home-Based Virtual Reality-Augmented Training Improves Lower Limb Muscle Strength, Balance, and Functional Mobility following Chronic Incomplete Spinal Cord Injury | Incomplete Spinal Cord Injury | 12 | 60 ± 10.2 | Home | Switzerland | Gait, Balance, Upright Mobility | Single-group, pre-baseline, baseline, post- 2-3 month f/u |

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| **Wüest** | 2014 | Usability and Effects of an Exergame-Based Balance Training Program | Elderly | 13 | 76.5 ± 5.4 | Not Reported | Switzerland | Balance | Single-group, pre-post- |
| **Xu** | 2021 | A Depth Camera–Based, Task-Specific Virtual Reality Rehabilitation Game for Patients With Stroke: Pilot Usability Study | Stroke | 22<br>CR: 11; VR:11 | CR: 52.82 ± 12.29<br>VR: 57.55 ± 14.22 | Hospital | China | Gait | Two-group, pre-post- |
| **Yang** | 2016 | Home-based virtual reality balance training and conventional balance training in Parkinson's disease: A randomized controlled trial | Parkinson's Disease | 23<br>CR: 12; VR:11 | CR: 75.4 ± 6.3<br>VR: 72.5 ± 8.4 | Home | Taiwan | Balance | Two-group, pre-post-, 2-week f/u RCT |
| **Yeh** | 2014 | Interactive 3-dimensional virtual reality rehabilitation for patients with chronic imbalance and vestibular dysfunction | Vestibular Disorder | 49 | 63 ± 16 | Not Reported | Taiwan | Balance | Single-group, pre-post- |
| **Yom** | 2015 | Effects of virtual reality-based ankle exercise on the dynamic balance, muscle tone, and gait of stroke patients | Stroke | 20<br>CG: 10; VR:10 | CR: 78.1<br>VR: 64.6 | Rehab Hospital | Korea | Gait & Balance | two-group, pre-post- |
| **Yousefi Babadi** | 2021 | Effects of virtual reality versus conventional balance training on balance of the elderly | elderly | 36<br>CR: 12; CG: 12; VR:12 | CR: 67.5 ± 3.1<br>CG: VR: 66.7 ± 3.2<br>VR: 66.5 ± 3.8 | Nursing Home | Iran | Balance | three-group, pre-post- RCT |

APPENDIX H: SUMMARY OF FINDINGS OF INCLUDED STUDIES

| First Author | Pub year | Intervention | Int. Length | Days/week | Duration (min) | VR hardware | VR software | Relevant Measures | Finding | Provided Cited Rationale for Intervention? |
|---|---|---|---|---|---|---|---|---|---|---|
| **Afridi** | 2018 | VR | 7 weeks | - | 30 | Nintendo Wii & Balance Board | Wii Fit Plus | BBS, TUG, FRT | Overall mean improvements on BBS, TUG and FRT | No |
| **Alahmari** | 2014 | VR vs. CR | 6 weeks | 1 | 60 | mutli-projection screens integrated with treadmill | Custom VR grocery store | DGI, FGA, gait speed, TUG, SOT | Significant improvement in DGI, FGA, gait speed and SOT for VR group. No significant between group differences for functional | Yes |
| **An** | 2018 | VR | 6 weeks | 3 | 30 | IREX | IREX-available programs | LOS, BBS, TUG, WISCI-II | Significant improvement in OLOS, TUG score | Yes |
| **Anson** | 2018 | VRTT vs. TT | 4 weeks | 3 | 30 | TV screen integrated with treadmill | Custom Target and cursor integrated with sensors on participant's trunk | BBS, BESTest, mBESTest, 6MWT | Significant improvement on BESTest and mBESTest for VR group | No |
| **Bang** | 2016 | VR vs. TT | 8 weeks | 3 | 40 | Nintendo Wii & Balance Board | Wii Fit | Pedoscan, Smart Step | Significant improvement in balance for both groups, significant difference between groups for balance in favor of VR group, significant improvement in gait for VR group. | No |
| **Bellomo** | 2020 | VR | 4 weeks | 3 | at least 15 | WeReha (tablet and bluetooth inertial sensors) | WeReha software with interactive games | BBS, FM | Significant improvement in BBS and FM at post-test and remained stable at f/u | No |
| **Brachman** | 2021 | VR | 4 weeks | 3 | 30 | WeReha (tablet and bluetooth inertial sensors) | WeReha software with interactive games | Quiet standing, LOS, FBT | Significant improvement in LOS and FBT | No |
| **Brachman** | 2021b | VR vs. CR | 4 weeks | 3 | 30 | Kinect sensors integrated with force platform and projected on a screen | Custom created games | Quiet standing, LOS, FBT | Significant improvements in static balance in both groups. Significant improvement in LOS and FBT in the VR group only. | Yes |
| **Cacau** | 2013 | VR+CR vs. CR | Varied | 2x/day | - | Not stated | Not stated | 6MWT | Greater improvement in 6MWT in VR group | Yes |

