2014

Effectiveness of commercial video gaming on fine motor recovery in chronic stroke within community-level rehabilitation

Kathleen C. Paquin
University of Windsor

EFFECTIVENESS OF COMMERCIAL VIDEO GAMING ON FINE MOTOR RECOVERY IN CHRONIC STROKE WITHIN COMMUNITY-LEVEL REHABILITATION

By

Kathleen C. Paquin

A Thesis
Submitted to the Faculty of Graduate Studies
Through the Faculty of Human Kinetics
In Partial Fulfillment of the Requirements for
the Degree of Master of Human Kinetics at the
University of Windsor

Windsor, Ontario, Canada

Effectiveness of commercial video gaming on fine motor recovery in chronic stroke within community-level rehabilitation

by

Kathleen C. Paquin

APPROVED BY:

J. Crawley
Faculty of Nursing

C. McGowan
Faculty of Human Kinetics

S. Horton, Advisor
Faculty of Human Kinetics

Date of Defense: December 13th, 2013

STATEMENT OF ORIGINALITY

I hereby certify that I am the sole author of this thesis and that no part of this thesis has been published or submitted for publication.

I certify that, to the best of my knowledge, my thesis does not infringe upon anyone's copyright nor violate any proprietary rights and that any idea, techniques, quotations, or any other material from the work of other people included in my thesis, published or otherwise, are fully acknowledged in accordance with the standard referencing practices. Furthermore, to the extent that I have included copyrighted material that surpasses the bounds of fair dealing within the meaning of the Canada Copyright Act, I certify that I have obtained written permission from the copyright owner(s) to include such material(s) in my thesis and have included copies of such copyright clearances to my appendix.

I declare that this is a true copy of my thesis, including any final revisions, as approved by my thesis committee and the Graduate Studies office, and that this thesis has not been submitted for a higher degree to any other University of Institution.

Abstract

Introduction: Chronic stroke survivors often live with persisting upper extremity deficits that affect their daily life, and are traditionally offered little rehabilitation. Commercial gaming can act as a motivating way to complete rehabilitation.

Purpose: To investigate the effectiveness of commercial gaming as an intervention for fine motor recovery in chronic stroke.

Methods: Ten chronic phase post-stroke participants completed a 16-session program using the Nintendo Wii for 15 minutes 2x/week with their more affected hand. Measures used at four testing sessions included: Jebsen Hand Function Test (JHFT), Box and Blocks Test (BBT), Nine Hole Peg Test (NHPT), Stroke Impact Scale (SIS).

Results: Significant improvements were found with the JHFT, BBT and NHPT from pre-testing to post-testing. There was an increase in perceived quality of life from pre-testing to post-testing, as determined by the SIS.

Conclusion: Commercial gaming may be a viable resource for those with chronic stroke.

Acknowledgements

First and foremost, I would like to put into words my utmost gratitude for my graduate advisor, Dr. Sean Horton. Not only has he provided guidance to me through many meetings and countless edits, but he has shared with me a wonderful wisdom that has helped me create a new perspective on life. Sean: thank you for forcing me to be independent, even though I did not want to be at times. Because of this, I have forged a path of my own; one that I will follow for a lifetime. Your knowledge is vast, and the lessons you taught me will not be forgotten.

I see.

I saw.

I have seen.

Thank you to my thesis committee members, Dr. Cheri McGowan and Dr. Jamie Crawley. Your insights and positive attitudes towards this project have been immensely helpful. As well, I am grateful for the WECHC and the CDMP for providing and maintaining such a wonderful program that I had the chance to be involved with.

To Kelly Carr, Sue Ali, and all of my other lab mates: I can only say how grateful I am for both your educational and emotional support, and for keeping me sane. I hope I can help you in the same way you have helped me.

I have a never ending gratitude for my mother, father, boyfriend, friends, and family – especially my grandmother, Clair. Without your overwhelming support and patience this would have never been possible.

Table of Contents

Statement of Originality iii
Abstract iv
Acknowledgements v
List of Tables viii
List of Figures ix
List of Appendices x
Introduction 1
Review of the Literature 5
Introduction to Stroke 5
Impact and Consequences of Stroke 7
Neuroplasticity and Chronic Stroke 11
Community Health Care 14
Gross and Fine Motor Rehabilitation 16
Feedback 19
Virtual Rehabilitation Techniques 20
Commercial Gaming 23
Purpose 26
Methods 28
Participants 28
Inclusion Criteria 28
Mini-Mental State Exam 28
Fugl-Meyer Assessment 29
Setting and Apparatus 29
Measurement 30
Jebsen Hand Function Test 30
Card Turning 30
Small Objects 31
Beans 31
Stack Objects 32
Empty and Large Cans 32
Box and Block Test 33
Nine Hole Peg Test 34
Stroke Impact Scale 34
Procedure 36
Statistical Analysis 38
Results 39
Jebsen Hand Function Test 40
Box and Block Test 41
Nine Hole Peg Test 42
Stroke Impact Scale 43

Discussion 45
Fine Motor Ability 45
Perceived Ability to Complete ADL 48
Role of the Lesser Affected Hand 50
Cross-Education 50
Practice Effect 52
Training Time 53
Implications 55
Limitations and Future Directions 56
Conclusion 58
References 60
Appendices 79
Vita Auctoris 99

List of Tables

TABLE 1:

Perceived Benefits and Challenges of Non-immersive VR for Stroke Rehabilitation 97

TABLE 2:

Participant Characteristics and Inclusion Scores 39

TABLE 3:

Means and Standard Errors for all Dependent Measures..98

List of Figures

FIGURE 1:

Box and Blocks Test 33

FIGURE 2:

Nine Hole Peg Test 34

FIGURE 3:

Jebsen Hand Function Test - Mean (*SE*) transformed time to complete each Session......41

FIGURE 4:

Box and Blocks - Mean (*SE*) number of blocks transferred across each Session.............42

FIGURE 5:

Nine Hole Peg Test - Mean (*SE*) transformed time across each Session..........................43

FIGURE 6:

Stroke Impact Scale - Mean (*SE*) SIS scores across each Session 44

List of Appendices

APPENDIX A:
Letter of Approval from WECHC 79

APPENDIX B:
Mini-Mental State Exam....................80

APPENDIX C:
Fugl-Meyer Assessment....................81

APPENDIX D:
Jebsen Hand Function Test 82

APPENDIX E:
Modified Stroke Impact Scale 83

APPENDIX F:
Consent Form for Participation....................85

APPENDIX G:
Participant Profile 89

APPENDIX H:
Letter of Information....................90

APPENDIX I:
Flowchart of Inclusion and Drop-out....................96

Introduction

Worldwide, stroke is the leading cause of long term disability in the adult population (Lloyd-Jones et al, 2010). Two thirds of stroke incidents affect those over the age of 65 years (Russo & Andrews, 2008), which suggests that rates will continue to rise as our population ages. There are 50,000 new stroke incidents each year in Canada, with 36,000 survivors (Statistics Canada, 2011). It is reported that 40% of all stroke survivors are left with a moderate to severe impairment. Consequently, each year 14,000 more Canadians are suffering the effects of their stroke, which leads to long term disability (Heart & Stroke, 2012).

With increasing acute care treatment options available for those who have suffered from a stroke, and progress in cerebrovascular disease prevention, the mortality rate caused by stroke has decreased substantially (Towfighi & Saver, 2011). However, with more survivors than ever before, the need for rehabilitation and care for stroke survivors has increased considerably (Teasell, Bayona, & Bitensky, 2005). This is especially important once a survivor enters the "chronic" phase of his or her rehabilitation, as a majority of their rehabilitation will be completed within the first six to 12 months of recovery (Taub, Uswatte, & Elbert, 2002; Teasell et al., 2005).

Patients who survive a stroke frequently live with lasting, or chronic disabilities. These lasting effects often stabilize between six to twelve months after onset, and this time frame is usually marked by a plateau in recovery (Page, Gater, & Bach-y-Rita, 2004). There is evidence to support rehabilitation for those with chronic stroke (Ferrarello et al., 2010), but because of the recovery plateau, it is uncommon for those who have chronic stroke to have their insurance cover physiotherapy (Langhammer &

Stranghelle, 2003; Ferrarello et al., 2010). Those with chronic stroke often rely on outpatient care, such as community-level rehabilitation (Holden, 2005).

Recent trends indicate an increasing reliance on community-level resources for rehabilitation, and the evidence shows beneficial effects for patients who utilize this level of care (Quinn et al., 2009). When presented with a community-level rehabilitative opportunity, the incidence of functional deterioration was reduced, with a corresponding improvement in activities of daily living (ADL) (Legg et al., 2004). Additionally, patients showed an overall increase in quality of life (QOL) measures (Fjaertoft, Indredavik, Johnsen, & Lynderson, 2004). Although there is considerable variability in the type and effectiveness of community-level care across regions, patients have reported improved outcomes when compared to no intervention (Forster, Young, & Langhorne, 2000). Recent research findings have also suggested that clients preferred a specialized stroke team (i.e., physiotherapist, speech pathologist, nurse), compared to a general rehabilitation ward, which did not offer them specialized stroke care such as occupational therapy or swallowing assessments (Langhorne et al., 2005).

While most survivors of stroke are able to regain walking ability (Kwakkel, Kollen & Wagenaar, 1999), upper extremity (UE) deficits persist, as 55-75% of those with UE problems will endure complications in their affected arm well beyond the onset of their injury (Levin, Knaut, Magdalon, & Subramanian, 2009). Additionally, research shows that a deficit in the UE can negatively affect the survivor's QOL (Burdea et al., 2011), and that even a fully recovered arm will not improve one's QOL unless the manipulative abilities of the hands are present (Adamovich et al., 2005). While there are many rehabilitative techniques available for UE deficits, Virtual Reality (VR) is showing particular promise for patient therapy and recovery (LeBlanc, Paquin, Carr, & Horton, 2013).

VR is a novel type of intervention that allows the patient to interact with a simulated environment that provides constant feedback (Saposnik & Levin, 2011). One advantage of VR is its flexibility to patients' needs, and that it can accommodate a wide spectrum of cognitive and physical impairments (Saposnik et al., 2011). VR complements the rehabilitative needs of those with chronic stroke; as a task oriented, repetitive, novel intervention with varied intensities are characteristics necessary for rehabilitation (Henderson, Korner-Bitensky, & Levin, 2007; Dobkin, 2008; Langhorne, Coupar, & Pollock, 2009; Edmans et al., 2009). Additionally, there is emerging evidence suggesting that VR treatments improve function in the chronic stages of stroke (Teasell et al., 2009). Studies examining rehabilitation of the UE in chronic stroke predominately utilize expensive data gloves as measurement tools (Burdea et al., 2011; Shen, Gu, Ong, & Nee, 2012). However, VR research has also expanded into more cost effective rehabilitation tools, such as commercial gaming (Flynn, Palma, & Bender, 2007; Saposnik et al., 2011; Alankus, Proffitt, Kelleher, & Engsberg, 2011).

Commercial gaming, another form of non-immersive VR that uses computer and video entertainment systems, is relatively underexplored compared to other rehabilitative strategies; very few studies have examined its utility with stroke patients in a rehabilitation setting. Most research examining commercial gaming and rehabilitation has consisted of case studies (Holden, Todorov, Callahan, & Bizzi, 1999; Deutsch et al., 2002; Merians et al., 2002; Holden, 2005; Burdea et al., 2011). This may be due to the fact that commercial gaming units have not been designed specifically for rehabilitative purposes (Saposnik et al., 2011), but preliminary evidence suggests that rehabilitative gains are possible (Saposnik et al., 2010a). Moreover, gaming has elicited motivation and engagement towards rehabilitation, where patients have shown both interest and enthusiasm for the intervention (Lewis & Rosie, 2012).

The Nintendo Wii (2006; Retail Value: $150; Nintendo, Kyoto, Japan) has shown potential as a motivating and cost effective tool for rehabilitation (Mouawad, Doust, Max, & McNulty, 2011). However, research in the area of community-level care, as well as chronic stroke, has been scarce. Studies show that community-level care is vital to chronic stroke survivors (Holden, 2005), and that motivating tasks which are repetitive and task-specific are imperative to rehabilitation in this population (Henderson et al., 2007; Dobkin, 2008; Langhorne et al., 2009; Edmans et al., 2009). The proposed study will examine the effect of commercial gaming as an intervention for fine motor recovery in chronic stroke within a community rehabilitation setting. It was hypothesized that participants would show an improvement in specific fine motor tasks as a result of Nintendo Wii training.

Review of the Literature

Introduction to Stroke

Stroke, also known as a cerebrovascular accident (CVA), is the worldwide leading cause of disability among the adult population (Lloyd-Jones et al., 2010). In Canada, stroke is the third leading cause of death, and is responsible for six percent of all deaths (Heart & Stroke, 2012). Two thirds of all strokes affect those over the age of 65 years (Russo & Andrews, 2008), and the risk of stroke doubles after the age of 55 years (Heart & Stroke, 2012). Thus, as our population ages, so too will the incidence and prevalence of stroke. Each year there are 50,000 new incidents of stroke, of which 36,000 survive (Statistics Canada, 2011). It has been reported that 40% of all stroke survivors suffer from moderate to severe impairment, indicating that 14,400 new survivors each year will be affected (Heart & Stroke, 2012).

There are two general categories of brain injury that can lead to a stroke: ischemic (blood clots), and hemorrhagic (bleeding). Ischemic incidents are caused by blood clots that form in, or travel to, the brain and interrupt blood flow (Heart & Stroke, 2012). This type of incident can be caused by blood clots, plaque buildup, or both, and are responsible for 80% of stroke incidents (Heart & Stroke, 2012). Hemorrhagic incidents are caused by uncontrollable bleeding, such as a ruptured vessel, and account for the other 20% of stroke incidents (Heart & Stroke, 2012). Both types of stroke stop blood flow to the brain for an extended period of time, resulting in damage to the brain due to lack of oxygen (Staley, 2010). One can suffer visual, cognitive, or motor impairments, dependent on where the blood flow was interrupted (Teasell, Bayona, & Heitzner, 2008a).

Following stroke the brain will usually experience the development of abnormal tissue, called *lesions*, at the site of injury. Generally, lesions that are formed on the right hemisphere of the brain, noted for learned behaviours that require initiation and planning, will affect visual-spatial perceptual skills, and may manifest emotional disorders and communication problems (Teasell et al., 2008a). Lesions formed on the left hemisphere of the brain, responsible for learning and use of language symbols, can be characterized by aphasia (disturbance in the communication of language), apraxia (disturbance in initiation of movement), and emotional disorders (Teasell et al., 2008a). Hemiparesis (weakness in one side of the body), quadriparesis (weakness in all four limbs), and ataxia (lack of muscle co-ordination) are motor deficits caused by lesions that form in the brainstem (Teasell et al., 2008a). Due to the location, brainstem lesions have the ability to affect the cerebellum, as well as the occipital and medial temporal lobes (Scremin, 2004). These lesions are also responsible for sensory loss, vertigo, and difficulty in swallowing (Teasell et al. 2008a).

Stroke is considered to be a disease of the elderly, and thus the risk of incident increases as we age (Russo et al., 2008). However, there are other risk factors that may make individuals more susceptible to a cerebral infarction. Co-morbidities such as high blood pressure, diabetes, stress, smoking, and physical inactivity are linked with higher incidence of stroke. These risk factors are considered to be *controlled*, in that individuals can modify their lifestyles to reduce risks of incidence (Heart & Stroke, 2012). There are however, *uncontrolled* risk factors that increase one's chance of stroke. Besides age, gender plays an important role, where males over the age of 55 years, as well as postmenopausal females, are at higher risk. Before reaching menopause, the number of incidents involving females is much lower than males of the same age. This may be, in part, due to the higher amount of estrogen created by females (Sampei et al., 2000), though this relationship remains unclear. Recent research suggests that the reintroduction of estrogen to the body, in the form of hormone replacement therapy (HRT), results in an increase of stroke risk by about one third in standard dose cases (Henderson & Lobo, 2012). In comparison, previous research suggested that a lower dose of transdermal estrodial may not increase stroke risk (Grodstein, Manson, Stampfer, & Rexrode, 2008), and therefore standard dose HRT should be avoided when possible.

Additional risk factors include those of First Nation, African, or South Asian descent. These populations are at higher risk for diabetes, as well as high blood pressure, and thus a higher risk of stroke incidence (Heart & Stroke, 2012). Lastly, family history plays an important role in the risk for stroke. Specifically, those who have had an immediate family member suffer from stroke or heart disease before the age of 55 years are at greater risk of incidence (Heart & Stroke, 2012).

Stroke is a devastating occurrence, and many of those that suffer from cerebral infarction have to endure multiple adverse effects, and often have to modify their lives to accommodate for such damage. In addition to psychological and social effects, taxing physical demands caused by impairment may alter how even basic functional tasks are completed.

Impact and Consequences of Stroke

Activities of daily living (ADL) are routine activities that individuals regularly complete on a daily basis. These self-care activities are often done inside of the residence, and are usually done without help (Fricke, 2010). A measure of an individual's ability to complete their ADL can be seen as a measure of a person's ability to live independently. Many of those with chronic diseases, such as stroke, are at risk for having difficulty with their ADL, and it is estimated that worldwide, up to 74% of stroke survivors require some form of assistance with their ADL (Miller et al., 2010).

The umbrella term of ADL can be further subdivided into two categories, basic activities of daily living (BADL) and instrumental activities of daily living (IADL) (Fricke, 2010). BADL are generally associated with personal care (e.g. feeding, hygiene, dressing) and functional mobility activities, such as ambulation (James, 2008), whereas IADL describe activities that involve adapting to, and coping with, environmental tasks, such as shopping, managing medication, transportation, and cooking (Katz, 1983).

In terms of functionality post-stroke, the ability to complete ADL, and the corresponding hand function that is required, is considerably lower in recovering stroke survivors as compared to stroke-free community dwelling adults (Lai, Studenski, Duncan, & Perera, 2002). Post-stroke, 85% of patients have an initial deficit in the arm (Feys et al., 1998), and these effects persist in 55% to 75% of patients three to six months after onset (Lai et al., 2002). Hand function plays a vital role in the completion of daily tasks, and a decline in that ability creates a taxing effect on completion of ADL, while also negatively affecting areas related to independence, mental health, and social engagement (Burdea et al., 2011).

Divani, Majidi, Barrett, Noorbaloochi, and Luft (2011) identified the frequencies and risks of five common co-morbidities following stroke in a cross-sectional and longitudinal analysis. Primarily, motor impairments were higher in the stroke population compared to the healthy population in both the cross-sectional and longitudinal studies.

The longitudinal aspect emphasizes not only the difference *between* those with and without stroke, but that motor impairments can develop as time goes on *after* the stroke. This could be due to learned disuse of the limb, or slowly accumulating cerebrovascular disease (Okawa, Nakamura, Kudo, & Ueda, 2009; Zhang, Yu, & Wang, 2010). Secondly, those who have suffered a stroke are at a greater risk for developing urinary incontinence (UI). This is especially evident in older individuals with impaired cognition, depression, and hemiparesis (Jorgensen, Engstad, & Jacobsen, 2005; Kovindha, Wattanapan, Dejpratham, Permsirivanich, & Kuptniratsaikul, 2009). Recurrent UI has been associated with mortality, dependence, and the need for institutionalized care (Patel, Coshall, Rudd, & Wolfe, 2001; Kolominsky-Rabas, Hilz, Neundoerfer, & Heuschmann, 2003). Third, sleep disturbances were identified frequently in cross-sectional studies, however, were not evident when examined longitudinally. This illustrates that sleep disturbances co-exist with stroke, as opposed to developing afterwards. Of note, sleep apnea, the most common sleep disturbance in older adults, was high in both stroke and stroke free older adult populations. Thus, sleep disturbances may be a pre-existing condition in those with stroke, as opposed to developing post injury. Fourth, falls are more frequent in stroke survivors compared to controls. Fall occurrence after a stroke is associated with advanced age, living alone, time from first stroke, psychiatric problems, UI, pain, motor impairment, and a history of falling and fall related injuries (Divani, Vazquez, Barrett, Asadollahi, & Luft, 2009). Risk of falls is slightly elevated over time, which was found longitudinally, although it did not reach statistical significance. Lastly, memory deficits are a common concern of stroke survivors. Cross-sectional analysis showed that 8% of those with stroke, as compared to 2% of healthy controls, had some form of memory deficit. There were no accumulated effects of memory deficits, as percentages did not significantly increase from cross-sectional to longitudinal collection. Furthermore, memory deficit may be a subjective expression of depression, or fatigue (Eskes & Barrett, 2009).

Fatigue is a lasting, yet neglected, effect following stroke incident (De Groot, Phillips, & Eskes, 2003), where 30% to 60% of survivors report some form of low energy or tiredness (Inges, Eskes, & Phillips, 1999; van der Werf, van der Broek, Anten, & Bleijenberg, 2001; Glader, Stegmayr, & Asplund, 2002). Inges et al. (1999) found that stroke survivors who reported a higher incidence of fatigue on a daily basis attributed more functional limitations to it in both physical and psychosocial domains. Additionally, Glader et al. (2002) reported that fatigue can predict a decrease in functional ability, the likelihood of institutionalization, as well as mortality. It has been suggested that impairment following stroke can act as causation for fatigue, and in turn, the fatigue can lead to further impairment, creating a cycle that results in declining functional independence (Glader et al., 2002). Similarly, inactivity caused by fatigue can lead to decreased adherence to a rehabilitation program, causing further physical deconditioning (Winningham, 2001). In addition to being a barrier to rehabilitation, fatigue has also been shown to negatively affect one's quality of life (QOL) (Michael, 2002).

Stroke survivors are affected by many long-term problems post injury, and in turn report lower QOL as compared to healthy controls (Kissela, 2006). In a longitudinal comparison of both stroke affected and healthy controls, stroke incident had a negative effect on depression, mental health, and physical health-related QOL measures (Haley, Roth, Kissela, Perkins, & Howard, 2011). Those most at risk for a perceived lower QOL were those who were living alone, were of a younger cohort, and were of African American descent (Haley et al., 2011). Furthermore, recent research suggests that impairment specific to the upper limb may contribute to a decreased QOL for survivors one year post-stroke (Franceschini, La Porta, Agosti, & Massucci, 2010).

