4-2020

The effects of virtual rehabilitation therapy on multiple sclerosis

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HNR 499 Winter 2020

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Abstract:

In this review article, the effect of virtual rehabilitation therapy on multiple sclerosis, a neurodegenerative disorder, is explored. Multiple sclerosis is characterized by damaged nerves that result in incomplete signal processing between the brain and the spinal cord. The symptoms of this condition can include vision loss, decreased coordination, pain, fatigue, and deteriorating motor output. The severity of the symptoms and the rate of progression of multiple sclerosis can vary from person to person; some individuals live the majority of their lives with mild symptoms while others become bedridden and immobile. There is no cure for this disease, however implementation of virtual reality rehabilitation therapy shows promise in slowing the progression of deterioration in motor output and cognition. Through a variety of methods incorporating virtual reality, this review investigates the effects of this type of therapy on balance, manual dexterity, and mental health in patients with multiple sclerosis.

Contents:

1. Introduction

Multiple sclerosis (MS) affects over two million people worldwide and nearly one million people living in the United States alone suffer from this condition. The population most affected by MS are typically women over the age of eighteen. MS is a neurodegenerative disease characterized by the degradation of myelin in the white matter of the Central Nervous System (CNS). Myelin is the protective coating surrounding the axons of nerves that help facilitate the travel speed and containment of chemical signals within the nervous system. Without myelin, signals traveling from the CNS to the periphery are delayed or lost, resulting in decreased motor output of effector organs and muscles. The areas of the brain that experience degradation of myelin is the white matter, which constitutes the cerebral hemispheres, brainstem, cerebellum, spinal cord, and optic nerves. These regions of the brain control a multitude of functions such as cognition, metabolic regulation, balance, coordination, muscle movement, integration of various stimuli, and vision. Due to the vast assortment of brain areas affected, the symptoms of MS can range from mild to severe and the rate of progression can differ from person to person. However, the disease ultimately results in changes of motor activity, sensation, and vision. The symptoms often lead to weakness, tremors, imbalance, slowed gait, spasms, contracture, vision impairment, and overstimulation of nociceptors causing the sensation of pain. Multiple sclerosis can also slow cognitive functions, causing attention deficits and abnormal behavioral patterns. In 60%-80% of MS cases, the symptoms become chronic and progress over time, causing a degeneration in motor output and impaired cognition (6, 17, 21, 23).

The current treatments for multiple sclerosis are aimed at slowing the advancement of the disease, allowing for better quality of life via lengthening the time to be able to execute motor commands and control cognitive processes. A more recent method involving virtual reality therapy in treatment of multiple sclerosis has shown to be promising in not only increasing motor performance but also improving the mental condition of those suffering from the disease. Virtual rehabilitation helps provide motivation and promote self-efficacy in patients, leading to more positive psychological states and cushioning motor deficits. Table 1 summarizes a variety of experiments that found virtual rehabilitation (VR) to be effective as a therapeutic tool in neurodegenerative diseases (17).

Table 1
Shows the main studies concerning the effects of virtual reality training in people with multiple sclerosis.

Study	Design	Patients	Major findings
Russo M at al. 2018	Explorative Study	45 patients randomized into CG or EG	The study provides evidence that robotic rehabilitation coupled with two-dimensional VR may be a valuable tool in promoting functional recovery in patients with MS.
Stratton ME et al. 2015	Explorative Study	26 EG 19 CG	VR environment can be a safe and useful tool to improve the ability to perform daily activities, such as street-crossing, in people with MS
Robinson S et al. 2015	Explorative Study	56 MS patients	The study supports the use of Wii Fit™ as an effective mean of balance and gait training for people with MS.
Gutiérrez RO et. Al. 2013	Explorative Study	25 EG 25 CG	The authors suggest that the VR program could be a valid and effective alternative to conventional therapy.
Behrendt F et al., 2018	Explorative Study	75 patients (PD; MS; Stroke; TBI; GB)	The study examined the effectiveness of two new developed virtual software modules for the BMT training device.
Kramer A et al., 2014	Explorative Study	70 MS patients	The authors observed that exergames seem to be an effective method to improve balance and gait in patients with MS.
Eftekharsadat B et al., 2015	Pilot Study	30 MS patients	The study shows that the VR-based balance training program could improve the balance ability of patients with MS.
Thomas S et al. 2014	Pilot Study	30 MS patients	The study showed that the home-intervention physiotherapist supported by the Wii device (Mii-vitaliSe) is effective in increasing the levels of activity in MS patients.
Thomas S et al. 2017	Pilot Study	30 MS patients	The results suggest that the virtual reality instrument used (Mii-vitaliSe) is accepted by most of the participants and useful for the physiotherapists who provide it.
Leocani L et al., 2007	Pilot Study	12 EG	The results show that VR training has promising results on short-term motor learning.
Jonsdottir J et al.	Pilot Study	10 EG 6 CG	The authors showed that serious games with VR are perceived positively by patients, and there have been significant improvements in the functionality of the arms.
Ortiz-Gutierrez R et al. 2013	Pilot Study	25 EG 25 CG	The study showed that patients have improved processing and integration of sensory information, with positive impact on motor outcomes.
Kalron A et al. 2016	Pilot Study	16 EG 16 CG	The study showed that VR-based balance training (CAREN) is an effective method of balance training for patients with MS.
Peruzzi A et al. 2016	Pilot Study	8 EG	VR is feasible and safe for patients with MS with moderate disabilities, and can positively influence motor and cognitive aspects, such as dual tasking and obstacle negotiation.
Prosperini L et al. 2013	Pilot Study	36 MS patients	A home-based VR training could potentially provide a rehabilitation solution for effective, engaging balance for people with MS.
Brichetto G et al., 2013	Pilot Study	36 MS patients	The study highlights that interactive exercises with visual feedback, such as Wii, could be more effective than conventional treatment in improving balance disorders in MS.
Calabrò RS et al., 2017	Pilot Study	34 MS patients	The authors showed that robotic rehabilitation combined with VR in patients with chronic hemiparesis promotes improved gait and balance.
Lamargue-Hamel D et al. 2015	Pilot Study	30 MS patients	VR assessments are promising in identifying cognitive impairment in MS.

