THE RELATIONSHIP BETWEEN TOUCH SENSATION OF THE HAND AND OCCUPATIONAL PERFORMANCE IN INDIVIDUALS WITH CHRONIC STROKE

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Dedication

I dedicate this manuscript to all of the stroke survivors who I have worked with through the years. It is you who has inspired me to dedicate my life to stroke research and motivated me to pursue the topic of my dissertation. Thank you for allowing me the opportunity to get to know you and learn from you and your story. Without you, I could not have completed my project and share my experience with other healthcare professionals, researchers, and students.

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ABSTRACT

Valerie A. Hill

THE RELATIONSHIP BETWEEN TOUCH SENSATION OF THE HAND AND OCCUPATIONAL PERFORMANCE IN INDIVIDUALS WITH CHRONIC STROKE

Stroke is the main cause of disability in the United States. Individuals with stroke commonly report sensory impairment affects their recovery. Motor recovery and sensory impairment are related and impact individuals' ability to perform valued occupations. Despite the prevalence of sensation impairment after stroke, many occupational therapists fail to include sensation assessment and intervention in treatment planning. The exclusion of sensation in occupational therapy interventions during stroke rehabilitation may be due to the lack of literature supporting the association between sensation and occupational performance. The current study aimed to determine the relationship between touch sensation of the affected hand and occupational performance and satisfaction in individuals with chronic stroke. Using a cross-sectional study design, this study associated factors related to hand sensation and function in individuals with chronic stroke. Fifty individuals with chronic stroke participated in a one-time testing session in which assessments related to sensation, movement of the hand and engagement in daily activities were administered. Correlation analyses were utilized to determine relationships between touch sensation of the affected hand with individuals' abilities to engage in valued daily activities, arm and hand disability, and manual abilities. The main finding of the study was that individuals with intact sensation reported greater ability to perform valued occupations and satisfaction with their performance, as compared with individuals with touch sensation impairment. For individuals with impaired touch sensation of the affected hand, impairment of touch sensation of the hand did not correlate with individuals' performance or satisfaction with valued occupations, arm or hand movement, or manual abilities. Collectively, the results of this study reflect the complex interaction between touch sensation, occupational performance, motor functioning, and manual abilities of the affected hand for individuals' who have experienced a stroke. This study

informs therapists, rehabilitation scientists, and other healthcare professionals that client-centered, individualized approaches, including a wide array of clinical assessments and intervention, including assessment of occupational performance and sensation, remain important components in stroke rehabilitation.

Thomas Fisher, PhD, OTR, CCM, FAOTA, Chair

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Chapter I: Introduction

Introduction/background

After stroke, individuals often experience physical impairments leading to activity limitations and participation restrictions. Somatosensory impairment is a common physical impairment experienced after stroke (Winward, Halligan & Wade, 1999) and refers to sensations of the body including touch sensation, two point discrimination, localization, proprioception, and kinesthesia (Bennet, Fasoli, & McKenna, 2010). Often times after stroke, individuals are unable to sense light tough which is determined to be touch sensation impairment (Winward, Halligan & Wade, 1999). Touch sensation impairments impact individuals' occupational performance and decrease their ability to perform everyday tasks and valued occupations (Busse, & Tyson, 2009; Christiansen & Matuska, 2004; Tyson, Hanley, Chillala, Selley, & Tallis, 2008). Stroke is the leading cause of long-term disability in the United States (Rosamond, Flegal, Friday, Furie, Go, Greenlund, et al., 2007; Hofgren, Björkdahl, Esbjörnsson, & Stibrant-Sunnerhagen, 2007) and it is possible that impairment of touch sensation of the affected hand may play a role.

Many studies have examined somatosensory function after stroke(Busse, & Tyson, 2009; Christiansen & Matuska, 2004; Tyson, Hanley, Chillala, Selley, & Tallis, 2008). None, however, have considered the relationship between touch sensation of the hand and occupational performance. Billions of dollars are spent annually on stroke motor rehabilitation; however rehabilitation focusing on sensory impairment is often overlooked. This is unfortunate as researchers have found that 53-89 percent of stroke survivors report sensory impairment that impacts their recovery (Winward, Halligan & Wade, 1999). Despite individuals' reports of sensory impairment, many occupational therapists do minimal or no sensation assessment and do not include sensory needs in treatment planning (Winward et al., 1999; Kusoffsky, Wadell & Nilsson, 1982). Neglecting somatosensory function is problematic as there is a relationship between sensation and motor recovery (Dannenbaum & Dykes, 1988). Motor recovery is related to individuals' ability to engage in valued occupations (Tyson, Hanley, Chillala, Selley, & Tallis, 2008). The relationship between occupational performance, motor recovery, and sensory function suggests that the inclusion of motor and sensation evaluation and intervention is appropriate to include in individual's rehabilitation plan. Additionally, researchers found that when individuals had increased somatosensory cortical activity, they exhibited better fine motor coordination and force maintenance of their affected arms (Dannenbaum & Dykes, 1988; Carey, Abbott, Egan, Berhardt & Donnan, 2005). The linkage of post-stroke disability, upper extremity sensation, and recovery of arm function illustrates a relationship between sensation and functional recovery and is the rationale for this study. That is, specifically, this study focuses on the association between touch sensation of the affected hand and occupational performance in individuals with chronic stroke.

Statement of the problem

The problem is that individuals with stroke continue to exhibit deficits in occupational performance and sensation of the upper extremity resulting in decreased functional abilities. Despite individuals' sensory deficits, somatosensory interventions are not included in individuals' rehabilitation plan. Failing to include sensory interventions may be due to the lack of literature relating sensory impairment of the hand with occupational performance.

Purpose and significance of the study

Purpose. The central purpose of this study was to:

1. Determine the association between occupational performance and touch sensation impairment of the affected hand in individuals with chronic stroke:
    a. Determine the association between individuals performance of chosen occupations and touch sensation levels.
    b. Determine the association between the individuals satisfaction with performance of chosen occupations and touch sensation levels.

There are factors other than touch sensation of the affected hand that impact occupational performance in individuals with stroke; therefore, the following secondary aims were used to capture these factors:

2. Determine the association between motor impairment and touch sensation impairment in the affected hand in individuals with chronic stroke.
3. Determine the association between hand function and touch sensation impairment of the affected hand in individuals with chronic stroke.

4. Determine the association between manual abilities and touch sensation level of the affected hand in individuals with chronic stroke.

Significance. Stroke remains the leading cause of long-term disability in the United States (Rosamond et al., 2007; Centers for Disease Control and Prevention, 2010; National Stroke Association, 2009; American Heart Association, 2010). Winward et al. (1999) found that over sixty percent of individuals who have had a stroke report sensory impairment that impacted their recovery. More specifically, sensory impairment impacted individuals overall recovery and decreased their ability to use the affected hand (Winward et al, 1999). Previous authors have correlated somatosensory impairment with motor function and functional limitations (Han, 2002; Patel, 2000). Specifically, function related to ADL independence and mobility correlated with sensation impairment of the hand (Busse & Tyson, 2009; Tyson, Hanley, Chillal, Selley, & Tallis, 2008). While there are ample data to suggest the importance of sensory impairment and hand function, no studies have considered the relationship between impairment of touch sensation of the hand and occupational performance in individuals with stroke.

Occupational performance refers to the dynamic experience of an individual to perform the occupations they want and need to be able to do (Law, Cooper, Strong, Stewart, Rigby, & Letts, 1996). After stroke, it is common for individuals to experience sensory deficits in his/her affected hand (Winward, Halligan & Wade, 1999). Studies have shown that for individuals' with sensory impairment in the affected hand, there is limited ability to engage in occupations that require the coordinated use of the upper limbs (Christiansen & Matuska, 2004). By assessing individuals' occupational performance after they have a stroke, occupational therapists can determine areas that need to be addressed in order to support performance in valued occupations.

The significance of this study is to provide rehabilitation scientists, health professionals, and others with a better understanding of how upper extremity touch sensation impairment impacts individuals occupational performance. Improved arm and hand rehabilitation strategies may provide stroke survivors with a newfound ability to use their arms and hands to engage in desired tasks of ordinary every day occupations (Christiansen, Clark, Keilhofner, & Rogers, 1995). Identification of an association between touch sensation and occupational performance will help determine whether sensation interventions ought to be included in the rehabilitation plan for individuals with stroke. The results of this study help fill a knowledge gap and serve as a foundation for future exploration of occupational performance and somatosensory interventions in individuals with stroke.

Hypotheses

The primary study hypothesis was that there will be a negative association between scores of the Canadian Occupational Performance Measure (COPM) performance and satisfactions scores and scores of the Touch-Test™ Evaluators. The study aims were accomplished by testing these specific hypotheses:

1a. There will be a significant negative correlation between individuals' scores of performance on the COPM and scores on the Touch-Test™ Evaluators.

1b. There will be a significant negative correlation between individuals' satisfaction with performance on the COPM and scores on the Touch-Test™ Evaluators.

2. There will be a negative correlation between scores on the Fugl Meyer and scores on the Touch-Test™ Evaluators.

3. There will be a negative correlation between scores on the Box and Block Test and scores on the Touch-Test™ Evaluators.

4. There will be a negative correlation between scores of ABILHAND and scores on the Touch-Test™ Evaluators.

The findings of this study contribute to our understanding of the association between touch sensation deficits and occupational performance. This new focus highlights an area in which occupational therapists can focus to enhance occupational performance after stroke. This study attempted to relate touch sensation of the affected hand and occupational performance for individuals with chronic stroke.

Definition of terms

Disability. The negative outcome of impaired body structure and functions and results in activity limitation and participation restriction [World Health Organization (WHO), 2001]. In this study, the operational definition for disability refers to the impairment of the upper extremity to reach and grasp objects with the hand and was measured by the Box and Block Test.

Function. A specific upper limb function, upper limb motor function, upper limb activity, and/or individuals' perceived level of arm use (Doyle, Bennett, Fasoli, & McKenna, 2010). More specifically, function is the positive outcome of working body functions and structures resulting in the ability to engage in everyday activities (WHO), 2001. For this study, the operational definition of function relates specifically to upper extremity function and was measured with the ABILHAND questionnaire. Impairment. Problems in the body functions or structures that result in significant loss of use (WHO, 2001). For this study, the operational definition of impairment refers to the significant loss of the specified body function or structure.

Motor impairment. For this study, the operational definition of motor impairment refers to the loss of use of the affected upper extremity and was measured by the Fugl Meyer.

Occupational performance. The ability to engage in a task related to areas of occupation including activities of daily living, instrumental activities of daily living, rest and sleep, education, work, play, leisure, and social participation (AOTA, 2008). Occupational performance incorporates performance skills, performance patterns, contexts, activity demands, and client factors (AOTA, 2002). Occupational performance is often interchanged with function and purposeful activity (Christiansen, Clark, Keilhofner, & Rogers, 1995). For this study, the operational definition of occupational performance refers to individuals' perceived performance of activities of daily living, work and productive activities, and leisure activities and their satisfaction with performance of these valued activities. Occupational performance was measured using the Canadian Occupational Performance Measure.

Touch sensation. The ability of an individual to feel tactile body senses (Doyle, Bennett, Fasoli, & McKenna, 2010). For this study, the operational definition of touch sensation refers to the touch sensation level of individuals' hand and arm and was measured by the Touch-Test™ Evaluators.

More affected arm. The arm that exhibits the most neurological impairment after an individual has a stroke. The impairments include: hemiparesis (weakness), hemiplegia (paralysis), and somatosensory deficits (Woodson, A, 2008).

Scope of the study

Through this study, a gap in the literature was addressed to better understand the relationship between touch sensation of the affected hand and functional abilities for 50 individuals who were in the chronic phase post-stroke. Functional abilities were explored through investigation of occupational performance, motor impairment, hand disability, and manual abilities.

Methodology

A cross sectional study design was used in which subjects were assessed one time. This study included a convenience sample of 50 community dwelling stroke survivors. After consenting, which included describing the study purpose, explaining the risks of the study, and asking if individuals had any questions, the individuals were administered a battery of tests. The investigator administered the Touch-Test™ Evaluators, Fugl Meyer, Box and Block Test and the Canadian Occupational Performance Measure. In addition, subjects completed the ABILHAND questionnaire. Once the subjects completed all tests they were finished with the study. Some subjects took up to two hours to test and required rest breaks, which were allowed as needed. Some tests were not administered due to time constraints that exceeded the two hour allocation and are noted in the results section.

Summary

Stroke is a debilitating disease and impacts individuals' function in a variety of ways. Sensation is one of many factors that contribute to individuals' dysfunction. Further research needs to be conducted to better understand the association of upper extremity touch sensation and function in individuals' affected arm after stroke. This study provides information through the analysis of touch sensation, hand and arm motor function, and occupational performance.

Chapter II: Review of the literature

Overview

There are 829,000 individuals per year who survive a stroke [Centers for Disease Control and Prevention (CDC), 2007]. Over 1 million stroke survivors experience difficulties performing everyday tasks and valued occupations and 15-30% experience chronic disability (CDC, 2007) resulting in primary and secondary issues for the individual. Primary issues often result in hemiparesis of the affected arm and secondary issues include muscle shortening, pain, edema, and learned nonuse (Sabari & Lieberman, 2008).

Stroke has an impact on individuals' occupational performance as evidenced by the 90% of stroke survivors who never achieve normal use of their affected arm (Kwakkel, Kollen, van der Grond, & Prevo, 2003) and 50% who regain only some arm movement (Broeks, Lankhorst, Rumping, & Prevo, 1999). Occupational performance problems are caused by residual impairments including: motor loss, sensory loss, and problems with sensory processing (Jorgensen, 1995; Winward, Halligan, & Wade, 1999). Such multifaceted occupational performance problem occur, because arm function requires a complex system of neuromuscular and sensorimotor integration in order to engage in everyday tasks (Feys, De Weerdt, Selz, Steck, Spichiger, Vereeck, et al., 1998). Motor loss, sensory loss and sensory processing difficulties impact this complex system; therefore negatively contributing to the recovery of the arm after one has a stroke. All of these impairments complicate individuals' rehabilitation and slows functional recovery.

Furthermore, stroke damages the cells in the brain causing loss of movement in the upper extremities needed to engage in valued tasks. Often times, the motor and sensory systems are damaged by a stroke. This study examines the association of touch sensation of the hand and function of the upper extremity in individuals with chronic stroke. By considering individuals' valued occupations with his/her affected hand touch sensation levels, we may conclude an association between occupational performance and touch sensation in individual's with stroke. This would add to the connection between motor function, sensory function, and occupational performance. In this review the author will review appropriate theoretical frameworks and literature which supports to this dissertation.

Impact of somatosensory impairment on function

The presence of somatosensory deficits often leads to poorer functional outcomes for individuals with a stroke (Smania, Montagnana, Faccioli, Fiaschi, & Agliotti, 2003), because impairments of the upper extremity are the most common contributors to activity limitations and participation restrictions (Sveen, Bautz-Holter, Sodring, Wyller, & Laake, 2011).

Arm function is impacted by a broad range of sensations. In order to engage in everyday tasks, the following sensations of the hand and arm are used.