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| **Calabrò** | 2020 | VR vs. CR within subjects | 5 weeks | 4 | 40 | CAREN | CAREN | BBS, TUG, 10MWT | Significant improvement in clinical masures following both CR and VR, however greater magnitude and retention at 3-month f/u only after VR | No |
| **Cannell** | 2018 | VR+CR vs. CR | up to 8 weeks | 2x/day | up to 60 | JRS | JRS Wave | Functional Reach, Step Test, Gait Velocity, TUG | Improvement functional outcomes, although not significant. No difference between groups | No |
| **Cho** | 2014 | VR vs. no tx | 8 weeks | 3 | 30 | Nintendo Wii & Balance Board | Wii Fit | Rhomberg measured on Bio-rescue | Improvement in COP excursions measured during Rhomberg eyes open and eyes closed in VR group only | No |
| **Cho** | 2012 | VR+CR vs. CR | 6 weeks | 1 | 30 | Nintendo Wii & Balance Board | Wii Fit | COP, BBS, TUG | Significant improvement in BBS and TUG in both groups with significant greater improvement in VR group vs. control | No |
| **Cikajlo** | 2020 | VR+CR vs. CR | 1 week | 5 | 15 | REWIRE System; Kinect camera, Nintendo Wii balance board, LCD screen | REWIRE games | FSST, TUG, 10mWT, ROM, STOLL, STORL, sROM, CTSIB | Significant improvement in favor of VR group on FSST and 10mWT. Significant difference between groups in sROM and STORL wih eyes closed | Yes |
| **ollado-Mateo** | 2017 | VR vs. no tx | 8 weeks | 2 | 60 | Microsoft Kinect, computer screen | VirtualEx-FM | TUG, Functional Reach Test, CTSIB | Significant improvement in TUG, CTSIB condition eyes closed on unstable surfaces, and functional reach test. Significant difference between groups in favor of VR group. | No |
| **de Melo** | 2018 | CR vs. TT vs. VR Gait Training | 4 weeks | 3 | 20 | Xbox Kinect, projector screen | Your Shape - Fitness Evolved 2012 - Run the World game | 6MWT, gait speed, symmetry index | Improvement in 6MWT and gait speed in both VR and TT groups compared to CR. | Yes |