It is evident that many changes to the body and brain occur following a brain injury. Depending on how the individual adapts to these changes, however, it is possible that successful rehabilitation can occur. While the most important rehabilitation window for recovery is directly following the incident (Veerbeek, Kwakkel, van Wegen, Ket, & Heymans, 2011), rehabilitation can be managed over many years with gains continuing well into the chronic phase of stroke. The term used to describe this ongoing activity is *neuroplasticity*, and is characterized by the brain's natural tendency to reorganize itself in response to changing internal, as well as external, demands (Lillard & Erisir, 2011).

Neuroplasticity and Chronic Stroke

Following a brain injury, such as stroke, it is imperative that the brain undergoes important neural reorganization for motor recovery to take place (Teasell et al., 2005). Initial research in the area of neural recovery proposed that, once matured, the central nervous system remains fixed with little to no capacity for reparation (Jorgensen, Nakayama, Raaschou, & Olsen, 1995). However, more recent research has suggested that not only does the brain hold the capacity to repair itself, it is constantly undergoing changes (Hallet, 2001; Taub et al., 2002). The idea of neuroplasticity has been groundbreaking for stroke research, as evidence emerges of the brain's capability to rewire itself post-injury (Hallet, 2001). This natural tendency of the brain to repair itself is found not only immediately following injury, but can be seen years after, during the chronic phase of stroke recovery (Ward & Cohen, 2004; Cramer, 2008).

There are two recovery phases that survivors go through after the onset of stroke: acute and chronic. The *acute phase* generally occurs in the first 6 to 12 months following injury, and is the period of time in which the majority of motor function is recovered (Teasell et al. 2005). As time goes on, the rate of recovery appears to decelerate, which can be described as reaching a “motor recovery plateau” (Cramer, 2008). It is at this time, approximately 12 months after the initial injury, that one enters the *chronic phase* of stroke recovery. Once reaching the motor recovery plateau, the patient may no longer exhibit signs of improvement in response to therapeutic intervention (Cramer, 2008). In terms of upper extremity (UE) related motor recovery, this plateau generally ensues once reaching the chronic phase of recovery (Skilbeck, Wade, Hewer, & Wood, 1983). This can be particularly stressful for stroke survivors, as reaching the plateau will often result in being discharged from rehabilitation programs (Demain, Wiles, Roberts, & McPherson; Page et al., 2004). Moreover, the existence of the motor recovery plateau suggests there may be a limit to late functional recovery post-stroke and thus further treatment may be denied (Ferrarello et al., 2010).

The amount of time required to achieve success with an intervention will vary from patient to patient, and a set window of rehabilitation has yet to be established empirically by researchers and therapists (Cramer, 2008). Although rehabilitation in the acute phase of stroke is generally met with a large amount of functional motor recovery, gains in the chronic phase of stroke are apparent as well (Jack et al., 2001; Deutsch et al., 2002; Merians et al., 2002; Deutsch et al., 2004; Adamovich et al., 2005; Holden, 2005;

Demain et al., 2006; Merians. Poizner, Boian, Burdea, & Adamovich, 2006; Carey et al., 2007; Cramer, 2008; Burdea et al., 2011), a notion that was once dismissed (Jorgensen et al., 1995). A meta-analysis conducted by Ferrarello et al. (2010), concluded that in comparison to no treatment or a placebo, motor rehabilitation applied to chronic stroke patients improved both motor and functional outcomes of recovery. However, research regarding recovery during the chronic phase of stroke remains limited due to the lack of randomized controlled trials and studies consisting of small sample sizes. Due to the gap in empirical evidence supporting late recovery, post-stroke chronic stroke patients are often not offered, or their insurance may not cover, physical rehabilitation services (Langhammer & Stanghelle, 2003; Ferrarello et al., 2010).

When entering the chronic phase of stroke, it is estimated that 50% of survivors aged 65 and over will experience some form of hemiparesis, and 30% will be unable to walk independently (Kelly-Hayes et al., 2003). In part due to a decreased opportunity for rehabilitation, these limitations leave the survivor at risk for diabetes, heart disease, and in turn, subsequent stroke (Ivey et al., 2006). The evidence suggests that management strategies to prevent progression of disability are not presently optimized (Saunders, Greig, Young, & Mead, 2004). This can create a decreased level of life satisfaction for those who have chronic stroke, which in turn can contribute to their inability to increase their activity level (Hartman-Maeir, Soroker, Ring, Avni, & Katz, 2007). Once discharged from hospital care, options for quality care, rehabilitation, and exercise are not as readily available. Therefore, many survivors rely on community-level health care for rehabilitation or exercise to increase their quality of life and decrease risk for disease.

Community Health Care

After a stroke incident, a Canadian will spend an average of 28 days in inpatient care where direct care is provided (Teasell, Meyer, Foley, Salter, & Willems, 2009). However, at one month post-stroke roughly 65% of patients are sent home, with or without care, with the rest going to rehabilitation hospitals, chronic care hospitals, nursing homes, and lastly, acute care (Teasell et al., 2009). Generally, once discharged from the hospital, responsibility and support of the survivor is given to a family member (Teasell, et al., 2009b). From here, survivors must adapt to their new home environment, and reintegrate themselves back in to their community. Ongoing follow ups with care providers are of importance to assess recovery and prevent deterioration, and survivors should continually be screened for depression or cognitive impairment (Lindsay, Gubitz, Bayley, & Phillips, 2013). These follow ups should be completed within two to four weeks of discharge, and again every six months for at least three years (Lindsay et al., 2013).

In Canada, there are no standard guidelines as to the extent rehabilitative care should be provided to stroke patients, and provision of care is highly variable between provinces (Landry, Passalent, & Cott, 2008). The Canada Health Act (CHA) is legislation specifying the conditions and criteria that health insurance programs must follow to receive payment. Although sometimes seen as protector of the health care system (Deber, 2004), others perceive the CHA as a barrier to a more progressive health care approach that is better suited to the needs of Canadians (Esmail, 2007). Comprehensively, any services outside of a physician delivering medical care in a hospital setting are not covered by the CHA, and there is no assurance that care will be given (Deber, 2004).

Rehabilitation services, unfortunately, are outside the insurable limits of the CHA, along with home care and prescription drugs (Landry, 2004).

Despite evidence of functional gain in the chronic stroke phase, not all will be offered rehabilitation training programs. However, it is important for those who are in the chronic phase to continue exercise, regardless of whether they are eligible for subsidized rehabilitation. This exercise is to prevent progressive diseases and secondary conditions (i.e., low cardiorespiratory fitness) and chance of subsequent stroke (Kurl et al., 2010). Despite the importance of physical activity for prevention of progressive or secondary diseases, the stroke population is especially vulnerable to inactivity (Rimmer & Wang, 2005). Both personal (e.g., self-efficacy, motivation), and environmental (e.g., accessibility, equipment) limitations may play a role in the ability of a stroke survivor to participate in exercise (Shaughnessy, Resnick, & Macko, 2006; Damush, Plue, Bakas, Schmid, & Williams, 2007). Rimmer, Wang, and Smith (2008) noted that stroke survivors identified particular barriers associated with participating in community-level exercise programs. The most common barrier to continuing physical activity after stroke was cost (61%), followed by lack of awareness of fitness centres in their area (57%), transportation (57%), lack of knowledge on how to exercise (46%), and where to exercise (44%). The barriers least reported were lack of interest (16%), lack of time (11%), and concern of worsening their condition (1%). These results illustrate that while stroke survivors may have personal barriers to overcome, the main barriers reside in environmental factors associated with accessibility, knowledge, and cost. Subsidized cost and transportation could provide individuals with an opportunity to manage their health proactively (Rimmer et al., 2008).

Task-related circuit training has been receiving increasing interest for chronic phase stroke survivors who have access to a form of community rehabilitation or exercise (Dean, Richards, & Malouin, 2000). Wevers and colleagues (2009) identified three key reasons as to why circuit training may be beneficial for this population (Wevers, van de Port, Vermue, Mead, & Kwakkel, 2009). First, with the use of individual workstations it allows participants to practice intensively in a meaningful and progressive way. Second, circuit classes provide a more efficient way for a therapist to use their time. This is important, as a therapist to patient ratio is approximately 1:7 for physiotherapy (Teasell et al., 2009b), and any increase in efficiency for the therapist will result in cost benefits for both the therapist and the patient (English, Hillier, Stiller, & Warden-Flood, 2007). Third, the use of circuit class will encompass group dynamics, such as peer support and social interaction. By increasing patients' motivation for the program with social support, adherence may also increase. Along with potential psychosocial benefits, psychological benefits such as increased confidence and mood can also occur (Wevers et al., 2009).

Through physical therapy there are a variety of interventions, much like circuit training, available within stroke rehabilitation. Choice of intervention will depend on the patient's functionality and what rehabilitative measures will increase the patient's overall ability to complete ADL. Further, both fine and gross motor movements are often impaired.

Gross and Fine Motor Rehabilitation

Gross movements are generally controlled by large muscles, or large muscle groups, such as, the biceps and triceps in the upper arm flexing and extending the elbow. Conversely, *fine movements* are generally controlled by small muscles, or small muscle groups, such as the muscles within the hand, fingers, and wrist, which are responsible for small, precise movements such as writing, sewing, or drawing (Payne & Isaacs, 2008).

Although regarded as separate classifications of movement, fine and gross motor movements primarily work together to achieve a common goal (Payne & Isaacs, 2008). For instance, writing requires the larger shoulder muscles to position the arm before smaller hand and finger muscles can begin movement. Likewise, movement patterns that would generally be seen as gross motor often require fine motor co-ordination, such as throwing. Although a gross motor movement, throwing requires precision and accuracy from the hand muscles to be successful (Payne & Isaacs, 2008). Thus, rehabilitative strategies should aim to recover both fine and gross motor skills, as this will simulate partial or whole skill sets required to complete common ADL (Harris et al., 2009).

A variety of rehabilitation techniques have been developed to aid in the improvement of gross and fine motor skills in the UE post-stroke. Notably, *bi-lateral arm training* has become a prominent stroke rehabilitation technique as new theories of neuroplasticity have developed (Teasell, Bayona, & Heitzner, 2008b). This technique involves patients practicing movement activities with both arms at the same time. The use of the less affected limb will promote recovery of the impaired limb through coupling effects, where the intact hemisphere of the brain will facilitate activation of the impaired side through neural networks in the corpus callosum (Summers et al., 2007; Morris et al., 2008). There is conflicting evidence as to whether bi-lateral arm training is superior to uni-lateral arm training (van Delden, Peper, Beek, & Kwakkel, 2012), and research suggests both training types can be advantageous for moderately impaired stroke survivors (Stoykov, Lewis, & Corcos, 2009). However, reviews show that bi-lateral training showed no significant results in ADL function, or *functional movement* of the arm and hand (Coupar, Pollock, van Wijck, Morris, & Langhorne, 2010).

Research has found that for motor learning to occur, the practice must be *task-specific* (Schmidt & Wrisberg, 1999). As a result, task-specific rehabilitation strategies have been developed, where a high intensity of task-specific practice has led to functional gains in post-stroke therapeutic interventions (Duncan, 1997). Karni and colleagues (1995) reported seeing experience-dependent reorganization of the primary motor cortex following daily task-specific motor activities. Furthermore, task movements for as short as 15 minutes per day have been shown to induce lasting cortical changes (Butefisch, Hummelsheim, Denzler, & Mauritz, 1995; Karni et al., 1995). Although not all studies have yielded significant results (Timmermans, Spooren, Kingma, & Seelen, 2010), it is generally accepted that task-specific training may be a very valuable tool for stroke rehabilitation (Teasell, et al. 2008b).

Unlike task-specific training, *constraint induced movement therapy* (CIMT) focuses on the movement outcome as opposed to the results from the repetition of specific tasks (Michaelsen, Dannenbaum, & Levin, 2006). Designed to address the issue of *learned nonuse*, by which an individual suppresses certain movement patterns based on unfavorable reactions or previous failures (Taub, Uswatte, Mark, & Morris, 2006), CIMT is comprised of two components. First, the less affected UE is constrained by being swathed to the torso. Second, the more affected UE is forced to engage in a mass amount of training (Morris, Taub, & Mark, 2006). Traditional protocol runs for two weeks, where the less affected UE is constrained for 90% of the time, and the patient will endure six hours of therapy per day (Kunkel et al., 1999; Morris et al, 2006). Many review studies have been published showing positive results of CIMT (Taub & Morris, 2001; Van Peppen et al., 2004; Hakkenes & Keating, 2005), however its effectiveness remains unclear. Certain criteria (e.g. being active for six hours with little rest, passive range of motion that is at least half of normal range) must be met in order to participate in trials, making the target population for CIMT very small, and limiting its generalizability (Wolf et al., 2006). With the exception of one large sample study (N = 222; Cramer, 2007), only small to moderate sample sizes (< 50) and case studies have been conducted. Although it is important to avoid learned nonuse of the affected UE through increased usage of the limb, the extreme nature of CIMT makes adherence difficult over a long period of time, and may result in post-stroke fatigue (Rowe, Blanton, & Wolf, 2009).

Feedback. The effectiveness of a stroke rehabilitation intervention can be altered by the type and amount of feedback given to the participant (Krakauer, 2006). There are two common types of feedback that can be available to participants: intrinsic and extrinsic (Van Vliet & Wulf, 2006). *Intrinsic feedback* refers to the information that comes from within the body (e.g., muscles, joints, and sensory information), whereas *extrinsic feedback* refers to the information that comes from the environment (e.g., comments from a therapist) (Van Vliet et al., 2006). Further, extrinsic feedback can be classified as either knowledge of results (KR) or knowledge of performance (KP). KR refers to the outcome of the task, and is usually given once the action is complete, whereas KP educates participants of the movement characteristics that led to their outcome (Van Vliet et al., 2006). When looking at feedback, results indicate that there is strong evidence to support giving extrinsic feedback to improve motor learning (Van Vliet et al., 2006; Subramanian, Massie, Malcolm, & Levin, 2010). Furthermore, KP in the form of verbal, videotape, robotics, and virtual environments was reported to be beneficial in the improvement of motor skills in the more affected limb of stroke patients (Subramanian et al., 2010).

There are many rehabilitative techniques available to stroke survivors to aid in their recovery of functional skills. However, more research is needed in order to find the most efficient way to achieve these goals. Innovative treatments, such as virtual reality, have shown promise, and are able to motivate and capture the interest of participants (LeBlanc, Paquin, Carr, & Horton, 2013).

Virtual Rehabilitation Techniques

Virtual reality (VR) can be defined as a computer-based technology that allows users to interact with a simulated environment and receive continuous, immediate feedback with respect to performance (Saposnik & Levin, 2011; Henderson et al., 2007; Edmans et al., 2009). Since motor recovery depends on factors such as patients' motivation, their ability to learn, and the quality and intensity of the intervention applied, as opposed to simply stroke severity, it is vital to employ interventions that will meet such needs (Teasell et al., 2005). VR lends itself to the facilitation of neural plasticity through its relevant application of principles such as task-oriented training of the affected limb, repetition, novelty and appropriately varied intensities (Henderson et al., 2007; Dobkin, 2008; Langhorne et al., 2009; Edmans et al., 2009). VR-based therapy can be classified on a continuum from fully immersive to non-immersive, and will be dependent on the degree to which the user is *immersed* in the virtual environment (Smith, Read, Bennie, Hale, & Milosavljevic, 2012; Saposnik et al., 2011).

Immersive VR allows the user to feel they are within the virtual environment that is presented to them, which is referred to as “presence” (Henderson et al., 2007). This presence can be achieved through a range of equipment both worn by, and in front of, the user (e.g., head mounted displays, specially designed stereoscopic glasses) (Holden, 2005; Henderson et al., 2007). In contrast, *non-immersive* VR can be likened to looking through a window at a scene, and often involves the use of smaller-scale, 2-dimensional screens (e.g., computer or television screens), and can be used with or without the use of interface devices (e.g., cyberglove, joy stick, or computer mouse) (Holden, 2005; Henderson et al., 2007; Smith et al., 2012; Sanchez-Vives & Slater, 2005). Unlike its immersive counterpart, non-immersive VR does not make use of additive reality-altering peripherals, such as headsets or glasses.

Evidence exists for the use of non-immersive VR as a supplement to conventional rehabilitation practices for persons with stroke (Smith et al., 2012; Piron et al., 2009). However, the use of VR is accompanied by both benefits and challenges (for a comprehensive list, please see Table 1). The observed benefits give promise to the future use of VR as a therapeutic tool, where the perceived challenges are mostly founded in unfamiliarity, perhaps due to the novelty of the tool.

The sustainment of VR within rehabilitation is heavily influenced by the perspectives of the users (LeBlanc et al., 2013). Lewis and colleagues (2011) examined user perspectives and beliefs towards a VR intervention in order to better understand what aspects were important. Although there were no clinically significant gains reported, there were perceived gains in hand function. Furthermore, participants reported increased ease with completing ADL and the usability of the VR games (Lewis et al., 2011). Common themes regarding experiences that emerged through user responses were as follows: stretching oneself, purpose and expectations, and future improvements. *Stretching oneself* was regarded as a positive outcome to a novel activity (Lewis et al., 2011). Through challenging their current skills, participants were able to stretch themselves into areas that were not previously explored, and engage in activities (e.g., virtual reality) that they are not used to. *Purpose and expectations* of VR revealed that the users only wished to use VR in the context of rehabilitation, as opposed to using VR for the use of entertainment (Lewis et al., 2011). Expectations of VR were influenced by previous experiences in rehabilitation, and a combination of both VR and physical rehabilitation was regarded as most favorable. *Future improvements* regarding the VR intervention were also given by the users (Lewis et al., 2011). The most common suggestions for improvement were on scoring systems, increases in how realistic and accurate the virtual environment was, and more opportunity for competition.

Overall, patient acceptance of a VR intervention will rely on the participants' ability to achieve control, experience success, and maintain an environment in which they are constantly challenged and progressing (Lewis & Rosie, 2012). A VR intervention that contains these qualities will promote not only enjoyment, but also increased commitment to the rehabilitation process. User perspectives remain one of the most important aspects to participant commitment, and should be taken into consideration when evaluating a VR intervention (Lewis & Rosie., 2012).

Despite an increasing body of on VR and chronic stroke, the number of studies specific to fine motor rehabilitation is still limited. Sample size is one of the largest limitations to current research using VR, with most studies that involve UE impairment comprising between one and ten participants. Low participant numbers may be, in part, due to the novelty of VR as a means of rehabilitation. As VR evolves to become more user-friendly (Halton, 2008), and further evidence emerges with respect to VR's motivational component (Lewis et al., 2011), future studies will likely yield a higher number of participants.

Although non-immersive VR may still be considered a new tool, it has been used in rehabilitation for over 15 years, and was first implemented by using instrumented glove and sensor technologies to provide a new method of measurement for different physical disabilities (Greenleaf & Tovar, 1994). Shortly after, VR was used as a tool specific to chronic stroke and rehabilitation of the UE through use of a data glove and learning through imitation (Holden, Todorov, Callahan, & Bizzi, 1999). Recent studies looking at rehabilitation of the UE in chronic stroke still make use of the data glove as a measurement tool (Burdea et al., 2011; Shen, Gu, Ong, & Nee, 2012), however VR has also expanded into more cost effective rehabilitation tools, such as commercial gaming (Flynn, et al., 2007; Saposnik et al., 2011; Alankus et al., 2011).

Commercial Gaming

Commercial gaming is another form of non-immersive VR that uses computer and video entertainment systems (Saposnik et al., 2011). Conventional VR modalities, such as data gloves and customized hardware and software, can be very costly. Consequently, many individuals and institutions are unable to afford the necessary hardware required for such therapy (Merians et al., 2006). Commercial gaming is a type of VR that is more affordable than the majority of clinically developed VR interventions (Crosbie, Lennon, Basford, & McDonough, 2007). As such, these systems have been adopted by clinicians as an accessible alternative to expensive therapeutic technologies.

Stroke rehabilitation programs utilizing commercial gaming may develop custom software and accessories for clients, or may opt to use “off-the-shelf” systems and software. Both options have pros and cons, and should be chosen based on the needs of the client. Custom accessories and games can be tailored to meet specific impairments, but can become costly and hard to replace or repair. On the other hand, off-the-shelf bundles are easily accessible and more cost-effective, but will not be as individually tailored as a custom system. Although not originally designed for rehabilitative purposes (Saposnik et al., 2011), commercial gaming interventions holds promise in community-level rehabilitation settings, where funding is usually minimal. Furthermore, commercially available VR becomes advantageous as it evolves into more user friendly technology, (Burdea, 2003).

Functional gains and improved quality of life have been seen in interventions that use commercial gaming (Flynn et al., 2007; Alankus et al., 2011). However, it is an area of research that has not yet been thoroughly investigated, as interventions using both commercially available hardware and software are scarce. In addition, research that is available is heavily focused on commercial gaming for gross motor rehabilitation, with few studies examining fine motor skills.

Flynn et al. (2007) implemented a chronic stroke rehabilitation intervention with an elderly participant at two years post-stroke. Both commercial hardware and software were used (Sony Playstation Eyetoy, and Eyetoy:Play 2, respectively), and the participant was given a variety of target-based UE games from which to choose. After 20 one-hour sessions of game play the authors found trends towards improvement on the Fugl-Meyer Assessment, and the UE Functional Index.

The Nintendo Wii has also been used in studies concerning gross motor rehabilitation in chronic stroke. Alankus et al. (2011), and Proffitt, Alankus, Kelleher, and Engsberg (2011) both conducted case-studies using the Wii as an intervention with a chronic stroke participant. Using motion-based games in a home setting, these interventions strived to regain lost range of motion (ROM) and motor control in an older participant that was 17 years post-stroke. While using the Wii hardware, custom software games (e.g. helicopter, pong, and baseball catch) were created to suit the participant's likes and dislikes. After six weeks, the participant showed functional gains toward ADL, as well as increased UE ROM.