- Kinesthesia, which is the ability to detect the body's position, weight and movement of the musculoskeletal system particularly at the joints (Bennet, Fasoli, & McKenna, 2010). This sensation is essential to help individual's feel their arm's position and able to position the arm and hand properly in order to grasp and manipulate objects.
- Proprioception, which refers to one's ability to sense their body (i.e. muscle, joints, and tissue) and the body's position in relation to itself (Gutman, 2008). Seventeen-52% of individuals experience proprioception deficits after a stroke (Bennet, Fasoli, & McKenna, 2010). This is important in order for individuals' to be able to control their arm and hand muscles to purposefully move the arm and control grasp and release of objects in the hand.
- Two-point discrimination, one's ability to sense two different points on the skin that are positioned adjacent to each other (Bennet, Fasoli, & McKenna, 2010), determines the innervations of slow adapting muscle fibers (Callahan, 2002). The ability to feel two adjacent points on the skin helps individuals manipulate smaller objects in the hand and represents an increased sense of touch in the hand.
- Localization, which refers to one's ability to determine where they feel a cutaneous stimulus (Bennet, Fasoli, & McKenna, 2010). Being able to feel the accurate place of the stimuli helps individuals manage objects in the hand.
- Lastly, touch sensation, requires the activation of the low threshold type A muscle fibers of the muscles (Rood, 1956) and is required when purposely using the hands in a task. The way in which the hand touches objects helps the brain

collect somatosensory data in order to appropriately interact with the objects in the hand.

As described before, when there is a brain lesion along the somatosensory pathways, sensations may be impaired, which in turn, impairs individuals' ability to use their hands. An inability to use the hands limits individuals' ability to engage in valued occupations as they had before the stroke. The current study is concentrating on the association between touch sensation of the hand and function of the upper extremity in individuals with chronic stroke.

Review of neurological systems

Anatomy of sensation. For the purpose of this dissertation sensation refers to touch sensation or the ability of an individual to feel tactile body senses (Doyle, Bennett, Fasoli, & McKenna, 2010) specifically related to the upper extremity. In order to appreciate what this means to a stroke survivor it is important to understand the complexity of the sensory system and the neural pathways.

Systems/ Pathways. Each sensation in the somatosensory system has its own neural pathway; however in order for the somatosensory system to work optimally, the different sensations share neural pathways, making it difficult to fully understand the somatosensory system. A simplistic understanding of how sensation impacts motor control follows. Sensory signals from the muscles and skin are essential for motor control. In order for individuals to use their muscles, the mechanoreceptors in the muscle and skin control movement by sensing the stimuli on the skin and contracting or inhibiting movement of the muscles (Dannenbaum & Dykes, 1988). This process pertains to all muscles in the body; however the hand is more complex and requires more input from the skin, whereas other body parts require more input from the muscles (Dannenbaum & Dykes, 1988). When an individual grasps an object, the pressure from movement and stretch of the skin provides the feedback to the brain needed to control the muscle contraction force in order to maintain the necessary function (Dannenbaum & Dykes, 1988).

Practice Model/ Conceptualization. The sensory system involves a rather complex structure and processes incorporating surface receptors, spinal processes and multiple brain processes. A top down hierarchy related to the acquisition of touch sensation involves the broad umbrella of perception, and narrows to haptic perception, then to the somatosensory system, and finally to touch sensation (Gutman, 2008).

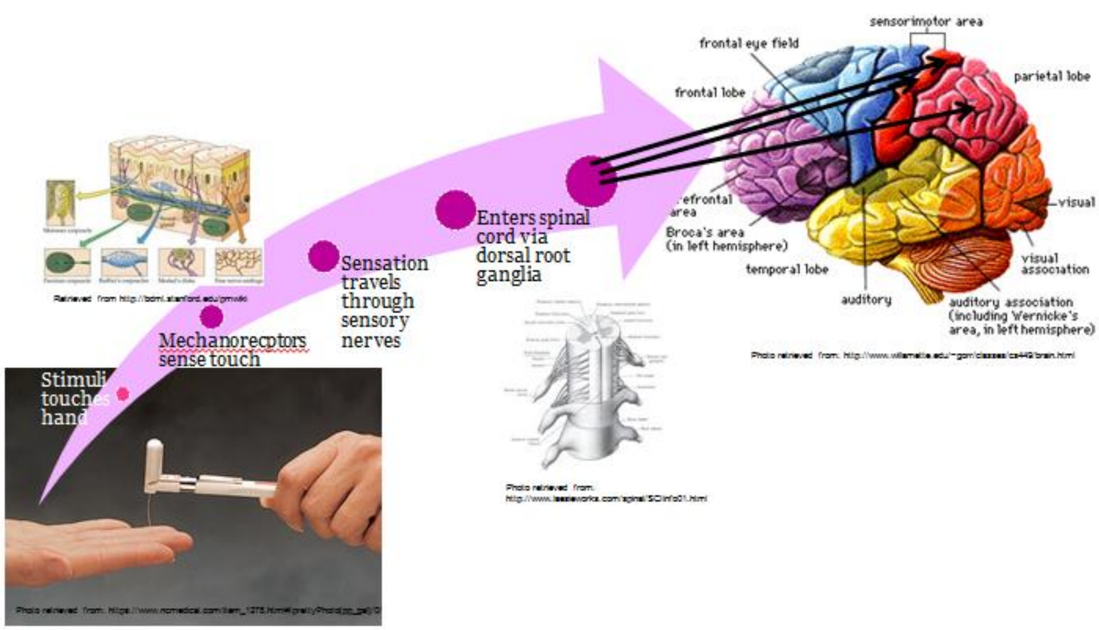
Perception is the process of attaining awareness or understanding of sensory information. There are many types of perception including: amodal, color, visual, depth, form, haptic, speech, perception as interpretation, numeric value perception, pitch perception, harmonic perception, and rhythmic perception (Gutman, 2008). The type of perception related to touch sensation is haptic perception. Haptic perception is responsible for the process of recognizing objects through touch via touch sensation and proprioception. The somatosensory system helps the brain organize the sensations of touch sensation.

The somatosensory system is a diverse sensory system with receptors and processing centers that produce sensation such as touch, temperature, proprioception, taste, sound, smell and nocioception. These sensory perceptions are achieved through receptors that travel on sensory nerves through the spinal cord tracts and into the brain. These perceptions are processed in the primary somatosensory area in the parietal lobe of the cerebral cortex (Gutman, 2008). The sense is perceived via the triggering of the sensory neuron, sending the sensory receptor to the area of the brain responsible for that specific sense in the homunculus (Gutman, 2008). It is thought that the somatosensory cortical regions (Xerri, Merzenich, Peterson, & Jenkins, 1997) represent the cortical areas impacting touch sensation. This information is then processed by the brain and the body responds accordingly. For example, if one’s left thumb is lightly pricked with a pin, the mechanoreceptors send a signal through the spinal cord to the primary somatosensory cortex in which the brain recognizes that the hand was touched and the signal is also sent to the secondary sensory association area to determine that the left thumb was the part of the hand that was touched. This example exemplifies that different parts of the brain are responsible for different components of sensation. If one area is altered, it may impact the other processes needed to accurately identify a sensation.

Touch sensation is controlled through the somatosensory system. The neurological process associated with touch is as follows: the mechanoreceptors sense touch and send an action potential up the dorsal root ganglia through the spinal cord to the thalamus to the parietal lobe of the brain to the post central gyrus to the primary somatosensory cortex (Gutman, 2008). See figure 1 for an illustration. These complex neurological processes contribute to the difficulties identifying how somatosensory impairments impact individual's functioning after stroke. Brain damage in any of these cortical areas will result in touch sensation and functional impairment in the upper extremity.

Figure 1

Touch sensation afferent processing from touch stimuli to brain reception



More specifically, nerve endings are stimulated when the soft tissue of the hand statically or dynamically touches an object (Shao, Chen, Barnes & Henson, 2009). The peripheral nervous system depends on the cutaneous mechanoreceptors in the fingertips and palm, which consists of type-1 afferent neurons which are slowly adapting neurons that end at Merkel discs; rapidly adapting afferent neurons ending at Meissner corpuscles; Pacinian corpuscles which are normal adapting neurons that end in Pacinian corpuscles; and type-2 afferent neurons which are slowly adapting neurons that end in Ruffini endings (Shao, Chen, Barnes & Henson, 2009). Merkel discs can be activated by static contact and recognizes the overall area, shape, and intensity load of an object and detect low frequency vibration (Shao, Chen, Barnes & Henson, 2009). Ruffini endings are stretch receptors that detect tangential forces (Shao, Chen, Barnes & Henson, 2009). This process is important because the fingertips are the first point of contact enabling the individual to assess their environment; i.e.: textures, shape, size, and preparation for grasping the object (Dannenbaum, Michaelsen, Desrosiers, & Levin, 2002). The touch sensation process is important because it prepares the body to initiate and maintain the needed grasp; i.e. force and fine motor coordination object (Dannenbaum, Michaelsen, Desrosiers, & Levin, 2002). Touch sensation is essential for individuals to optimally engage in everyday tasks and valued occupations and damage to the somatosensory system will result in residual deficits.

It is clear that the somatosensory system entails a complex system, and just one sensation, such as touch sensation, requires complex neurological processes in order for the sensation to respond accurately. If one part of the process is interrupted or injured, such as a lesion from a stroke, then the sensation or sensations may be impaired.

Impact of stroke on somatosensory cortices. The brain lesion site from a stroke influences the residual deficits an individual experiences. The location of the lesions, including the cortices and hemispheres in which the lesion is found both have an impact on the deficits an individual will experience. Right brain hemispheric lesions have resulted in 37% of patients with sensory deficits as compared with 25% of individuals with left brain hemispheric lesions with sensory deficits (Sterzi, Bottini, Celani, Righetti, Lamassa, Ricci, & Vallar, 1993). After a stroke, individuals' brains experience diaschisis, a temporary delay of functioning of the cells affected by the brain lesion (Xerri, Merzenich, Peterson, & Jenkins, 1997). Once the diaschisis resolves, it is up to neuroplastic cortical reorganization to recover motor and somatosensory functioning (Xerri, Merzenich, Peterson, & Jenkins, 1997). It is important to remember that the somatosensory pathways overlap and impact one another's functioning. This overlap influences both the sensory and the motor potential of an individual who has a brain lesion. Brain imaging studies have corroborated this sensorimotor connection by showing cortical links between motor control and somatosensory brain regions when looking at functional outcome measures in individuals with stroke (Borstad, Schmalbrock, Choi, & Nichols-Larsen, 2012; Carey, Abbott, Egan, Bernhardt, & Donnan, 2005; Carey, Abbott, Harvey, Puce, Seitz, & Donnan, 2011; Conforto, Cohen, dos Santos, Scaff, & Nagahashi, 2007; Kim, 2007; Skidmore, Rogers, Chandler, Jovin, & Holm, 2007).

Four structural models

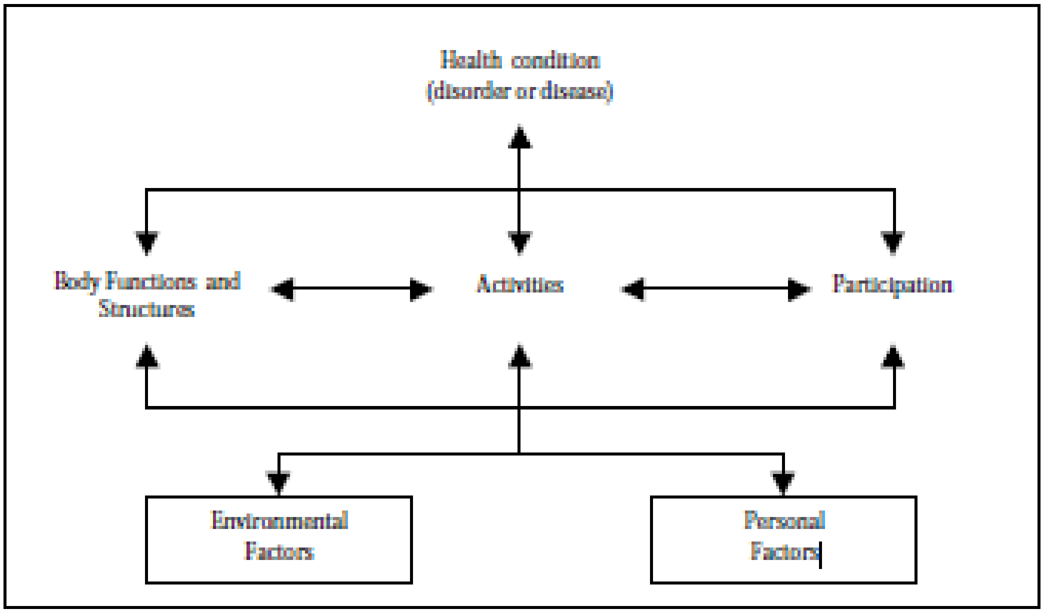
Currently, there is no single theory explaining the association between touch sensation of the upper extremity and occupational performance. Highlighted below is the amalgamation of a classification system, framework, and two models that help develop a foundational understanding of the complexity of the association between touch sensation and occupational performance. Included in the foundational underpinning is the International Classification of Functioning, Disability, and Health; Occupational Therapy Practice Framework; Person-Environment-Occupation Model; and Multisensory Integration Model.

International Classification of Functioning, Disability, and Health. The International Classification of Functioning, Disability, and Health (ICF) provides a conceptual model regarding the consequences that a stroke has on individuals' health and functioning (Fortini, Michaelsen, Cassiano, & Teixeria-Salmela, 2011). After stroke, impairments of the arm and hand include muscle spasticity and contractures, and a decrease in the upper extremity strength, dexterity, range of motion, speed, bilateral activity and sensation (Boissy, Bourbonnais, Carlotti, Gravel, & Aresenault, 1999; Burridge, Turk, Notley, Picerking, & Simpson, 2009; Roby-Brami, Fuchs, Mokhtari, Bussel, 1997; Zackowski, Dromerick, Sahrman, Thach, & Bastian, 2004). These impairments impact individuals in various ways and can be seen at each level of the ICF.

The ICF was developed by the World Health Organization (WHO) and reflects a universal rehabilitation language that can be used across disciplines and countries (Stucki, Ewert, & Cieza, 2003). The ICF provides a taxonomy for rehabilitation professionals to describe individuals' health and health-related domains (WHO, 2011). Please see Figure 2 for the ICF model.

Figure 2

ICF model: Interaction between ICF components.



(World Health Organization, 2001)

The classification incorporates a multitude of domains. : body functions and structures, activity and participation, and environmental context and personal factors(WHO, 2011). Activity is the central domain and is impacted by all other domains. The ICF views health and disability on a continuum and individuals shift on this health scale based on factors related to each of the ICF domains. The extent to which an individual with stroke could be examined using the ICF is more than will be covered in this dissertation; therefore, examples will be provided considering the impact that touch sensation impairment has on an individual.

The body functions and structures domain are broken down; only the components essential to touch sensation and occupational performance will be highlighted here. Body functions includes mental functions, sensory functions and pain, neuromusculoskeletal and movement related functions, and skin and related structures functions. Structures includes systems of the following: nervous system, movement structures, and skin and related structures. After an individual experiences a stroke, many of these systems' structures and functions are impaired. Touch sensation is specifically identified and defined as sensing the texture or quality of surfaces (WHO, 2011).