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|---|---|---|---|---|---|---|---|---|---|---|
| **Feng** | 2019 | VR vs. CR | 12 weeks | 5 | 45 | Not stated | Not stated | BBS, TUG, FGA | Significant improvement in functional outcomes in both groups with significant difference between groups in favor of VR group. | No |
| **Ferraz** | 2018 | CR vs. Cycle vs. VR | 8 weeks | 3 | 50 | Xbox Kinect | Kinect Adventures | 6MWT, 10mWT, SRT | Significant improvement in 6MWT, 10mWT, and SRT in all groups with no significant difference between groups | Yes |
| **Gagliardi** | 2018 | VR | 4 weeks | 5 | 30 | GRAIL | D-flow | GMFM88, 6MWT, gait analysis on GRAIL | Significant improvement in GMFM-88, gait speed, stride length and 6MWT. | No |
| **Gandolfi** | 2017 | CR vs. VR telerehab | 7 weeks | 3 | 50 | Nintendo Wii & Balance Board | Wii Fit | BBS, 10MWT, DGI | Improvement in functional outcomes following training in both groups. Significant between-group difference in improvement on BBS in favor of VR group | No |
| **Garcia** | 2013 | VR vs. no rehab tx | 6 weeks | 2 | 45 | BRU System | BRU Modules | Posturography | Significant improvement in limits of stability seen in VR group | No |
| **Gianola** | 2020 | VR vs. CR | ~10 days | Daily | 60 | VRRS | VRRS-based exercises | Strenght of quadriceps and hamstrings, active ROM, proprioception via VRRS | Significant improvement in proprioception in favor of VR group. | No |
| **Gonçalves** | 2014 | VR | 7 weeks | 2 | 40 | Nintendo Wii | Wii Fit Plus | Motor sub-scale of UPDRS | Significant improvement in motor sub-scale of UPDRS | No |

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|---|---|---|---|---|---|---|---|---|---|---|
| **Gutiérrez** | 2013 | CR vs. VR telerehab | 10 weeks | 4 | 20 | Xbox 360 w/ Xbox Kinect via Videoconference | Kinect Sports, Joy Ride, Adventures | SOT, MCT, BBS, Tinetti | Significant betwee-group post-intervention improvement on composite equilibrium score of SOT, BBS and Tinetti in favor of VR group | Yes |
| **Hadamus** | 2021 | CR vs. CR+VR | 4 weeks | 3 | - | Balance plate integrated with Kinect 2 camera | Virtual Balance Clinic | COP displacement, COP path length, COP velocity, sample entropy | Improvement in COP linear measures in VR group, although not at leave of significance. | No |
| **Holmes** | 2013 | VR | 12 weeks | 3 | 30 | Nintendo Wii & Balance Board | Balance domain of Wii Fit Plus | COP length | Improvement in COPL from pre-testing to midtraining and decreased back toward baseline at post-testing, however this was a nonsignificant change | No |
| **Ibrahim** | 2016 | Biodex Balance Group vs. VR | 4 weeks | 3 | 15 | Nintendo Wii & Balance Board | Wii Fit Plus | Overall balance on Biodex Balance System | Signinficant improvement in overall balance in both groups without significant difference between groups. | No |
| **Jelsma** | 2013 | VR | 3 weeks | 4 | 25 | Nintendo Wii & Balance Board | Wii Fit | TUDS, RSA, Subtests 5 and 6 of BOT-2 | Singificant improvement in Balance subtest of BOT-2, and non-significant changes in RSA and TUDS | Yes |
| **dos Santos Junior** | 2019 | PNF vs. PNF/VR vs. VR | 8 weeks | 2 | 50 | Nintendo Wii | Wii Fit | FMA | Improvement on FMA in all groups without significant between-group differences. Significant improvement in lower limb motor performance on FMA only in VR group. | No |