CG Control Group; EG Experimental Group; MS Multiple Sclerosis; VR Virtual Reality.

(17)

2. Treatment of Multiple Sclerosis

2.1 Current Treatments

While there are treatments available to those suffering from the effects of multiple sclerosis, there is no cure for the disease. Prescribed medications administered to patients with MS are geared to slow the progression of the symptoms, extending their life expectancy and maintaining a higher quality of life. Various immunosuppressors, immunomodulators, and corticosteroids are prescribed to MS patients in order to reduce the severity of present symptoms (17). People will often go through stages of experiencing mild symptoms only to relapse into periods of increasing severity. These medications also lead to suppression of the immune system, the body's natural defense system, increasing risk for infection and disease from invading pathogens. There is a necessity for development of alternative therapies in order manage symptoms of multiple sclerosis without compromising the body's ability to fight off bacterial and viral diseases. However, the goal of virtual rehabilitation is to re-direct the execution of motor and cognitive processes to promote performing activities of daily living (ADLs) through new strategies, rather than just prolonging the inevitable (5, 6, 14).

2.2 The Potential Benefits of Virtual Rehabilitation

Virtual rehabilitation is a modern approach to treating neurodegenerative diseases, such as MS. The utilization of this particular type of technology is mediated through different gaming systems, such as Nintendo Wii or Microsoft Kinect, and also through using other types of programs (21). Virtual rehabilitation is designed to expose the patient to a simulation of daily activities, such as walking or even execution of some sort of task, testing coordination or cognition. Unlike current medications, virtual rehabilitation provides realistic scenarios for accomplishing functional tasks that occur in everyday life. Access to medications can often be quite expensive, especially in the United States, and since this is a life-long condition, prescriptions would also be a life-long investment. VR, while it might be costly at first, could be a more affordable approach to treating the symptoms of MS (19, 21). VR also provides sensory feedback that helps the patient to receive intrinsic or extrinsic motivation to reward completion of a virtual assignment.

Patients not only see their progress but also formulate goals on their future physical and mental performance. Medications do not always yield apparent evidence as to whether or not they're effective; they also do not directly inspire a drive to attain certain objectives (13). In addition to providing motivators for physical and cognitive tasks, VR has also been seen to improve psychological states by providing a higher quality of life, improving mood, and reinforcing self-efficacy.

2.3 Effects of Virtual Rehabilitation Therapy on Balance

One of the most common symptoms present in the progression of MS is deficits in balance control. Unfortunately, this leads to an increased risk of falls and injuries, hindering accomplishment of daily activities. While physiotherapy is usually included in the treatment plan for patients with multiple sclerosis, it is not typically executed through the use of virtual reality. In contrast to regular physiotherapy techniques, VR helps to provoke more engagement and motivation in patients through a computer simulated achievement of levels and targets in unison with physiotherapy goals (6, 15).

The benefits of VR therapy compared to traditional physiotherapy were investigated in a study that focused on the improvement in balance of patients with MS. The goal of this study was to evaluate the feasibility and potential benefits of VR therapy on patients with multiple sclerosis. Participants were randomized into one of two groups: the intervention group or the control group. The intervention group experienced at home VR sessions while the control group underwent home-based exercises. Blinded assessors analyzed the balance deficits and limitations on motor ability in all participants prior to beginning their exercise regimes. The intervention group attended two visits per week to undergo their VR program under the supervision of a physiotherapist. After six weeks, both groups were analyzed and assessed by a physiotherapist in regard to fatigue and quality of life. The participants in the intervention group were tasked with six different scenarios: standing up from a chair, reaching to grab a virtual object while standing, shifting weight from one foot to another, rising on toes, squatting, and stepping over virtual objects. There were ten different levels for each of the tasks were achieved by increasing the speed of the game. The feasibility of the program was measured by adherence to the VR sessions, both with a physiotherapist and at home. 93.75% of the intervention group completed over 50% of their sessions resulting in a generalized conclusion that VR therapy is a feasible approach to treating MS (15).