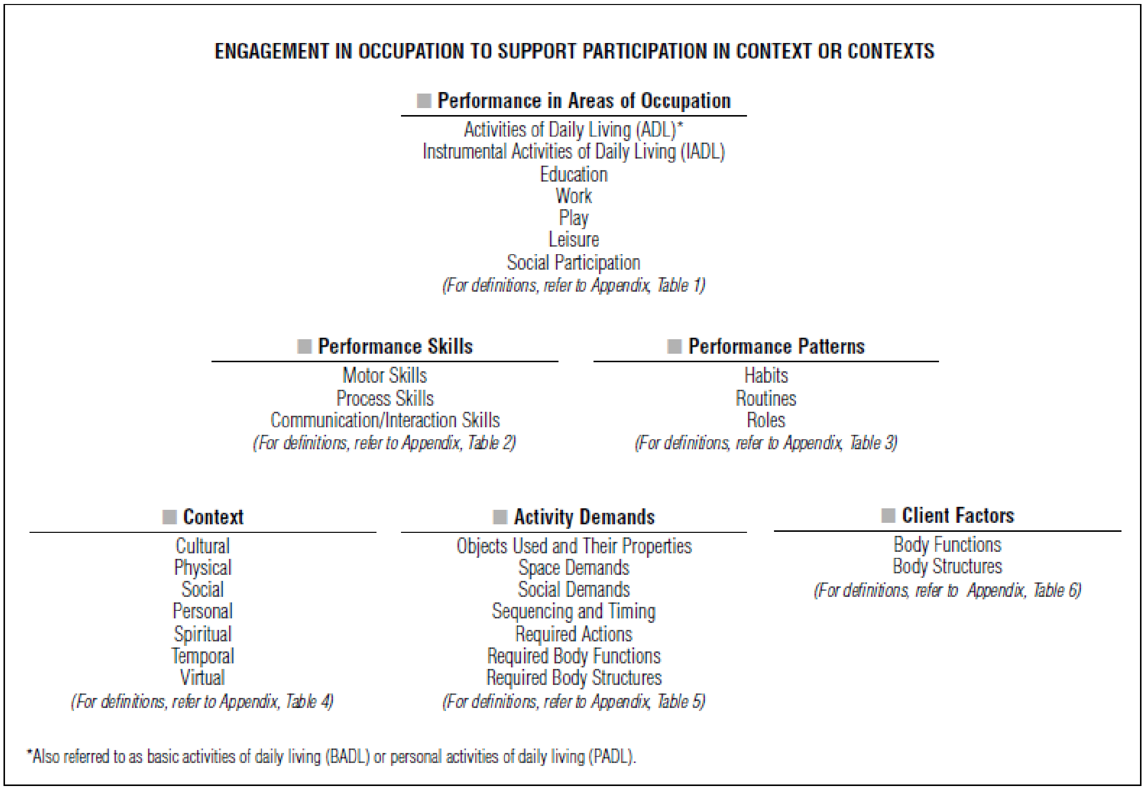
Activity and participation are broken down into the following areas: learning and applying knowledge, general tasks and demands, communication, mobility, self-care, domestic life, interpersonal interactions and relationships, major life areas, and community, social, and civic life. The activity and participation domain needs to be considered on an individual basis. For example, an individual with touch sensation impairment may experience difficulty with self-care, which is broken down to include: washing oneself, caring for body parts, toileting, dressing, eating, drinking, and looking after one's health. It is also possible that someone with a touch sensation deficit may experience limitations with major life areas which includes: education, work and employment, and economic life. The environmental factors are also included in the model; however will not be further discussed here.

The ICF has been used to design discipline-specific frameworks, such as the Occupational Therapy Practice Framework which will be presented in more detail below. Many healthcare disciplines have also used the ICF to restructure their practice; however due to the focus of this dissertation, we will expand on the use of the ICF within the field of occupational therapy.

Occupational Therapy Practice Framework. The Occupational Therapy Practice Framework: Domain and Process, 2nd Edition (OTPF) defines the scope of occupational therapy practice. See Figure 3 for an illustration of the framework. The OTPF incorporates the domain and process of occupational therapy. The domain encompasses individuals' activity demands, performance skills, performance patterns, client factors, areas of occupation, and context and environment, which interact with each other and contributes to individuals' potential to engage in occupations, participation and health [American Occupational Therapy Association (AOTA), 2008]. More specifically, the components of the domains are particularly helpful in identifying how an individual is able to engage in desired occupations and what limitations may be preventing them from optimal functioning. Touch sensation of the upper extremity may impact functioning across the areas of occupation, performance skills, performance patterns, and activity demands.

Figure 3

Occupational Therapy Practice Framework



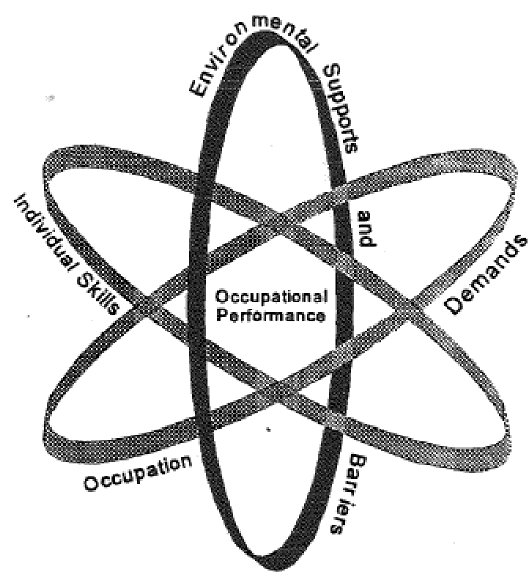
(American Occupational Therapy Association, 2008)

Person-Environment-Occupation Model. The Occupational Therapy Practice Framework introduces occupational performance and the importance of occupational performance in the context of an individual’s life. The Framework defines occupational performance as the accomplishment of an occupation through the transaction of the client, the context, and the activity. This definition is derived from the Person-Environment-Occupation (PEO) Model. The PEO Model is an ecological perspective of the interactional relationship between an individual, their environment, and occupations (Law, Cooper, Strong, Stewart, Rigby, & Letts, 1996); all of which contribute to one’s occupational performance.

In this model, the person is viewed as a holistic being that is shaped by his/her roles, personal attributes and experiences. One key factor to occupational performance is personal competence, which includes one’s motor and sensory abilities, cognitive functioning, and general health (Law et al, 1996). The environment is complex and for the purpose of this dissertation, only components related to touch sensation of the upper extremity and occupational performance will be addressed. The environment impacts one's behavior and encompasses the many contexts from the perspective of the person (Law, Cooper, Strong, Stewart, Rigby, & Letts, 1996). Occupation includes clusters of activities and tasks that meet individuals' intrinsic needs related to self-maintenance, self-expression, and fulfillment (Law, et al, 1996). Fulfillment in occupation relates to one's satisfaction with his/her occupational performance. The complex transaction between the person, environment, and occupation results in one's occupational performance. This interaction is constantly changing across time and the more the components overlap with the other, the more congruence one will experience in their occupational performance (Law, Cooper, Strong, Stewart, Rigby, & Letts, 1996). See Figure 4 for details.

Figure 4

Person-Environment-Occupation Model



(Law, Cooper, Strong, Stewart, Rigby, & Letts, 1996)

When an individual has a stroke it is possible that all components of the OTPF and PEO model are affected. For the purpose of this dissertation two examples emphasizing touch sensation impairment will be described. A classic example is when an individual has a stroke he/she may experience occupational limitations, particularly with basic activities of daily living (ADL). He/she may have limited sense of touch of the affected upper limb which may limit his/her ability to hold onto the soap or washcloth needed to bath, put tooth paste on a tooth brush, retrieve pills from pill bottles, put on make-up, put on under garments, zip pants and so on. With these limitations, one's daily routine of getting ready in the morning is impacted, and habits associates with getting ready, are also affected.

Another example highlights how a limitation with touch sensation of the hand may limit an individual's social participation. Social participation involves engaging in meaningful activities within a social context. For example, handing out programs or passed the offerings plate at church, may be a desired occupation. If touch sensation of one's hand is impaired after stroke, he/she may not be able to feel or grasp the program or the offerings plate, therefore impacting his/her role as a church volunteer.

For both examples, the PEO model can be applied to better understand the fit of the person, environment, and occupation with occupational performance. This is relevant to this dissertation because impaired touch sensation of the hand is one element of the person, personal competence, which impacts one's ability to engage in desired occupations. Regarding both examples from above, routines and activity demands change to accommodate engagement in desired occupations and align the components of the PEO in order to enhance one's occupational performance. These two examples are simple, yet emphasize how sensation is implicit in the OTPF and PEO model.

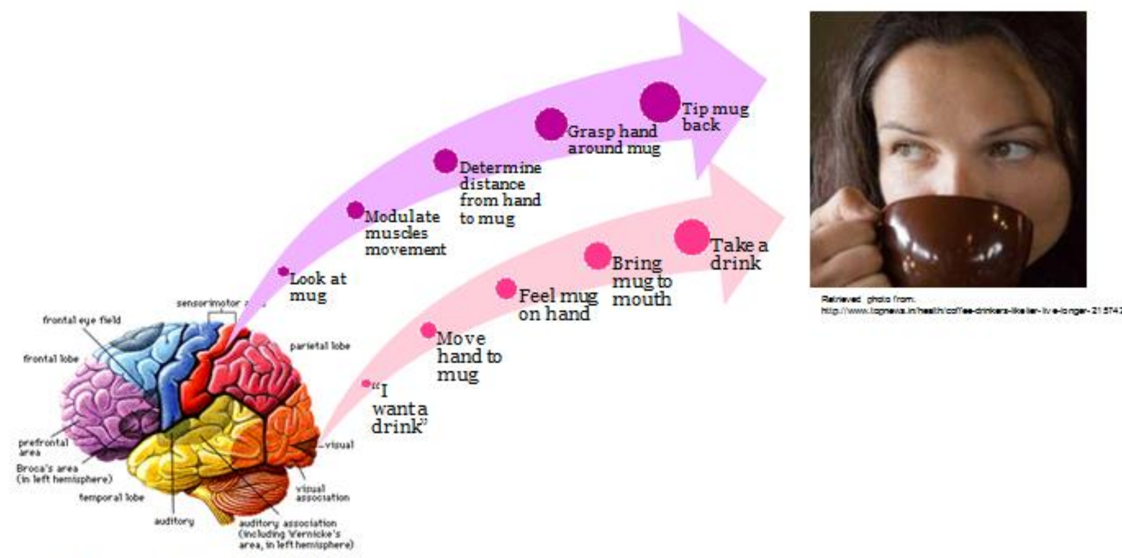
Since sensation is implicit at the foundational level of these models/frameworks, sensory functioning impacts the higher order levels impacting performance skills and performance patterns. Sensation impacts motor skills and the way in which individuals engage in their habits, routines, and roles. Sensory functioning may impact the highest level of the framework, performance in areas of occupation, which impacts individuals' abilities to perform activities they want and need to do on a daily basis.

Occupational therapists have long been interested in sensation and the impact of sensation on their client's function. As described in the models above, occupational therapists include sensation function and its' impact on individuals' areas of occupational performance. The inclusion of sensation and occupational performance validates the need for occupational therapist to address impairment of touch sensation of the upper limb and the relationship between touch sensation and occupational performance.

Multisensory Integration Model. The Multisensory Integration Model (MIM) is a compelling model that illustrates the integration of sensory functions in order for an individual to produce motor output. The MIM is based on the idea that human beings function at the most optimal level when using multiple senses to integrate information (Meyer & Noppeney, 2011). The MIM stems from a multidisciplinary approach comprised of psychophysics, neurophysiology, and non-invasive imaging of humans (Meyer & Noppeney, 2011). MIM researchers are exploring how multisensory integration is impacted by disease or specific, constraints related to the integration of multisensory signals, multisensory processing constraints, characterizing the multisensory integration neural basis, and developing computational models of multisensory integration (Meyer & Noppeney, 2011). See Figure 5 for an example of multisensory integration.

Figure 5

Example of mutlisensory integration required to drink from a mug.



One example using the MIM that is applicable to this dissertation is highlighted by a recent study in which touch sensation was shown to be altered by introducing object and spatial imagery (Lacey, Lin, & Sathian, 2011). In this article individuals wore a virtual haptic system to touch various objects. Different images of the object with various visuals of textures and shapes were flashed in goggles while the individual felt the object. It was determined that the various textures and spatial representations altered their understanding of the object they were touching (Lacey, Lin, & Sathian, 2011). More specifically, using touch and vision, individuals could discriminate textures if the shape of the object was changed and could not discriminate shape if texture was changed. However, when using virtual haptics, the opposite was true; individuals could not discriminate textures when the shape was changed and could discriminate shape when the texture was changed. These findings support the foundation of the Multisensory Integration Model. Another example of multisensory integration is that it is necessary for individuals to change the sensory focus between visual sensations and proprioception when moving their body. When considering positioning the arm, proprioception is needed to determine the proper joint angle and vision is needed to determine the general movement of the arm in relation to the need for movement (Sober & Sabes, 2003). Another area MIM researchers are exploring is that of touch sensation in individuals with amputations, transplantations, congenital absent limbs, and elongation of muscles (Serino & Haggard, 2011) to better understand the impact of touch sensation in various conditions. The MIM research supports the complexity of the somatosensory system and any interruption in this system may present a multifaceted sensory limitation.

The International Classification of Functioning, Disability, and Health, the Occupational Therapy Practice Framework, Person-Environment-Occupation Model, and the Multisensory Integration Model provide a sound basis for better understanding the relationship between individuals touch sensation of the hand and occupational performance.

Summary

Previous studies have explored the association between sensory impairment and motor impairment, hand function, and manual abilities. No studies have considered the relationship between touch sensation of the upper limb and occupational performance in individuals with chronic stroke. Previous reports have begun to explore the complexities of sensory and motor impairment related to brain lesion; however none have focused on occupational performance. Using a multisensory integration model combined with occupational therapy models, one can begin to better understand the connection between impairment of touch sensation of the hand and occupational performance in individuals with chronic stroke.

Chapter III: Methodology

Research design

A cross sectional design was used. A convenience sample of 50 individuals with stroke participated. This study included data from 25 participants from another study exploring the efficacy of using the Touch-Test™ Evaluators to test touch sensation in the affected hands of individuals with chronic stroke. The 25 participants from that study were included in this study and the following outcome scores were used: Touch-Test™ Evaluators, Fugl Meyer, Box and Block Test, and ABILHAND Questionnaire. The individuals were administered the Canadian Occupational Performance Measure (COPM) at a later testing session. The additional 25 participants were brought in for a one-time testing session and administered the battery of tests including all of the above-mentioned tests: Touch-Test™ Evaluators, Fugl Meyer, Box and Block Test, Canadian Occupational Performance Measure and ABILHAND Questionnaire. Once participants completed all tests, they were finished with the study.