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| **Kalron** | 2016 | VR vs. CR | 6 weeks | 2 | 30 | CAREN | D-flow | Instrumented Posturography, FRT, BBS, FSST | Both groups improved COPL and sway with eyes open, FST, and FSST. Significant between group difference on FST in favor of VR group. | Yes |
| **Kaminska** | 2018 | VR | 30 days | 3 | 30 | Xbox 360 & Kinect | Kinect Sports | 6MWT, DGI, TST TWT | Significant improvement in 6MWT, DGI, TST and TWT. | No |
| **Karasu** | 2018 | CR vs. VR+CR | 4 weeks | 5 | 20 | Nintendo Wii & Balance Board | Wii Fit | BBS, FRT, TUG, SBI on KAT | Significant improvement on BBS, FRT, A/P M/L COP with eyes open and closed, and weight shifting in favor of the VR group | No |
| **Khalil** | 2018 | home-basedCR vs. VR | 6 weeks | 2 | 1/level | Kinect sensors & Wii Balance Board | 6 VR scenarios developed in pre-study focus group | BBS, TUG, 10mWT, 3MWT | Improvements in funcitonal outcomes in both groups. Significant between-group difference on BBS in favor of VR group. | Yes |
| **Kim** | 2013 | VR vs. no tx | 8 weesk | 3 | 60 | Xbox 360 & Kinect | Your Shape Fitness Evolved - Zen | Hip muscle strength testing via dynamometer, backward step and crossover step test on force plate | Significant improvement in hip extensor, flexor, abductor and adductor strength and increased GRF in backward step and crossover step test in VR group. | Yes |

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| **Kim** | 2015 | VR1 Strength vs. VR2 balance | 4 weeks | 3 | 20 | Nintendo Wii & Balance Board | Wii Fit Plus | Static and Dynamic balance measured by Biodex Balance System | Significant improvement in M/L static balance and overall dynamic balance in VR1 Strength group. Significant improvement in A/P, M/L, and overall static balance and M/L and overall dynamic balance in VR2 Balance group. Significant between group differences on Overall static and dynamic balance in favor of VR2 balance group. | No |
| **Kim** | 2019 | VR vs. CR | 4 weeks | 3 | 20 | Nintendo Wii & Balance Board | Wii Fit Plus | Static and Dynamic balance measured by Biodex Balance System | Significant improvement in static and dynamic balance betweeng groups in favor of VR group. | No |
| **Kim** | 2015b | CR vs. CR+VRTT | 4 weeks | 3 | 30 | Video projector integrated with treadmill | Custom video scene with optic flow adjusted based on treadmill speed | COP on force plate | Significant improvement in COPL in A/P direction and total COPL in VRTT group | No |
| **Kiper** | 2020 | Subacute VR vs.. Chronic VR | 3 weeks | 5 | 60 | VRRS | VRRS-based exercises | FMLE, BBS, 10mWT, kinematic assessment in main axes of LE joints | Significant improvement in clinical and kinematic variables in subacute group, in clinical variables in chronic group, and no significant differences between groups. | Yes |

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|---|---|---|---|---|---|---|---|---|---|---|
| **Lee** | 2015 | VR+CR vs. TO+CR | 6 weeks | 3 | 30 | Nintendo Wii & Balance Board | Wii Fit Plus | COP on force plate, FRT | Static balance FRT improved significantly more in VR group than task-oriented (TO) group | No |
| **Lee** | 2019 | VR cycling +CR vs. Cycling +CR | 6 weeks | 5 | 40 | Speed-interactive stationary bike, TV screen | Smartphone app - Virtual Active | FMA, gait assessment via Optogait | FMA and gait assessment significantly better in VR group than control | No |
| **Lee** | 2020 | TT vs. VRTT | 4 weeks | 5 | 50 | Speed-interactive non-motorized treadmill, TV screen | Smartphone app - Virtual Active | One-leg standing test, BBS, FRT, TUG, gait assessment via Optogait | Significant improvement in TUG, and spatiotemporal gait parameters of velocity, step width, stride length and step length in VRTT group. | No |
| **Lee** | 2015b | CR vs. VR+CR | 6 weeks | 5 | 30 | Nintendo Wii | K-Pop Dance Festival | BBS | Significant improvement in balance in VR group after training and in comparison to CG. | No |
| **Lee** | 2013 | no tx vs. VR | 10 weeks | 2 | 50 | PlayStation 2 & EyeToy | EyeToy Play 1, 2,3 | One-leg standing test, BBS, FRT, TUG, STS, gait assessment via GAITRite | t in balance, improved STS anc | Yes |
| **Liao** | 2015 | no tx vs. TE. Vs. VR | 6 weeks | 2 | 45 | Nintendo Wii & Balance Board | Wii Fit Plus | Obstacle crossing performance, LOS test, SOT, TUG | Great improvement in obstacle crossing velocity, stride length, dynamic balance, SOT and TUG in VR than CG. Greater improvement in LOS movement velocity than TE group. | No |
| **Lima Rebêlo** | 2021 | VR vs. CR | 8 weeks | 2 | 8/game | Oculus Rift | Balance games in Oculus Rift library | DGI, CTSIB, TUG, FRT | Significant improvement in DGI and FRT in both CR and VR groups. Significant improvement in TUG in VR group. No significant between group differences. | Yes |