The results of the study found that balance improved significantly in the intervention group compared to the control group (p=.012). The baseline measurements for the intervention group for the balance scale was 43.69(6.58) and after six weeks the scale measurements increased to 50.44(3.76). The control group began with a similar baseline at 42.31(10.82), however although control of balance was slightly enhanced to 45.19(8.64), balance increased significantly less compared to the intervention group. Evaluation of mental conditions also occurred throughout the study. Fatigue was measured in both the intervention group and the control group at the beginning of the experiment, 42.00(11.40) and 38.56(13.19) respectively. The intervention group reported feeling less fatigued, 31(11.50), compared to the control group, 43.31(12.62). Fatigue differed significantly in the intervention group compared to the control group (p=.008), with the incidence of fatigue decreasing in the group that experienced VR therapy (15).

The results of this study not only provided evidence supporting the feasibility of VR therapy but also that the participants benefited more from the intervention than the control in balance and fatigue. However, the sample size of the study was small, with only 16 participants finishing the study in each group. While the outcomes are positive regarding the effectiveness of VR, there is a need for further data and experimentation to fully encompass the benefits of virtual reality therapy.

Several other studies have tested the effects of virtual reality therapy on balance deficits in patients with MS. One study in particular used a specific type of VR through a computer assisted rehabilitation environment (CAREN). Figure 1 illustrates the set-up of CAREN, consisting of a motion platform and simulation projection.

Figure 1: Virtual reality therapy simulation using the CAREN system (14).

Participants with MS were separated into two groups: the intervention group receiving VR while the control group underwent conventional exercise regimes. Each person was randomly assigned to their groups and attended two physical therapy sessions for thirty minutes every week over the course of six weeks. Outcome measurements for balance were compiled before beginning the program and after six weeks when the physical therapy sessions using CAREN concluded. The intervention group experienced an increase in balance performance following the six weeks compared to the control group ($p=.009$) using the functional reach test (FRT). The participants in the intervention group also reported feeling more confident in their balance ability and felt less afraid of falling compared to the control group ($p=.021$) according to the results of the falls efficacy scale international (FES-I) questionnaire (14). Overall the results of this study provide evidence supporting the use of VR in the place of conventional exercise in patients with MS suffering from balance deficits.

2.4 Effects of Virtual Reality Therapy on Manual Dexterity

Multiple sclerosis affects a variety of motor functions, not just limited to balance, but also dexterity on manual skills. Manual dexterity refers to the ability to perform coordinated hand movements in order to pick up and move objects. The ability to perform manual skills, such as writing, buttoning a shirt, or placing keys into a car ignition are often activities that occur in daily life. Deficits in manual dexterity often affect one limb in the beginning but ultimately spread across both arms as the disease progresses. The upper limbs perform many movements to aid accomplishment of infinite tasks and without proper their proper functioning often lead to increased frustration and diminishing autonomy. 80% of MS patients usually suffer from dysfunctions in the motor ability of their hands after fifteen years of having the disease. These symptoms place limitations on the amount of independence MS patients feel that they have, which correlates with a reported decrease in quality of life (6, 13). Utilization of virtual rehabilitation could be a potential therapy for slowing the degeneration of dexterity capabilities as MS progresses.

Although arms play a pivotal role in everyday life, there haven't been very many studies focused on the rehabilitation of upper limbs. Most studies focus on providing therapy for the legs in order to lessen fall risks (13). A study designed an experiment geared to evaluate the effects of VR on manual skills and functional hand capacity in patients with MS. The intervention group received traditional physical therapy sessions incorporated with VR (OT+VR) while the control group underwent only conventional methods (OT). Each participant experienced two OT sessions every week, lasting for a duration of 30 minutes. In addition to conventional therapy, the OT+VR group experienced an additional 20 minutes of VR through an online website "motiongamingconsole.com". The intervention group and the control group attended 100% of these sessions over the course of ten weeks. Both the OT therapy and the VR focused on movement of the upper limbs, geared to evaluate the functionality of manual dexterity. VR therapy provided games through the website, providing execution of specific types of hand, wrist, elbow, and arm movements through virtual simulations such as Air Hockey, Counting Fish, Robo Maro, and DunkIt. The participants were instructed to remain seated in a chair and focus only on using both of their arms to accomplish the goals of the games; a timer was used to record the speed in order to generate feedback. The results of the study found that there was a significant difference between the intervention and the control group in moving objects with their non-dominate hands ($p=.036$), writing with their non-dominate hand ($p=.018$), and moving large light objects with their dominate hand ($p=.017$). Although this type of VR did not provide significant differences in the manual dexterity between the two groups, the improvement of the hand's functional capacity developed as a consequence of virtual reality therapy. However, the sample size of this experiment was low ($n=16$), leading to the conclusion that more experimentation would need to be done in order to draw more reliable resolutions regarding the effects of VR on manual dexterity (23).