The Touch-Test™ Evaluators, also known as the Semmes Weinstein Monofilaments, were used to measure individuals' touch sensation of the affected hand as they have been used in other research studies for testing touch sensation (Dannenbaum, Michaelsen, Desrosiers, & Levin, 2002). The Touch-Test™ Evaluators are handheld monofilaments that are applied to the skin to determine individuals' ability to sense varied forces of stimuli from light touch sensation to protective sensation. The Canadian Occupational Performance Measure was used as this is the best measure of occupational performance in individuals with stroke (Phipps & Richardson, 2007). The Fugl Meyer is an impairment based assessment commonly used to assess upper extremity movement (Fugl-Meyer, Jaasko, Leyman, Olsson, & Steglind, 1975). The Box and Block Test is a disability assessment commonly used in stroke studies for studying impairment of the hand and its impact on using the hand for functional activity, specifically grasp and release (Desrosiers, Bravo, Herbert, Dutil, &Mercier, 1994). The ABILHAND was used to determine the stroke survivors' perception of their manual abilities (Penta, Tesio, Arnould, Zancan, & Thonnard, 2001).

Hypotheses

The central hypothesis was that there is a negative association between occupational performance and satisfaction scores on the COPM and level of touch sensation scores on the Touch-Test™ Evaluators. Chapter I provides greater detail on the specific hypotheses.

Sample/population of interest

A convenience sample of community dwelling stroke survivors residing in the Midwestern United States participated in the study. Individuals were recruited through community stroke support groups and the stroke recovery center at the Drake Center, a premier long-term acute care and rehabilitation hospital. Participants were also recruited from an existing pool of stroke survivors from the University of Cincinnati's Neuromotor Recovery and Rehabilitation Lab and the Drake Center outpatient therapy clinic both located at the Drake Center. Participants did not receive compensation for study participation.

Privacy was respected with all participants. Participants volunteered for this study by contacting the principle investigator directly, or through clinicians or caregivers. The lab was located in a private and separate hallway of the rehabilitation hospital, which further assured that others did not know that individuals were involved in a study. There was neither disclosure nor displaying of individuals conditions or deficits, nor any sign up lists or other postings that would reveal participants' affiliations with this research. Participants' safety was considered at all times and no adverse events occurred during the study.

Selection of subjects

Inclusion criteria included men and women based on the following criteria: 1) between 18-90 years of age; 2) had an intact central nervous system as determined by a sensation level of 0.008-0.07g of force on the less affected side with the Touch-Test™ Evaluators; 3) had intact cognition as evidenced by at least 25/26 on the MMSE short version (Schultz-Larson, Lombolt, & Kreiner, 2007); 4) had only 1 stroke or multiple strokes with similar effects; and 5) had chronic stroke;the individual had their stroke more than 6 months prior to study involvement.

Individuals were excluded if they: 1) exhibited neglect to either side of their body; 2) had neck or upper extremity injury that may interfere with sensation of either upper extremity; 3) had other peripheral nervous system or central nervous system problems, for example: spinal cord injury, neuropathy; 4) could not feel the smallest monofilament sensation level of 0.008-0.07g of force (determined as intact sensation) when applied to less affected side; and 5) could not feel the largest monofilament, 300g of force (determined as lacking protective sensation), on the more affected side.

Demographics

Fifty individuals were recruited for this study, 49 were eligible and included in these analyses. One individual was excluded due to reporting he was unable to feel the largest Touch-Test™ Evaluator, which is equivalent to lacking protective sensation, on either hand. All potential participants were in the chronic phase post-stroke, having had a stroke at least six months prior to study enrollment. The participants were between the ages of 46- 72 years of age and 63% were male. The majority, 69%, of participants were experiencing no pain (0/10) in their affected upper extremity and the minority, 31%, experienced pain ranging from 1-5/10. Affected wrist and finger spasticity varied, with the majority of individuals having no spasticity, 29%, 35% respectively, or, alternatively, having an increase in spasticity with passive movement difficult, 27%, 33% respectively. Refer to Table 1 for the frequencies and percentages related to the descriptive statistics. Sixteen participants, 33%, exhibited sensation impairment of the hand and 33 participants, 67%, exhibited intact touch sensation in their affected hands. Refer to Table 2 for the frequency of the presence of sensation impairment for the individual participants as well as for each of the testing locations of the hand.

Table 1

Mean (Std) and Ratios of Demographics and Health Factors of 49 Participants

Age in Years	59.67 (+/-13.14)
Months Post Stroke	72 (+/-58.8)
Gender (M:F)	63%: 37%
CVA side (R:L)	47%:53%
Pain of Affected Arm (0:1:2:3:4:≥5)	34:7:3:2:0:3
Spasticity of Affected Wrist: Modified Ashworth Scale (0:1:1+:2:3:4)	14:7:6:7:13:2
Spasticity of Affected Fingers: Modified Ashworth Scale (0:1:1+:2:3:4)	17:3:7:6:16:0
Movement of Affected Upper Extremity: Fugl Meyer [Mean (std)]	33.02 (+/-20.20)

Table 2

Frequencies of Sensation Impairment of 49 participants and 245 testing occurrences.

	Frequency
Individuals Overall Hand Sensation: (Normal: Impairment)	33:16
Maximum Monofilament Size Felt (1:2:3:4:5)	155:52:19:5:14

Instrumentation

Touch-Test™ Evaluators. All of the study hypotheses related to touch sensation using the Touch-Test™ Evaluators'. The Touch-Test™ Evaluators, also known as the Semmes Weinstein Monofilaments, were used to determine individuals' level of touch sensation of their affected hands by recognition of the smallest target force of the Touch-Test™ Evaluators applied to the skin. The monofilaments can be used in a 20-kit set, a hand kit or a foot kit. The current study used the Touch-Test™ Evaluators 5-piece hand kit, which has been deemed reliable for testing touch sensation threshold of the hand (North Coast Medical, Inc., 2006). This kit includes 5 monofilaments with application forces ranging from 0.007g- 300g representing various levels of sensation including:

intact touch sensation, diminished light touch, diminished protective sensation, loss of protective sensation, deep pressure sensation, and no response based on the individual's response to the touch of the monofilament (North Coast Medical, Inc., 2006). For this study's data analysis the forces were ranked into categories 1-5 with the smallest force, representing normal sensation, as 1 and the largest force, representing deep pressure sensation as 5. A higher number represented more impairment of touch sensation. This instrument is available in a small pocket sized hand held kit, making it quick to administer and accessible. The Touch-Test™ Evaluators have been shown to be reliable and valid; therefore making this tool a better option for touch sensation testing than using a cotton swab or finger-tip test. The Touch-Test™ Evaluator Kit has been shown to be reliable and valid with an inter rater kappa of .74. In addition, the Touch-Test™ Evaluators have a high correlation, in older adults R=.89-.93 (Shaffer, Harrison, Brown, & Brennan, 2005); however has not been studied in the stroke population. The Semmes Weinstein monofilament kits have been shown to be reliable in the healthy population (Bell & Tomancik, 1987; Shaffer, Harrison, Brown, & Brennan, 2005; Spagnuolo, 2004). Multiple testers were compared with 450 applications with no significant differences (Bell & Tomancik, 1987). As compared with other handheld touch sensation tools the monofilaments provide a reliable reading with a small standard deviation, SD= 0.0061-0.31, p< .01-.05, as compared with other tests, SD= 11.78- 28.71 (Bell & Tomancik, 1987). Multiple stroke rehabilitation studies have used the Touch-Test™ Evaluators for testing arm sensation for comparison of arm sensation and function (Chen, Liang, & Shaw, 2005; Dannenbaum, Michaelsen, Desrosiers, & Levin, 2002; Harris & Eng, 2006). The monofilaments require yearly calibration from the manufacturer. The Touch-Test™ Evaluators used for this study were calibrated prior to study use.

The Touch-Test™ Evaluators were administered by a study therapist following standardized guidelines After the hand was touched by the monofilament, the participants were informed to respond immediately with *yes* or *no* to indicate if they can feel the monofilament. The monofilaments were applied in the following sequence: a) The unaffected upper extremity was tested first and then the affected upper extremity. If the unaffected side did not test as normal, as determined by detecting the normal monofilament, the participant was excluded from the study; b) Testing began with no stimulus for ten seconds to determine false positives; c) The monofilaments were applied in an ascending pattern, starting with the lightest monofilament until the patient was able to sense the touch; d) If the monofilament was not detected, then the next stronger monofilament was administered; e) Each monofilament was applied up to five times until it was detected; f) If the strongest monofilament was not detected test, then the test was applied in an adjacent point up to five times, still within the specified area: g) Then, steps a-g were repeated. If the participant continued to be unable to detect the monofilament, then they were excluded from the study; h) The last monofilament detected determined the individual’s level of sensation according to the Touch-Test™ Evaluators Chart.

The study therapists were instructed to apply the monofilaments with the same force, speed and length of time as follows: each monofilament was applied perpendicular to the skin for 1.5 seconds, held on the skin for 1.5 seconds and removed from the skin for 1.5 seconds. The following specific sites were used for this study based on the Touch-Test™ Sensory Evaluator Instructions from North Coast Medical (2006) including: a) the pulpa of digit 1; b) the pulpa of digit 2; c) the pulpa of digit 5; d) the hypothenar eminence; and e) radial dorsum for the following nerves respectively: the median nerve, the ulnar nerve, and the radial nerve. See figure 6 for an illustration of the testing sites of the hand. Once the testing was complete the participants were thanked for their participation and excused with no further obligation.

Figure 6

Touch Test Evaluator™ testing sites of the hand

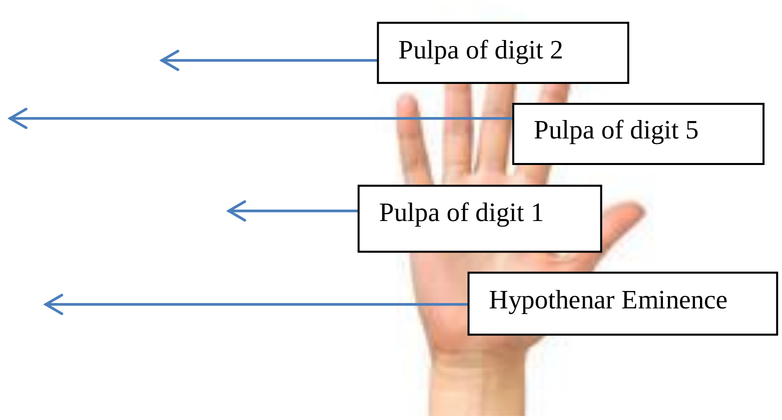


Photo retrieved from: http://www.fotosearch.com/photos-images/palm-hand.html

Note: The fifth testing location, dorsum, is not shown in this picture.

Canadian Occupational Performance Measure. Hypotheses 1a and 1b considered the correlation between scores on the COPM and the Touch-Test™ Evaluators. Hypothesis 1a related occupational performance scores from the Canadian Occupational Performance Measure (COPM) with touch sensation of the affected hand as measured by the Touch-Test™ Evaluators. Hypothesis 1b correlated occupational performance satisfaction scores from the COPM with touch sensation of the affected hand from the Touch-Test™ Evaluators. The COPM is an interview used by occupational therapists to identify occupational performance problems in individuals' daily life functioning (Law, Polatajko, Pollock, McColl, Carswell, & Baptiste, 1994). The COPM is a client-centered assessment in which individuals chose their most valued occupations and rate their occupational performance and satisfaction of performance of those selected tasks (Pollock, 1993). The COPM involves multiple steps in which the interviewer asks the individual to identify problems in occupational performance related to the COPM subcategories: self-care, productivity, and leisure (Pollock, 1993). Once the occupational performance problems are identified, each are weighted by the individual, rating them from 1-10, *not important* to *extremely important* respectively (Pollock, 1993). The top five items that are most important are then scored based on the individuals' perception of how well they perform the occupation and how satisfied they are with their performance. Performance is rated 1-10, *do not perform well- perform very well* and a higher score represents that an individual is better able to perform valued occupations satisfaction. Satisfaction is rated 1-10, *not satisfied- very satisfied*, and a higher score represents that an individual is more satisfied with his/her performance of valued occupations (Pollock, 1993). The COPM has been used in physical and cognitive disabilities studies showing change of occupational performance and satisfaction with occupational therapy (Bodiam, 1999; Chen 2002; Jansa, 2004). Content, criterion, and construct validity have all been shown for the COPM (McColl, Paterson, Davies, Doubt, & Law, 2000). The COPM has shown test-retest reliability (r=.87 for performance; r=.88 for satisfaction) and interrater reliability (Spearman's rho correlation coefficient=0.89 for performance and.88 for satisfaction) in the stroke population (Cup, Scholte op Reimer, Thijssen, & Kuyk-Minis, 2003). The COPM has shown criterion validity in community dwelling individuals with disabilities; 21% of problems indicated on the COPM were also indicated on the Perceived Problem Check List (McColl et al, 2000). It is important to note that the COPM has shown strong discriminative construct validity with assessments of occupational performance (e.g., Barthel Index, r=-.225; Rankin Scale, r=.209) (Cup et al, 2003). Performance and satisfaction scores have highly correlated in past studies of individuals with stroke, r=.5; p<.001 (Cup, et al, 2003).

Fugl Meyer Scale. Hypothesis 2 considered the correlation between scores on the Touch-Test™ Evaluators and the Fugl Meyer Scale. The upper extremity scale of the Fugl-Meyer Scale [(FM); Fugl-Meyer, Jaasko, Leyman, Olsson, & Steglind, 1975] was used to determine affected upper extremity impairment. The FM assesses several dimensions of impairment, including range of motion, pain, sensation, and movement. These dimensions are based on a 3-point ordinal scale (0=*cannot perform*; 1= *partially perform*; 2=*can perform fully*), and items are summed to provide a maximum score of 66. A lower score represents greater arm impairment. The FM has shown test-retest reliability with an ICC of .97 (Platz, et al, 2005) and a high correlation of interrater reliability (r=.98-.99) (Duncan, Propst, & Nelson, 1983). The FM has shown construct validity with the Barthel Index in individuals with chronic stroke (r=.67) (Dettermann & Linder, 1987) and with Action Research Arm Test (r=.73), Wolf Motor Function Test time (r=.76), and Functional Independence Measure- motor section (r=.49) (Hsieh & Wu, 2009). The FM has been used extensively in studies measuring recovery and is recommended for studies evaluating changes in motor impairment after stroke (Gladstone, Daniells, & Black, 2002).

Box and Block Test. Hypothesis 3 considered the correlation between the Touch-Test™ Evaluators and the Box and Block Test. The Box and Block Test (BBT) is an upper limb performance measurement and was used to assess disability of the affected hand. The test consists of picking up a block out of a box and transferring it over a wall into the other side of the box within two minutes. The individual is encouraged to transfer as many blocks as possible. The score is measured on an interval scale by counting the blocks dropped into the other side after the two minutes. A lower score represents greater hand disability. The BBT has been shown to have test-retest reliability when testing the affected hand, r=.98 (Chen & Chen, 2009) and interrater reliability with individuals with paresis, ICC=.99 (Platz, et al, 2005) and spastic hemiplegia, r=.95 (Siebers, et al, 2010). The BBT has shown criterion validity with the FM, r=.44 (Lin, et al, 2010) and construct validity with the FM, r=.92 (Desrosiers, Bravo, Herbert, Dutil, & Mercier, 1994).