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|---|---|---|---|---|---|---|---|---|---|---|
| **Lloréns** | 2013 | VR vs. CR | 20 sessions | 3 to 5 | 20 | PC, panoramicc screen, tracking system, BioTrak | Balance games in BioTrak | BBS, Tinetti, posturography | Significant improvement in BBS, Tinetti, and A/P weight shifting control, and gains remained at 1-month f/u | No |
| **Lloréns** | 2015 | CR vs. CR+VR | 4 weeks | 5 | 60 | Computer, video display, motion tracking, 3D audio | Custom VE with participant's feet mapped into the VE and were used to reach for targets. | BBS, gait & balance sub-scales of Tinetti, Brunel Balance Assessment, 10mWT | Significant improvement in BBS and 10mWT in both groups. Significant between group difference on these measures in favor of VR group. | No |
| **Luna-Oliva** | 2013 | VR | 8 weeks | 2 | 30 | Xbox 360 & Kinect | Kinect Sports I, Kinect Joy Ride, Kinect Disneyland Adventures | AMPS, PRT, 10mWT, GMFM | Significant improvement in all functional variables from pre- to post-training and pre- to 2-month f/u. Non-significant difference in functional variables from post-training to 2-month f/u. | No |
| **Malik** | 2017 | VR vs. CR | 6 weeks | 3 | 15 | Xbox 360 & Kinect | 20,000 water leaks, riv | FMA-LE, TUG | Improvement in FMA-LE and TUG from pre- to post-training | No |
| **McEwen** | 2014 | CR+ non-balance VR vs. CR+ balance VR | 3 weeks | 10-12 sessions | 30 | IREX | IREX-available programs | TUG, 2MWT, Chedoke McMaster Stroke Assessment Scale Leg domain | Improvements in both groups following training. Both groups met MCID on TUG and 2MWT following training with effect sizes favoring the group perform standing balance VR tasks. | No |

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| **Meldrum** | 2015 | VR vs. CR | 6 weeks | 5 | 15 | Wii Fit & Balance Board + Frii Board | Wii Fit Plus | Self-preferred gait speed, gait parameters and SOT | Improvements in both groups following training with no significant difference between groups in gait speed or SOT score. No significant difference between groups on functional outcomes at 6-month f/u. | Yes |
| **Micarelli** | 2019 | VR vs. CR | 4 weeks | 7 | 30-45 | 5.2'' phone display in Revelation HMD | Track Speed Racing 3D game | DGI | Significant improvement in DGI in both CR and VR groups. VR older adults significantly higher improvement in DGI than CR Older Adults, CR MCI and VR MCI. VR MCI group had significant greater improvement in DGI than VR Older Adults | Yes |
| **Morone** | 2016 | VR vs. CR | 8 weeks | 2 | 60 | Wii Fit & Balance Board | Wii Fit | BBS | Significant improvement in BBS in both groups with higher scores in VR group | No |
| **Nuic** | 2018 | CR + VR | 6 weeks | 18 sessions | 15-40 | TV screen and computer integrated with Kinect sensors | Custom "Toap Run" game | Gait kinematics via foce plate, Motor scale of UPDRS, GABS | Significant improvement in gait parameters following training including increased step length and gait velocity and decreased double-stance time. Increase in step length and velcoity persisted after 3 months. | No |