Another study evaluated the effects on VR in patients with MS experiencing manual dexterity deficits. Each participant underwent analysis to determine the most affected arm using tests known as the box and block test (BBT) and the 9 hole peg test (9HPT). The BBT assesses the degree of deficits in the arms by recording the time it takes for the participant to grab, move, and release blocks in a certain amount of time. The 9HPT evaluates the limitations of manual dexterity by timing the participant's speed at which they can insert and remove 9 wooden pegs from a board. These scores provided a baseline for each arm prior to beginning treatment with VR using serious game scenarios. The arm that yielded the poorest results from the 9HPT was the limb used in VR. Kinect software was used to generate VR simulations in order to generate scenarios of grasping objects, moving objects, and avoiding other targets such as touching a flower surrounded by bees but being cautious not to interact with the bugs present. The goal of each game was to improve coordination, speed, reaction time, and spatial awareness.

There were a variety of different tasks, such as moving cans onto a shelf or moving a basket to collect objects that were falling, each with a varying level of difficulty. The player received points following each game to help provide feedback on their accomplishments and progress (13).

After the completion of VR therapy, the participants were evaluated again using the BBT and 9HPT. The velocity of hand movements using 9HPT improved significantly by 17% in the treated arm compared to the non-treated arm (p=.011) when compared to baseline values. However, the difference between the two arms were not significant (p=.407). After undergoing serious game rehabilitation, the participants were able to move more blocks compared to baseline analysis with both the treated arm and the non-treated arm. Only the treated arm yielded significant changes from baseline, resulting in an 18% increase in the number of blocks moved (p=.043) whereas the non-treated arm had a 10% increase (p=.12). Figure 2 represents the percent changes in the treated and non-treated arms using BBT and 9HPT tests before and after VR therapy (13).

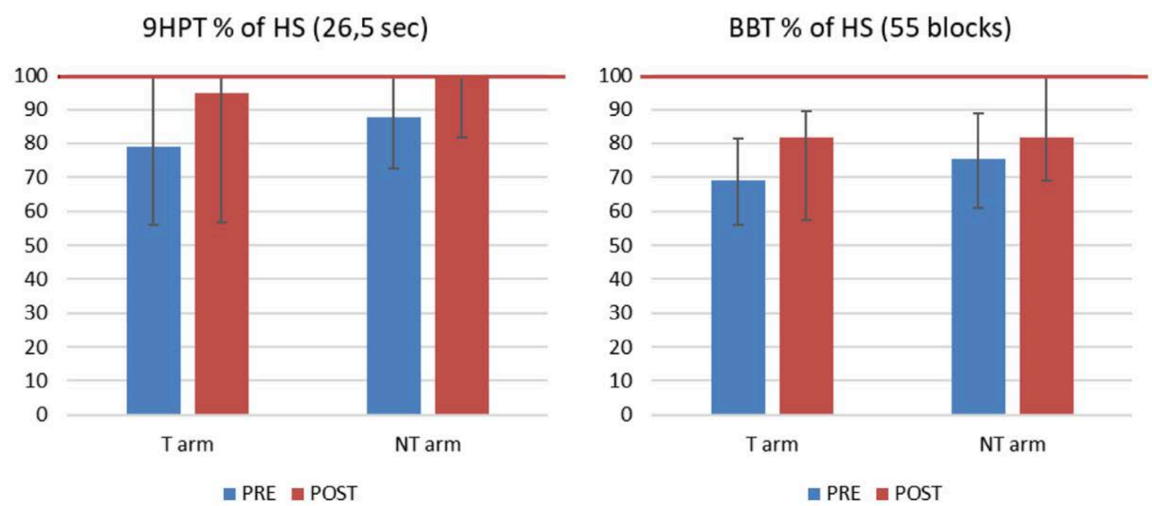

Figure 2: Percent differences in MS patient BBT and 9HPT scores before and after serious game therapy. (13)

Overall the results of this study indicate that manual dexterity and functionality are improved using VR in the form of serious game scenarios. The functionality and dexterity of the treated arm improved by 18% with a cross over effect of improving the non-treated arm's dexterity by 10% and functionality by 15%. The results of this study support the idea that VR is an efficient and safe method of therapy in MS patients suffering from deficits in manual dexterity and functionality. However, this study did not compare VR to conventional methods of physical therapy, nor did it have a control group, aside from the non-treated arm. Although the results of this study are promising, it's cannot be discerned whether or not VR would be a more efficient and effective form of therapy compared to conventional methods.