ABILHAND Questionnaire. Hypothesis 4 considered the correlation between the Touch-Test™ Evaluators and the ABILHAND. Individuals' functional ability was measured by the ABILHAND, which is a questionnaire of hand manual ability. The questionnaire comprises questions related to bi-manual abilities of the hand (e.g. pulling up pants, peeling an onion, sharpening a pencil). There are 23 questions in which individuals are asked to rate his/her ability to execute a standard list of activities on a scale from 0-2, *impossible, difficult,* and *easy* respectively. The score ranges from 0-46 and a higher score represents that is it easy to use the hands. The ABILHAND was shown to be reliable using a Rasch reliability test (M=0.90), which indicates a good fit between the questions and the general population (Penta, Tesio, Arnould, Zancan, & Thonnard, 2001). The ABILHAND has shown construct validity using a Wilcoxon signed rank for grip strength ($t=-1.72$, $p<0.001$) and dexterity ($t=-4.19$, $p<0.001$) (Penta, Tesio, Arnould, Zancan, & Thonnard, 2001).

There was a 4-hour competency training session for the student occupational therapists and allied health sciences students (referred to as study therapists for the rest of the document) related to the study protocol and administration of the assessments. The study therapists learned how to administer the Touch-Test™ Evaluators, Box and Block

Test, Fugl Meyer, and ABILHAND via standardized administration procedures to preserve inter-rater reliability. An occupational therapist, the primary investigator, administered the COPM to all study participants.

The study therapists collaborated with the primary investigator continuously to ensure that the protocol was followed precisely. Testing occurred in a private room that was controlled to ensure minimal distractions during testing.

Procedures

Subjects were escorted by a primary investigator to a private room in the affiliated university or hospital. Upon arrival, the principle investigator explained the study to the individual and answered any questions. A screening, using the inclusion criteria, was conducted if the individual desired to participate in the study. If individuals did not want to participate in the study or they were not eligible, they were excused with no further obligation. Once the screening was completed, the participant was consented and testing began. The participants from the first study met with the study therapists to complete testing for all of the instruments, except the COPM. The occupational therapist administered the COPM at a later date within the year. For the last 25 participants, all five instruments were administered within a 2-hour timeframe.

Data collection and analyses

The data were recorded on respective assessment logs and transferred into an Excel file. The data were transferred into Serial Attached Small Computer System Interface (SAS®). The following population parameters were described using descriptive statistics: individuals' age in years, months post stroke, gender, side of hemispheric lesion, pain of affected arm, spasticity of affected hand, upper extremity impairment based on the Fugl Meyer score, frequency of maximum force sensed with the Touch-Test™ Evaluators at each testing location, frequency of touch sensation impairment at each testing location and the frequency of the number of digits with sensation impairment per participant.

Sensation impairment was analyzed in two ways. For the first criterion, overall sensation of the hand was considered as either *normal* or *impaired* for each individual. If one testing location was considered impaired, then the affected hand was considered to have abnormal sensation (i.e., sensation impairment). Furthermore, the number of the monofilament correlates with the size of the monofilament, that is, 1, 2, 3, 4, 5 correlates with the following monofilament sizes respectively: 2.83, 3.61, 4.31, 4.54, 6.65. Normal sensation was defined as the ability to feel the 2.83 monofilament size. Impairment was defined as the inability to feel the 2.83 monofilament size; therefore, any individual that required a larger monofilament size to feel the stimulus was regarded as having sensation impairment of the affected hand (Bell-Krotoski, Fess, Figarola, & Hiltz, 1995). The second criterion considered the sensation of each testing location of each hand, rather than the overall sensation of the individuals' affected hand. The five hand testing locations comprised of the pulpas of digit 1, 2, and 5, the hypothenar eminence, and the dorsum of the hand. Impairment was identified the same as described above, with the 2.83 monofilament size indicating normal sensation and any larger monofilament size indicating sensation impairment.

Hypothesis 1. In order to analyze Hypothesis 1a and 1b, the COPM performance and satisfaction scores were combined due to the similarity in the distribution percentiles. The combination of occupational performance and satisfaction resulted in the combination of Hypothesis 1a and 1b into Hypothesis 1. Then, the COPM scores were dichotomized into two groups based on high and low COPM scores, ≥ 5.9 and <5.9, respectively. The median was chosen to divide the groups into the higher half of the COPM scores and the lower half. These groupings were used to analyze the association between occupational performance and hand sensation impairment.

It was hypothesized that there would be a negative association between individuals' scores of performance and satisfaction on the COPM and the touch sensation scores on the Touch-Test™ Evaluators. To test this hypothesis we ran a Chi-Square test comparing the mean COPM performance and satisfaction scores with the largest gram force level of the Touch-Test™ Evaluators. Since there is no known or theoretical distribution of the population (Portney & Watkins, 2009), a Test of Independence was used. It was anticipated that the greater performance and satisfaction (higher COPM scores), the lesser the hand touch sensation impairment (lower Touch-Test™ Evaluator score). According to Portney and Watkins (2009), correlations range from little to no relationship (0.00-.25) to fair relationship (.25-.50) to moderate to good relationship (.50-

.75) to good to excellent relationship (above .75) and this scale was used when determining the correlation strength amongst variables.

Hypothesis 2. It was hypothesized that there would be a negative correlation between motor impairment scores on the Fugl Meyer and hand touch sensation scores on Touch-Test™ Evaluators. To test this hypothesis, we ran a Spearman Correlation comparing the Fugl Meyer total score with the largest gram force level felt of the Touch-Test™ Evaluators. A Spearman Correlation was used to test the strength of the relationship between the variables (i.e.: Fugl Meyer and Touch-Test™ Evaluator scores) (Portney & Watkins, 2009). A Spearman Correlation considers the Spearman rank correlation coefficient of a continuous variable (i.e.: Fugl Meyer score) and an ordinal variable (Touch-Test™ Evaluator score), hence the reason for use in this study (Kielhofner, 2006). It is anticipated that the greater the motor impairment (i.e.: lower Fugl Meyer score), the more impaired touch sensation (i.e.: higher Touch-Test™ Evaluator scores), hence it is anticipated that there will be a negative correlation present.

Hypothesis 3. It was hypothesized that there would be a negative correlation between hand disability scores on the Box and Block Test and hand touch sensation scores on the Touch-Test™ Evaluators to determine if individuals who experience sensation impairment will also experience greater hand disability. To test this hypothesis we ran a Pearson Correlation comparing the Box and Block Test score, a continuous variable and the Touch-Test™ Evaluator score, an interval variable, in order to test the strength of the relationship (Portney & Watkins, 2009) between the individual's hand disability and the level of touch sensation of the affected hand. It is anticipated that the greater the hand disability (i.e., lesser number of blocks transferred in the box) the greater the touch sensation impairment (i.e, higher Touch-Test™ Evaluator scores).

Hypothesis 4. It was hypothesized that there would be negative correlation between scores of the ABILHAND Questionnaire and scores on the Touch-Test™ Evaluators. To test this hypothesis we ran a Pearson Correlation comparing the average score on the ABILHAND with the largest gram force level of the Touch-Test™ Evaluators. A Pearson Correlation was chosen to consider the Pearson product-moment correlation coefficient of the ABILHAND score, a continuous variable, and the Touch-Test™ Evaluator scores, an interval variable (Portney & Watkins, 2009). It was anticipated that the greater the sensation impairment (i.e.: Touch-Test™ Evaluator score), the lesser manual ability the individuals' expressed (i.e, ABILHAND score).

Summary

Occupational performance, motor performance, and manual abilities are all key facets of individuals' recovery from stroke and are impacted by one's touch sensation. Through the use of a cross-sectional design of 50 stroke survivors using a strict inclusion criteria, testing protocol, and correlation analysis, it was hoped to determine the relationship between touch sensation of the affected hand after stroke and one's functional abilities.

Chapter IV: Results

The relationship between sensation impairment and occupational performance

The Canadian Occupational Performance Measure (COPM) was used to determine individuals' performance and satisfaction with self-selected, valued occupations. The COPM measures an individuals' perception of his/her occupational performance and satisfaction of these occupations. The COPM performance and satisfaction scores' means and standard deviations were examined separately and the scores were:5.57,+/-2.40; 5.48, +/-2.68, respectively. The percentiles of the distributions were similar for COPM criterion of performance and satisfaction, respectively, 25%=3.4, 3.0, 50%= 5.8, 6.0, 75%= 7.8, 8.0, with a high correlation between the two criterion, 0.92, $p < .0001$. Due to the similarities amongst the two criterion scores, the percentiles of the means of performance and satisfaction were combined, 25%=3.3, 50%=5.9, 75%= 7.4.

Furthermore, the COPM performance and satisfaction scores were next dichotomized into two groups whose values were above (PS1) the median of the averaged values (5.9) and below (PS0) as shown in Table 3. There were 105 hand locations tested in the PS1 group and 110 in the PS0 group with a total of 215 occurrences of hand sensation testing in the five hand testing locations. These groupings were used to analyze the association between occupational performance and hand sensation impairment.

Table 3

Dichotomized Groupings Based on COPM Scores for 43 participants and 215 testing occurrences.

	Percentage of hand testing occurrences	Range of COPM scores
Higher COPM score ranges (PS1)	49%	5.9-9.6
Lower COPM score ranges (PS0)	51%	1.2-5.8

Note: 30 missing data for the COPM scores of 6 participants.

Moreover, due to the similarity in percentile distributions of performance and satisfaction scores, Hypothesis 1a and 1b were combined and viewed as one hypothesis. For Hypothesis 1, it was hypothesized that there would be a statistically significant association between individuals' scores of perceived performance and satisfaction on the COPM and scores on the Touch-Test™ Evaluators. To test this hypothesis, a Chi-Square Contingency Table was completed to determine an association between the dichotomized mean COPM scores (i.e., PS0 and PS1) with the largest monofilament size of the Touch-Test™ Evaluators based on two criteria (i.e., the overall presence of sensation impairment in individuals' affected hands, normal and impaired, and the largest monofilament size felt based on the sensation testing of the five hand testing locations. Refer to Table 4 for frequencies and percentages of normal versus impaired sensation for PS0 and PS1 groups.

Table 4

Results of Chi-square for Hand Sensation with PS0 and PS1 for 43 participants.

	Frequency (Percentage) of Sensation at Hand Testing Locations					
	1	*2*	*3*	*4*	*5*	*Chi-Square*
PS0 Normal sensation	13(59%)	13(59%)	14(63%)	12(55%)	13(59%)	X^2=0.523 p=0.97
PS0 Impaired sensation	9(41%)	9(41%)	8(37%)	10(46%)	9(41%)	
PS1 Normal sensation	6(29%)	16(76%)	19(91%)	10(48%)	15(71%)	X^2=9.800* p<.05
PS1 Impaired sensation	15(71%)	5(24%)	2(10%)	11(52%)	6(29%)	

Note: *statistically significant

Based on these analyses, the null hypothesis for Hypothesis 1 was rejected for PS1 and overall hand sensation, X^2=9.800, p<.05. There was a good to excellent relationship between individuals who scored higher on the COPM and lower on the Touch-Test™ Evaluators for touch sensation of the affected hand. However, the null hypothesis for Hypothesis 1 was accepted for PS0 for overall hand sensation, X^2=.523, p=.97; therefore there was little-no relationship between touch sensation of the hand and occupational performance for those who scored lower on the COPM. Furthermore, as shown in Table 5, the null hypothesis for Hypothesis 1 was accepted for PS0 and PS1 for specific hand testing locations, X^2= 6.803, p= .14; therefore there was little to no relationship between COPM scores and touch sensation related to specific hand testing locations.

Table 5

Results of Chi- square for Maximum Size Detected for PS0 and PS1 for Specific Hand Testing Locations for 43 participants.

	Frequency (Percentages)	
Monofilament Size	PS0	PS1
2.83	6 (40%)	9 (60%)
3.61	8 (44%)	10 (56%)
4.31	2 (50)	2 (50%)
4.54	2 (100%)	0 (0)
6.65	4 (100%)	0 (0)
		X^2= 6.803
		p= 0.1467

Note: 30 missing data for the COPM scores of 6 participants.

The relationship of motor impairment, disability, and function with sensation

The relationship between sensation and motor impairment. The upper extremity scale of the Fugl Meyer Scale was used to determine upper extremity motor impairment. This scale assesses range of motion, pain, sensation, and movement of the upper extremity. It was hypothesized that there would be a negative association between scores on the Fugl Meyer and the Touch-Test™ Evaluators. As shown in Table 6, the Fugl Meyer scores ranged from 3/66 to 65/66 and varied with a mean of 33/66 and a standard deviation of 20.39 points. To test this hypothesis, a Spearman correlation was conducted to determine the association between upper extremity motor impairment and the overall presence of affected hand sensation impairment (normal versus impaired) and the maximum monofilament size felt for each affected hand testing location. As shown in Table 7, there is little to no relationship between arm motor impairment and the overall hand sensation impairment, $r_{s=}$ -.06, p= .70, or between arm motor impairment and the maximum monofilament felt for each occurrence of hand testing, r_s =-.08, p= .58.

Table 6

Mean (std) and Range for Fugl Meyer, Box and Block Test and ABILHAND.

	Sample	Mean (Std)	Minimum	Maximum
Fugl Meyer	45 participants	33.022 (20.39)	3	65
Box and Block Test	245 testing locations	14.86 (19.23)	0	68
ABILHAND	245 testing locations	28.78 (9.45)	3	46

Note: Fugl Meyer data missing for four participants.

Table 7

Spearman Correlation of Motor Impairment and Hand Sensation Impairment of 45 participants.

	Overall sensation impairment	Maximum monofilament size
Fugl Meyer correlation	$r_{s=}$ -.06 p= .70	r_s =-.08 p= .58

Note: Fugl Meyer data missing for four participants.

The relationship between sensation impairment and disability. Disability was measured with the Box and Block Test, which determines upper extremity disability based on the individuals performance of transferring blocks from one box to another using their affected upper extremity and hand. For Hypothesis 3, it was hypothesized that there would be a negative correlation between disability and touch sensation levels of the affected hand in individuals with chronic stroke. As shown in Table 6, the number of blocks individuals were able to transfer widely ranged from 0-68 with a mean (SD) of 14.86 (19.23). Both of the sensation criteria were considered (i.e., overall hand sensation and maximum monofilament size felt) and based on the Pearson product- moment correlation coefficient there was little to no relationship between the number of blocks transferred on the Box and Block Test with the sensation level felt on the Touch-Test™ Evaluators for overall hand sensation, r= .02, p= .75 and specific hand testing locations, r= -.12, p= .06, as shown in Table 8. Therefore, there is little to no relationship between sensation impairment and disability.

The relationship between sensation impairment and function. The ABILHAND was used to determine individuals' functional ability of the hand. The ABILHAND is a questionnaire in which the individual reports his/her ability to complete a list of functional tasks. For Hypothesis 4, it was hypothesized that there would be a negative correlation between scores of the ABILHAND Questionnaire and scores on the Touch-Test™ Evaluators. As shown in Table 6, there was a wide range of scores of the ABILHAND ranging from 3-46/46 with the mean score 28.78 and standard deviation 9.45. Based on the Pearson Correlation, there was little to no correlation in the average score on the ABILHAND and hand sensation (normal versus impaired sensation) r= -.05, p= 0.4351. There was little to no correlation in the average score of the ABILHAND and the touch sensation at specific hand testing locations, r= -.23, p=.001, expressing little to no relationship between sensation impairment and manual abilities as shown in Table 8.