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| **Ortiz-Gutiérrez** | 2013 | VR vs. CR | 10 weeks | 2 | 40 | Xbox 360 & Kinect | Kinect Sports, Joy Ride, Adventures | SOT | Improvement in overall balance in both groups. Significant difference in improvement in visual preference and vestibular contribution in favor of VR group | No |
| **Park** | 2015 | VR vs. CR | 8 weeks | 3 | 30 | Nintendo Wii & Balance Board | Wii Fit balance games: Soccer Heading, Snowboard Slalom, Table Tilt | 30s sway length and average sway speed, TUG | Significant improvement in static balance and TUG in both groups. Significant difference between groups in sway length in favor of VR group. | No |
| **Pazzaglia** | 2020 | VR vs. CR | 6 weeks | 3 | 40 | NIRVANA & motion analysis equipment | NIRVANA exercises | BBS, DGI | Significant improvement in BBS and DGI in VR group, greater improvement than CR group. | No |
| **Pedreira da Fonseca** | 2017 | VR vs. CR | 3 months | 20 sessions | 60 | Nintendo Wii | Wii Fit: tennis, soccer, boxing | DGI | Improvement in DGI in VR group, significant improvement in DGI in CR group. No significant between group differences. | No |
| **Peri** | 2019 | CR+VR | 1 month | 20 sessions | 45 | GRAIL | GRAIL games tailored to each patient | SARA, GMFM-88, 6MWT, BBS, gait analysis via GRAIL | Significant improvement on SARA motor domains, walking and balance abilities post-training | No |
| **Phu** | 2019 | CR vs. VR vs. CG w/ no tx | 6 weeks | 2 | 30 | BRU System | BRU Modules | 5STS, TUG, gait speed, posturography via BRU | Both CR and VR groups improved on gait and balance assessments, and LOS posturography significantly over CG. Only VR group improved static balance posturography. | Yes |

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| **Punt** | 2017 | CR vs. VR vs. CG w/ no tx | 6 weeks | 2 | 30 | Nintendo Wii & Balance Board | Wii Fit | Gait speed, temporal-spatial gait parameters, ankle kinematics | Improvement in all groups for gait speed, cadence and step length from pre- to post-training. Single-limb support time only improved in VR group, however no between-group differences seen for temporal-spatial gait parameters. | No |
| **Rajaratnam** | 2013 | VR vs. CR+VR | - | 15 sessions | 20 | Nintendo Wii & Xbox Kinect | Games associated with each console | FRT, TUG, BBS, COP, MBI | Significant improvement in TUG, FRT and MBI in VR group. Significant improvement in TUG and MBI in CR group. Significant improvement between groups on FRT in favor of VR group. | No |
| **Rendon** | 2012 | VR vs. no tx | 6 weeks | 3 | 35-45 | Nintendo Wii | Wii Fit | 8-ft up & go | Significant improvement in 8-ft up & go test compared to CG | No |
| **Rodrigues** | 2018 | VR fall/non vs. No tx fall/non | 12 weeks | 3 | 40 | Xbox 360 & Kinect | Dance Central Game | Concentric and eccentric isokinetic peak torque of quadriceps and hamstrings and muscle bulk, TUG, gait speed, 5STS | VR non-fallers significantly increased hamstring peak torque over other groups. No other significant differences between groups. | Yes |
| **Rosiak** | 2018 | VR vs. CR | 2 weeks | 10 sessions | 30 | Motion sensors, force plate and display | 2 VR games requiring COP excursion to accomplisht the target task | Posturography | Significant improvement in posturography in both groups, but without significant differene between groups. | No |