2.5 Effects of Virtual Rehabilitation Therapy on Mental Health

Quality of life in MS patients often declines due to the degenerative nature of the disease. Limitations on physical activity and cognitive lead exhibited in patient with MS facilitate the occurrence of fatigue, depression, and lack of motivation to engage in active forms of exercise (20). While traditional hospital or physical therapy visits can be beneficial to help alleviate the onset of these symptoms, it can be debilitating and stressful for patients who still work full time and/or take care of a family. The use of virtual rehabilitation at home can be a fun, efficient, and cost-effective method to engage in activity at home without having to travel to appointments.

One study tested the effects of implementing the Nintendo Wii gaming system as a form of VR therapy in the homes of patients with MS. Measurements for balance, gait, depression, anxiety, and self-efficacy at baseline, six months, and after twelve months were taken for each participant. The system used was a gaming software called, Mii-vitalSe, and the subjects of the trial were instructed to use it every day for twenty-seven minutes. According the questionnaires following six months and twelve months after baseline, the majority of participants reported improvements in physical activity, mood, sleep, and confidence coinciding with decreases in stress, pain, and fatigue. They also noticed that their motor ability at home improved in performing daily tasks such as lower rates of dropping small objects, getting in and out of the shower, becoming more in tune with the beat of music when dancing, general manual dexterity especially when reaching for door handles, and longer walking distances. The positive results of this VR gaming system also promoting more involvement in physical activities outside of the simulations. As the ability to be able to execute more motor functions and not suffer from obvious signs of the degenerative properties of MS, self-confidence and overall reports of quality of life increased in the majority of patients after using the Mii-vitalSe Wii game. Overall the results of this study indicate that the use of VR is beneficial in regard to improving quality of life by increasing self-confidence in MS patients (21).

While the primary focus of many studies has been improving motor output in MS patients, the majority of these studies have also investigated the development of increased mental health and quality of life in conjunction with physical deficits. Improvements in mental health significantly increased in intervention groups undergoing VR compared to control group's involvement in conventional therapy ($p=.01$). The intervention group also experienced reported increases in vitality, physical functioning, and bodily pain ($p=.009$, $p=.04$, $p=.03$) which are indications of higher quality of life (15). Additionally, the majority of participants expressed interest in continuing forms of VR therapy since they found it engaging, motivating, fun, and more practical than attending weekly sessions limiting leisure time spent with family or more enjoyable life activities (15, 19, 21, 23).

In conclusion of the effect of virtual rehabilitation on the quality of life in MS patients, VR improves overall self-confidence, leading to more motivation to engage in various forms of exercise. Mental and physical health improved with the incorporation of VR into daily routine, supporting the idea that virtual rehabilitation is a beneficial method for treatment of multiple sclerosis.

3. Analysis of Methods

The utilization of virtual rehabilitation therapy has provided positive results regarding improving deficits in motor ability and quality of life. However, there are some inconsistencies and disparities present throughout the various experiments testing the efficacy and effectiveness of virtual reality therapy in MS patients. Throughout many of the studies there have been small sample sizes, varying forms of VR, and different progression of MS that can all interfere with the accuracy of the results.

3.1 Sample Size

Throughout the majority of the studies, many began with a sample size of 20-30 participants. However, as the study progressed there were several withdrawals from the experiment for a variety of reasons. Some people withdrew from the study due to the worsening state of their condition, problems at home, and other non-disclosed factors (5, 12, 13, 15, 20, 21, 23). As a result, the sample sizes of these experiments are quite small, ranging between 16-30 finalized participants at the end of the studies. Although the results of the studies are positive, it is hard to generalize conclusions about the effects of virtual rehabilitation therapy on multiple sclerosis for larger populations. While VR might have been effective in alleviating motor deficits and improving quality of life, more experimentation using a larger sample size is necessary to garner more evidence to support these resolutions. The more data available on the subject of virtual reality therapy including a broader scope of multiple sclerosis patients, the more reliable and applicable the treatment will be. While there is significant data to support further exploration of this type of therapy, there are various forms of VR implemented throughout multiple studies that could skew the results.

3.2 Variation in Virtual Rehabilitation Strategies

Incorporation of VR technology differed between each study in both the system used and whether it took place at home or in a hospital type setting. The usage of VR was mediated through multiple forms of electronic software such as the Nintendo Wii, Microsoft Kinect, online websites or specially designed virtual simulations such as the CAREN system (13, 14, 15, 21, 23) . While each of these forms provided evidence supporting their effectiveness is motor abilities and cognitive functions such as balance, manual dexterity, and mental health, the variations in the technology could result in inconsistencies in the effectiveness of different technologies (2, 17). VR performed in a hospital setting could be documented, holding the participants accountable for engaging in their required exercise, however there are no records as to whether or not subjects actually adhered to those routines at home (15, 21). In the trials that included at home intervention strategies for MS patients, they were required to report how often they engaged in their VR programs, but there isn't any assurance that their accounts are reliable. Furthermore, every participant had a varying degree of symptoms and progression of MS, which could also cause discrepancies in the data.