Table 8

Pearson Correlation of Hand Sensation with Functional Use of Hand and Perceived Abilities.

	Overall Hand Sensation	Specific Hand Testing Locations
Box and Block Test:	r= 0.020 p= 0.7475	r= -0.118 p= 0.0638
ABILHAND:	r= -0.050 p= 0.4351	r= -0.234 p= 0.0002

Summary

In summary, results show that based on individuals' COPM performance and satisfaction scores, there is a good to excellent relationship between individuals' who score higher on the COPM regarding occupational performance and satisfaction in valued occupations with that of touch sensation of the affected hand. There was little to no relationship between touch sensation of the affected hand and occupational performance and satisfaction for those who scored lower on the COPM. Lastly, there is little to no relationship between touch sensation of the affected hand and motor impairment, disability or function of the arm and hand in individuals with chronic stroke. These results lead us to the discussion phase of the study.

Chapter V: Discussion

The purpose of the current study was to study people with chronic stroke and determine the association between touch sensation of the hand and performance and satisfaction with valued occupations, motor impairment, hand function, and manual ability. The results of the current study showed that participants in the chronic phase of stroke who experience intact touch sensation of the hand are likely to report high levels of performance and satisfaction in performing valued occupations. Conversely, individuals who experience impaired touch sensation of the hand vary in their reports of performance and satisfaction with valued occupations, and that their sensation is not associated with performance or satisfaction with valued occupations. Additionally, the findings suggest that there is no relationship between touch sensation of the hand and motor impairment, hand function, and manual ability of the hand, as assessed in the current study. This is not surprising as previous reports have shown varied results based on the relationship between somatosensory and motor impairment, hand function, and manual abilities.

Impairment of touch sensation of the affected hand

The current study found 33% of the participants to have impairment of touch sensation of the hand. This is inconsistent with previous reports of somatosensory function, in which individuals could have a variety of somatosensory dysfunction, including proprioception, localization, stereognosis, kinesthesia, two point discrimination and touch sensation. Connell, Lincoln and Radford (2008), found 53-89% of participants had sensory impairment after stroke. More specifically, 53% of the participants had impairment of tactile sensation, 89% with impaired stereognosis, and 64% with impaired proprioception in a study of 70 individuals. In Connell, Lincoln and Radford’s study, a higher percentage of participants presented with touch sensation impairment as compared with the current study. It is important to note that individuals experienced touch sensation impairment less often than the other reported sensations. The current study did not measure stereognosis or proprioception; however this may represent a trend that touch sensation impairment is experienced less often than other sensory impairments.

Relationship of touch sensation of the hand and occupational performance and satisfaction

The results of this study suggest a high correlation between intact touch sensation of the affected hand and occupational performance and satisfaction of valued occupations for individuals with chronic stroke in this sample. In the current study, individuals who reported lower occupational performance and satisfaction (< 5.9/10 on the COPM) exhibited varied levels of touch sensation in their affected hands. Individuals, regardless of sensation function, reported similar valued occupations: improve ADL; IADL; functional mobility; work; driving; active and passive leisure; exercise; speech; family involvement; and ability to use affected upper extremity. To our knowledge, this is the first study attempting to relate touch sensation of the affected hand and occupational performance.

Factors influencing occupational performance. Occupational performance is complex and warrants a macro approach to examining influential factors within and beyond the individual. Confounding factors may stem from various aspects of a person's life that extend outside of the individual and influence his/her occupational performance. This can be seen through the ICF and PEO models. Both models emphasis activity and the factors related to an individual's ability to perform the valued activity. The ICF values the impaired body function, however it also factors in the participation, environment, and other personal factors. According to the Person-Environment-Occupation Model (PEO), occupational performance is influenced by a complex interactive process of the individual, environment, and his/her occupations (Law, Cooper, Strong, Stewart, Rigby, & Letts, 1996). An individuals' ability to engage in valued occupations is impacted by personal factors, such as sensation, which are likely key elements affecting occupational performance. Personal factors, beyond that of touch sensation of the hand, such as motor and cognitive impairments, have been shown to impact function in previous reports (McEwen, Polatajko, Huijbregts, & Ryan, 2009). Both models represent the complex system required for an individual to perform valued occupations. In the current study, intact sensation was associated with higher reports of occupational performance and satisfaction; however sensation impairment did not correlate with occupational performance and satisfaction. Due to the unknown influence of other cofactors, it cannot be expected that touch sensation of the hand alone will have an impact on individuals performance and/or satisfaction with desired occupations. It may be helpful to examine the other key elements of occupational performance as described by the PEO.

The environment and valued occupations chosen by the individuals are two additional key elements to the PEO. Individuals' chosen occupations are discussed in detail later; however individuals' environment was not assessed in the current study. To understand the influences on occupational performance in individuals with stroke, it may be more useful to investigate the multifaceted relationship of individuals' environment and valued occupations. In future studies it would be beneficial to examine environments of individuals with stroke and the relationship between the environments and occupational performance in addition to personal factors and valued occupations.

Touch sensation and function in areas of occupation. No other literature has compared the relationship between touch sensation of the hand and occupational performance or satisfaction with occupational performance. Other studies demonstrated associations of sensory impairment of the hand with performance of pre-selected occupations (Busse & Tyson, 2009; Tyson, Hanley, Chillala, Selley, & Tallis, 2008). For example, Tyson, Hanley, Chillala, Selley, and Tallis (2008) found a moderate correlation between tactile sensation and functional mobility (r_2=0.5; $p<0.001$) independence in ADLs (r_2=0.518; $p<0.001$); and recovery of ADL function (r_2=0.495; $p<0.001$) post sub-acute rehabilitation. There was little to no correlation between tactile sensation and recovery of functional mobility (r_2=.287 $p< 0.11$). In 2009, Busse and Tyson found that individuals with intact, impaired or absent sensation showed significantly greater impairment in functional mobility, ADL independence, balance, and weakness ($p<0.001$). There were significant differences between individuals with absent and intact sensation, but no significant differences between individuals with impaired and absent sensation ($0.001 < p0.05$) (Busse & Tyson, 2009). When comparing the current study findings with that of Busse and Tyson (2009) and Tyson et al. (2008), not all occupational pursuits correlate with sensation as shown in the functional mobility recovery outcomes. In the current study, individuals across sensation groups reported ADL and functional mobility tasks as valued occupations. Together, these studies highlight the inconsistency in the relationship between tactile sensation and performance in daily occupations.

Sensation groupings. For the current study, results were analyzed for two groups, intact and impaired sensation. The absence of this third group, *absent sensation*, may contribute to the lack of discrimination between the groups, specifically individuals with impaired sensation. The addition of a third group could have differentiated occupational performance scores between the groups and better addressed the aims of the current study. The aims could have been better addressed by analyzing the outcomes of both groups, impaired and absent sensation. The groups were not differentiated into two separate groups and were included as one group in the *impairment group*. It is possible that there were differences between the two groups that were not captured in the current study. To increase the sensitivity of our analyses, 3 groupings (e.g., *intact*, *minimally to moderately impaired*, and *severely impaired sensation*) were formed to examine the occupational performance reports of individuals in the current study. See Table 9 for a comparison of COPM tasks across a sampling of the sensation groupings.

Table 9

Sample COPM Tasks and Performance Scores of a Sample of 15 Participants across Sensation Groupings.

Sensation impairment group	Intact n=5	Impaired: Minimally to moderately n=5	Impaired: Severely n=5
List of categories	Improve ADL Improve functional mobility Improve IADL Improve work Improve driving Engage in leisure- active and passive Exercise Improve speech/ communication skills Family involvement Improve ability to use affected arm	Improve ADL Improve functional mobility Improve IADL Improve work Improve driving Engage in leisure- active and passive Exercise Family involvement Improve ability to use affected arm	Improve ADL Improve functional mobility Improve IADL Improve work Improve driving Engage in leisure- active and passive Improve speech/ communication skills Family involvement Improve ability to use affected arm
Occupational Performance	5-7.8	1.8-5.8	1.6-5.2

Variability in occupational performance. It is no surprise that there is a lack of a correlation between sensation and occupational performance, when considering the variability in valued occupations chosen by individuals in the current study. To understand the current study findings, it is helpful to consider that the tasks were chosen by the participants. While this is desirable in that it is client centered, it is possible that the chosen tasks were not impacted by the touch sensation impairment of the affected hand. This could explain one potential reason for the lack of association between touch sensation of the affected hand and occupational performance and satisfaction in the current study. When analyzing the occupations chosen by individuals, they appeared to vastly vary. However, when the reported occupations where categorized into similar areas of occupations (e.g, ADL, mobility), the chosen occupations were quite similar within the current study and to other individuals' with stroke (Phipps & Richardson, 2007). Individuals with stroke in both studies reported self-care; functional mobility; IADL; vocational skills; and leisure skills. The current findings demonstrate the variability of responses of individuals' valued occupational pursuits post-stroke.

In the current study, the areas of occupations selected by the individuals minimally varied across the sensation groupings. The intact sensation group encompassed each occupation category as listed in Table 9. For the sample with minimal to moderate sensation impairment, there were no reports of speech or communication as a valued occupation. For the sample with more severely impaired sensation, there were no reports of exercise as a valued occupation. The differences in the chosen occupations across the sensation groupings may be attributed to personal preferences of the individuals in the current study. Yet, it is important that the areas of occupations that individuals chose as valued occupations are consistent with other reports and provides a basis for areas of occupations that individuals with stroke may value. From these findings we conclude that the use of occupation-focused tools, such as the COPM, assist occupational therapists to determine valued occupations for individuals with stroke. The current study reiterates the importance of occupational therapists assessing and including in intervention planning a variety of areas of occupation (e.g., ADL, mobility, leisure, family involvement, speech and communication, and ability to use the affected upper extremity) post stroke.

Somatosensory system complexities. As described above, occupational performance is impacted by various factors. A neurological approach provides insight into the complexities of the somatosensory system in relation to touch sensation of the hand. In the current study, the lack of a correlation between varied touch sensation levels and occupational performance may be impacted by the complex interaction of the individuals' somatosensory systems.

As presented in Chapter II, the Multisensory Integration Model, as well as a review of basic neurology, illustrates the complex integration of the somatosensory system and motor function. Touch sensation is one of many somatosensory functions. Somatosensory sensations run along various pathways and are processed in multiple brain regions. The somatosensory system involves the recognition of stimuli through peripheral nerves at the skin, transmission of the stimulus along the spinothalmic tract, reception of stimuli in the thalamus and processing in designated brain regions (Lundy-Ekman, 2007). It is possible through neuroplastic changes, that additional areas of the brain may assume responsibility for sensory processing (Borstad, Schmalbrock, Choi, & Nichols-Larsen, 2012; Carey, Abbott, Harvey, Puce, Seitz, & Donnan, 2011).

Many studies that assessed sensory functioning utilized peripheral sensation assessments, observed function or individuals' self-report (Borstad, Schmalbrock, Choi, & Nichols-Larsen, 2012; Carey, Abbott, Egan, Bernhardt, & Donna, 1995; Carey, Abbott, Harvey, Puce, Seitz, & Donnan, 2011). Other studies have assessed sensory function by examining cortical somatosensory functioning with brain imaging (Carey & Seitz, 2007). Using brain imaging to assess somatosensory functioning provides insight to the recovery of neural functioning in individuals with stroke (Connell, 07; Winward, 07).

In 1995 Carey, Abbott, Egan, Bernhardt, and Donnan used fMRI studies to find that sensory modalities run on similar, yet different neural pathways. Through fMRI, these authors determined that pathways interact, integrate, and overlap information, yet the neural pathways run independent of each other. More specifically, Carey, Abbott, Harvey, Puce, Seitz, & Donnan (2011) found that for individuals with cortical lesions, there was little to no correlation between touch sensation and somatosensory cortical activity and was due to the variation in lesion sites. In the same study, Carey et al. found that for individuals with subcortical lesions, touch discrimination of the hand negatively correlated with touch stimulation during fMRI in the following areas: ipsilesional primary somatosensory cortex (SI); ipsilesional secondary somatosensory cortex (SII);

contralesional thalamus; and frontal and occipital brain regions. Studies have corroborated findings of activation in the SI with touch sensation stimuli (Cramer, Moore, Finkelstein, & Rosen, 2000). Conversely, other studies have found activation in other brain regions (i.e., parietal lob, precentral gyrus/ motor cortex, central sulcus) (Borstad, Schmalbrock, Choi, & Nichols-Larsen, 2012; Cramer et al., 2000; Skidmore, Rogers, Chandler, Jovin, & Holms, 2007). These studies show the varied rates of cortical recovery and neural pathways of recovery of touch sensation after stroke.

The numerous neural pathways and rates of recovery possible for somatosensory function after an individual expresses the complexities related to individuals recovery of touch sensation after stroke. In individuals with stroke, it may be beneficial to indicate the brain lesion site and recovery of somatosensory pathways prior to attempting to relate touch sensation with occupational performance. Comparing brain lesion sites and occupational performance may shed more useful information regarding this triads' relationship. The current study did not include brain imaging techniques; however it is recommended that future research include neurological and observed reports.

Relationship of touch sensation of the hand and motor impairment

The results of the current study show that there is no relationship between motor impairment and touch sensation of the hand among the sample of individuals with stroke. Similar studies examining the association between sensation and motor impairment have conflicting results. Past studies linked motor and sensory brain regions to functional outcomes of motor and somatosensory functioning. (Berman, 1984; Kandel, 2000; Tatu, 2001). Reading (1988) showed individuals with stroke who have somatosensory impairment recover motor functioning slower than individuals who have intact somatosensory functions. Other researchers have reported that people who suffer from motor impairments, generally, have lower functional outcomes (Han, 2002; Patel, 2000; Sanchez-Blanco, 1999). Other studies found similar findings to the current study and found little to no correlations between recovery of sensory and motor functions after therapeutic intervention (Busse & Tyson, 2009; Cambier, Corte, Danneels, & Witvrouw, 2003).

On the contrary, other studies found conflicting results to the studies listed above. For example, Gao, Ng, Kwok, Chow, and Tsang (2010) studied the relationships between tactile sensation, motor function, strength, hand function and hand movement accuracy (finger pointing). Gao, et al. found that there was a moderate correlation between finger pointing accuracy and both, tactile sensation and motor function (r_2=0.55, r_2=0.59 respectively); however the researchers failed to directly test the relationship between tactile sensation and motor function. Hedman and Sullivan (2010) found little to no correlation between sensation and movement or function of the upper extremity. More specifically, Hedman and Sullivan concluded that tactile sensation does not represent the complex somatosensory requirements needed for arm and hand function. Based on the complexities of the somatosensory system, touch sensation should not be expected to correlate with motor impairment using peripheral sensory assessments and observations of function.