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| **Sadeghi** | 2021 | CR vs. VR vs. Mix vs. CG | 8 weeks | 3 | 40 | Xbox 360 & Kinect | Xbox Sports games: The Light Race, Target Kick, Goalkeeper | Isokinetic muscle strength, SLS on firm and foam surfaces, tandem stance, TUG, 10mWT | Mix group (VR+CR) had greater improvement in strength, balance and functional measures compared to CR, VR and CG. VR group improved more than CR and CG on balance and functional mobility. CR demonstrated better balance and functional mobility than CG. | No |
| **Salem** | 2012 | VR vs. CR | 10 weeks | 2 | 30 | Nintendo Wii | Wii Sports and Wii Fit | Gait speed, TUG, SLS test, 5STS, time up & down stairs, 2MWT, grip strength, GMFM | Both groups demonstrated improvements in functional outcomes. Significant improvement in SLS in VR group over CR group. | No |
| **Santos** | 2019 | CR vs. VR vs. CR + VR | 2 months | 2 | VR: 40 CR+VR: 20 | Nintendo Wii & Balance Board | Wii Fit and Wii Sports | BBS, TUG, DGI | Significant improvement in funcitonal outcomes in all groups without significant differences between groups. Greater effect sizes demonstrated by CR+VR group. | No |
| **Sengupta** | 2020 | CR vs. CR+VR | 3 weeks | 5 | 30 | Rhetoric VR | Rhetoric Games | BBS, balance section of Tinetti, and FRT | Significant improvements in functional outcomes in both groups post-training, however no significant betwee-group differences | No |

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| **Severiano** | 2018 | VR | 10 weeks | 2 | 50 | Nintendo Wii & Balance Board | Wii Fit: Soccer Heading, Table Tilt, Tightrope Walk and Ski Slalom | BBS, SRT | Significant improvement in SRT after treatment. Improvement in BBS after treatment. Significant changes in functional capacity related to Tightrope Walk and Ski Slalom game. | No |
| **Shema** | 2017 | VR+TT | 5 weeks | 3 | 60 | Projector screen and LED diodes on participants' shoes | Outdoor scene with obstacles | Gait speed, FSST, TUG | Significant improvement in gait speed, TUG and FSST after treatment. | No |
| **Shema** | 2014 | VR+TT | 5 weeks | 3 | 60 | Projector screen and LED diodes on participants' shoes | Outdoor scene with obstacles | Gait speed, TUG, 2MWT, FSST | Significant improvement in gait speed, TUG and FSST after treatment. | No |
| **Singh** | 2013 | CR vs. VR+CR | 6 weeks | 2 | 30 | Nintendo Wii & Balance Board, Xbox 360 & Kinect | Balance Bubble on Wii Fit Plus, Rally Ball on Kinect | TUG, 30sSTS, 10mWT, 6MWT, Static Balance Ability via Probalance Board, Barthel Index | Significant improvement in TUG and 30sSTS. No significant difference between groups. | No |
| **Singh** | 2013b | VR vs. CR | 6 weeks | 2 | 40 | Nintendo Wii & Balance Board | Wii Fit: Ski Slalom, Table Tilt, Penguin Slide, Soccer Heading, Tight Rope Walk, Perfect 10 and Tilt City | Ten Step Test, Posture Sway, TUG | Both groups improved postural sway, TST, and TUG with significant difference between groups on TUG. | No |
| **Song** | 2015 | Ergometer vs. VR | 8 weeks | 5 | 30 | Xbox Kinect | Kinect Sport, Kinect Season 2, Kinect Adventure, Kinect Gunstringer | Posturography, TUG, 10mWT | Both groups demonstrated significant improvement in posturography and balance ability. | No |