3.3 Inconsistent Progression of Multiple Sclerosis

Multiple sclerosis progresses at different rates with varying degrees and onsets of symptoms. The characterization of MS depends on the appearance of symptoms and whether or not they are constant or random as certain regions of the CNS are affected by the disease. There are four different categorizations of MS: relapsing-remitting, primary-progressive, secondary-progressive, and progressive-recurrent. The most common form of multiple sclerosis is the relapsing-remitting type whereas progressive-recurrent has the lowest incidence in most MS cases (23). Relapse-remitting MS is characterized by experiencing temporary flare-up of symptoms, lasting from a few days to a few weeks, by remission, or disappearance, of the disease's manifestations. Primary-progressive MS occurs when symptoms appear slowly and steadily without causes sudden flare-ups or reverting to remission stages. Secondary-progressive MS is like primary-progressive, however there may be incidences of flare-ups and remission stages of the disease. As many as 50% of relapse-remitting progress to this form of MS. The rarest form of MS, progressive-recurrent, is indicated by the steady worsening progression of the symptoms with the onset of occasional flare-up but no remission from the signs of illness (6). The differences in MS could influence the results of the study. Although there was significant improvement in a multitude of tasks, perhaps these occurred during remission stages of the disease. Additionally, in the areas of the experiments where there were no significant findings, perhaps this was because of relapses in symptoms and not the true efficiency of virtual rehabilitation therapy.

4. Potential Use of VR in Other Diseases

Since the evidence regarding VR therapy has demonstrated positive effects in patients with MS, perhaps this form of treatment could be incorporated into other realms of the medical field. VR could be useful for treating other pathological conditions, especially different forms of neurodegenerative diseases, not limited to multiple sclerosis. There are a variety of different conditions that affect the neuropathways of the CNS producing limitations in motor ability and cognitive functions. Virtual reality therapy could be applied to different neurodegenerative conditions such as stroke, Parkinson disease, and cerebral palsy.

4.1 Stroke

In the United States, over 800,000 people experience a cerebrovascular accident (CVA) every year. Cerebrovascular accidents, more commonly referred to as a stroke, result in the death of brain tissue as a consequence of inhibited blood flow to the brain. A stroke can be caused by a blood clot or a ruptured artery and can provoke a variety of symptoms depending on the area of the brain that was affected. A large amount of the population suffers from the aftermath of CVAs, causing a necessity for therapies to be available to help regain as much functionality as possible. The effects of stroke can lead to similar impairment caused by MS on motor ability and mental capacity, initiating deficits in balance, gait, walking, manual dexterity, and cognition. If the use of VR is effective on MS, then it could potentially help in treating the ramifications of undergoing a cerebrovascular accident (9, 10, 22).

Independence and quality of life are often compromised by the devastating effects that strokes can have on the human population. VR therapy has been used on stroke victims as way to help regenerate ability to execute motor movement. One study in particular focused on stroke patients suffering from upper limb limitations as a result of CVA and the capability for VR to alleviate the symptoms. Participants were required to exhibit partial paralysis on one side of their body (hemiparesis) in addition to being mentally sound enough to undergo the therapy and have experienced a stroke sometime within the previous six months. Baseline analysis occurred to record their motor performance prior to beginning the intervention strategies. The subjects were separated into experimental and control groups. Both cohorts experienced conventional therapy five days a week over a four-week period, while the experimental group also underwent VR using Microsoft Kinect software. This particular system required active movement of the upper arm in order to complete various simulations such as Mouse Mayhem, Traffic Control, and Balloon Buster. The results of the study showed that both groups significantly increased their motor output ability in their upper arm ($p<.001$). However, the experimental group experienced a significantly higher increase in motor ability compared to the control group ($p=.04$). Overall, the results of this study indicate that virtual rehabilitation is a beneficial source of treatment for individuals enduring the impact of cerebrovascular accidents (1).

4.2 Parkinson Disease

Parkinson disease (PD) is the second most common neurodegenerative disease characterized by the decay of part of the basal ganglia in the brain called the substansia nigra (11). This region of the brain is responsible for the release of a particular neurotransmitter called dopamine. As these tissues deteriorate, the release of dopamine decreases resulting in an onset of symptoms such as tremors, rigidity, slowed movement, postural alterations, cognitive decline and depression. The cause of PD is unknown and the current treatments available are various forms of medication and deep brain stimulation (4, 16, 24). However, both of these methods are geared to inhibit the occurrence of symptoms rather than cure the condition. Experimentation with VR therapy in PD patients has shown promise in alleviating symptoms and providing positive outcomes.

The purpose of a particular type of virtual reality system, Leap Motor Control (LMC), was used to evaluate the effective of VR on upper limb (UL) motor control in PD patients. The games were designed to improve muscle grip strength, coordination, and speed of both fine and gross motor movements. Participants were randomly assigned into the intervention group, receiving LMC therapy, or the control group which underwent conventional physical therapy for upper limbs. The LMC sensor was designed to evaluate and record hand movements in response to a variety of simulated environments. Figure 3 represents the different games simulated using LMC technology.