The capacity for home application of commercial gaming is more realistic than other, more complex, VR tools. Telerehabilitation is a form of VR-based therapy completed on a computer from a distant location, such as home use, and can be directed by a therapist or clinician (Carey et al., 2007). Patients who are no longer offered physical therapy, or have no access to clinical programs are able to undergo therapeutic interventions from a more accessible location (Holden, 2005). However, there are perceived challenges associated with telerehabilitation. Without direct contact with the health provider some patients might experience difficulty adhering to the prescribed treatment as a result of feeling that they are not receiving sufficient attention from the clinician (Adamovich et al., 2005). Moreover, from a motor learning perspective, the distribution of rest time between the intensive VR therapies may become compromised with telerehabilitation (Carey et al., 2007). Previous research emphasizes the need for proper rest time in between therapies in order to process and organize ongoing task information (Savion-Lemiuex & Penhune, 2005). With the use of telerehabilitation, intensive therapies must be intricately scheduled and monitored to ensure all patients reach their full potential of recovery, and that patients do not over (or under) exercise (Carey et al., 2007). Based on existing challenges, commercial gaming therapy may be better suited for use in a clinical or community setting, where patients can be given proper feedback and attention, and can be monitored to ensure no balance, dizziness, or nausea issues, or other side effects, arise.

There is also a large motivational aspect attached to commercial gaming. Compliance issues are regularly seen in rehabilitation (Flynn et al., 2007), with patients experiencing barriers such as lack of interest, depression, and low outcome expectations (Forkan et al., 2006). By engaging with a rehabilitation tool that is considered fun and enjoyable and providing challenging tasks with increasing difficulty, patients may be more motivated to complete otherwise tedious rehabilitative tasks (Lewis et al., 2011). It is in a virtual environment that movement can be perceived as play, where the drive to win can correlate with a higher motivation level and creative movement patterns (Flynn et al.). More research on commercial gaming is warranted, not only to expand the limited research of this novel tool, but to develop the use of commercial gaming into an evidence-based practice to be used by therapists in both clinical, community, and home settings.

Purpose

This study examined the effect of commercial gaming as an intervention for fine motor recovery in chronic stroke. The main goal of this research study was to improve the participants' ability to complete fine motor tasks. However, additional secondary outcomes included assessing the perceived gains in QOL that are possible for those with chronic stroke, and showcase the usefulness of community-level rehabilitation, especially for clients low on time and resources. We also provided clients with an innovative, enjoyable, and cost effective form of rehabilitation that can act as a supplement to their current training. We hypothesized that participants would show an increase in fine motor skills at completion of the intervention.

Methods

Participants

Participants were recruited from the Chronic Disease Management Program (CDMP) that is run by the Windsor Essex Community Health Centre (WECHC) at the University of Windsor, and its satellite locations, St. Gethsemane Church, and Teutonia Club. A rolling recruitment was conducted by Ms. Donna Ofner, who is a co-coordinator and physiotherapist with the CDMP. Ms. Ofner approached clients and informed them of a fine motor rehabilitation study that was to supplement their current exercise program. All experimental procedures were approved by the University of Windsor Research Ethics Board, and the WECHC Research Board (please see Appendix A).

Inclusion criteria. Participants must have been (1) in the chronic phase of stroke (12 months or longer since incident), (2) score 22 or higher on the Mini Mental State Examination (MMSE), (3) score 10 or higher on the UE portion of Fugl-Meyer Assessment (FMA).

Mini-mental state exam. The MMSE is a short duration questionnaire used to evaluate cognitive impairment (Folstein & Folstein, 1975). The measure consists of 11 questions in regards to orientation, attention, language, and visual construction (Appendix B), with a maximum score of 30. Scoring ≥ 22 ensures that the participant can follow instructions, and can complete the intervention. The MMSE is one of the most commonly used tests of cognitive impairment (McClure, Salter, Foley, Mahon, & Teasell, 2012), has normative data for healthy adults (Jacqmin-Gadda, Fabrigoule, Commenges, & Dartigues, 1997) and stroke populations (Blake, McKinney, Treece, Lee,

& Lincoln, 2002), as well as excellent test-retest reliability (r = 0.82-0.98) (Folstein & Folstein, 1975).

Fugl-meyer assessment. Minimal UE movement standards must be met in order for the participant to interact with the Nintendo Wii, and to perform the intervention as a whole. The FMA is a performance based impairment index which assesses motor functioning post-stroke (Fugl-Meyer, Jääskö, Leyman, Olsson, & Steglind, 1974) (Appendix C). It is used to plan and assess treatments. Items are scored from 0-2, with the upper extremity portion of this test reaching a maximum score of 66. Previous research has shown that a score of over 10 will ensure the participant is able to physically complete the intervention (Harris, Eng, Miller, & Dawson, 2009), and the FMA is one of the most widely used quantitative measures of stroke impairment (Gladstone, Dannells, & Black, 2002). This measure has normative data for stroke patients (Duncan, Lai, & Keighley, 2000), and excellent test-retest reliability (ICC = 0.97) (Platz et al., 2005).

Setting and Apparatus

All sessions were completed at the indoor track of the St. Denis Centre, in the multi-purpose room of the St. Gethsamane Church, or in the multi-purpose room of the Teutonia Club. Participants completed their video gaming sessions on a Nintendo Wii (2006; retail value: $150; Nintendo; Kyoto, Japan), using the Nintendo WiiMote and the THQ uDraw game tablet accessory (2010; retail value: $49.99; THQ; Agoura Hills, California). Three games were utilized for the study: **(1)** Kororinpa Marble Mania (controlled by WiiMote), **(2)** Spongebob Squigglepants (controlled by uDraw game tablet), and **(3)** Instant Artist: Studio – Alien Splat (controlled by uDraw game tablet).

Measurement

In addition to testing for inclusion criteria, each participant was tested on four dependent measures at four different time periods. First, participants were given a familiarization trial with the measures, followed by baseline testing at their next session. They were tested again after eight Nintendo Wii sessions and finally after sixteen Nintendo Wii sessions. The four dependent measures used: Jebsen Hand Function Test (JHFT), Box and Block Test (BBT), Nine Hole Peg Test (NHPT), and the Stroke Impact Scale (SIS).

Jebsen hand function test. The JHFT is an evaluative measure used to assess a wide range of uni-manual hand functions required for ADL (Jebsen, Taylor, Trieschman, Trotter, & Howard, 1969). For this test, the dependent variable was time, and the longer it took for a participant to perform, the greater was their impairment in hand function. The JHFT is comprised of seven subtests. Six of the seven tests were utilized in this study; the writing subtest was eliminated in order to shorten the time of administration, to minimize the potential of participant frustration, and because not all stroke patients used their paretic hand for handwriting before injury (Carey et al., 2007). Both the left and right hands were tested independently using a series of six tasks that are related to ADL, and were timed with a stop watch (Appendix D).

Card turning. Five 7.6 x 12.7 cm cards were placed vertically in front of the participant on a table. Participants began by placing their lesser affected hand on the edge of the table in front of the centre card, while keeping their more affected hand rested at their side. When told to begin, the participant began flipping the cards over starting with the furthest card from their active shoulder (e.g., if the lesser affected hand was their right hand, the participant would start with the left-most card). This process would be repeated with the more affected hand, and started with the card on the opposite end of which the previous trial started. Participants were not required to flip the cards with accuracy (Jebsen et al., 1969), and a final time was taken once the fifth card was turned over.

Small objects. An empty tin can was placed directly in front of the participant, and the participant was asked to place their lesser affected hand on the table directly in front of the tin. Two paper clips, two standard bottle caps, and two pennies were placed in a line next to the tin on the same side as the lesser affected extremity (e.g. if the lesser affected hand was their right hand, the objects would be lined up on the right side of the can). When instructed, participants would begin picking up the furthest object from the tin, one at a time, and placing them in the tin. This process would be repeated with the more affected hand, and the small objects mirrored to the opposite side of the tin. A final time was taken for each hand once all objects were placed in the tin.

Beans. Five plastic kidney beans were placed on the table up against a ¾ inch wooden board. Participants would begin with their lesser affected hand resting on the centre edge of the table holding a spoon, and when prompted, would scoop up the beans, one at a time, and place them into a tin can. When told to begin, the participant started scooping up the bean closest to their active shoulder (e.g. if the lesser affected hand was their right hand, the participant would start with the right-most bean) with the spoon they were holding. This process was repeated with the more affected hand, and started with the bean on the opposite end of which the previous trial started. A final time was taken for each hand once all beans were placed in the tin.

Stacking objects. Four white checkers were placed side by side on a table up against a ¾ inch wooden board. Participants began with their lesser affected hand resting on the table, and when prompted, stacked the checkers one at a time on top of each other on the wooden board. The order in which checkers were stacked did not matter (Jebsen et al., 1969). The exact process was repeated for the more affected hand, and both hands were timed independently.

Moving large empty and weighted cans. Five empty cans were placed in a horizontal line on the table in front of a ¾ inch wooden board. Participants began with their lesser affected hand in front of the centre can, and when instructed, moved the cans from the table onto the wooden board one at a time. Participants began with the can furthest from their active shoulder (e.g. if the lesser affected hand was their left hand, the participant would start with the right-most can). This process was repeated with the more affected hand, and started with the can on the opposite end of which the previous trial started. After both hands were timed with the empty cans, the identical process was administered on both hands with heavier (0.45 kg) cans.

The JHFT required approximately 20 minutes to administer and is widely used with those suffering from neurological impairments such as stroke (Sears & Chung, 2010). Normative data have been established for adults aged 20 to 94 (Jebsen et al., 1969), and the measure has excellent test-retest reliability (r = 0.92) (Beebe & Lang, 2009) as well as adequate criterion validity (r = 0.69) (Sears & Chung, 2010).

Box and block test. The BBT is a quick to administer (< 5 minutes) test that assesses both fine and gross motor activity, and was first created in 1957 (Mathiowetz, Volland, Kashman, & Weber, 1985). Participants were seated at a table facing a box divided into two square compartments separated by a partition. One hundred and fifty 2.5 cm x 2.5 cm x 2.5 cm cubes were placed into one side of the partitioned box, and the individual was asked to move as many blocks as possible from one side of the box to the other within a one minute time span. The participant's hand must cross over the divide in order for the block to count. Blocks that happen to bounce out of the second compartment still count as a point. Both the left and right hands were tested twice independently and the better of the two scores was taken. Fewer blocks moved indicated a more extensive unilateral manual impairment of the hand. The BBT is a standardized, inexpensive test that is commonly used as a measurement for those with stroke-induced manual dexterity impairments (Carey et al., 2007; Saposnik et al., 2010b; Chanubol et al., 2012). Additionally, normative data have been established in those aged 20 to 70+ based upon testing over 600 healthy adults (Mathiowetz et al., 1985). As a measurement, the BBT has excellent test-retest reliability on both the more affected (r = 0.98) and less affected (r = 0.93) hand (Chen, Chen, Hsueh, Huang, & Hsieh, 2009), as well as adequate to excellent concurrent validity to several different measures (Lin, Chuang, Wu, Hsieh, & Chang, 2009).

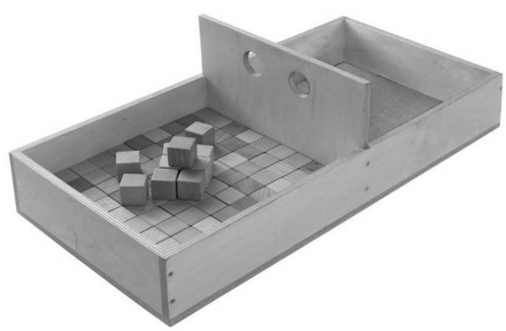


Figure 1: Box and Blocks Test

Nine hole peg test. The NHPT is an inexpensive and easily administered test that measures finger dexterity (Kellor, Frost, Silberberg, Iverson, & Cummings, 1971). The measure is made of wood, and has nine holes that are 10 mm diameter, 15 mm in depth, and 32 mm apart. Nine pegs that are 7 mm in diameter and 32 mm in length were placed in a container next to the test board (Mathiowetz et al., 1985). Participants were seated at a table in front of the NHPT, and were instructed to take a peg from the container and place it into one of the peg holes on the board. Once all nine pegs were placed onto the board, removed, and placed back into their container, the time was recorded. The NHPT took approximately one minute to complete, and was performed on both the left and right hands twice. The better of the two scores was taken as a final score. This measurement is commonly used in research examining fine motor recovery from neurological impairment (Yancosek & Howell, 2009), and has been used previously in studies concerning virtual reality and fine motor rehabilitation (Deutsch, Merians, Adamovich, Poizner & Burdea, 2004; Crosbie, Lennon, McGoldrick, McNeill, & McDonough, 2012). Normative data have been reported in healthy adults (Grice et al., 2003), as well as acute stroke (Beebe et al., 2009), and the NHPT has good test-retest reliability (ICC = 0.85) (Chen et al., 2009).

Figure 2: Nine Hole Peg Test

Stroke impact scale. The SIS is a self-report health status questionnaire that was developed in 1999 to act as a quality-of-life measure post-stroke (Duncan et al., 1999). The measure is a 59 item questionnaire that spans eight separate domains (strength, hand function, ADL, mobility, communication, emotion, memory and thinking, and participation). However, for the purpose of this study, we have extracted 18 items from three domains (strength, hand function, and ADL) (Appendix E). Example questions include asking the participant to reflect back on the past two weeks and rate such things as: how difficult it was to carry a bag with their affected hand, how they would rate their ability to tie a shoe, or how difficult it was to dress the top part of their body. Participants were asked to answer questions on a 5 point Likert scale, indicating whether they have *a lot of trouble* to no *trouble at all* with that particular item. Although relatively new, the SIS has been used frequently in recent literature to assess participants' views of their capabilities post-stroke (e.g., Saposnik et al., 2010; Wagner et al., 2011; Eriksson, Aasnes, Tistad, Guidetti, & von Koch, 2012). The original measure has good to excellent test-retest reliability (ICC = 0.70-0.92) (Duncan et al., 1999), as well as internal consistency, and normative data (Duncan et al., 2002). Content validity has been established by using feedback from interviews and focus groups with patients, caregivers, and health care professionals (Duncan, Wallace, Studenski, Lai, & Johnson, 2001). Additionally, the measure has been previously modified to include only 16 items from the original questionnaire with minimal reliability loss (Duncan, Lai, Bode, Perera, & DeRosa, 2003).

In order to control for investigator bias, an individual trained in the administration of the four dependent measures was responsible for their conduction at each of the testing sessions.

Procedure

Interested participants filled out a written informed consent and received a letter of information for collection of inclusion data (Appendix F). Participants were then screened to ensure they met inclusion criteria. Those who met inclusion criteria were asked to complete a participant profile (Appendix G) before their first session, were given a second consent form and letter of information specific to the research project (Appendix H), and asked to a attend a familiarization trial on their next visit. In addition, participants completed a rolling verbal consent once a week (Monday), which tracked changes in medication, physical activity, and video game interaction. Following the familiarization trial, baseline measures were then taken on the four dependent measures; JHFT, BBT, NHPT, and SIS at their next session.

Participants completed a total of 16 sessions, with two sessions per week, for approximately eight weeks. Each session was 15 minutes in length and required the participants to interact with games that emphasize fine motor skills. All gaming was completed with the participants' more affected hand and by using both the WiiMote and the uDraw Game Tablet.

Three games were played during each session, and were chosen based on the use of fine motor muscles through interaction with the games. **(1)** Kororpina–Marble Mania: The objective of the game was to control a marble through a maze. Levels increase in difficulty and thus help to maintain a player's interest as skill improves. Accurate guidance of the marble throughout the maze promotes grasp, wrist stability, and wrist flexibility, which can aid in the use and control of the UE when completing the JHFT, BBT, and NHPT. This game was played for 6 minutes per session. **(2)** uDraw Spongebob

Squigglepants: The participant engaged in rapid fire mini-games that are controlled by drawing or tapping on the uDraw tablet controller using a stylus. Use of the uDraw gaming stylus in a time-based environment promotes increased fine motor control and dexterity of the fingers, as well as increased reaction time, which is prevalent in the JHFT, BBT, and NHPT. Players advanced by achieving certain time scores. This game was played for 6 minutes per session. **(3)** uDraw Alien Splat!: The participant used the uDraw tablet controller to "splat" as many aliens as possible in a certain time span (3 minutes). This game promotes fine motor control and stability of the fingers through the use of the stylus on the uDraw tablet, which can aid in completion of the JHFT, BBT, and NHPT.

Participants completed their Wii training as a supplement to the current CDMP neuro-circuit, which is a station-based exercise circuit program that includes exercises designed for gross motor UE, lower extremity (LE) training, and balance. There are 10 stations within the CDMP exercise program, and participants spend 4 minutes at each station before rotation. Participants were asked to complete their Wii training immediately prior to, or following, their exercise circuit. A total of eight kinesiology undergraduate students aided as research assistants and volunteers with the Wii training, and were present to assist the participants with any difficulties they had and to monitor their progress throughout each session. All volunteers and research assistants received police clearance to work with vulnerable populations, and received orientation training through WECHC. Wii training occurred through a series of mock trial runs conducted by the primary researcher, and the primary researcher was present at all times to oversee the multiple running Wii stations. Additionally, all participants remained seated during their Wii sessions, which promoted a safe playing environment.

Statistical Analysis

A dependent t-test was run between pre-training and post-training data for each dependent measure on each hand, based on the previously stated hypothesis. In addition, a repeated measures ANOVA (Session: familiarization vs. baseline vs. 8 sessions vs. 16 sessions) was performed on the SIS, and a 2 (hand: left vs right) X 4 (session: familiarization vs. baseline vs. 8 sessions vs. 16 sessions) repeated measures ANOVA was performed on the remaining three dependent measures, the JHFT, BBT, and NHPT. Significant F tests ($p < 0.05$) were further evaluated using Bonferroni pairwise comparisons. Greenhouse-Geisser corrections were used for three dependent measures (JHFT, BBT & SIS) where sphericity was violated. All statistical analyses were conducted using the Statistical Package for Social Sciences (SPSS) for Windows (version 20).

Results

Of the 17 chronic phase stroke survivors that were initially recruited for the study, 10 (mean age = 72.1, mean time since injury = 31.2 mos.) novice gaming males completed the intervention (Appendix I). In addition, not all participants were able to complete all of the tests. Due to these factors, there is variance in the number of participants for each dependent measure. All 10 participants completed the Box and Block Test and Stroke Impact Scale, while nine completed the Nine Hole Peg Test, and eight completed the Jebsen Hand Function Test. Participants did not report engaging in extra exercise outside of what they had stated in their participant profile prior to beginning the intervention, and they did not report any extra video gaming outside of the Wii program. Participants were consistent in the timing of their Wii training (i.e. completion of the Wii consistently before or after their regular neuro-circuit). The range of completion time was 8.5 to 14 weeks, with a mean completion time of 11.05 weeks. Additionally, no adverse events were reported during or after completion of the Wii intervention. One participant was self-report colour-blind. This did not affect his ability to complete any of the games used throughout the intervention. Table 2 includes a description of individual participant characteristics.

ID	Age	Time Since CVA (mos.)	Dominant Hand	Affected Hand	MMSE Score (max. score = 30)	FMA Score (max. score = 66)
1	76	72	R	R	26	25
2	51	15	R	R	30	61
3	67	24	R	R	28	53
4	59	86	R	R	25	61
5	85	N/A	R	R	26	48
6	73	54	R	L	25	44
7	84	18	R	L	28	57
8	79	14	R	L	26	39
9	64	25	R	L	30	60
10	83	28	R	L	28	53

Table 2. Individual Participant Characteristics

JHFT

The JHFT was used to determine whether use of commercial gaming through the Nintendo Wii translated into an increase in ability to complete ADL. Complete data was compiled for eight of 10 participants, and all but one of the eight participants saw improvements from pre-testing to post-testing in their more affected hand. Two participants were omitted due to an inability to complete the test. A Shapiro-Wilks test was conducted to test for normality because of a mean kurtosis level within the more affected hand (5.61), and the lesser affected hand (6.58). Due to a non-normal distribution, a natural log transformation was completed. Participant scores improved from pre-testing to post-testing on both the more affected [(M = 4.29, ± 0.23) to (M = 4.09, ± 0.18)] and the lesser affected hand [(M = 4.03, ± 0.20) to (M = 3.84, ± 0.16)]. A dependent t-test was performed based on planned comparisons which showed significance between pre-testing and post-testing on both the more affected hand [$t_{(7)}$ = 2.687, p = 0.031, d = 0.34] and the lesser affected hand [$t_{(7)}$ = 3.345, p = 0.012, d = 0.38] (Figure 3). Results of a 2 x 4 repeated measures ANOVA indicated a main effect of session [$F_{(1.405,9.836)}$ = 7.441, p = .001], as well as hand [$F_{(1,7)}$ = 8.447, p = .023], with no Session x Hand interaction. Bonferroni comparisons revealed no significant differences between Sessions, with pre-testing to post-testing approaching significance (p = 0.068).