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| **Tarakci** | 2016 | VR+CR vs. CR | 12 weeks | 2 | 50 | Nintendo Wii & Balance Board | Wii Fit | FFRT, FSRT, TUG, STST, 10mWT, 10 SCT | Significant improvement in balance scores in both groups. Significant improvement in all balance tests in VR group compared to CR group. | No |
| **Tefertiller** | 2019 | CR HEP vs. VR HEP | 12 weeks | 3 to 4 | 30 | Xbox Kinect | Kinect Games | Community Balance & Mobility Scale, BESTest | No significant between group differences on CB&M or BESTest, however both groups improved significantly on these tests from baseline to post-intervention to 12-week f/u. | No |
| **Tsang** | 2016 | VR vs. CR | 6 weeks | 3 | 60 | Nintendo Wii | Wii Fit: Soccer Heading, Table Tilt, Balance Bubble | BBS, TUG, LOS | Significant improvement in BBS, TUG, and maximal LOS excursions in all four directions in the VR group. VR demonstrated significantly better improvement on BBS than CR. | No |
| **Valiani** | 2017 | VR | 4 weeks | 2 | 30 | Jinxtronix, TV screen, Kinect camera | Jintronix Wave | Short Physical Performance Battery | Significant improvement in SPPB post-training and at 3-month f/u | Yes |
| **van Dijsseldonk** | 2018 | VR | 6 weeks | 12 sessions | 60 | GRAIL | D-flow | 2MWT, spatiotemporal gait parameters, gait stability measures | Improvement in gait speed, stride length and postural stability measures in A/P direction following training. These improvements persisted at 6-month f/u. | No |

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| **Villiger** | 2013 | VR | 4 weeks | 16-20 sessions | 45 | Shoe sensor system adapted from YouGrabber | Custom developed games including Footbag, Hamster Splash, Star Kick, and Planet Drive | 10mWT, BBS, Muscle Strength, SCIM, gait parameters | Improvements noted in walking capacity, balance and lower extremity strength following training which persisted at f/u | No |
| **Villiger** | 2017 | VR | 4 weeks | 16-20 sessions | 30-45 | YouKicker, computer | Footbag, Hamster Splash, Get to the Game, Star Kick, Planet Drive | LEMS, TUG, BBS, 10mWT, WISCI II, SCIM | Singificant improvements in BBS, TUG and LEMS following training. Improvement in TUG persistent at 2-3month f/u. | No |
| **Wüest** | 2014 | VR | 12 weeks | 3 | 20 | Force platform and display | Five games integrated with force platform: Scarecrow, Tractor driver, Fruit cather, Worm Hurdler, Mix soup | BBS, TUG, SPPB, Posturography, gait analysis on GAITRite | Significant improvement in functional outcomes of BBS, TUG and SPPB. No changes in COP area in quiet stance or in walking parameters. | No |
| **Xu** | 2021 | CR vs. CR+VR RCT | 2 weeks | 5 | 30 | Monitor, PrimeSense 3D Awareness Sensor | Custom-created StompJoy | FMA-LE, MBI, BBS, SLS | Signifcant improvements in functional measures FMA-LE, MBI, BBS, and SLS in both groups. Significant between group difference only on SLS seen in VR group. | No |
| **Yang** | 2016 | VR vs. CR | 6 weeks | 2 | 50 | Computer, balance board | Developed by Cycling and Health Center of Taichun, Taiwan. Used COP to control virtual objects and perform tasks. | BBS, DGI, TUG, motor score of UPDRS | Improvements seen in both group son BBS, DGI, and TUG after training and at post-test f/u. No significant difference found between group. | No |

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| **Yeh** | 2014 | VR | 4 weeks | 6 sessions | - | 3D Glasses, Kinect, Wii Balance Board | Wii Fit | COP and balance indices including mean M/L & A/P excursion | Significant improvement in COP displacement and maximal mediolateral balance following training. | No |
| **Yom** | 2015 | VR vs. no tx | 6 weeks | 5 | 30 | Projector screen, computer, projector | Virtual-reality Ankle Exercise Program | TUG and gait analysis on GAITRite | Significant improvement in TUG and gait parameters in VR group following training and when compared to CG | No |
| **Yousefi Babadi** | 2021 | VR vs. CR vs. no tx | 9 weeks | 3 | 60 | Xbox Kinect | Kinect Sports 1and 2: Boxing, table tennis, soccer, golf, skiing, american football | SLS, FRT, TUG, FABS | Significant improvement in SLS, FRT, TUG and FABS in both CR and VR groups, but no significant difference between these groups | Yes |