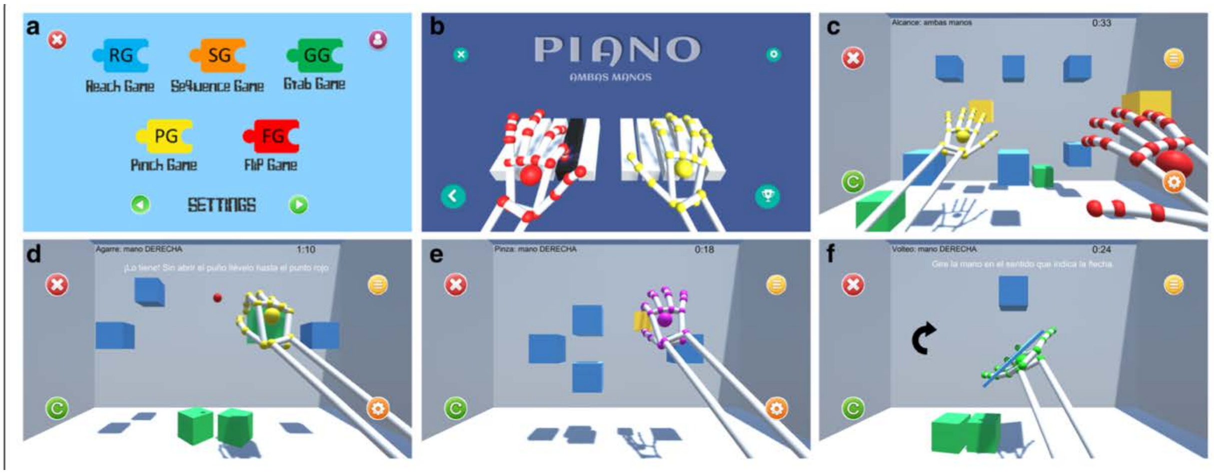

Figure 3: Leap motor control serious game simulations for PD patients using Microsoft Kinect software. (11)

After accomplishing various tasks, the participant received a score, the higher the score the greater the performance. Baseline measurements of performance were taken before the study began by using Jamar, BBT, and the Purdue Pegs Test (PPT) in order to provide indication as to whether or not improvement occurred in motor output after the conclusion of the experiment. While both groups improved significantly over the course of the trial, there were only two areas where the intervention group improved more than the control group. The intervention group yielded significantly higher results when performing PPT on the affected side and PPT assembly after the treatment concluded ($p=.036$, $p=.006$) when compared to the control group. Table 2 indicates the results of the study comparing the differences between the experimental and control groups.

Table 2: Comparison of experimental and control group scores in Jamar, BBT, and PPT outcomes in PD patients. Significance defined as p<.05. (11)

Variable			Median (Interquartile range)		p-value
			Experimental group	Control group	
Pre	Jamar	More affected	14.66 (9.00)	18.66 (14.66)	.648
		Less affected	19.33 (15.67)	20.00 (11.50)	1.000
	BBT	More affected	42.00 (23.00)	39.00 (17.50)	.424
		Less affected	46.00 (26.00)	48.00 (16.00)	.909
	PPT	More affected	8.00 (4.33)	8.66 (3.67)	.819
		Less affected	9.00 (5.00)	10.00 (3.50)	.879
	PPT both hands		8.66 (3.33)	10.66 (7.67)	.447
	PPT assembly		12.66 (13.66)	14.66 (7.67)	.790
Post	Jamar	More affected	27.33 (17.33)	19.66 (12.83)	.087
		Less affected	26.33 (28.00)	24.00 (9.67)	.210
	BBT	More affected	46.00 (12.00)	45.00 (8.50)	.381
		Less affected	49.00 (13.00)	49.00 (11.00)	.518
	PPT	More affected	12.33 (8.33)	9.66 (3.00)	.036*
		Less affected	11.66 (5.00)	10.50 (2.50)	.447
	PPT both hands		10.33 (8.00)	12.00 (6.33)	.879
	PPT assembly		23.66 (13.67)	16.00 (4.17)	.006*

The results of this study indicate that VR is an effective strategy for providing therapy for PD patients. However, no conclusions can be drawn to determine if VR is more effective than conventional therapy in improving upper limb dexterity in Parkinson disease. VR provides a potential method for facilitating advancement in motor movement in people who suffer from PD, but more experimentation is needed to derive the extent at which this form of treatment can alleviate the symptoms of this neurodegenerative disease.

4.3 Cerebral Palsy

The number one cause of childhood physical disability is the incidence of cerebral palsy (CP). This type of disease damages different parts of the developing brain depending on the case, resulting in a various degree of symptoms. Ultimately, CP causes issues with motor function, sensation, perception, cognition, and communication. Muscle weakness, spasms, struggle in maintaining posture and changing physical positions, limitations on walking and mobility may all occur as a result of the manifestations of CP. Much like PD, MS, and stroke there is no cure for this condition, only medications and physical therapy are present to keep the symptoms at bay. The use of virtual reality therapy in children with CP has shown promise mitigating the symptoms of this disease (7, 8).