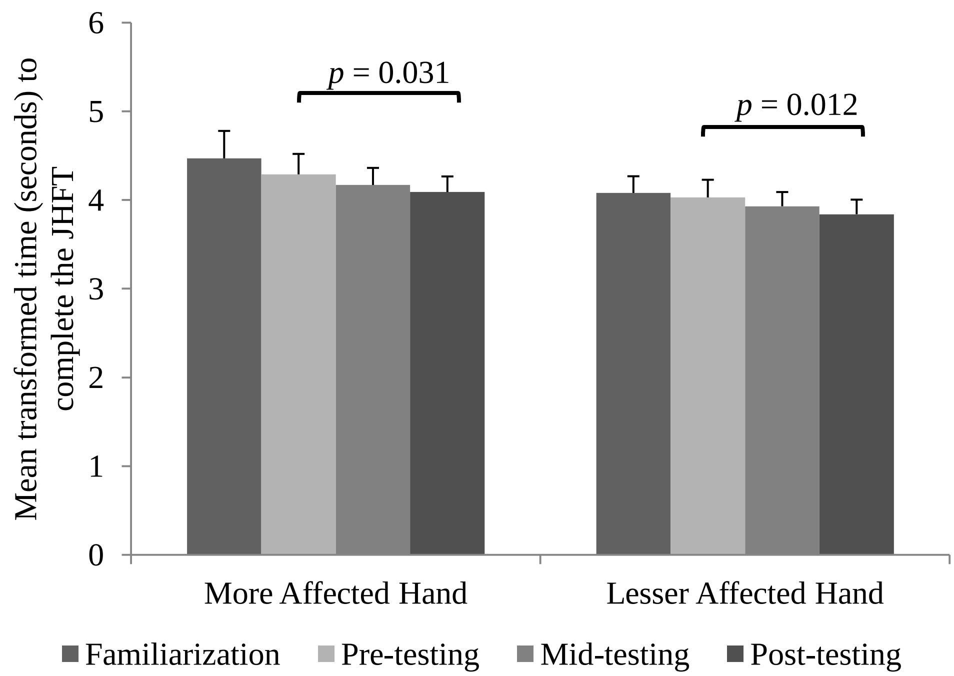


Figure 3: Mean (*SE*) transformed time to complete the JHFT for each Session. Significance is shown between pre-testing and post-testing for both hands.

BBT

The BBT was used to test if commercial gaming through the Nintendo Wii had a positive effect on gross manual dexterity. Data was collected on all 10 participants. Participant scores increased from pre-testing to post-testing on both the more affected [(M = 31, ± 5.27) to (M = 36, ± 6.77)] and the lesser affected hand [(M = 45, ± 4.63) to (M = 51, ± 4.71)]. A dependent t-test was performed based on planned comparisons which showed significance between pre-testing and post-testing on both the more affected hand [$t_{(9)}$ = 2.572, p = 0.030, d = 0.29] and the lesser affected hand [$t_{(9)}$ = 3.331, p = 0.009, d = 0.37] (Figure 4). Results of a 2 x 4 repeated measures ANOVA indicate a main effect of session [$F_{(1.312,11.81)}$ = 6.708, p = .018], as well has hand [$F_{(1,9)}$ = 8.525, p = .017], with no Session x Hand interaction. Bonferroni comparisons indicated no significant differences among the different sessions, although a trend towards significance is evident between mid-testing and post-testing ($p = 0.054$).

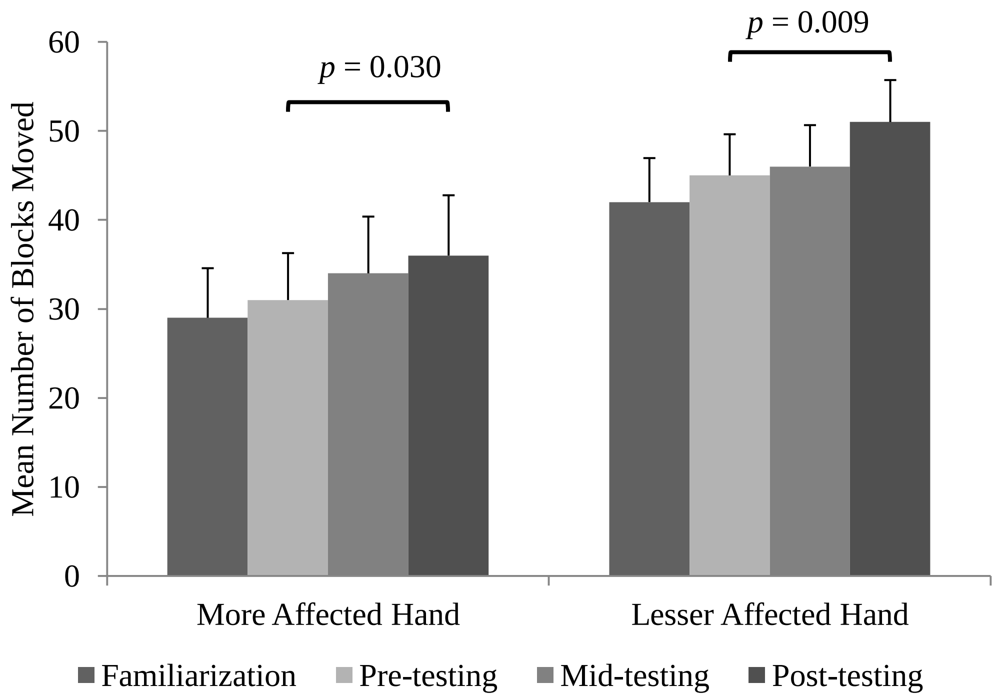


Figure 4: Mean (*SE*) number of blocks transferred across each Session. Significance is shown between pre-testing and post-testing for both hands.

NHPT

The NHPT tested to see if commercial gaming through the Nintendo Wii had a positive effect on fine motor skills. Data was collected on 9 out of 10 participants, and all participants saw an improvement from pre-testing to post-testing in their more affected hand. One participant was omitted due to an inability to insert any pegs into the peg board. A Shapiro-Wilks test was conducted to test for normality due to a mean kurtosis level within the more affected hand (3.44), and the lesser affected hand (5.31). Due to a non-normal distribution, a natural log transformation was completed. Participant scores improved from pre-testing to post-testing on both the more affected [($M = 4.35$, ± 0.39) to

(M = 3.94, ± 0.25)] and the lesser affected hand [(M = 3.48, ± 0.13) to (M = 3.34, ± 0.09)]. A dependent t-test was performed based on planned comparisons which showed significance between pre-testing and post-testing on both the more affected hand [$t_{(8)}$ = 3.023, p = 0.016, d = 0.42] and the lesser affected hand [$t_{(8)}$ = 2.328, p = 0.048, d = 0.42] (Figure 5). Results of a 2 x 4 repeated measures ANOVA on the log transformed NHPT data indicate a main effect of session [$F_{(3,24)}$ = 7.227, p = .001], as well has hand [$F_{(1,8)}$ = 5.903, p = .041], with no Session x Hand interaction. Bonferroni comparisons revealed significant differences between familiarization and post-testing (p = 0.012), as well as pre-testing and post-testing (p = 0.026).

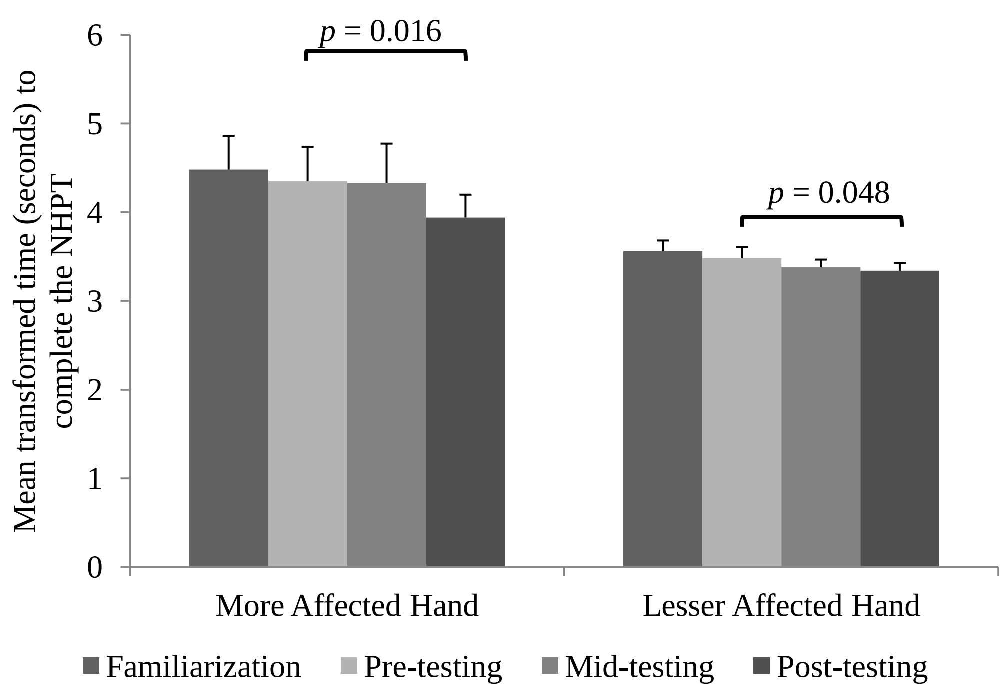


Figure 5: Mean (*SE*) transformed time to complete the NHPT across each Session. Significance is shown between pre-testing and post-testing for both hands.

SIS

The SIS was used to establish if commercial gaming through the Nintendo Wii as rehabilitation affected perceived quality of life. Data was collected on all 10 participants for this measure. Participant scores increased from pre-testing (*M* = 60, ± 4.39) to post-testing (*M* = 65, ± 4.59). A dependent t-test was performed based on planned comparisons which showed significance between the two sessions [$t_{(9)} = 3.332$, $p = 0.009$, $d = 0.38$] (Figure 6). Results of a repeated measures ANOVA indicated a main effect of session [$F_{(1.501,13.513)} = 7.884$, $p = .008$]. Bonferroni comparisons suggest a significant difference between familiarization and post-testing ($p = 0.034$), as well as mid-testing and post-testing ($p = 0.001$), and approaching significance between pre-testing and post-testing ($p = 0.053$).

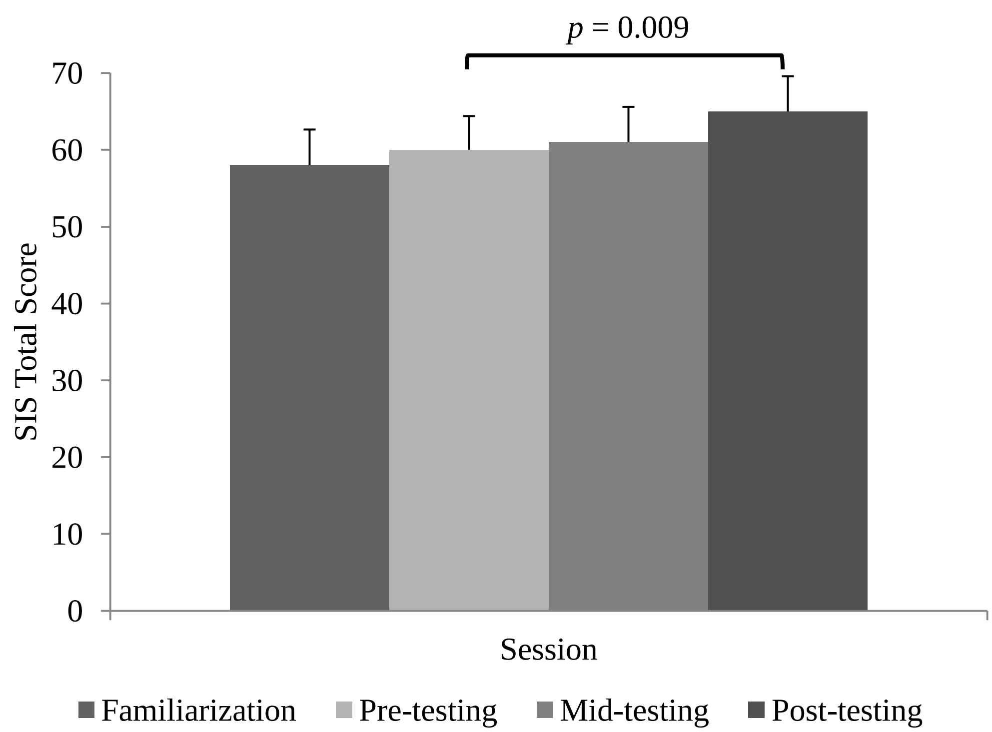


Figure 6: Mean (*SE*) SIS scores across each Session. Significance is shown between pre-testing and post-testing.

Means and standard error for each dependent measure on each of the four testing sessions are displayed in Table 3.

Discussion

The purpose of this study was to improve the fine motor skills, as well as the perceived ability to complete ADL, of a group of individuals who suffer from chronic stroke. This was accomplished through a 16-session VR intervention using a commercially available gaming system (Nintendo Wii, 2005, retail value: $150). There was a wide spectrum of functional ability among the participants, particularly with their *more affected* hand. As such, it was important that all participants were tested relative to their own ability, and is why each participant served as their own control. In addition to using their *more affected* hand for comparison pre- and post-intervention, a secondary form of control was implemented by comparing the participants' *more affected* hand, which received treatment, to their *lesser affected* hand, which was only engaged in their primary exercise neuro-circuit.

It was hypothesized that participants would experience improvements of fine motor skill as a result of their involvement in the training intervention. Additionally, it was also hypothesized that participants would have a perceived increase in their ability to complete ADL following the Wii intervention. Results indicate that significant improvements occurred between pre-testing and post-testing on all four standardized measures.

Fine Motor Ability

Fine motor skill plays a vital role in completion of ADL, and loss of hand function through stroke can result in a decreased capacity to complete self-care activities (Lai et al., 2002). This impaired functional ability can in turn lead to a negative effect in relation to independence, mental health, and social engagement (Burdea et al., 2011).

Due to the limited rehabilitation options available to those with chronic stroke (Langhammer & Stanghelle, 2003), novel and promising rehabilitative techniques should include this target group. Through practice with a commercial gaming device, participants in the current study saw significant increases on all three functional ability measures.

The JHFT is a timed measure that evaluated the participants' ability to complete a range of uni-manual hand functions required for ADL. There was a significant improvement in completion time (seconds) of the JHFT between pre-testing in post-testing, and this was found in both the *more affected* and *lesser affected* hand. The *more affected* hand improved an average of 16.1 percent between the two testing periods, where the *lesser affected* hand improved an average of 22.5 percent. The JHFT has been widely used within VR and stroke rehabilitation, but not with commercial gaming. A number of VR studies reported significant improvements in the *more affected* hand following treatment (Deutsch et al., 2004; Adamovich et al., 2005; Merians et al., 2006; Carey et al., 2007; Merians et al., 2010). Additionally, a number of studies utilizing VR exhibited findings that did not reach statistical significance, although participants experienced an improvement in the time to complete the JHFT (Jack et al., 2001; Merians et al., 2002; Deutsch et al., 2002; Deutsch et al., 2004).

To examine the effect of commercial gaming on gross manual dexterity, we used the BBT. The commercial gaming intervention elicited a significant increase of transferred blocks between pre-testing and post-testing for both hands, with a mean increase of 16.1 percent for the *more affected* hand and 13.3 percent in the *lesser affected* hand. Previous research within VR and stroke rehabilitation using the BBT has not resulted in improvements that have been statistically significant (Saposnik et al., 2010a; Levin, Snir, Liebermann, Weingarden, & Weiss, 2012), but one intervention did see increases that approached statistical significance (Saposnik et al., 2010b). However, this study was with 20 acute phase stroke survivors (< 3 mos. since injury), and may not be reflective of those in the chronic phase of stroke. Huang and colleagues (2013) analyzed the effectiveness of commercial gaming with 12 stroke survivors who were three to 48 months post injury. Through use of the Nintendo Wii and XaviX gaming devices, participants saw significant increases in the BBT, and reported being satisfied with using gaming for their rehabilitation. There is no breakdown of individual demographics within the study, so it is difficult to determine what percentage of the participants were in the chronic phase of their stroke; however, this is the most similar, and only, study to corroborate with our results on the BBT.

Finger dexterity was measured through the NHPT, and our participants significantly improved their time of completion (seconds) from pre-testing to post-testing. There was a mean improvement of 28.2 percent in the *more affected* hand, as well as a 12.6 percent improvement in the *lesser affected* hand. Participants' performance on the NHPT was variable, and those with moderate to severe impairment took much longer compared to those with mild impairment. Use of the NHPT in studies of a similar nature has been inconsistent and limited, as previous literature indicates that the NHPT has not been widely used in VR or commercial gaming. The study that most closely resembles our specific population, Merians and colleagues (2010), used robotic assistance and virtual reality to improve UE function in 11 chronic stroke participants. A CyberGlove was used in conjunction with four different gaming simulations to train the more affected hand, and their NHPT results showed statistically significant advances.

It was once perceived that recovery while in the chronic phase of stroke was not possible (Jorgensen et al., 1995), however the present study adds to the growing body of literature that suggests otherwise (Jack et al., 2001; Deutsch et al., 2002; Merians et al., 2002; Deutsch, et al., 2004; Adamovich et al., 2005; Holden, 2005; Demain et al. 2006; Merians et al., 2006; Carey et al., 2007; Cramer, 2008; Burdea et al., 2011). Furthermore, because options for rehabilitation for those in the chronic stroke phase are limited (Langhammer & Stranghelle, 2003, Ferrarello et al., 2010), survivors must often rely on community-level rehabilitation if they wish to continue recovery post 12 months injury (Holden, 2005). Our findings on rehabilitation of the UE post-stroke add to the notion that community-level rehabilitation can be an important component of recovery, and may potentially influence guidelines towards rehabilitation after stroke (Landry et al., 2008).

Perceived Ability to Complete ADL

The perceived ability to complete ADL was measured through the SIS, a quality of life questionnaire. Following the intervention, the participants' perceived ability to complete ADL improved. From pre-testing to post-testing there was a mean increase of 8.3 percent, which is equivalent to a 5 point increase on the SIS. Furthermore, participants completed the questionnaire with no knowledge of their performance on the functional ability standardized measures; therefore this increase in the participants' perceived ability occurred in a manner irrespective of their knowledge regarding their functional scores. Previous research in this area has resulted in inconsistent findings. With respect to VR, one study saw improvement in QOL based on the SIS (Lo et al., 2010), however others found no improvement (Finley et al., 2005; Wagner et al., 2011). Specific to commercial gaming, previous studies using the SIS saw no signficiant improvements (Saposnik et al., 2010a; Reinthal et al., 2012; Combs et al., 2013).

The SIS utilized in the current study was modified for ease of implementation and applicability to the participants. Because of this modification, the SIS we used is not identical to those used in similar studies. This may account for the contrasting results we had compared to other studies in the area of commercial gaming. Previous modification of the instrument resulted in the SIS-16 (Duncan et al., 2003), which includes 16 items from the original 59 item questionnaire. Although it has never been utilized in VR or commercial gaming, the SIS-16 is frequently used in other stroke rehabilitation studies (Nadeau et al., 2005; Riachy et al., 2008; Shobha, Sylaja, Kapral, Fang, & Hill, 2010). In comparison, our modified version contains 18 items, and while similar to the SIS-16, it is geared more specifically to our population. Importantly, items from our modified version were taken from the same domains utilized in the SIS-16, specifically strength, hand function, and ADL.

QOL and the functional abilities required to complete ADL are important aspects of recovery; however, perceived recovery can play a vital role as well. Stroke survivors often report a lower perceived QOL as compared to healthy controls (Kissela, 2006), and those in the chronic phase of stroke recovery with UE impairment are especially susceptible to reporting low levels of QOL (Franceschini et al., 2010). Perceived QOL and ability to complete ADL will have an effect on a survivors' confidence, and individuals with higher perceived capabilities are more likely to display daily self-care abilities that not only build on rehabilitative gains, but help with consistency in performance and promote future functional gains (O'Leary, 1985).

Role of the Lesser Affected Hand

Although the *lesser affected* hand was not active during the Wii intervention, results from the statistical analyses indicated that both the *more affected* hand and the *lesser affected* hand displayed a significant improvement between pre-testing and post-testing on all three measures that tested the hands independently, and that there were no interactions between the two hands for any of the tests. For the most part, researchers in the area of stroke rehabilitation do not tend to measure both hands independently, and if so, information is generally only provided on the *more affected* hand (Saposnik et al., 2010a; Saposnik et al., 2010b; Combs et al., 2012; Reinthal et al., 2012). While preliminary in nature, we have proposed three different reasons as to why both the *more affected* hand and *lesser affected* hand showed significant improvements.

Cross education. First reported over a century ago (Scripture, Smith, & Brown, 1894), the existing literature on cross education has since grown; however, research on cross education and its impact on stroke rehabilitation is scarce. Cross education can be defined as a contralateral effect of chronic motor activity in one limb (Enoka, 1988). In other words, giving one hand strength treatment, while leaving the other without, may actually result in the non-active hand increasing in strength. Within the current study only the *more affected* hand received fine motor treatment. Theoretically, the *lesser affected* hand may have increased in functional ability based on the treatment provided for the *more affected* hand.

The exact mechanism for cross education is unknown, but researchers have theorized that neurological pathways play a role (Hendy, Spittle, & Kidgell, 2012). Suggested mechanisms for cross education include cortical mechanisms (Carson, 2005; Perez & Cohen, 2008), and to a lesser extent, spinal mechanisms (Fimland et al., 2009; Dragert & Zehr, 2011), and muscular mechanisms (Houston, Froese, St P, Green, & Ranney, 1983; Hortobagyi et al., 1996). Little research has been done on cross education and its effects, and research that is available appears to be conflicting. Some research suggests that cross education may be unidirectional, and occurs more prominently from the dominant limb to the non-dominant limb in right handed individuals (Farthing, Chilibeck, & Binstead, 2005; Farthing, 2009). Participants in the current study were self-reported right-handed, and of the 10, half were right-hand affected. If previously drawn conclusions are correct, then theoretically the participants in the current study who are right hand affected would see larger cross education effects than those who are left hand affected. As expected, those who were cross-training from left (non-dominant hand) to right (dominant hand) had a lower overall mean improvement when compared to those who were cross-training from right (dominant hand) to left (non-dominant hand). There are other studies, however, that suggest the exact opposite; that there is a greater magnitude in cross education from the non-dominant to dominant limb (Parlow & Kishbourne, 1990; Niebor et al., 2012). Overall, research looking at the effect of cross education on stroke recovery is limited, and since neural mechanisms are believed to be heavily involved in cross education, training may differ between a healthy population and those who have experienced a stroke.