Based on the literature, somatosensory function plays a role in motor function. Individuals with somatosensory impairment have shown slower recovery and lower functional outcomes than individuals with intact sensation function. Other studies have shown low to no correlation between tactile sensation and movement or function with and without therapeutic intervention. Other studies have failed to analyze the relationship between sensation and motor function. It is apparent that somatosensory function has an impact on motor function. Yet, when analyzing the association of somatosensory function, touch sensation appears less associated with motor impairment of the upper extremity than other somatosensory functions. According to other studies, other somatosensory functions (i.e., proprioception, kinesthesia, steregonosis, and localization) are associated with motor function (Cambier, Corte, Danneels, & Witvrouw, 2003; Hedman & Sullivan, 2009; Helliwell, 2009) and should be analyzed in future research studies. Analyzing multiple sensory functions may provide more insight into the association of somatosensory function with motor function in the upper extremity after stroke.

Sensory and motor changes with intervention. Other studies tracked sensory and motor changes during therapeutic interventions with mixed results. Cambier, Corte, Danneels, and Witvrouw (2003) found that when using pneumatic compression treatment, there were significant changes in motor impairment and somatosensory function. Touch sensation significantly improved for both groups; experimental

($p<0.001$) and control ($p=0.017$). Motor function significantly improved for the experimental group ($p=0.023$). Consistent with the current study, there was no relationship between motor and somatosensory function ($p=0.68$) post stroke. Based on these intervention studies, recovery of sensation and motor functioning is evident; however recovery of both modalities does not guarantee a correlation between the two variables.

The relationship between sensory and motor impairment is complex. One modality alone cannot be expected to represent or correlate with another modality. Different neurological pathways and brain regions are responsible for the reception and processing of somatosensory and sensorimotor stimuli. It is useful to review studies utilizing neurological assessment measures to compare and contrast sensory and motor impairment and expected outcomes.

Sensorimotor cortical regions. Based on past studies, there is a relationship between cortical activation for somatosensory and motor function (Carey, Abbott, Egan, Bernhardt, & Donnan, 2005). In Carey et al.'s study (2005), activation in the SMI was found for both touch sensation and motor activity. Initially, the sites of activation included: supplementary motor area (SMA); bilateral cingulate; contralesional insula; and ipsilesional SMI. At 6 month follow up, the activation sites included the ipsilateral SMI into the cingulate gyrus. The authors noted a reduction in contralesional activity in middle frontal gyrus and insula regions and increased activity in the ipsilesional postcentral gyrus/ SI. This finding suggests, that for some individuals with stroke, motor function may be related to sensory function if the functions share cortical regions.

The current study did not consider brain imaging techniques. It is possible that the addition of brain imaging may be beneficial to determine the brain lesion site and recovery pathways related to sensorimotor and somatosensory function. The addition of brain imaging may provide a better explanation of sensory and motor capacities and should be considered when providing occupational therapy service to individuals with stroke.

Relationship of touch sensation of the hand and hand disability

The current study found little to no correlation between touch sensation of the hand and hand function. One study explored the relationship between sensory impairment and hand function; however studying different sensory functions. Dannenbaum, Michaelsen, Desrosiers, and Levin (2002) found a relationship between moving touch pressure and sustained touch pressure and hand function (r= 0.42-0.48). It cannot be anticipated that the results of one sensory modality (i.e., moving touch sensation or sustained touch pressure) will result in the same outcome for another modality (touch sensation).

Many studies have examined the relationship between motor impairment and ADL independence; some of which consider the impact of sensory impairment. This is not a direct relationship with hand function; however worth exploring to glean linkages to hand function and sensation. Tyson, Hanley, Chillala, Selley, and Raymond (2008) found that sensory impairments are associated with stroke severity and weakness, especially in the lower extremity, and are related to ADL independence and mobility. Ward (2011) found that impaired affected hand functioning leads to disability of the hand and an inability for individuals to use their hand for ADLs. Additionally, studies have identified that sensory impairments relate to upper limb recovery. Tyson et al (2008) concluded that individuals with sensory loss of the hands tend to have weaker hands, which influences individuals' motor recovery and ability to use their hands. Interestingly, when strength or motor impairment were controlled for in the analysis, sensation was no longer significant (Feys, de Weerdt, Nuygens, van de Winckel, Selz, & Kiekens, 2000; Tyson et al., 2008). In fact, the only studies to find sensation as an independent factor are studies that do not consider strength or motor recovery (Sommerfield & von Arbin, 2004; Lai, Duncan, & Keighley, 1998). Tyson et al. questioned whether sensory impairment is the cause or co-factor of hand disability, yet no study has addressed this question to date.

The lack of a correlation between touch sensation of the hand and hand function may be attributed to other factors, such as strength and motor impairment. The current study did not analyze strength or control for strength in the analysis. It is possible that strength plays a valuable role in hand function and attention should be directed to strength. It is recommended that future research includes an analysis of hand strength and controls for hand strength when analyzing the relationship between hand function and other variables (e.g., touch sensation).

The results of the current study are congruent with other studies, without controlling for strength and motor impairment. The linkage of strength and motor recovery on hand function is an important variable to consider for future study designs and clinical practice. The connection between strength, motor function and hand function help therapists guide intervention and determine appropriate modalities to facilitate increased hand function. If hand strength is a key determinant of hand function, then hand strengthening activities need to be included in treatment. The linkage of strength and lack of association of touch sensation with hand function reiterates the importance of considering multiple assessments including, strength with sensory and motor function, during clinical assessment post-stroke.

Relationship of touch sensation of the hand and manual abilities

The current study found little to no correlation between touch sensation of the hand and self-reported manual abilities. There is a lack of evidence regarding the relationship between sensation impairment of the upper extremity and perceived ability to use the affected hand after stroke. This may be due to the lack of reliable and valid instruments to measure individuals' self-reported ability to use their hands after stroke. The ABILHAND, which was used in this study, assesses individuals' self-report of ability to use the hands to engage in a list of pre-determined tasks. Blennerhassett, Avery, and Carey (2010) developed the Hand Function Survey (HFS), a self-report tool specifically designed to measure individuals' ability to use their affected hand for selected tasks. In contrast to the current study, Blennerhassett, et al. found a moderate correlation between ability to use the affected hand and observed performance of hand ability; however the researchers failed to assess somatosensory functioning. This may be because the HFS better assessed one's ability to use his/her affected hand after stroke, and may be a more viable measure of self-reported affected hand abilities than the ABILHAND. The current study did not control for the use of the less affected hand or ability to use both hands. The ability to use both hands may have contributed to the lack of a correlation between manual abilities and sensation of the hand. It is concluded that the ability to manually use both hands may not be impacted by touch sensation impairment of the affected hand.

Clinical implications

This study informs occupational therapists, rehabilitation scientists, and other healthcare professionals that sensory evaluation continues to be important in clinical assessment. Touch sensation of the hand was associated with occupational performance and satisfaction, particularly for individuals with intact sensation and reports of better occupational performance and satisfaction.

The current study reiterates the importance of including a wide array of clinical assessments to guide intervention for individuals with stroke. It is important for occupational therapists to continue to assess performance of self-care activities, IADL, functional mobility, work-related skills, leisure skills, and ability to use the affected arm. These activities have been identified as valuable occupations to samples of individuals with stroke (Phipps & Richardson, 2007). Using an occupation-based assessment, such as the COPM, provides a client-centered approach to care by identifying occupations that are valued by the individual. Occupational therapists can use chosen occupations to set goals and guide intervention. Comparing individuals' self-reported performance and satisfaction of valued occupations with observations of performance of chosen tasks can be used to assess client's awareness and insight regarding their performance.

It is important to include assessments of sensorimotor function to help identify the component parts that comprise movement. Touch sensation, proprioception, motor function, and strength impact one's ability to move (Gao, Ng, Kwok, Chow, & Tsang, 2010; Tyson, Hanley, Chillala, Selley, & Raymond, 2008). Occupational therapists can incorporate the use of these assessments to provide conditions for treatment goals and guide therapeutic gradations needed during intervention. These assessments may also highlight preparatory and supplementary activities needed that may expedite recovery (Cambier, Corte, Danneels, & Witoux, 2003).

Occupational therapists need to consider varied treatment approaches for individuals with sensory impairment of the hand with a focus on recovery of sensory function (Gao, Ng, Kwok, Chow, & Tsang, 2010). Improved arm and hand rehabilitation strategies are necessary that include a focus on somatosensory assessment and intervention in order to provide individuals with stroke with a newfound ability to use their affected arms and hands for recovery of ADL and functional mobility (Busse &

Tyson, 2009; Tyson, Hanley, Chillala, Selley, & Tallis, 2008). Interventions focusing on tactile localization, proprioception, strength and movement accuracy all need to be included in sensory programs aimed to enhance somatosensory functioning (Gao, et al., 2010).

The incorporation of occupation-based and impairment-based assessments provides a solid foundation for a client-centered, individualized intervention plan. By selecting an assortment of assessments, including individuals related to sensory function, somatosensory impairment will be identified and addressed throughout individuals' stroke rehabilitation.

Limitations and suggestions for future research

There are several limitations noted in the current study. First, the results cannot be generalized as it employed a relatively small sample size and utilized a cross-sectional design of community dwelling individuals with chronic stroke. Additionally, 25 participants were administered the COPM within the year after testing of the assessments occurred, rather than the same day. This could have resulted in a Type II Error due to individuals taking the COPM at a later date. Factors may have changed for the client during the year, including the domains measured with the assessments. Second, individuals who experience stroke often experience other impairments related to the stroke. The variables analyzed here were not exhaustive and other variables may be important (e.g., proprioception, brain lesion location). It is also possible that confounding factors interact with the dyads analyzed in the current study (e.g., upper extremity strength, stroke severity).

Although the sample studied in the current study was representative of the sensation impairment experienced by individuals with stroke, a larger sample with stratifications into three sensation groupings (*intact sensation, impaired sensation, absent sensation*) would have allowed further discrimination of groups. This grouping would allow for evaluation of the sensation and occupational performance relationship. It is recommended that occupational therapists continue to include a broad assessment of occupational performance (e.g., ADL, family involvement, use of affected upper extremity). It is recommended to include a brain imaging assessment to determine cortical function related to somatosensory function, specifically brain regions related to lesion site and recovery of somatosensory function. It is suggested to include additional sensory tests, specifically proprioception and localization, as each have been shown to be correlate with touch sensation (Gao, Ng, Kwok, Chow, & Tsang, 2010; Tyson, Hanley, Chillala, Selley, & Raymond, 2008). Additionally, it is suggested to control for other variables, such as spasticity and strength as they have been shown to impact hand function and sensation (Cambier, Corte, Danneels, & Witvrouw, 2003). Lastly, it is suggested to include a self-report of *affected hand use*, such as the Hand Function Survey (Blennerhassett, Avery, & Carey, 2010). The addition of these recommendations will help fill the gaps noted in the current study.

In addition to sensory assessment, it is essential that rehabilitation professionals begin to address somatosensory function during intervention. Previous research reports have found that generalized sensory discrimination interventions administered over a four week, 10 session time period is effective to redevelop hand touch sensation (Carey, Macdonell, & Matyas, 2011). The sensory modalities focusing on included texture discrimination, proprioception, and stereognosis. Therapists used gradation to progress through easy to difficult discriminations, and feedback and intensive training (Carey, Macdonell, & Matyas, 2011). Another study found that thirty 50-minute treatment sessions including a behavioral training program that encompasses a wide range of somatosensory modalities in conjunction with motor control was an effective intervention to enhance return of somatosensory functioning and is recommended as a sensory tool for rehabilitation specialists.

Chapter VI: Conclusion

Collectively, the results of the current study reflect the complexity of touch sensation function for individuals with stroke. The study resulted in one confirmed hypothesis: the individuals who exhibited intact sensation of the hand also reported higher scores of performance and satisfaction of valued occupations. The remaining hypotheses− that there would be an association between touch sensation of the affected hand and occupational performance and satisfaction, motor impairment, hand function, and manual abilities− were not confirmed.

It is essential to recognize the complex interaction between touch sensation, occupational performance, motor functioning, and manual abilities of the affected hand for individuals' who have experienced a stroke. Additionally, this study shows that individuals with stroke have varied reports of occupational performance and satisfaction in relationship to their hand sensation, disability, function, and motor impairment. It is important for occupational therapists to incorporate a wide array of tools including assessment of occupational performance, hand sensation, motor impairment, hand function and manual abilities in order to capture individuals' global functioning. This collection of assessments can be integrated into practice to provide client-centered, occupation-based intervention planning focused on the specific needs of the individual.

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Yekutiel, W. & Guttman, E. (1993). A controlled trial of the retraining of the sensory function of the hand in stroke patients. *Journal of Neurology, 56,* 241-244.

Curriculum Vitae

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EDUCATION:

Indiana University Purdue University-Indianapolis, Indianapolis, IN

Ph.D. of Health and Rehabilitation Sciences August 2013

Dissertation: "The relationship between occupational performance and touch sensation impairment in adults with chronic stroke."

Emphasis: Gerontology

Indiana University Purdue University-Indianapolis, Indianapolis, IN

M.S. of Health Sciences Education December 2005

Practicum: Developed an interdisciplinary dementia course for healthcare professionals

Indiana University Purdue University-Indianapolis, Indianapolis, IN

B.S. of Occupational Therapy May 2004

Minor: Psychology

CERTIFICATIONS & LICENSES:

National Board for Certification in Occupational Therapy

Certification #: 1072737

Ohio Occupational Therapy, Physical Therapy, and Athletic Trainers Board

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PROFESSIONAL EXPERIENCES:

University of Southern California, Los Angeles, CA August 2013

Postdoctoral Scholar in NIH T32 Training in Rehabilitation Efficacy and Effectiveness Trials (TREET)

• Intensive, mentored, and individualized training program for development and conduction of randomized controlled trials for complex rehabilitation interventions.

• Immersions in Well Elderly and Pressure Ulcer Prevention Studies
• Special focus in life management in stroke populations with the goal to develop a tailored, individualized life management program for individuals with stroke.