There was a study that tested the effects of VR on children with cerebral palsy using Microsoft Kinect for the PC. Children were randomly assorted into two different groups both receiving traditional occupational therapy regime, but the experimental group also incorporated additional virtual reality strategies. The dynamic occupational cognitive assessment for children (DOTCA-Ch) was used to evaluate the mental capacity of children with CP before and following the conclusion of VR therapy. The duration of the therapies lasted for ten weeks, involving a total of sixteen forty-five-minute VR sessions. The VR games provided were Jet Run, a racing game, Boxing trainer, a game with punching goals, Air challenge, an air diving game, and Superkick, a shootout game.

These four different simulations tested for a variety of skills such as visual-spatial abilities, perception, reaction time, praxis, cognition, and visuomotor construction. The results of the study found that while both groups enhanced their cognitive functions significantly, the intervention cohort improved significantly more than the control group. Table 3 summarizes the differences between the two cohorts after completion of the trial (3).

Table 3: Comparisons of changes in the dynamic occupational therapy cognitive assessment for children with cerebral palsy. (3)

DOTCA-Ch	Study group (X ± SD)	Control group (X ± SD)	*P* value
Orientation	0.63 ± 0.11	0.59 ± 1.03	0.044[a]
Spatial perception	1.27 ± 0.32	0.51 ± 1.09	0.0001[b]
Praxis	1.82 ± 0.32	0.9 ± 0.23	0.0001[b]
Visuomotor construction	4.92 ± 0.74	2.62 ± 0.18	0.0001[b]
Thinking operations	1.82 ± 0.97	1.59 ± 1.15	0.036[a]

Dotca-Ch, The Dynamic Occupational Therapy Cognitive Assessment for Children.
[a] $P < 0.05$.
[b] $P < 0.01$

The effects of VR on children with CP provided significant increases in cognitive ability compared to conventional methods. However, this was only one study therefore making it unwise to draw conclusions on VR based solely on this clinical trial. Virtual rehabilitation therapy provides promising benefits in treating the cognitive symptoms of cerebral palsy by increasing the capacity for orientation, spatial perception, praxis, visuomotor construction, and thinking operations.

5. Evaluation of Virtual Rehabilitation Therapy

Overall, the results of virtual rehabilitation therapy are promising as a potential therapy for neurodegenerative disorders such as multiple sclerosis, Parkinson disease, cerebral palsy, and stroke. However, whether or not it is more effective than standard methods remain to be discovered. There is some evidence supporting the idea that VR helps to provide more intrinsic motivation to be active and therefore result in improved condition of symptoms, but there is not a substantial amount of data to support those generalized ideas. The small sample sizes of the studies along with the varying manifestations of MS and the diverse assortment of technology bring about inconsistencies in the efficacy of VR in neurodegenerative disorders.

While VR can be a more cost-effective, motivational, and time-saving method it would not be advised to eradicate all other forms of treatment such as medications and conventional therapy strategies. Virtual reality therapy is effective in improving balance deficits, manual dexterity, and cognitive function in MS patients however it is still not a cure for this disease.

6. Future Directions

Virtual rehabilitation therapy provides a method to treat a variety of different disorders in addition to medications and conventional strategies. The extent at which VR can be used has yet to be discovered. While the implementation of virtual reality therapy improves the mental capacities and motor functions of individuals suffering from neurodegenerative diseases, supplementary experiments should be performed to test the effectiveness of VR on other conditions. This type of therapy provides motivational factors as well as incorporation of fun compared to traditional techniques, which helps to increase the involvement of patients in their therapeutic sessions. Perhaps this type of technique could be used in spinal cord injuries or even mental illnesses such as depression or anxiety. In MS patients the simulations increased self-confidence levels; people suffering from cognitive diseases often experience low confidence and self-esteem and could benefit from VR. The range of issues virtual reality therapy could potentially bolster is unknown and therefore should be explored further in the future.

7. Conclusion

Overall, the effects of virtual rehabilitation therapy on multiple sclerosis are positive and significantly help improve the conditions of people suffering from both mental and physical deficits as a result of the disease. While VR is by no means a cure for this condition, the implementation of virtual reality therapy could help postpone the progressive severity of symptoms until a remedy for MS is discovered.

The medications prescribed to alleviate the appearance of symptoms are often costly and the physical therapy required takes up a lot of time and money as well, especially for adults who are probably trying to work and care for a family. VR could be a decent alternative to conventional treatments if someone cannot afford the modern strategies or needs to free up their time in their schedule in order to attend their job and manage the needs of their loved ones. Doing something, even if it’s just VR, is better than nothing at all. However, more experimentation on larger sample sizes is necessary in order to provide more consistent and clear resolutions on the true effectiveness of VR.

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