The effect of cross-education on dorsiflexor foot muscles post-stroke has been observed, and is the only study to date that looks at the implications cross-education can have on post-stroke recovery. Dragert and Zehr (2013) recruited 19 participants who completed six weeks of maximal isometric dorsiflexor training using their *lesser affected* ankle. Following the intervention, maximal voluntary isometric contraction force increased by 14.7% in the trained (*lesser affected*) limb, and 8.4% in the untrained (*more affected*) limb. Thus, significant increases in the *more affected* dorsiflexor muscles are possible through training of the *lesser affected* ankle. Although minimal research is available regarding cross education and stroke, the proposed neural mechanisms and preliminary studies suggest that this type of training could be beneficial in stroke recovery (Hendy et al., 2012).

Practice effect. Practice effects are a subtype of order effect that occur when participants see improvement in test performance based on repeated evaluation with the same testing materials, as opposed to seeing increases based on treatment (Heiman, 2002). In regards to the current study, participants may have seen improvements in the *more affected* and *lesser affected* hand as both hands were equally exposed to the same testing materials for the same amount of time.

All research using pre-testing and post-testing with the same materials on the same participants runs the risk of incurring a practice effect. The JHFT, BBT and SIS are particularly resistant to practice effects based on their high test-retest reliability (Jebsen et al., 1969; Duncan et al., 1999; Chen et al., 2009), however the NHPT is especially sensitive to practice effects (Grice et al., 2003). To minimize the potential for practice effects artificially inflating our results, we included the familiarization session prior to baseline data collection for all of the dependent measures. While slight improvements did occur between familiarization and pre-testing, this helped to avoid inflating the difference between pre-testing and post-testing and provides a more accurate measure of participant improvement.

Training time. Following stroke, it is common for survivors to favor their *lesser affected* hand when completing ADL, which is thought to result from a process termed *learned non-use* (Taub et al., 2006). This increased usage of the *lesser affected* hand may have indirectly affected the results of the current study. As a survivor begins to rely on their *lesser affected* hand to complete daily tasks, small increments of time are accumulated that will give that hand an increased advantage. Within this study, this increase in training time occurs not only in everyday tasks, but through their bi-weekly exercise regimen as well. Participants who were part of the Wii program still actively participated in their normal neuro-circuit regimen. Through watching and speaking with the participants, it was very clear that most of the exercise burden is placed on their *lesser affected* hand. Through personal experience as a volunteer with the neuro-circuit, it is evident that participants favoured the *lesser affected* hand throughout their circuit training. For example, if participants are given four minutes to do bicep curls, three minutes would be spent working out the *lesser affected* arm, while only one minute would be spent on their *more affected* hand. This type of favouring spans not only across the neuro-circuit’s five arm stations, but often occurs throughout their daily tasking as well. This became evident through informal conversations with the participants about their daily usage of their *more affected* hand, where all mentioned favouring their *lesser affected* hand, and most mentioned using their *lesser affected* hand whenever possible.

Our Wii program may have acted as an equalizer for the *more affected* hand. As the *lesser affected* hand appears to be utilized more heavily during participants' regular exercise, the Wii program may have helped the *more affected* hand keep up. In other words, since the Wii program was the only source of exercise that was solely completed with the *more affected* hand, its absence may result in a lack of improvement or even a decrease in performance on the standardized measures.

This concept of *training time* is very prevalent within CIMT, a rehabilitation method that focuses on repetitive tasks completed by the *more affected* hand, while keeping the *lesser affected* hand constrained for several hours at a time (Michaelsen et al., 2006). This increased amount of *training time* has resulted in positive results MT (Taub & Morris, 2001; Van Peppen et al., 2004; Hakkenes & Keating, 2005), although its effectiveness and practicality remains unclear.

In our attempt to control for confounding variables we asked that participants limit their involvement in video gaming and/or initiating new fine motor activities outside of the Wii program, potentially leaving more time for the *lesser affected* hand to flourish outside of the current treatment. This may have inadvertently limited the potential improvement for the *more affected* hand, but was necessary in order to be confident that the improvement was a result of the Wii training as opposed to other tasks. Overall, with accumulated increases in training activity for the *lesser affected* hand it is plausible that the results of the three fine motor standardized measures were indirectly affected.

Implications

Concurrent with previous studies (Jack et al., 2001; Deutsch et al., 2002; Merians et al., 2002; Deutsch et al., 2004; Adamovich et al., 2005; Holden, 2005; Demain et al., 2006; Merians, et al., 2006; Carey et al., 2007; Cramer, 2008; Burdea et al., 2011), the present study further emphasizes that rehabilitation once entering the chronic phase of stroke recovery is possible. Due to a lack of rehabilitative options for those with chronic stroke (Langhammer, et al., 2003; Ferrarello et al., 2010), more resources should be allocated towards rehabilitation in this phase. Furthermore, due to lack of funding and rehabilitation coverage, many post-stroke survivors may believe that rehabilitation is not possible during the chronic phase of recovery. The current study provides evidence which suggests the contrary, yet many stroke survivors remain sedentary due to lack of education and resources (Rimmer & Wang, 2005). In turn, sedentary behaviours may lead to secondary conditions such as low cardiorespiratory fitness and chance of subsequent stroke (Kurl et al., 2010). An increase in health promotion directed towards this population, and education for stroke survivors, may drastically lower the incidence rate of secondary conditions.

VR is a novel tool that has been well-received by those in rehabilitation, and has created a perceived ease, as well as increased confidence, in the ability to complete ADL (Lewis et al., 2011). Furthermore, commercial gaming consoles are a low cost tool for rehabilitation, although they are being underutilized in clinical settings. Outpatient centres and community-level rehabilitation groups can potentially make productive use of commercial gaming by implementing them in their recovery regimens. Survivors may also want to consider home use of commercial gaming. The gaming setup used for the current study is off-the-shelf, easy to use, and costs no more than $200 for the system, games, and accessories. With increased exposure to a variety of rehabilitation techniques, a more comprehensive recovery could be expected for survivors of stroke. Such recovery will then contribute to more effective engagement in ADL.

Limitations and Future Directions

Due to participant drop out or not meeting inclusion criteria, the sample size for the current study did not meet the target of 13 which was originally proposed. Seventeen participants were initially recruited for the program, however only 10 completed the full intervention. Due to the small sample size and the pattern of drop out, our findings may have limited generalizability. The reasons for dropout varied, and included failing to meet inclusion criteria (n = 2), transportation issues (n = 1), death (n = 1), unrelated secondary injury (n = 1), and poor attendance for unspecified reasons (n = 2). As witnessed in the current study, many stroke survivors face multiple barriers within exercise post-injury (Rimmer, Wang, Smith, 2008). Programmers must take this into account when designing interventions for those with chronic stroke, as they are highly susceptible to inactivity (Rimmer & Wang, 2005). Moreover, of the 17 participants that were initially recruited, two were female. This is somewhat reflective of previously compiled stroke data, where incidence of CVA is 33% higher in males, and prevalence is 41% higher in males (Appelros, Stegmayr, & Terént, 2009). As neither of the females completed the intervention, our final sample consisted only of males, which further limits the generalizability of our findings.

Future studies using a control group would elucidate some of the issues that remain unclear, such as the notion of practice effects. Our initial intention was to run an

RCT for this study; however this did not happen for two reasons. First, the low sample size made randomization difficult, and came at the cost of power for the study. Secondly, because of the low-risk nature of the study it was advised that, ethically, all participants should receive treatment. In this manner we were able to maximize the treatment given to those with chronic stroke.

There is a distinct lack of studies looking at the effect commercial gaming can have on chronic stroke recovery, so future research is warranted. In addition to addressing the aforementioned limitations, future research should focus on each hand independently. Particularly, the effect of hand dominance on rehabilitation should be explored, as well as how the *lesser affected* hand can impact the *more affected* hand, and vice versa. Although it has not been thoroughly researched within stroke, the findings within cross-education research showcase the delicate balance that exists between both hands (Farthing et al., 2007; Farthing, 2009). Furthermore, researchers should look at the effect cross-education may have specifically on UE recovery, as this has the ability to have an important impact on recovering survivors, particularly those with severe impairment in their *more affected* hand. Lastly, grouping participants based on functional ability or impairment may be helpful. Participants in the current study had a wide range of ability with their *more affected* hand, and thus treatment should be specialized to the functional level of each participant. Within specialized groups games could be chosen based on ability. In the current study, some participants progressed through the game levels quickly, while others found even the most basic levels extremely challenging. Dividing participants according to impairment and choosing games to reflect their current ability may ease frustration and promote success.

Previous research using commercially available gaming within UE rehabilitation in a post-stroke population utilized a much longer treatment time compared to the current study, generally upwards of 60 minutes per session (Yavuzer, Senel, Atay, & Stam, 2008; Saposnik et al., 2010a; Yong et al., 2010). These studies examined acute stroke, however, and commercial gaming research within chronic stroke is non-existent outside of a small number of case reports (Flynn et al., 2007; Alankus et al., 2011; Pastor, Hayes, & Bamberg, 2011; Proffit et al., 2011), or treatments using specialty gaming devices (Combs et al., 2012). While we were initially concerned that our strict time limitations might prevent meaningful improvement, our findings suggest that 15 minutes two times per week is enough to show functional gain, which is in agreement with previous studies which show that task movements for as short as 15 minutes per day have been shown to induce lasting cortical changes (Butefisch et al., 1995; Karni et al., 1995). This is important, as many chronic stroke survivors need to reintegrate back into the community following initial rehabilitation, and may not have long periods of time to devote to their recovery. Moving forward, it is important to investigate various rehabilitation schedules and the extent to which they can elicit recovery. Shorter interventions may be both more appealing and more feasible for those in the chronic phase of stroke recovery.

Conclusion

The purpose of the present study was to evaluate the effectiveness of commercial gaming on fine and gross motor skills in those with chronic stroke. Previous research in the area of commercial gaming and stroke rehabilitation has generally been in the form of case reports (Flynn et al., 2007; Alankus et al., 2011; Proffit et al., 2011), or examining acute stroke (Yavuzer et al., 2008; Saposnik et al., 2010; Yong et al., 2010). Results of previous studies have been favorable but larger, more specific studies are necessary in order to reveal the true rehabilitative potential of those with chronic stroke.

Ten chronic stroke participants completed a 16 session Wii program intervention by engaging with video games using only their *more affected* hand. Participants were given an initial familiarization session, followed by pre-testing, mid-point, and post-testing data collection on four standardized measures. Results showed a significant difference on all four measures from pre-testing to post-testing, illustrating an increase in fine motor ability as well as an increase in the participants' perceived ability to complete ADL.

Research in the area of chronic stroke is vital, as those with this condition are extremely susceptible to inactivity (Rimmer et al., 2005), and are not offered many resources towards their rehabilitation (Langhammer et al., 2003, Ferrarello et al., 2010). Results from the current study showcase the rehabilitative possibilities that are available to chronic stroke survivors, however, community-level care and support are necessary for these possibilities to be realized. Future action in the area of commercial gaming and stroke recovery should include integration of commercial gaming into community-level care, and education on the benefits of outpatient and in-home use.

References

Adamovich, S.V., Merians, A.S., Boian, R., Lewis, J.A., Tremaine, M., Burdea, G.S...Poizner, H. (2005). A virtual reality-based exercise system for hand rehabilitation post-stroke. *Presence*, *14*(2), 161-174.

Alankus, G., Proffitt, R., Kelleher, C., & Engsberg, J. (2011). Stroke therapy through motion based games: A case study. *ACM Transactions on Accessible Computing, 4*(1), 3.

Appelros, P., Stegmayr, B., & Terént, A. (2009). Sex differences in stroke epidemiology a systematic review. *Stroke, 40*(4), 1082-1090.

Beebe, J.A., & Lang, C.E. (2009). Relationships and responsiveness of six upper extremity function tests during the first six months of recovery after stroke. *Journal of Neurologic Physical Therapy, 33*(2), 96-103.

Blake, H., McKinney, M., Treece, K., Lee, E., & Lincoln, N.B. (2002). An evaluation of screening measures for cognitive impairment after stroke. *Age Ageing, 31*(6), 451-456.

Boyd, L.A., & Winstein, C.J. (2001). Implicit motor-sequence learning in humans following unilateral stroke: The impact of practice and explicit knowledge. *Neuroscience Letters*, *298,* 65–69.

Burdea, G.C. (2003). Virtual rehabilitation-benefits and challenges. *Methods of Information in Medicine*, *42,* 519–23.

Burdea, G., Cioi, D., Martin, J., Rabin, B., Kale, A., & DiSanto, P. (2011). Motor retraining in virtual reality: A feasibility study for upper-extremity rehabilitation in individuals with chronic stroke. *Journal of Physical Therapy Education*, *25*(1), 20-29.

Butefisch, C., Hummelsheim, H., Denzler, P., & Mauritz, K.H. (1995). Repetitive training of isolated movements improves the outcome of motor rehabilitation of the centrally paretic hand. *Journal of the Neurological Sciences, 130*(1), 59-68.

Carey, J.R., Durfee, W.K., Bhatt, E., Nagpal, A., Weinstein, S.A., Anderson, K.M...Lewis, S.M. (2007). Comparison of finger tracking versus simple movement training via telerehabilitation to alter hand function and cortical reorganization after stroke. *Neurorehabilitation and Neural Repair*, *21,* 216–232.

Carson, R. G. (2005). Neural pathways mediating bilateral interactions between the upper limbs. *Brain Research Reviews*, *49*(3), 641-662.

Chanubol, R., Wongphaet, P., Chavanich, N., Werner, C., Hesse, S., Bardeleben, A., et al. (2012). A randomized control trial of cognitive sensory motor training therapy on the recovery of arm function in acute stroke patients. *Clinical Rehabilitation, 26*(12), 1096-1104.

Chen, H.M, Chen, C.C., Hsueh, I.P., Huang, S.L., & Hsieh, C.L. (2009). Test-retest reproducibility and smallest real difference in 5 hand function tests in patients with stroke. *Neurorehabilitation & Neural Repair*, 23(5), 435-440.

Combs, S. A., Finley, M. A., Henss, M., Himmler, S., Lapota, K., & Stillwell, D. (2012). Effects of a repetitive gaming intervention on upper extremity impairments and function in persons with chronic stroke: a preliminary study. *Disability and Rehabilitation*, *34*(15), 1291-1298.

Coupar, F., Pollock, A., van Wijck, W.F., Morris, J., & Langhorne, P. (2010). Simultaneous bilateral training for improving arm function after stroke. *Cochrane Database of Systematic Reviews*, *4*, CD006432.

Cramer, S.C. (2007). The EXCITE trial: A major step forward for restorative therapies in stroke. *Stroke*, *38*, 2204-2205.

Cramer, S.C. (2008). Repairing the human brain after stroke: I. Mechanisms of spontaneous recovery. *Annals of Neurology*, *63*(3), 272-287.

Crosbie, J.H., Lennon, S., Basford, J.R., & McDonough, S. (2007). Virtual reality in stroke rehabilitation: still more virtual than real. *Disability and Rehabilitation, 29*(14), 1139–46.

Crosbie, J.H., Lennon, S., McGoldrick, M.C., McNeill, M.D.J., & McDonough, S.M. (2012). Virtual reality in the rehabilitation of the arm after hemiplegic stroke: A randomized controlled pilot study. *Clinical Rehabilitation*, *26*(9), 798-806.

Damush, T.M., Plue, L., Bakas, T., Schmid, A., & Williams, L.S. (2007). Barriers and facilitators to exercise among stroke survivors. *Rehabilitation Nursing*, *32*, 253-260.

Dean, C.M., Richards, C.L., & Malouin, F. (2000). Task-related circuit training improves performance of locomotor tasks in chronic stroke: A randomized, controlled pilot trial. *Archives of Physical Medicine and Rehabilitation, 81*. 409-417.

Deber, R.B. (2004). Delivering health care services: public, not-for profit, or private? In: Marchildon, G.P., McIntosh, T., & Forest, P.G., (Eds.) *The fiscal sustainability of health care in Canada: Romanow papers, volume 1* (198-233). Toronto: University of Toronto Press.

De Groot, M.H., Phillips, S.J., & Eskes, G.A. (2003). Fatigue associated with stroke and other neurologic conditions: Implications for stroke rehabilitation. *Archives of Physical Medicine and Rehabilitation, 84*(11), 1714-20.

Demain, S., Wiles, R., Roberts, L., & McPherson, K. (2006). Recovery plateau following stroke: fact or fiction? *Disability Rehabilitation*, *28*, 815-821.

Deutsch, J.E., Merians, A.S., Burdea, G.C., Boian, R., Adamovich, S.V., & Poizner, H. (2002). Haptics and virtual reality used to increase strength and improve function in chronic patients post-stroke: Two case reports. *Neurology Report*, *26*, 78–85.

Deutsch, J.E., Merians, A.S., Adamovich, S., Poizner, H., & Burdea, G.C. (2004). Development and application of virtual reality technology to improve hand use and gait of individuals post-stroke. *Restorative Neurology & Neuroscience, 22*(3-5), 371-86.

Divani, A.A., Vazquez, G., Barrett, A.M., Asadollahi, M., & Luft, A.R. (2009). Risk factors associated with injury attributable to falling among elderly population with history of stroke. *Stroke*, *40,* 3286 –3292.

Divani, A.A., Majidi, S., Barrett, A.M., Noorbaloochi, S., & Luft, A.R. (2011). Consequences of stroke in community-dwelling elderly: The health and retirement study, 1998 to 2008. *Stroke, 42,* 1821-1825.

Dobkin, B.H. (2008). Training and exercise to drive post-stroke recovery. *Nature Clinical Practice Neurology, 4,* 76-85.

Dragert, K., & Zehr, E.P. (2011). Bilateral neuromuscular plasticity from unilateral training of the ankle dorsiflexors. *Experimental Brain Research, 208*(2), 217-227.

Dragert, K., & Zehr, E.P. (2013). High-intensity unilateral dorsiflexor resistance training results in bilateral neuromuscular plasticity after stroke. *Experimental Brain Research, 225*(1), 93-104.

Duncan, P.W. (1997). Synthesis of intervention trials to improve motor recovery following stroke. *Topics in Stroke Rehabilitation*, *3,* 1–20.

Duncan, P.W., Wallace, D., Lai, S.M., Johnson, D., Embretson, S., & Laster, L.J. (1999). The stroke impact scale version 2.0. evaluation of reliability, validity, and sensitivity to change. *Stroke, 30*(10), 2131-2140.

Duncan, P.W, Lai, S.M., & Keighley, J. (2000). Defining post-stroke recovery: Implications for design and interpretation of drug trials. *Neuropharmocology*, *39*(5), 835-841.

Duncan, P.W., Wallace, D., Studenski, S., Lai, S.M., & Johnson, D. (2001). Conceptualization of a new stroke-specific outcome measure: the stroke impact scale. *Stroke Rehabilitation*, *8*(2), 19-33.

Duncan, P.W., Lai, S.M., Tyler, D., Perera, S., Reker, D., & Studenski, S. (2002). Evaluation of proxy responses to the stroke impact scale. *Stroke*, *33*, 2593-2599.

Duncan, P. W., Lai, S. M., Bode, R. K., Perera, S., & DeRosa, J. (2003). Stroke Impact Scale-16 A brief assessment of physical function. *Neurology*, *60*(2), 291-296.

Edmans, J., Gladman, J., Hilton, D., Walker, M., Sunderland, A., Cobb, S...Pridmore, T. (2009). Clinical evaluation of a non-immersive virtual environment in stroke rehabilitation. *Clinical Rehabilitation*, *23*(2), 106–16.

English, C.K, Hillier S.L., Stiller, K.R., & Warden-Flood, A. (2007). Circuit class therapy versus individual physiotherapy sessions during inpatient stroke rehabilitation: A controlled trial. *Archives of Physical Medicine and Rehabilitation, 88*, 955-963.

Enoka, R.M. (1988). Muscle strength and its development. New Perspectives. *Sports Medicine, 6*(3), 146-168.

Eriksson, G., Aasnes, M. Tistad, M. Guidetti, S., & von Koch, L. (2012). Occupational gaps in everyday life one year after stroke and the association with life satisfaction and impact of stroke. *Stroke Rehabilitation, 19*(3), 244-255.

Eskes, G.A., & Barrett, A.M. (2009). *Neuropsychological rehabilitation*. In: Festa, J.R., Lazar, R.M. (Eds.) Neurovascular Neuropsychology (281–306), New York: Springer Science Publications.

Esmail, N. (2007) Complementary and alternative medicine in Canada: trends in use and public attitudes, 1997–2006. *Public Policy Sources*, *87*, Vancouver: The Fraser Institute.

Farthing, J., Chiilibeck, P.D., & Binstead, G. (2005) Cross-education of arm muscular strength is unidirectional in right-handed individuals. *Medicine and Science in Sports, 37*(9), 1594-1600.

Farthing, J. (2009). Cross-education of strength depends on limb dominance: implications for theory and application. *Exercise and Sport Sciences Reviews, 37*(4), 179-187.

Ferrarello, F., Baccini, M., Rinaldi, L.A., Cavallini, M.C., Mossello, E., Masotti, G...Di Bari, M. (2010). Efficacy of physiotherapy interventions late after stroke: A meta-analysis. *Journal of Neurology, Neurosurgery, & Psychiatry, 82*(2), 1-28.

Feys, H.M., De Weerdt, W.J., Selz, B.E., Cox Steck, G.A., Spichiger R, Vereeck, L.E...Van Hoydonck, G.A. (1998). Effect of a therapeutic intervention for the hemiplegic upper limb in the acute phase after stroke: A singleblind, randomized, controlled multicenter trial. *Stroke*, *29*, 785–792.

Fimland, M. S., Helgerud, J., Solstad, G. M., Iversen, V. M., Leivseth, G., & Hoff, J. (2009). Neural adaptations underlying cross-education after unilateral strength training. *European Journal of Applied Physiology*, *107*(6), 723-730.

Finley, M. A., Fasoli, S. E., Dipietro, L., Ohlhoff, J., MacClellan, L., Meister, C., ... & Hogan, N. (2005). Short-duration robotic therapy in stroke patients with severe upper-limb motor impairment. *Journal of Rehabilitation Research and Development*, *42*(5), 683-692.

Fjaertoft, H., Indredavik, B., Johnsen, R., & Lydersen, S. (2004). Acute stroke unit care combined with early supported discharge. Long-term effects on quality of life. A randomized controlled trial. *Clinical Rehabilitation*, *18*, 580–586.

Flynn, S., Palma, P., & Bender, A. (2007). Feasibility of using the Sony Playstation 2 gaming platform for an individual post-stroke: A case report. *Journal of Neurological Physical Therapy, 31*(4), 180-189.

Folstein, M.F, & Folstein, S.E. (1975). Mini-mental state. A practical method for grading the cognitive state of patients for the clinician. *Journal of Psychiatric Research, 12*, 189-198.

Forkan, R., Pumper, B., Smyth, N., Wirkkala, H., Ciol, M.A., & Shumway-Cook, A. (2006). Exercise adherence following physical therapy intervention in older adults with impaired balance. *Physical Therapy, 86*(3), 401-410.

Forster, A., Young, J., & Langhorne, P. (2000). Medical day hospital care for the elderly versus alternative forms of care. *Cochrane Database of Systematic Reviews*, CD001730.

Franceschini, M., La Porta, F., Agosti, M., & Massucci, M. (2010). Is health-related-quality of life of stroke patients influenced by neurological impairments at one year after stroke? *European Journal of Physical and Rehabilitation Medicine, 46*(3), 389-399.

Fricke, J. (2010). Activities of Daily Living. In: *International Encyclopedia of Rehabilitation* (1-6). Online: Center for International Rehabilitation Research Information and Exchange (CIRRIE). Retrieved from: http://cirrie.buffalo.edu/encyclopedia/en/article/37/

Fugl-Meyer, A. R., Jääskö, L., Leyman, I., Olsson, S., & Steglind, S. (1974). The post-stroke hemiplegic patient. 1. A method for evaluation of physical performance. *Scandinavian Journal of Rehabilitation Medicine*, *7*(1), 13-31.

Glader, E.L., Stegmayr, B., & Asplund, K. (2002). Post-stroke fatigue: A 2-year follow-up study of stroke patients in Sweden, *Stroke*, *33*(5), 1327-33.

Gladstone, D.J., Dannells, C.J., & Black, S.E. (2002). The Fugl-Meyer assessment of motor recovery after stroke: A critical review of its measurement properties. *Neurorehabilitation & Neural Repair, 16*(3), 232-240.

Greenleaf, W.J., & Tovar, M.A. (1994). Augmenting reality in rehabilitation medicine. *Artificial Intelligence in Medicine, 6*(4), 289-299.

Grice, O.K., Vogel, K.A., Le, V., Mitchell, A., Muniz, S., & Vollmer, M.A. (2003). Adult norms for a commercially available Nine Hole Peg Test for finger dexterity. *American Journal of Occupational Therapy*, *57*(5), 570-573.

Grodstein, F., Manson, J.E., Stampfer, M.J., & Rexrode, K. (2008). Postmenopausal hormone therapy and stroke: Role of time since menopause and age at initiation of hormone therapy. *Archives of Internal Medicine, 168*(8), 861-866.

Hakkenes, S., & Keating, S.L. (2005). Constraint-induced movement therapy following stroke: A systematic review of randomized controlled trials. *Australian Journal of Physiotherapy, 51*, 221-231.

Haley, W.E., Roth, D.L., Kissela, B., Perkins, M., & Howard, G. (2011). Quality of life after stroke: A prospective longitudinal study. *Quality of Life Research, 20*(6), 799-806.

Hallett, M. (2001) Plasticity of the human motor cortex and recovery from stroke. *Brain Research Reviews, 36*, 169-174.

Halton, J. (2008). Virtual rehabilitation with video games: A new frontier for occupational therapy. *Occupational Therapy Now, 9*(6), 12-14.

Harris, J.E., Eng, J.J., Miller, W.C., & Dawson, A.S. (2009). A self-administered Graded Repetitive Arm Supplementary Program (GRASP) improves arm function during inpatient stroke rehabilitation: A multi-site randomized controlled trial. *Stroke, 40*, 2123-2128.

Hartman-Maeir, A., Soroker, N., Ring, H., Avni, N., & Katz, N. (2007). Activities, participation and satisfaction one-year post-stroke. *Disability & Rehabilitation, 29*, 559–566.

Heart & Stroke Foundation. (2012). Statistics. *Heart & Stroke Foundation.* Retrieved on December 18th, 2012 from http://www.heartandstroke.on.ca/site/c.pvI3IeNWJwE/b.3581729/k.359A/Statistics.htm

Heiman, G. W. (2002). *Research Methods in Psychology*. 3rd Edition. Boston & New York: Houghton Mifflin Company.

Henderson, A., Korner-Bitensky, N., & Levin, M. (2007). Virtual reality in stroke rehabilitation: A systematic review of its effectiveness for upper limb motor recovery. *Topics in Stroke Rehabilitation, 14*, 52–61.

Henderson, V.W., & Lobo, R.A. (2012). Hormone therapy and the risk of stroke: Perspectives 10 years after the Women's Health Initiative trials. *Climacteric, 15*(3), 229-234.

Hendy, A.M., Spittle, M., & Kidgell, D.J. (2012). Cross education and immobilisation: Mechanisms and implications for injury rehabilitation. *Journal of Science and Medicine in Sports, 15*, 94-101.

Holden, M.K., Todorov, E., Callahan, J., & Bizzi, E. (1999). Virtual environment training improves motor performance in two patients with stroke: Case report. *Neurology Report*, *23*, 57–67.

Holden, M.K. (2005). Virtual environments for motor rehabilitation: Review. *Cyberpsychology, Behaviour, and Social Networking*, *8*(3), 187-211.

Holden, M.K., Dyar, T.A., & Dayan-Cimadoro, L. (2007). Telerehabilitation using a virtual environment improves upper extremity function in patients with stroke. *IEEE Transactions on Neural Systems and Rehabilitation Engineering*, *15*(1), 36–42.

Hortobagyi, T. I. B. O. R., Hill, J. P., Houmard, J. A., Fraser, D. D., Lambert, N. J., & Israel, R. G. (1996). Adaptive responses to muscle lengthening and shortening in humans. *Journal of Applied Physiology*, *80*(3), 765-772.

Houston, M. E., Froese, E. A., St P, V., Green, H. J., & Ranney, D. A. (1983). Muscle performance, morphology and metabolic capacity during strength training and detraining: A one leg model. *European Journal of Applied Physiology and Occupational Physiology*, *51*(1), 25-35.

Huang, L. L., Lee, C. F., & Chen, M. H. (2013). Applying commercial digital games to promote upper extremity movement functions for stroke patients. In *ACHI 2013, The Sixth International Conference on Advances in Computer-Human Interactions* (pp. 250-255).

Inges, J.L., Eskes, G.A., & Phillips S.J. (1999). Fatigue after stroke. *Archives of Physical Medicine and Rehabilitation*, *80*(2), 173-8.

Ivey, F.M., Ryan, A.S., Hafer-Macko, C.E., Garrity, B.M., Sorkin, J.D., Goldberg, A.P...Macko, R.F. (2006). High prevalence of abnormal glucose metabolism and poor sensitivity of fasting plasma glucose in the chronic phase of stroke. *Cerebrovascular Disease*, *22*, 368–371.

Jack, D., Boian, R., Merians, A.S., Tremaine, M., Burdea, G.C., Adamovich, S.V...Poizner, H. (2001). Virtual reality-enhanced stroke rehabilitation. *IEEE Transactions on Neural Systems and Rehabilitation Engineering*, *9*, 308–318.

Jacqmin-Gadda, H., Fabrigoule, C., Commenges, D., & Dartigues, J.F. (1997). A 5-year longitudinal study of the mini-mental state examination in normal aging. *American Journal of Epidemiology*, *145*(6), 498-506.

James, A.B. (2008). Activities of daily living and instrumental activities of daily living. In: Crepeau, E.B., Cohn, E.S., Schell, B.B. (Eds.). *Willard and Spackman's Occupational Therapy* (538-578). Philadelphia: Lippincott, Williams and Wilkins.

Jebsen, R.H., Taylor, N., Trieschman, R.B., Trotter, M.J., & Howard, L.A. (1969). An objective and standardized test of hand function. *Archives of Physical Medicine & Rebilitation*, *50*, 311-319.

Johansson, B.B. (2011). Current trends in stroke rehabilitation. A review with focus on brain plasticity. *Acta Neurologica Scandinavica*, *123*, 147–159.

Jorgensen, H.S., Nakayama, H., Raaschou, H.O., & Olsen, T.S. (1995). Recovery of walking function in stroke patients: The Copenhagen Stroke Study. *Archives of Physical Medicine and Rehabilitation*, *76*(1), 27-32.

Jorgensen, L., Engstad, T., Jacobsen, B.K. (2005). Self-reported urinary incontinence in noninstitutionalized long-term stroke survivors: A population-based study. *Archives of Physical Medicine and Rehabilitation*, *86*, 416 – 420.

Karni, A., Meyer, G., Jezzard, P., Adams, M.M., Turner, R., & Ungerleider, L.G. (1995). Functional MRI evidence for adult motor cortex plasticity during motor skill learning. *Nature, 377,* 155-158.

Katz, S. (1983). Assessing self-maintenance: Activities of daily living, mobility, and instrumental activities of daily living. *Journal of the American Geriatrics Society, 31*(12), 721-727.

Kelley-Hayes, M., Beiser, A., Kase, C.S., Scaramucci, A., D'Agostino, R.B., & Wolf, P.A. (2003). The influence of gender and age on disability following ischemic stroke: The Framingham study. *Journal of Stroke and Cerebrovascular Diseases, 12*, 119–126.

Kellor, M., Frost, J., Silberbeg, N., Iverson, I., & Cummings, R. (1971). Hand strength and dexterity. *American Journal of Occupational Therapy, 25*, 77-83.

Kissela, B. (2006). The value of quality of life research in stroke. *Stroke*. *37*, 1958–1959.

Kolominsky-Rabas, P.L., Hilz, M.J., Neundoerfer, B., & Heuschmann, P.U. (2003). Impact of urinary incontinence after stroke: Results from a prospective population-based stroke register. *Neurology and Urodynamics, 22*, 322–327.

Kovindha, A., Wattanapan, P., Dejpratham, P., Permsirivanich, W., & Kuptniratsaikul, V. (2009). Prevalence of incontinence in patients after stroke during rehabilitation: A multi-centre study. *Journal of Rehabilitation Medicine, 41*, 489 – 491.

Krakauer, J.W. (2006). Motor learning: its relevance to stroke recovery and neurorehabilitation. *Current Opinion in Neurology and Neurosurgery, 19*, 84-90.

Kunkel, A., Kopp, B., Muller, G., Villringer, K., Villringer, A., Taub, E...Flor, H. (1999). Constraint induced movement therapy for motor recovery in chronic stroke patients. *Archives of Physical Medicine and Rehabilitation, 80*, 624-628.

Kurl, S., Laukanen, J.A., Rauramaa, R., Lakka, T.A., Sivenius, J., & Salonen, J.T. (2010). Cardiorespiratory fitness and the risk for stroke in men. *Archives of Internal Medicine*, *163*(14), 1682-1688.

Kwakkel, G., Kollen, B.J., & Wagenaar, R.C. (1999). Therapy impact on functional recovery in stroke rehabilitation: a critical review of the literature. *Physiotherapy*, *13*, 457–470.

Lai, S.M., Studenski, S., Duncan, P., & Perera, S. (2002). Persisting consequences of stroke as measured by the stroke impact scale. *Stroke, 33*, 1840-1844.

Landry, M.D. (2004). *Physical therapy services in Ontario: assessing a changing public/private mix* [dissertation]. Toronto: Faculty of Medicine, University of Toronto.

Landry, M.D., Passalent, L.A., & Cott, C.A. (2008). Availability and structure of ambulatory rehabilitation services: A survey of hospitals with designated rehabilitation beds on Ontario, Canada. *Physiotherapy Canada, 60*, 246-254.

Langhammer, B., & Stanghelle, J.K. (2003). Bobath or motor relearning programme? A follow-up one and four years post-stroke. *Clinical Rehabilitation*, *17*, 731-734.

Langhorne, P., Dey, P., Woodman, M., Kalra, L., Wood-Dauphinee, S., Patel, N., et al. (2005). Is stroke unit care portable? A systematic review of the clinical trials. *Age Ageing*, *34*, 324–330.

Langhorne, P., Coupar, F., & Pollock, A. (2009). Motor recovery after stroke: A systematic review. *Lancet Neurology, 8*(8), 741–754.

LeBlanc, S., Paquin, K., Carr, K., & Horton, S. (2013). Non-immersive virtual reality for fine motor rehabilitation in patients with chronic stroke: A review. *Aging Science*, *1*(105), 2.

Legg, L., Langhorne, P., Drummond, A.E., Gladman, J.R., Logan, P.A., & Walker, M.F. (2004). Rehabilitation therapy services for stroke patients living at home: Systematic review of randomised controlled trials. *Lancet, 363*, 352–356.

Levin, M.F., Knaut, L.A., Magdalon, E.C., & Subramanian, S. (2009). Virtual reality environments to enhance upper limb functional recovery in patients with hemiparesis. *Studies in Health Technology and Informatics*, *145*, 94-108.

Levin, M. F., Snir, O., Liebermann, D. G., Weingarden, H., & Weiss, P. L. (2012). Virtual reality versus conventional treatment of reaching ability in chronic stroke: Clinical feasibility study. *Neurology and Therapy*, *1*(1), 1-15.

Lewis, G.N., Woods, C., Rosie, J.A., & McPherson, K.M. (2011). Virtual reality games for rehabilitation of people with stroke: A perspective from the users. *Disability and Rehabilitation: Assistive Technology, 6*(5), 453-463.

Lewis, G.N. & Rosie, J.A. (2012). Virtual reality games for movement rehabilitation in neurological conditions: How do we meet the needs and expectations of the users? *Disability & Rehabilitation*, *34*(22), 1880-1886.

Lillard, A.S., & Erisir, A. (2011) Old dogs learning new tricks: Neuroplasticity beyond the juvenile period. *Developmental Review*, *31*, 207-239.

Lin, K., Chuang, L., Wu, C., Hsieh, Y., & Chang, W. (2009). Responsiveness and validity of three dextrous function measures in stroke rehabilitation. *Journal of Rehabilitation Research & Development, 47*(6), 563-572.

Lindsay, M.P., Gubitz, G., Bayley, M., & Phillips, S. (2013). Canadian best practice recommendations for stroke care (Update 2013). On behalf of the Canadian Stroke Strategy Best Practices and Standards Writing Group, Ottawa, Ontario Canada: Canadian Stroke Network. Retrieved from: http://strokebestpractices.ca/wp-content/uploads/2013/10/Ch6_SBP2013_Transitions-_28Oct13_Final_Post.pdf

Lloyd-Jones, D., Adams, R.J., Brown, T.M., Carnethon, M., Dai, S., De Simone, G...Wylie-Rosett, J. (2010). On behalf of the American Heart Association Statistics Committee and Stroke Statistics Subcommittee. Executive summary: heart disease and stroke statistics - 2010 update: a report from the American Heart Association. *Circulation*, *121*, 948-954.

Lo, A. C., Guarino, P. D., Richards, L. G., Haselkorn, J. K., Wittenberg, G. F., Federman, D. G., ... & Peduzzi, P. (2010). Robot-assisted therapy for long-term upper-limb impairment after stroke. *New England Journal of Medicine*, *362*(19), 1772-1783.

Mathiowetz, V., Volland, G., Kashman, N., & Weber, K. (1985). Adult norms for the box and block test of manual dexterity. *American Journal of Occupational Therapy, 39*(6), 386-391.

McClure, J.A., Salter, K., Foley, N., Mahon, H., & Teasell, R. (2012). Adherence to Canadian Best Practice Recommendations for stroke care: Vascular cognitive impairment screening and assessment practices in Ontario inpatient stroke rehabilitation facility. *Topics in Stroke Rehabilitation, 19*(2), 141-148.

Merians, A.S., Jack, D., Boian, R., Tremaine, M., Burdea, G.C., Adamovich, S.V...Poizner, H. (2002). Virtual reality-augmented rehabilitation for patients following stroke. *Physical Therapy, 82*, 898–915.

Merians, A.S., Poizner, H., Boian, R., Burdea, G., & Adamovich, S. (2006). Sensorimotor training in a virtual reality environment: Does it improve functional recovery post-stroke? *Neurorehabilitation and Neural Repair, 20*(2), 252–67.

Merians, A. S., Fluet, G. G., Qiu, Q., Saleh, S., Lafond, I., & Adamovich, S. V. (2010). Integrated arm and hand training using adaptive robotics and virtual reality simulations. In *Proceedings of the 2010 International Conference on Disability, Virtual Reality and Associated Technology* (pp. 213-222).

Michael, K. (2002). Fatigue and stroke. *Rehabilitation Nursing, 27,* 89-94, 103.

Michaelsen, S.M., Dannenbaum, R., & Levin, M.F. (2006). Task-specific training with trunk restraint on arm recovery in stroke. *Stroke, 37*, 186-192.

Miller, E.L., Murray, L., Richards, L., Zorowitz, R.D., Bakas, T., Clark, P…Billinger, S.A. (2010). Comprehensive overview of nursing and interdisciplinary rehabilitation care of the stroke patient: A scientific statement from the American Heart Association. *Stroke, 41*, 2402-2448.

Morris, D.M., Taub, E., & Mark, V.W. (2006). Constraint-induced movement therapy: Characterizing the intervention protocol. *Europa Medicophysica*, *42,* 257-268.

Morris, J.H., van, W.F., Joice, S., Ogston, S.A., Cole, I., & MacWalter, R.S. (2008). A comparison of bilateral and unilateral upper-limb task training in early post-stroke rehabilitation: A randomized controlled trial. *Archives of Physical Medicine and Rehabilitation*, *89*, 1237-1245.

Mouawad, M.R., Doust, C.G., Max, M.D., & McNulty, P.A. (2011). Wii-based movement therapy to promote improved upper extremity function post-stroke: A pilot study. *Journal of Rehabilitation Medicine, 43*, 527-533.

Nadeau, J. O., Shi, S., Fang, J., Kapral, M. K., Richards, J. A., Silver, F. L., & Hill, M. D. (2005). TPA use for stroke in the Registry of the Canadian Stroke Network. *The Canadian Journal of Neurological Sciences, 32*(4), 433-439.

Niebor, T. E., Sari, V., Kluivers, K. B., Weinans, M. J. N., Vierhout, M. E., & Stegeman, D. F. (2012). A randomized trial of training the non-dominant upper extremity to enhance lacroscopic performance/ *Minimally Invasive Therapy and Allied Technologies 21(4)*, 259-264.

O'Leary, A. (1985). Self-efficacy and health. *Behaviour Research and Therapy, 23*(4), 437-451.

Okawa, Y., Nakamura, S., Kudo, M., & Ueda, S. (2009). An evidence-based construction of the models of decline of functioning. Part 1: Two major models of decline of functioning. *International Journal of Rehabilitation Research, 32*, 189 –192.

Page, S.J. (2003). Intensity versus task-specificity after stroke: how important is intensity? *American Journal of Physical Medicine & Rehabilitation*, *82*(9), 730–732.

Page, S.J., Gater, D.R., & Bach-y-Rita, P. (2004). Reconsidering the motor recovery plateau in stroke rehabilitation. *Archives of Physical Medicine & Rehabilitation*, *85*, 1377-1381.

Parlow, S. E., & Kinsbourne, M. (1990). Asymmetrical transfer of Braille acquisition between hands. *Brain Language 39*, 319-330.

Pastor, I., Hayes, H.A., & Bamberg, S.J. (2011). A feasibility study of an upper limb rehabilitation system using kinect and computer games. In *Proceedings of the 34th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBS '12* (1286-1289).

Patel, M., Coshall, C., Rudd, A.G., & Wolfe, C.D. (2001). Natural history and effects on 2-year outcomes of urinary incontinence after stroke. *Stroke, 32*, 122–127.

Payne, V.G., & Isaacs, L.D. (2008). Introduction to Motor Development. *Human Motor Development* (1-23), McGraw-Hill: New York, NY.

Perez, M. A., & Cohen, L. G. (2008). Mechanisms underlying functional changes in the primary motor cortex ipsilateral to an active hand. *The Journal of Neuroscience*, *28*(22), 5631-5640.

Piron, L., Turolla, A., Agotini, M., Zucconi, C., Cortese, F., Zampolini, M...Tonin, P. (2009) Exercises for paretic upper limb after stroke: A combined virtual-reality and telemedicine approach. *Journal of Rehabilitation Medicine, 41*(12), 1016–20.

Platz, T., Pinkowski, C., van Wijck, F., Kim, I.H., di Bella, P., & Johnson, G. (2005). Reliability and validity of arm function assessment with standardized guidelines for the Fugl-Meyer Test, Action Research Arm Test and Box and Block Test: A multicentre study. *Clinical Rehabilitation, 19*(4), 404-411.

Proffitt, R.M., Alankus, G., Kelleher, C.L., & Engsberg, J.R. (2011). Use of computer games as an intervention for stroke. *Topics in Stroke Rehabilitation, 18*(4), 417-427.

Quinn, T.J., Paolucci, S., Sunnerhagen, K.S., Sivenius, J., Walker, M.F., Toni, D., et al. (2009). Evidence-based stroke rehabilitation: an expanded guidance document from the European Stroke Organisation (ESO). Guidelines for management of ischemic stroke and transient ischaemic attack 2008. *Journal of Rehabilitation Medicine, 41*, 99-111.

Reinthal, A., Szirony, K., Clark, C., Swiers, J., Kellicker, M., & Linder, S. (2012). ENGAGE: guided activity-based gaming in neurorehabilitation after stroke: A pilot study. *Stroke Research and Treatment, 2012*.

Riachy, M., Sfeir, F., Sleilaty, G., Hage-Chahine, S., Dabar, G., Bazerbachi, T., ... & Koussa, S. (2008). Prediction of the survival and functional ability of severe stroke patients after ICU therapeutic intervention. *BMC neurology*, *8*(1), 24.

Rimmer, J.H., & Wang, E. (2005). Aerobic exercise training in stroke survivors. *Topics in Stroke Rehabilitation, 12*(1), 17-30.

Rimmer, J.H., Wang, E., & Smith, D. (2008). Barriers associated with exercise and community access for individuals with stroke. *Journal of Rehabilitation Research and Development, 45*(2), 315-322.

Rizzo, A.A., & Kim, G.J. (2005). A SWOT analysis of the field of VR rehabilitation and therapy. *Teleopera Virtual Environment*, *14*, 119-146.

Rowe, V.T., Blanton, S., & Wolf, S.L. (2009). Long-term follow-up after constraint-induced therapy: A case report of a chronic stroke survivor. *American Journal of Occupational Therapy, 63,* 317-322.

Russo, C.A., & Andrews, R.M. (2008). Hospital stays for stroke and other cerebrovascular diseases, 2005. *Healthcare cost and utilization Project Statistical Brief #51*. Rockville, MD: Agency for healthcare research and quarterly.

Sampei, K., Goto, S., Alkayed, N.J., Crain, B.J., Korach, K., Traystman, R.J…Hurn, P.D. (2000). Stroke in estrogen receptor-α-deficient mice. *Stroke, 31*, 738-744.

Sanchez-Vives, M., & Slater, M. (2005). From presence to consciousness through virtual reality. *Nature Reviews Neuroscience, 6*, 332-339.

Saposnik, G., Teasell, R., Mamdani, M., Hall, J., McIlroy, W., Cheung, D,… Bayley, M. (2010a). Effectiveness of virtual reality using Wii gaming technology in stroke rehabilitation: A pilot randomized clinical trial and proof of principle. *Stroke, 41,* 1477-1484.

Saposnik, G., Mamdani, M., Bayley, M., Thorpe, K.E., Hall, J., Cohen, L.G., et al. (2010b). Effectiveness of Virtual Reality Exercises in Stroke Rehabilitation (EVREST): Rationale, design, and protocol of a pilot randomized clinical trial assessing the wii gaming system. *International Journal of Stroke, 5*, 47-51.

Saposnik, G., & Levin, M. (2011). Stroke Outcome Research Canada Working Group. Virtual Reality in Stroke Rehabilitation: A Meta- Analysis and Implications for Clinicians. *Stroke, 42*, 1380-1386.

Saunders, D.H., Greig, C.A., Young, A., & Mead, G.E. (2004). Physical fitness training for stroke patients. *Cochrane Database of Systematic Reviews, 4*, CD003316.

Savion-Lemieux, T., & Penhune, V.B. (2005). The effects of practice and delay on motor skill learning and retention. *Experimental Brain Research*, *161*(4), 423-31.

Schmidt, R.A., & Wrisberg, C.A. (1999). Motor Learning and Performance. *From Principles to Practice, 2nd edition.* Human Kinetics: Chicago, IL.

Scremin, O.U. (2004). Cerebral Vascular System. In: Paxinos G., Mai J.K. (Eds.), *The Human Nervous System* (1325-1348). San Diego: Elsevier Academic Press.

Scripture, E.W., Smith, T.L., & Brown, E.M. (1894). On the education of muscular control and power. *Yale Psychology Studies, 2*, 114-119.

Sears, E.D., & Chung, K.C. (2010). Validity and responsiveness of the Jebsen Taylor Hand Function Test. *Journal of Hand Surgery, 35*, 30-37.

Shaughnessy, M., Resnick, B.M., & Macko, R.F. (2006). Testing a model of post-stroke exercise behavior. *Rehabilitation Nursing*, *31*(1), 15–21.

Shen, Y., Gu, P.W., Ong, S.K., & Nee, A.Y.C. (2012). A novel approach in rehabilitation of hand-eye co-ordination and finger dexterity. *Virtual Reality, 16*(2), 161-171.

Sheridan, T.B. (1992). Musings on telepresence and virtual presence. *Teleopera Virtual Environment*, *1*, 120-126.

Shobha, N., Sylaja, P. N., Kapral, M. K., Fang, J., & Hill, M. D. (2010). Differences in stroke outcome based on sex. *Neurology*, *74*(9), 767-771.

Sivak, M., Mavroidis, C., & Holden, M.K. (2009). Design of a low cost multiple user virtual environment for rehabilitation (MUVER) of patients with stroke. *Studies in Health Technology and Informatics*, *142*, 319–24.

Skilbeck, C.E., Wade, D.T., Hewer, R.L., & Wood, V.A. (1983). Recovery after stroke. *Journal of Neurology. Neurosurgery, & Psychiatry*, *46*, 5–8.

Smith, C.M., Read, J.E., Bennie, C., Hale, L.A., & Milosavljevic, S. (2012) Can non-immersive virtual reality improve physical outcomes of rehabilitation? *Physical Therapy Reviews*, *17*(1), 1-15.

Staley, K. (2010). Stroke: Recovery inhibitors under attack. *Nature*, *468*(7321), 176-177.

Statistics Canada. (2011). Mortality, Summary List of Causes 2008. Released October 18, 2011.

Stoykov, M., Lewis, G., & Corcos, D. Comparison for bilateral and unilateral training for upper extremity hemiparesis in stroke. *Neurorehabilitation and Neural Repair*, *23*(9), 945-953.

Subramanian, S.K., Massie, C.L., Malcolm, M.P., & Levin, M.F. (2010). Does provision of extrinsic feedback result in improved motor learning in the upper limb post-stroke? A systematic review of the evidence. *Neurorehabilitation and Neural Repair*, *24*, 113-124.

Summers, J.J., Kagerer, F.A., Garry, M.I., Hiraga, C.Y., Loftus, A., & Cauraugh, J.H. (2007). Bilateral and unilateral movement training on upper limb function in chronic stroke patients: A TMS study. *Journal of the Neurological Sciences*, *252*, 76-82.

Taub, E., & Morris, D.M. (2001). Constraint-induced movement therapy to enhance recovery after stroke. *Current Atheroscleroris Reports*, *3*(4), 279-286.

Taub, E., Uswatte, G., & Elbert, T. (2002). New treatments in neurorehabilitation founded on basic research. *Nature Reviews Neuroscience*, *3*, 228-236.

Taub, E., Uswatte, G., Mark, V.W., & Morris, D.M. (2006). The learned nonuse phenomenon: implications for rehabilitation. *Europa Medicophysica*, *42*, 241-255.

Teasell, R., Bayona, N.A., & Bitensky, J. (2005). Plasticity and reorganization of the brain post-stroke. *Topics in Stroke Rehabilitation*, *12*(3), 11-26

Teasell, R., Bayona, N., & Heitzner, J. (2008a). Clinical consequences of stroke. In *Evidence Based Review of Stroke Rehabilitation.* Retrieved from: http://www.ebrsr.com/uploads/Module-2_clinical-consequences.pdf

Teasell, R., Bayona, N., & Heitzner, J. (2008b). Upper extremity interventions. In *Evidence Based Review of Stroke Rehabilitation.* Retrieved from: http://www.ebrsr.com/uploads/Module-10_upper-extremity.pdf

Teasell, R., Foley, N., Salter, K., Bhogal, S., Jutai, J., & Speechley, M. (2009a). Evidence-based review of stroke rehabilitation: executive summary, 12th edition. *Topics in Stroke Rehabilitation, 16*(6), 463-488.

Teasell, R., Meyer, M.J., Foley, N., Salter, K., & Willems, D. (2009b). Stroke rehabilitation in Canada: A work in progress. *Topics in Stroke Rehabilitation, 16*(1), 11-19.

Timmermans, A.A., Spooren, A.I., Kingma, H., & Seelen, H.A. (2010). Influence of task-oriented training content on skilled arm-hand performance in stroke: A systematic review. *Neurorehabilitation and Neural Repair*, *24*(9), 858-870.

Towfighi, A., & Saver, J.L. (2011). Stroke declines from third to fourth leading cause of death in the United States. *Stroke*, *42*, 2351-2355.

van Delden, A.E., Peper, C.E., Beek, P.J., & Kwakkel, G. (2012). Unilateral versus bilateral upper limb exercise therapy after stroke: A systematic review. *Journal of Rehabilitation Medicine*, *44*, 106-117.

Van der Werf, S.P., van den Broek, H.L., Anten, H.W., & Bleijenberg, G. (2001). Experience of severe fatigue long after stroke and its relation to depressive symptoms and disease characteristics. *European Neurology*, *45*(1), 28-33.

Van Peppen, R.P., Kwakkel, G., Wood-Dauphinee, S., Hendriks, H.J., Van der Wees, P.J., & Dekker, J. (2004). The impact of physical therapy on functional outcomes after stroke: What's the evidence? *Clinical Rehabilitation, 18,* 833-862.

Van Vliet, P.M., & Wulf, G. (2006). Extrinsic feedback for motor learning after stroke: What is the evidence? *Disability and Rehabilitation*, *28*(13-14), 831-840.

Veerbeek, J.M., Kwakkel, G., van Wegen, E., Ket, J., & Heymans, M.J. (2011). Early prediction of outcome of activities of daily living after stroke: A systematic review. *Stroke, 42,* 1482-1488.

Wagner. T.H., Lo, A.C, Peduzzi, P., Bravata, D.M., Huang, G.D., Krebs, H.I., et al. (2011). An economic analysis of robot assisted therapy for long term upper-limb impairment after stroke. *Stroke*, *42*, 2630-2632.

Ward, N.S., & Cohen, L.G. (2004*).* Mechanisms underlying recovery of motor function after stroke. *Archives of Neurology*, *61*, 1844-1848.

Wevers, L., van de Port, I., Vermue, M., Mead, G., & Kwakkel, G. (2009). Effects of task-orientated circuit class training on walking competency after stroke. *Stroke, 40*, 2450-2459.

Winningham, M.L. (2001). Strategies for managing cancer-related fatigue syndrome: A rehabilitation approach. *Cancer, 92,* 988-997.

Wolf, S.L., Winstein, C.J., Miller, J.P., Taub, E., Uswatte G., Morris, D...Nichols-Larsen, D. (2006). Effects of constraint induced movement therapy on upper extremity function 3 to 9 months after stroke: The EXCITE randomized clinical trial. *Journal of the American Medical Association*, *296*(17), 2095-2104.

Yancosek, K.E., & Howell, D. (2009). A narrative review of dexterity assessments. *Journal of Hand Therapy, 22,* 258-270.

Yavuzer, G., Senel, A., Atay, M.B., & Stam, H.J. (2008). ‘Playstation eyetoy games’ improve upper extremity-related motor functioning in subacute stroke: A randomized controlled clinical trial. *European Journal of Physical Rehabilitation and Medicine, 44,* 237–244.

Yong Joo, L., Soon Yin, T., Xu, D., Thia, E., Pei Fen, C., Kuah, C.W., Kong, K.H. (2010). A feasibility study using interactive commercial off-the-shelf computer gaming in upper limb rehabilitation in patients after stroke. *Journal of Rehabilitation Medicine, 42,* 437– 441.

Zhang, A.J., Yu, X.J., & Wang, M. (2010). The clinical manifestations and pathophysiology of cerebral small vessel disease. *Neuroscience Bulletin*, *26*, 257–264.

Appendix A

Windsor Essex Community Health Centre
Centre de santé communautaire de Windsor Essex

January 7, 2013

Kathleen Paquin
University of Windsor
HK 133, Department of Kinesiology
University of Windsor
401 Sunset Ave
Windsor, ON N9B 3P4

Dear Ms. Paquin

RE: Letter of Collaboration

Please accept this letter as evidence of our support for your research program at the University of Windsor, and specifically of our involvement in the Effectiveness of Commercial Video Gaming on fine motor recovery in chronic stroke within community level rehabilitation research.

Our Active Aging and Health Management, Chronic Disease Management Program, Windsor Essex Community Health Centre, will be a source of recruitment for your study. This relationship is an extension of our relationship that was first established in the Fall of 2009 with our former Windsor-Essex Cardiac Rehabilitation Program at the University of Windsor for the recruitment of medicated hypertensives (REB #09-060: isometric handgrip training study).

Our continued collaboration will create a long-standing opportunity to foster knowledge translation via:

- the dissemination of novel research findings from researcher to health care provider(s) in the field to clients/community,
- the opportunity for students to link theoretical and research-based knowledge with applied learning in community-based exercise rehabilitation programs,
- the fostering of permanent links between institutes of higher learning (University of Windsor) and ground roots, government supported prevention programs, thus positively affecting the health of Canadians from "cell to society".

Together with my colleagues, I look forward to our continued collaboration.

Yours Sincerely

CEO

Appendix B

Mini-Mental State Examination

1. What is the: Year? Season? Date? Day? Month? **Maximum 5 points.**

2. Where are we: Province? County? City? Building? Room? **Maximum 5 points.**

3. Name three objects (Apple, Penny, Table), taking one second to say each. Then ask the participant to tell you the three. Repeat the answers until the participant learns all three. **Maximum 3 points.**

4. Spell *WORLD* backwards. **Maximum 5 points.**

5. Ask for the names of the three objects learned in #3. **Maximum 3 points.**

6. Point to a pencil and watch. Have the participant name them as you point. **Maximum 2 points.**

7. Have the participant repeat "No ifs, and, or buts." **Maximum 1 point.**

8. Have the participant follow a three stage command: "Take the paper in your right hand. Fold the paper in half. Put the paper on the floor." **Maximum 3 points.**

9. Have the participant read and obey the following. "CLOSE YOUR EYES." Write it in large letters. **Maximum 1 point.**

10. Have the participant write a sentence of his or her own choice. **Maximum 1 point**.

11. Have the participant copy the following design (overlapping pentagons). **Maximum 1 point.**

Maximum Total: 30

(Folstein et al., 1975)

Appendix C

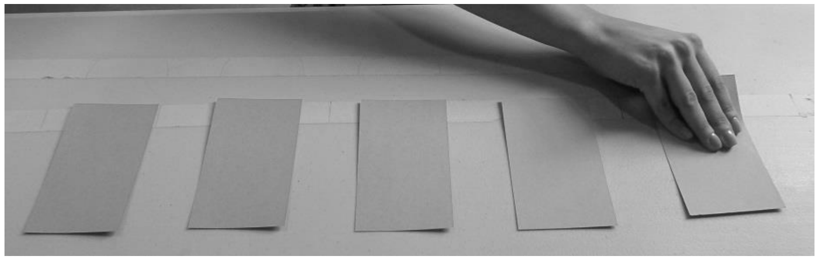
Fugl-Meyer Assessment

Item	0 = None, 1 = Partial, 2 = Full		
1 Shoulder / elbow / forearm			
1.1 Reflex activity			
1.1.1 Flexors (biceps and finger flexors)	**0**	**1**	**2**
1.1.2 Extensors (triceps)	**0**	**1**	**2**
1.2 Flexor synergy – volitional movement within synergy			
1.2.1 Shoulder retraction	**0**	**1**	**2**
1.2.2 Shoulder elevation	**0**	**1**	**2**
1.2.3 Shoulder abduction	**0**	**1**	**2**
1.2.4 Shoulder external rotation	**0**	**1**	**2**
1.2.5 Elbow flexion	**0**	**1**	**2**
1.2.6 Forearm supination	**0**	**1**	**2**
1.3 Extensor synergy – volitional movement within synergy			
1.3.1 Shoulder adduction / internal rotation	**0**	**1**	**2**
1.3.2 Elbow extension	**0**	**1**	**2**
1.3.3 Forearm pronation	**0**	**1**	**2**
1.4 Volitional movement mixing the dynamic flexor and extensor strategies			
1.4.1 Hand on lumbar spine	**0**	**1**	**2**
1.4.2 Shoulder flexion	**0**	**1**	**2**
1.4.3 Forearm pronation / supination	**0**	**1**	**2**
1.5 Volitional movements are performed with little or no synergy dependence			
1.5.1 Shoulder abduction	**0**	**1**	**2**
1.5.2 Shoulder flexion	**0**	**1**	**2**
1.5.3 Forearm pronation-supination	**0**	**1**	**2**
1.6 Normal reflex activity	**0**	**1**	**2**
2 Wrist			
2.1 Wrist stability – elbow 90˚	**0**	**1**	**2**
2.2 Wrist flexion/extension – elbow 90˚	**0**	**1**	**2**
2.3 Wrist stability – elbow 0˚	**0**	**1**	**2**
2.4 Wrist flexion/extension – elbow 0˚	**0**	**1**	**2**
2.5 Circumduction	**0**	**1**	**2**
3 Hand			
3.1 Mass flexion	**0**	**1**	**2**
3.2 Mass extension	**0**	**1**	**2**
3.3 Grasp A – distal finger grasp	**0**	**1**	**2**
3.4 Grasp B – thumb adduction grasp	**0**	**1**	**2**
3.5 Grasp C – thumb to index finger grasp	**0**	**1**	**2**
3.6 Grasp D – cylinder grasp	**0**	**1**	**2**
3.7 Grasp E – spherical grasp	**0**	**1**	**2**
4 Co-ordination/speed			
4.1 Tremor	**0**	**1**	**2**
4.2 Dysmetria	**0**	**1**	**2**
4.3 Speed	**0**	**1**	**2**
Upper limb score			**/66**

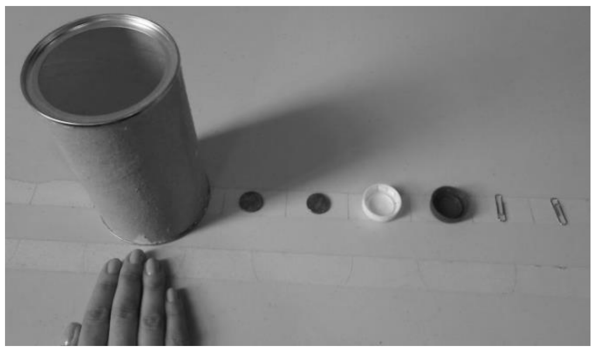
(Fugl-Meyer et al., 1974)

Appendix D

Tasks Included in the JHFT for the Current Study



Task 1: Flipping over a series of five index cards



Task 2: Picking up small objects (paperclip, penny, bottle cap), and placing them into a can

Task 3: Scooping of five beans into a can

Task 4: Stacking objects (checkers)

Task 5 & 6: Lifting and transportation of heavy (0.45 kg) and empty cans

(Jebsen et al., 1969)

Appendix E

Modified Stroke Impact Scale – 18 items

In the past week, how would you rate the strength of your...

1 = No strength at all, 2 = A little strength, 3 = Some strength, 4 = Quite a bit of strength, 5 = A lot of strength

1. Arm that was most affected by your stroke?	**1**	**2**	**3**	**4**	**5**
2. Grip of your hand that was most affected by your stroke?	**1**	**2**	**3**	**4**	**5**

In the past 2 weeks, how difficult was it to...

1 = Cannot do at all, 2 = Very difficult, 3 = Somewhat difficult, 4 = A little difficult, 5 = Not difficult at all

3. Cut your food with a knife and fork?	**1**	**2**	**3**	**4**	**5**
4. Dress the top part of your body?	**1**	**2**	**3**	**4**	**5**
5. Bathe yourself?	**1**	**2**	**3**	**4**	**5**
6. Clip your toenails?	**1**	**2**	**3**	**4**	**5**
7. Do light household tasks/chores (e.g. dust, make the bed)?	**1**	**2**	**3**	**4**	**5**
8. Go shopping?	**1**	**2**	**3**	**4**	**5**
9. Do heavy household chores (e.g. vacuum, laundry)?	**1**	**2**	**3**	**4**	**5**

In the past 2 weeks, how difficult was it to use your hand that was most affected by your stroke to...

1 = Cannot do at all, 2 = Very difficult, 3 = Somewhat difficult, 4 = A little difficult, 5 = Not difficult at all

10. Carry heavy objects (e.g. bag of groceries)?	**1**	**2**	**3**	**4**	**5**
11. Turn a doorknob?	**1**	**2**	**3**	**4**	**5**
12. Open a can or jar?	**1**	**2**	**3**	**4**	**5**
13. Tie a shoe lace?	**1**	**2**	**3**	**4**	**5**
14. Pick up a dime?	**1**	**2**	**3**	**4**	**5**

During the past 4 weeks, how much of the time have you been limited in...

1 = All of the time, 2 = Most of the time, 3 = Some of the time, 4 = A little of the time, 5 = None of the time

15. Your social activities?	**1**	**2**	**3**	**4**	**5**

16. Quiet recreation (e.g. crafts, reading)?	**1**	**2**	**3**	**4**	**5**
17. Active recreation (e.g. sports, travel)?	**1**	**2**	**3**	**4**	**5**
18. Your role as a family member and/or friend	**1**	**2**	**3**	**4**	**5**

(Adapted from Duncan et al., 1999)

Appendix F

University of Windsor

CONSENT TO PARTICIPATE IN RESEARCH – PART A

Title of Study: **Effectiveness of the Nintendo Wii on hand and finger rehabilitation after stroke**

You are asked to participate in a research study conducted by **Kathleen Paquin** (Primary Investigator), and **Dr. Sean Horton** (Primary Advisor) from the **Department of Kinesiology** at the University of Windsor**, the results of which will contribute to Ms. Kathleen Paquin's thesis.**

If you have any questions or concerns about the research, please feel to contact **Ms. Kathleen Paquin** *(Primary Investigator): paquink@uwindsor.ca or* ***(519) xxx-xxxx,*** *or* ***Dr. Sean Horton*** *(Primary Advisor): hortons@uwindsor.ca or* ***(519) 253-3000 ext. 2442.***
PURPOSE OF THE STUDY

The proposed study will look at the effect that the Nintendo Wii can have for rehabilitation of hand and finger use after stroke.

PROCEDURES

If you volunteer to participate in this study, you will be asked to:

1) Fill out a brief profile regarding personal information and health history.
2) Complete two inclusion criteria tests: the upper extremity portion of the Fugl-Meyer Assessment, and Mini Mental State Exam.
a) **Fugl-Meyer Assessment (FMA)**: You must receive between 10 and 57 on the upper arm portion of the FMA. The FMA is a tool to describe your recovery, and help to plan and assess treatment. Scoring between 10 and 57 means you are physically able to complete the Wii sessions.

b) **Mini-Mental State Exam (MMSE)**: You must receive a 20 or higher on the MMSE. The MMSE is a test designed to measure memory, orientation, and language.

COMPENSATION FOR PARTICIPATION
You will receive a Kinesiology research t-shirt at the beginning of the study.

CONFIDENTIALITY

Any information that is obtained in connection with this study and that can be identified with you will remain confidential. As we are interested in the results of the group as a whole, individual data will not be reported in any public forum. Publications or conference presentations will focus exclusively on group results. All data will be stored in the Lifespan Development Lab in the Department of Kinesiology. Only the researchers (Kate Paquin and Sean Horton) will be able to access the data.

PARTICIPATION AND WITHDRAWAL

You can choose whether or not to be in this study. If you volunteer to be in this study, you may withdraw at any time without consequences of any kind. The investigator may withdraw you from this research if circumstances arise which warrant doing so.

FEEDBACK OF THE RESULTS OF THIS STUDY TO THE PARTICIPANTS

Your individual data results will be available to you, and group results of the study in its entirety will be available online.
Web address: http://web4.uwindsor.ca/units/researchEthicsBoard/studyresultforms.nsf
Date when results are available: August 2013

SUBSEQUENT USE OF DATA

These data may be used in subsequent studies.

RIGHTS OF RESEARCH PARTICIPANTS

If you have questions regarding your rights as a research participant, contact: Research Ethics Coordinator, University of Windsor, Windsor, Ontario, N9B 3P4; Telephone: 519-253-3000, ext. 3948; e-mail: ethics@uwindsor.ca

SIGNATURE OF RESEARCH PARTICIPANT/LEGAL REPRESENTATIVE

I understand the information provided for the study **Effectiveness of the Nintendo Wii on hand and finger rehabilitation after stroke** as described herein. My questions have been answered to my satisfaction, and I agree to participate in this study. I have been given a copy of this form.

____
Name of Participant

______________________________________ ____________________
Signature of Participant Date

SIGNATURE OF INVESTIGATOR

These are the terms under which I will conduct research.

_____________________________________ ____________________
Signature of Investigator Date

LETTER OF INFORMATION FOR CONSENT TO PARTICIPATE IN RESEARCH – PART A

Title of Study: **Effectiveness of the Nintendo Wii on hand and finger rehabilitation after stroke**

Participants are asked to participate in a research study conducted by **Kathleen Paquin** (Primary Investigator), and **Dr. Sean Horton** (Primary Advisor) from the **Department of Kinesiology** at the University of Windsor**, the results of which will contribute to Ms. Kathleen Paquin's thesis.**

If participants have any questions or concerns about the research, please feel to contact **Ms. Kathleen Paquin** *(Primary Investigator): paquink@uwindsor.ca or* ***(519) xxx-xxxx,*** *or* ***Dr. Sean Horton*** *(Primary Advisor): hortons@uwindsor.ca or* ***(519) 253-3000 ext. 2442.***

PURPOSE OF THE STUDY

The proposed study will look at the effect of the Nintendo Wii as an intervention for fine motor recovery after stroke.

PROCEDURES

Participants who volunteer to participate in this study will be asked to:

1) Fill out a brief profile regarding personal information and health history.
2) Complete two inclusion criteria tests: Fugl-Meyer Assessment, and Mini Mental State Exam.

a) **Fugl-Meyer Assessment (FMA)**: Participants must receive between 10 and 57 on the upper arm portion of the FMA. The FMA is a tool to describe recovery, and help to plan and assess treatment. Scoring between 10 and 57 means one is physically able to complete the Wii sessions.

b) **Mini-Mental State Exam (MMSE)**: Participants must receive a 22 or higher on the MMSE. The MMSE is a test designed to measure memory, orientation, and language.

COMPENSATION FOR PARTICIPATION

Participants will receive a kinesiology research t-shirt at the beginning of the study.

CONFIDENTIALITY

Any information that is obtained in connection with this study and that can be identified with you will remain confidential. As we are interested in the results of the group as a whole, individual data will not be reported in any public forum. Publications or conference presentations will focus exclusively on group results. All data will be stored in the Lifespan Development Lab in the Department of Kinesiology. Only the researchers (Kate Paquin and Sean Horton) will be able to access the data.

PARTICIPATION AND WITHDRAWAL

Participants can choose whether or not to be in this study. Participants who volunteer to be in this study may withdraw at any time without consequences of any kind. The investigator may withdraw participants from this research if circumstances arise which warrant doing so.

FEEDBACK OF THE RESULTS OF THIS STUDY TO THE PARTICIPANTS

Participants' individual data results will be available, and group results of the study in its entirety will be available online.
Web address: http://web4.uwindsor.ca/units/researchEthicsBoard/studyresultforms.nsf
Date when results are available: August 2013

SUBSEQUENT USE OF DATA

These data may be used in subsequent studies.

RIGHTS OF RESEARCH PARTICIPANTS

If participants have questions regarding your rights as a research participant, contact: Research Ethics Coordinator, University of Windsor, Windsor, Ontario N9B 3P4; Telephone: 519-253-3000, ext. 3948; e-mail: ethics@uwindsor.ca

SIGNATURE OF INVESTIGATOR

These are the terms under which I will conduct research.

___________________________________ ________________
Signature of Investigator Date

Appendix G

Participant Profile

Last Name: ______________________ First Name: ________________________

Telephone: ___________________________

Email (optional): ___________________________________

Birth Year: ____________________ Gender: _______

Do you currently engage in video gaming (e.g., Wii, Xbox)? ______YES ______NO

Address: ____

If YES: What type of games do you play?

____

____

____

Average Session Length? __________ How many times per week? __________

How many years? _______________________

Health Information

- ☐ Migraines
- ☐ Epilepsy
- ☐ Blood clots
- ☐ Arthritis
- ☐ Stroke
- ☐ Ear implant
- ☐ Diabetes
- ☐ Active infection
- ☐ High Blood Pressure (≥140/90 mmHg)
- ☐ Recent back (disc) problems-if so when _______________________

Current Medications:

____

Signature: ____________________________ Date: _____________________

Appendix H

CONSENT TO PARTICIPATE IN RESEARCH – PART B

Title of Study: **Effectiveness of the Nintendo Wii on hand and finger rehabilitation after stroke**

You are asked to participate in a research study conducted by **Kathleen Paquin** (Primary Investigator), and **Dr. Sean Horton** (Primary Advisor) from the **Department of Kinesiology** at the University of Windsor**, the results of which will contribute to Ms. Kathleen Paquin's thesis.**

If you have any questions or concerns about the research, please feel to contact **Ms. Kathleen Paquin** *(Primary Investigator): paquink@uwindsor.ca or* ***(519) xxx-xxxx,*** *or* ***Dr. Sean Horton*** *(Primary Advisor): hortons@uwindsor.ca or* ***(519) 253-3000 ext. 2442.***
PURPOSE OF THE STUDY

The proposed study will look at the effect that the Nintendo Wii can have for rehabilitation of hand and finger use after stroke.

PROCEDURES

If you volunteer to participate in this study, you will be asked to:

1) Complete 16 Wii intervention sessions that are 15 minutes each in length. The Wii intervention will include games that are designed to use hand and finger skills to be successful.
2) Complete four assessment protocols: Jebsen Hand Function Test, Box and Block Test, Nine Peg Hole Test, and Stroke Impact Scale. These protocols will be completed at baseline, after 8 sessions and at the end of the study (16 sessions).

a) **Jebsen Hand Function Test**: You will be asked to complete of tasks that use hand and finger skills, and to finish them as quickly as possible. This test will be run on both hands. There are seven tasks to complete in this test:

i) Turning play cards over
ii) Picking up common objects – such as pennies, paper clips, bottle caps and placing in a jar.
iii) Stacking checkers
iv) Simulated eating – scooping beans into a bowl.
v) Moving light objects – empty cans
vi) Moving heavy objects – weighted cans (1lb)

b) **Box and Block Test**: You will be asked to move as many small blocks from one side of a box to the other in a one minute time span. This test will be run on both hands.

c) **Nine Peg Hole Test**: You will be asked to move nine pegs from a container into their designated spots on a pegboard, and then remove the pegs and place them back into a container. This test will be run on both hands.

d) **Stroke Impact Scale:** The Stroke Impact Scale is a self-report, health status questionnaire. It is designed to assess your view of your stroke outcome. You will be asked questions on strength, hand function, and activities of daily living.

All Wii sessions will take place in the St. Denis Centre Indoor Track Area attached to the Human Kinetics Building and the St. Gethsemane Church on Cabana Road

POTENTIAL RISKS AND DISCOMFORTS

The risk involved with this study is extremely low. With any video game there is a chance of overuse of the playing arm. Additionally, some people may experience motion sickness and dizziness from playing video games.

Potential risks will be managed by always having research assistants or volunteers present to monitor the sessions as they occur. You will be seated while you interact with the game, thus minimizing any fall risk, and you are only playing in short intervals (15 minutes). The brief playing time will also be helpful in reducing any chance of motion sickness or dizziness.

POTENTIAL BENEFITS TO PARTICIPANTS AND/OR TO SOCIETY

We expect to see important gains in fine motor control, which will have a positive impact on your activities of daily living. Additionally, you will be able to experience a novel type of therapy, and learn more about the Nintendo Wii and its usefulness for rehabilitation.

Potential benefits to the scientific community include a more thorough understanding of gaming technology, and the extent to which it can affect fine motor recovery for patients who have chronic stroke.

Participation or non-participation has no relation to your treatment current or ongoing. Consent or withdrawal will not affect your current treatment.

COMPENSATION FOR PARTICIPATION

There will be no compensation for this part of the research.

CONFIDENTIALITY

Any information that is obtained in connection with this study and that can be identified with you will remain confidential. As we are interested in the results of the group as a whole, individual data will not be reported in any public forum. Publications or conference presentations will focus exclusively on group results. All data will be stored in the Lifespan Development Lab in the Department of Kinesiology. Only the researchers (Kate Paquin and Sean Horton) will be able to access the data.

PARTICIPATION AND WITHDRAWAL

You can choose whether or not to be in this study. If you volunteer to be in this study, you may withdraw at any time without consequences of any kind. The investigator may withdraw you from this research if circumstances arise which warrant doing so.

FEEDBACK OF THE RESULTS OF THIS STUDY TO THE PARTICIPANTS

Your individual data results will be available to you, and group results of the study in its entirety will be available online.
Web address: http://web4.uwindsor.ca/units/researchEthicsBoard/studyresultforms.nsf
Date when results are available: August 2013

SUBSEQUENT USE OF DATA

These data may be used in subsequent studies.

RIGHTS OF RESEARCH PARTICIPANTS

If you have questions regarding your rights as a research participant, contact: Research Ethics Coordinator, University of Windsor, Windsor, Ontario, N9B 3P4; Telephone: 519-253-3000, ext. 3948; e-mail: ethics@uwindsor.ca

SIGNATURE OF RESEARCH PARTICIPANT/LEGAL REPRESENTATIVE

I understand the information provided for the study **Effectiveness of the Nintendo Wii on hand and finger rehabilitation after stroke** as described herein. My questions have been answered to my satisfaction, and I agree to participate in this study. I have been given a copy of this form.

____
Name of Participant

_________________________________ ____________________
Signature of Participant Date

SIGNATURE OF INVESTIGATOR

These are the terms under which I will conduct research.

_________________________________ ____________________
Signature of Investigator Date

LETTER OF INFORMATION FOR CONSENT TO PARTICIPATE IN RESEARCH – PART B

Title of Study: **Effectiveness of the Nintendo Wii on hand and finger rehabilitation after stroke**

Participants are asked to participate in a research study conducted by **Kathleen Paquin** (Primary Investigator), and **Dr. Sean Horton** (Primary Advisor) from the **Department of Kinesiology** at the University of Windsor**, the results of which will contribute to Ms. Kathleen Paquin's thesis.**

If participants have any questions or concerns about the research, please feel to contact **Ms. Kathleen Paquin** *(Primary Investigator): paquink@uwindsor.ca or* ***(519) xxx-xxxx, or Dr. Sean Horton*** *(Primary Advisor): hortons@uwindsor.ca or* ***(519) 253-3000 ext. 2442.***

PURPOSE OF THE STUDY

The proposed study will look at the effect of the Nintendo Wii as an intervention for fine motor recovery after stroke.

PROCEDURES

If participants volunteer to participate in this study, they will be asked to:

1) Complete 16 Wii intervention sessions that are 15 minutes each in length. The Wii intervention will include games that are designed to use hand and finger skills to be successful.
2) Complete four assessment protocols: Jebsen Hand Function Test, Box and Block Test, Nine Peg Hole Test, and Stroke Impact Scale. These protocols will be completed at baseline, after 8 sessions and at the end of the study (16 sessions).

a) **Jebsen Hand Function Test**: Participants will be asked to complete a series of tasks that involve fine motor skills, and to finish them as quickly as possible. This test will be run on both hands. There are seven tasks to complete in this test:

i) Writing – a short sentence
ii) Turning play cards over
iii) Picking up common objects – such as pennies, paper clips, bottle caps and placing in a jar.
iv) Stacking checkers
v) Simulated eating – scooping beans into a bowl.
vi) Moving light objects – empty cans
vii) Moving heavy objects – weighted cans (1lb)

b) **Box and Block Test**: Participants will be asked to move as many small blocks from one side of a box to the other in a one minute time span. This test will be run on both hands.

c) **Nine Peg Hole Test**: Participants will be asked to move nine pegs from a container into their designated spots on a pegboard, and then remove the pegs and place them back into a container. This test will be run on both hands.

d) **Stroke Impact Scale:** The Stroke Impact Scale is a self-report, health status questionnaire. It is designed to assess participants' view of stroke outcome. Participants will be asked questions on strength, hand function, and activities of daily living.

All Wii sessions will take place in the St. Denis Centre Indoor Track Area attached to the Human Kinetics Building, and the St. Gethsemane Church on Cabana Road

POTENTIAL RISKS AND DISCOMFORTS

The risk involved with this study is extremely low. With any video game that involves movement, there is a chance of overuse of the playing arm. Additionally, some people may experience motion sickness and dizziness from playing video games.

Potential risks will be managed by always having research assistants or volunteers present to monitor the sessions as they occur. Participants will be seated while they interact with the game, thus minimizing any fall risk, and are only playing in short intervals (15 minutes). The short playing time interval will also be helpful in reducing any motion sickness or dizziness caused by the game.

POTENTIAL BENEFITS TO PARTICIPANTS AND/OR TO SOCIETY

We expect to see important gains in fine motor control, which will have a positive impact on participants' activities of daily living. Additionally, participants will be able to experience a novel type of therapy, and learn more about the Nintendo Wii and its usefulness for rehabilitation.

Potential benefits to the scientific community include a more thorough understanding of gaming technology, and the extent to which it can affect fine motor recovery for patients who have chronic stroke.

COMPENSATION FOR PARTICIPATION

There will be no compensation for this part of the research.

CONFIDENTIALITY

Any information that is obtained in connection with this study and that can be identified with you will remain confidential. As we are interested in the results of the group as a whole, individual data will not be reported in any public forum. Publications or conference presentations will focus exclusively on group results. All data will be stored in the Lifespan Development Lab in the Department of Kinesiology. Only the researchers (Kate Paquin and Sean Horton) will be able to access the data.

PARTICIPATION AND WITHDRAWAL

Participants can choose whether or not to be in this study. Participants who volunteer to be in this study may withdraw at any time without consequences of any kind. The investigator may withdraw participants from this research if circumstances arise which warrant doing so.

FEEDBACK OF THE RESULTS OF THIS STUDY TO THE PARTICIPANTS

Participants' individual data results will be available, and group results of the study in its entirety will be available online.
Web address: http://web4.uwindsor.ca/units/researchEthicsBoard/studyresultforms.nsf
Date when results are available: August 2013

SUBSEQUENT USE OF DATA

These data may be used in subsequent studies.

RIGHTS OF RESEARCH PARTICIPANTS

If participants have questions regarding your rights as a research participant, contact: Research Ethics Coordinator, University of Windsor, Windsor, Ontario N9B 3P4; Telephone: 519-253-3000, ext. 3948; e-mail: ethics@uwindsor.ca

SIGNATURE OF INVESTIGATOR

These are the terms under which I will conduct research.

___________________________________ ____________________
Signature of Investigator Date

Appendix I

Flow Chart of Inclusion and Drop-out

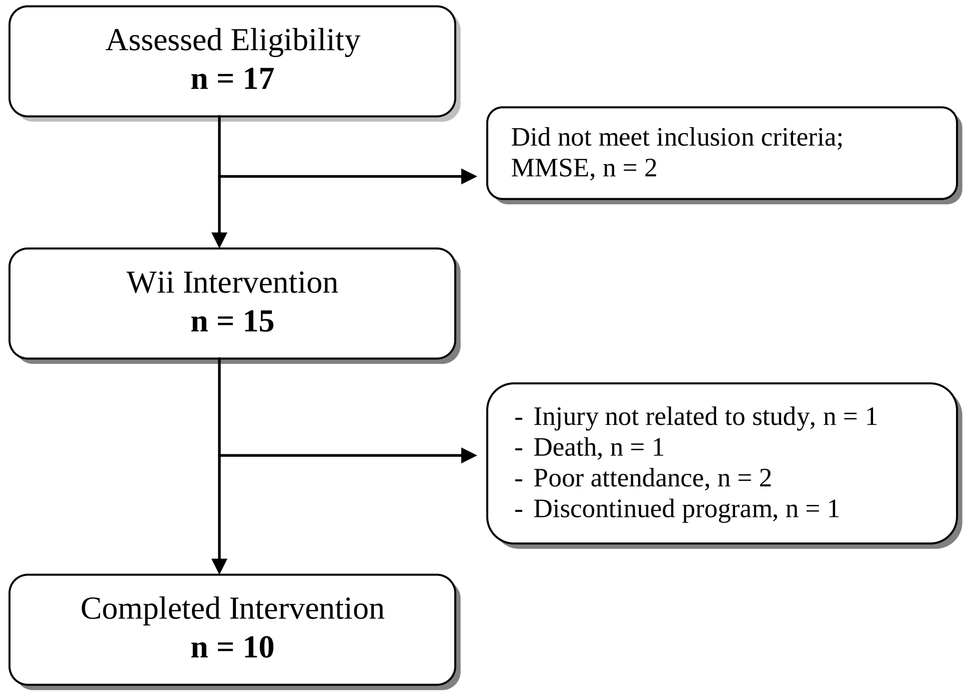


Table 1. Overview of the perceived benefits and challenges of non-immersive VR for stroke rehabilitation (Boyd & Winstein, 2001; Burdea, 2003; Henderson et al., 2007; Holden, Dyar, & Dayan-Cimadoro, 2007; Johansson, 2011; Merians et al., 2002; Page, 2003; Rizzo & Kim, 2005; Sheridan, 1992; Sivak, Mavroidis, & Holden 2009; Smith et al., 2012).

Benefits	**Challenges**
Provision of a non-threatening practice environment, which may prove dangerous otherwise (e.g., preparing a hot beverage or operating a motor vehicle)	Therapists' resistance to technology for fear of being replaced or lack of conviction in its effectiveness
Simulation of objects and events that closely resemble those in real-world settings, and are therefore more likely to be transferable to real-world tasks	Lack of clinical acceptance due to the paucity of evidence needed to satisfy critics
Flexibility that allows for highly individualized learning environments	Virtual interfaces that have not been designed for medical purposes, therefore making sterilization for repeated use problematic
Ability to accommodate for a wide spectrum of cognitive and physical impairments	Commercial equipment that is unable to adequately accommodate all physical impairments
Low cost associated with commercially available VR systems	Unaffordability of VR software and associated hardware for individuals and organizations that lack subsidy
Increased patient enjoyment, motivation and thereby adherence	Patients' negative perception of VR
The potential for telerehabilitation in the absence of any therapist supervision	Lack of patient compliance in the absence of direct therapist interaction
Consistent and systematic manipulation of task-related variables (e.g., increasing the speed of tasks based on a patient's progress)	
Accurate longitudinal measurement of patients' progress	
Increased individual practice time	

Table 3. Means and Standard Errors for all Dependent Measures at each Session and Separated by Hand

	More Affected Hand		Lesser Affected Hand	
Dependent Measure	***M***	***SE***	***M***	***SE***
JHFT				
Familiarization	4.47	(0.31)	4.08	(0.19)
Pre-testing	4.29	(0.23)	4.03	(0.20)
Mid-testing	4.17	(0.19)	3.93	(0.16)
Post-testing	4.09	(0.18)	3.84	(0.16)
BBT				
Familiarization	29	(5.58)	42	(4.95)
Pre-testing	31	(5.27)	45	(4.63)
Mid-testing	34	(6.37)	46	(4.65)
Post-testing	36	(6.77)	51	(4.71)
NHPT				
Familiarization	4.48	(0.38)	3.56	(0.12)
Pre-testing	4.35	(0.39)	3.48	(0.13)
Mid-testing	4.33	(0.44)	3.38	(0.09)
Post-testing	3.94	(0.25)	3.34	(0.09)
	M		***SE***	
SIS				
Familiarization	58		(4.64)	
Pre-testing	60		(4.39)	
Mid-testing	61		(4.59)	
Post-testing	65		(4.59)	

Vita Auctoris

Name:	Kathleen Claira Paquin
Place of Birth:	Windsor, Ontario
Year of Birth:	1988
Education:	M.H.K. (Master of Human Kinetics) Applied Human Performance (Lifespan Development) University of Windsor, Windsor, Ontario, Canada 2011-2013
	B.H.K.[H]. (Bachelor of Human Kinetics) Kinesiology (Movement Science) University of Windsor Windsor, Ontario, Canada 2006-2010
	O.S.S.D. (Ontario Secondary School Diploma) Catholic Central High School Windsor, Ontario, Canada 2002-2006