Xavier University, Cincinnati, OH July 2011- July 2013
Clinical Faculty
• Teach theory, research, and domain and process courses in occupational therapy
• Serve as faculty tutor for graduate research projects
• Provide occupational therapy student supervision
• Provide academic advising to students
• Serve as a member on the advisory board and interprofessional teaming planning committee
• Serve as faculty member on the Guatemala service learning trip
• Contributed to accreditation self-study process
• Assisted with Pi Theta Epsilon project for international exchange with Mumbai, India; provided scholarly and technological support

Supplemental Health Care, Cincinnati, OH Aug 2009- Present
Occupational Therapist: PRN
• Provide per diem occupational therapy in acute care, sub-acute rehab, skilled nursing, and extended care facilities

University of Cincinnati, Cincinnati, OH Nov 2008- July 2011/ Oct 2005- Nov 2008
Senior Research Assistant/ Occupational Therapy Researcher
• Assisted research lab director with research study coordination and process
• Managed therapists and supervised students
• Provided study treatment/intervention
• Disseminated study findings to peers and the community by way of presentations and publications at national, state, and local levels
• Research focused on efficacy of interventions with individuals with stroke and spinal cord injury

• Studies ranged from single site to multi-site studies; case studies to large randomized controlled trials; funding from private companies (i.e., Interactive Metronome and Myomo) to large organizations/federal (i.e., National Institutes of Health and American Heart Association)

University of Cincinnati, Cincinnati, OH Mar- Dec 2010

Adjunct Instructor: Health Care Ethics

• Taught online course for spring and fall quarters

Indiana University Purdue University- Indianapolis, Indianapolis, IN Fall 2009

Lab Instructor: Neuroscience for Occupational Therapy

• Taught neuroscience application to occupational therapy

• Collaborated on curriculum and exam development with Lecture Instructor

Cincinnati State Technical and Community College, Cincinnati, OH

Adjunct Professor:

Introduction to Occupational Therapy Aug- Nov 2008

Splinting and Physical Agent Modalities Nov 2007- Feb 2008

• Taught and developed course PowerPoints in the occupational therapy assistant program

The Christ Hospital: Cincinnati, OH Aug 2004- Oct 2005

Occupational Therapist

• Provided occupational therapy intervention for adults and older adults primarily on rehabilitation unit

RELATED EXPERIENCES:

Cincinnati State Technical and Community College, Cincinnati, OH

Guest Lecturer for Occupational Therapy Assistant Program Dec 2012

• Taught electrical stimulation modalities related to physical Disabilities in occupational therapy

Xavier University, Cincinnati, OH

Clinical Research Tutor for Occupational Therapy Program Jan 2006- May 2011

• Clinical tutor for occupational therapy research projects

University of Cincinnati, Cincinnati, OH

Research Tutor for Allied Health Sciences Program June 2006- May 2011

• Research tutor for pre-physical therapy research projects

Brown Mackie College Northern Kentucky, Fort Mitchell, KY

Guest Lecturer for Occupational Therapy Assistant Program Dec 2010

• Taught occupational therapy interventions related to physical disabilities- lecture requested

Xavier University, Cincinnati, OH

Guest Lecturer for Occupational Therapy Assistant Program Mar 2009

• Presented use of constraint induced therapy for individuals with stroke- lecture requested

University of Indianapolis, Indianapolis, IN

Guest Lecturer for Physical Therapy Program Nov 2006, 2007, & 2008

• Presented electrical stimulation applications and demonstration including lab with multiple electrical stimulation devices- lecture requested

Indiana University Purdue University- Indianapolis, Indianapolis, IN

Guest Lecturer for Occupational Therapy Program Sept 2008

• Presented "Stroke Rehabilitation and Neuroplasticity"- lecturer requested

Xavier University, Cincinnati, OH

Guest Lecturer for Occupational Therapy Assistant Program Mar 2006 & 2007

• Presented "Validity of Measurements" with lecture and an activity

Xavier University, Cincinnati, OH

Guest Lecturer for Occupational Therapy Assistant Program Apr 2006

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COURSES TAUGHT:

Xavier University:

HOCS 321 Analysis of Occupational Performance

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MOCT 601 Graduate Research Project I

MOCT 607 Level I Fieldwork Domains and Process I Pediatrics

MOCT 609 Theoretical Foundations and Clinical Reasoning

MOCT 631 Graduate Research Project II

MOCT 633 Domains and Process II (Early Adults through the Elderly)

University of Cincinnati:

HLSC 37301 Distance Health Care Ethics

Indiana University:

T575 Applied Neuroscience for the Occupational Therapist

Cincinnati State Technical and Community College:

OTA 105 Theory of Occupational Therapy

OTA 231 Therapeutic Media for Physical Disabilities

RELATED CERTIFICATIONS & EXPERIENCES:

CPR: American Red Cross, Cincinnati, OH

CPR certification 2012

A-ONE certification training: New York, NY

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Myomo: Drake Center, Cincinnati, OH
Myomo training Apr 2008

Interactive Metronome: Drake Center, Cincinnati, OH
IM Provider Certification Nov 2007

Mentamove: Privat-Institut fur Reha-Anwendungen GmbH & Co., Karlsfeld, Germany
Mentamove Diploma/ Certification Feb 2006

Northstar Neuroscience: Rehabilitation Institute of Chicago, Chicago IL
Standardized Treating Therapist/ Standardized Rating Therapist Jan 2006

Bioness H200: Cincinnati, OH
Bioness H200 Clinical Certification for Occupational Therapists Jan 2006

PUBLICATIONS AND PAPERS:

PUBLICATIONS, PEER- REVIEWED

Hill, V., Dunn, L., Dunning, K., & Page, S. (2011) A Pilot Study of Rhythm and Timing Training as a Supplement to Occupational Therapy in Stroke Rehabilitation. Topics in Stroke Rehabilitation, 18(6):728–737. doi: 10.1310/tsr1806-728

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Page, S. J., Murray, C., & [Hill] Hermann, V. (2011). Affected upper extremity movement ability is retained 3 months after modified constraint-induced therapy. American Journal of Occupational Therapy, 65(5): 589-93.

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Hill Hermann, V., Herzog, A., Jordan, R., Hofherr, M., Levine, P., & Page, S. (2008). Telerehabilitation and Electrical Stimulation: An occupation based, client centered, stroke intervention. American Occupational Therapy Journal, 64(1): 73-81.

Bondoc, S., Powers, C., Henz, N., and [Hill] Hermann, V. (2010). Virtual Reality Based Rehabilitation. OTPractice, 15(11): CE-1¬-CE-8.

Boyne, P., Dunning, K., Levine, P., [Hill] Hermann, V., & Page, S. (2010). Orthotic functional electrical stimulation following botulinum toxin for a young adult with severe hand impairment due to childhood stroke. Physiotherapy Theory and Practice, 26(4): 267-74.

Boyne, P., Dunning, K., Levine, P., [Hill] Hermann, V., & Page, S.J. (2009). Orthotic functional electrical stimulation following botulinum toxin for a young adult with severe hand impairment due to childhood stroke. Archives of Physical Medicine and Rehabilitation, 90(10): E12.

Wu, A., [Hill] Hermann, V., Ying, J., & Page, S.J. (2009). Chronometry of mentally versus physically practiced tasks in stroke. Archives of Physical Medicine and Rehabilitation, 90(10): E61.

Hardy, K., Suerver, K., Sprague, A., [Hill] Hermann, V., & Page, S.J. (2009). Combined bracing, electrical stimulation, and functional practice for chronic, upper extremity spasticity. Archives of Physical Medicine and Rehabilitation, 90(10): E67.

Page, S., Maslyn, S., [Hill] Hermann, V., Wu., A., Dunning, K., & Levine, P. (2009). Activity based electrical stimulation training in a stroke patient with minimal movement in the paretic upper extremity. Neurorehabilitation and Neural Repair, 23(6): 595-599.

Barth, E., [Hill] Hermann, V., Levine, P., Dunning, K., & Page, S. (2008). Low-dose, EMG-triggered electrical stimulation for balance and gait in chronic stroke. Topics in Stroke Rehabilitation, 15(5): 451-455.

Dunning, K., Levine, P., & [Hill] Hermann, V. (2008). Author Response. Journal of Physical Therapy, 88(8): 970.

Hill Hermann, V., Strasser, A., Albers, B., Schofield, K., Dunning, K., Levine, P., & Page, S. (2008). Task specific, patient-driven neuroprosthesis training in chronic stroke: Results of a three-week, clinical study. American Journal of Occupational Therapy, 62(4): 466-472.

Dunning, K., Berberich, A., Albers, B., Mortellite, K., Levine, P., Hill Hermann, V., & Page S. (2008). A four-week, task specific neurprosthesis program for a person with no active wrist or finger movement because of chronic stroke. Journal of Physical Therapy, 88(3): 397-405.

Barth, E., Hill Hermann, V., Levine, P., & Page, S. (2007). Effects of EMG- Triggered electrical stimulation on gait and balance in chronic stroke: a case study. OPTA Fall conference.

Page S., Levine P., & Hill Hermann, V. (2007). Mental practice as a gateway to modified constraint- induced movement therapy: a promising combination to improve function. American Journal of Occupational Therapy; 61(3): 321-327.

Page, S. & Hill Hermann, V. (2007). Modified Constraint Induced Therapy: An Efficacious Outpatient Therapy for persons with Hemiparesis. Special Interest Section Quarterly: Physical Disabilities, 30(4): 1-4.

Strasser, A., Albers, B., Schofield, K., Dunning, K., Levine, P., Hill, V., & Page, S. (2006). Reaching Out: improving upper extremity function after stroke using electric stimulation. Journal of NeuroPhysical Therapy, 30(4): 208.

Borkholder, C., Hill, V., & Fess, E. (2004). The efficacy of splinting for lateral epicondylitis: a systematic review. Journal of Hand Therapy, 17(2): 181-199.

Boustani, M., Beitman, C., Moyers, P., Chase, C., Bowman, W., Emel, H., Hill, V., Jolly, S., & Stansberry, J. (2003). Curriculum design for systematic evidence review: connecting students to geriatric practice. The Gerontologist, 111.

PUBLICATIONS, NON-PEER REVIEWED

Hill Hermann, V. (2010). The NESS H200 for Stroke Rehabilitation. Advance for Occupational Therapy Practitioners, 26(1): 26.

Hill, V. (2006). Stroke of Genius. Advance for Directors in Rehabilitation, 15(4): 51.

RESEARCH/PROFESSIONAL PRESENTATIONS:

RESEARCH POSTER PRESENTATIONS

Page, S.J., Hill, V., & White, S. Portable Upper Extremity Robotics is as Efficacious as Upper Extremity Rehabilitative Therapy. Archi8ves of Physical Medicine and Rehabilitation; 93 (10); e21.

Hill, V. Sensation Testing in Individuals with Stroke. Ohio Occupational Therapy Association Annual Conference. October 2011.

Hill, V. Rhythmic Training as an Adjunct to Repetitive Task Specific Training in Chronic Stroke. Ohio Occupational Therapy Association Annual Conference. October 2010.

Hill, V. Optimal Daily Duration of Repetitive Task Specific Training Incorporating Electrical Stimulation in Moderately Impaired Stroke. Ohio Occupational Therapy Association Annual Conference. October 2010.

Hill, V. Evaluation of motor evoked potentials as a measure of impairment using navigated and non-navigated transcranial magnetic stimulation in stroke. Ohio Occupational Therapy Association Annual Conference. October 2010.

Hardy, K., Sprague, A., & [Hill] Hermann, V. The Efficacy of and Orthotic-Driven Electrical Stimulation Intervention on Upper Extremity Spastic Hemiparesis in Chronic Stroke. American Occupational Therapy Association Annual Conference. April 2010.

Hill, V. Results of the use of rhythmic auditory training in functional use of the affected arm after stroke: OH. Ohio Occupational Therapy Association Annual Conference. November 7, 2009.

Hill, V. Case Study: Effects of a combined occupation drive electrical stimulation bracing in stroke- AOTA Annual Conference, Houston TX. April 23, 2009.

Hill, V. Interactive Metronome Case Study. AOTA Annual Conference, Houston, TX. April 24, 2009.

Hardy, K., Sprague, A., & [Hill] Hermann, V. Effects of a combined occupation driven electrical stimulation bracing in stroke. OOTA Annual Conference, Toledo, OH. October 11, 2008.

Hill Hermann, V, Herzog, A, Hofherr, M, & Jordan, R. Using Telerehabilitation in Stroke Rehabilitation. AOTA Annual Conference, Long Beach, CA. April 2008.

Hill, V. Mental Practice Improves Reaching Kinematics in Stroke. Annual OOTA Conference, Youngstown, OH. October 26, 2007

SELECTED PROFESSIONAL PRESENTATIONS

Hill, V. Rehabilitation Roundtable Facilitator- Invited. OOTA Annual Conference, Zanesville, OH. November 2012.

Hill, V. Rehabilitation Roundtable Facilitator- Invited. OOTA Annual Conference, Cuyahoga Falls, OH. October 2011.

Griffin, C. & Hill, V. Maximizing Participation in Occupation for Individuals with Stroke: The Hemiplegic Shoulder and Incorporating Functional Electrical Stimulation into practice. OOTA Annual Conference. November 2010.

Griffin, C. & Hill, V. Maximizing Participation in Occupation for Individuals with Stroke: Incorporating Functional Electrical Stimulation into Practice. IOTA Annual Conference. September 2010.

Griffin, C. & Hill, V. Preconference Institute: Maximizing Participation in Occupation for Individuals with Stroke: The Hemiplegic Shoulder and Incorporating Functional Electrical Stimulation into practice. AOTA Annual Conference. April 2010.

Hill Hermann, V. Incorporating Functional Electrical Stimulation into Practice. OOTA Annual Conference, Dayton, OH. November 7, 2009.

Dunning, K., & Hill, V. Electrical Stimulation for the Neurological Patient. Education Resource, Inc, Course, Cincinnati, OH. August 14 & 15, 2009.

Hill, V. & Page, S. Applications of Electrical Stimulation in Stroke: Cincinnati, OH. American Society of Neuro Rehabilitation. June 20, 2009.

Dunn, L., Hill, V., & Levine, P. Testing Stroke: An Introduction to Practical Outcome Measures. American Society for Neurorehabilitation, Cincinnati, OH. June 19, 2009.

Hill Hermann, V. Making Changes with Innovative Stroke Interventions. IOTA Annual Conference- Invited Presentation. June 10, 2009.

Hill Hermann, V. Evidence Based Stroke Rehabilitation for Occupational Therapists. Indiana Occupational Therapy Association. Indianapolis, IN. May 2009.

Dunn, L., Finnen, L., & Hill Hermann, V. Physical Disabilities Annual Program: Paradigm Shift and Innovations in Stroke Rehabilitation. AOTA Annual Conference- Invited Presentation-Three Hour Webcast. April 26, 2009.

Dunning, K., & Hill, V. Electrical Stimulation for the Neurological Patient. Education Resource, Inc, Course, Cincinnati, OH. March 7, 2009.

Dunning, K., & Hill, V. Electrical Stimulation for the Neurological Patient. Education Resources Inc. Course, Wilkes-Barre, PA. January 29 & 30, 2009.

Klein, A., Little-Hayes, P., & [Hill] Hermann, V. Constraint Induced Movement Therapy Across the Lifespan. OOTA Cincinnati District Meeting, Cincinnati, OH. October 16, 2008.

Hardy, K., Sprague, A., & [Hill] Hermann, V. Occupation Driven Electrical Stimulation. OOTA Annual Conference, Toledo, OH. October 9, 2008.

Hill Hermann, V, Herzog, A, Hofherr, M, & Jordan, R. Telerehabilitation and Functional Electrical Stimulation: An exploration of home-based occupational therapy for patients post-stroke. OOTA Annual Conference, Toledo, OH. October 9, 2008.

[Hill] Hermann, V. Stroke Rehabilitation Innovative Interventions. IOTA Conference- Invited Presentation. October 4, 2008.

Hill Hermann, V, Herzog, A, Hofherr, M, & Jordan, R. Telerehabilitation and Functional Electrical Stimulation: An exploration of home-based occupational therapy for patients post-stroke. AOTA Annual Conference, Long Beach California. April 11, 2008.

Hill Hermann, V. Evidence Based Practice. Invited presentation for the KOTA Northern Kentucky District Meeting. February 26, 2008.

Hill Hermann, V & Page, S. Treatment Strategies and EBP for Neurologically Impaired Patients. OOTA Columbus Spring Workshop- Invited presentation. February 16, 2008.

Hill Hermann, V. E-stim and OT: Let’s make friends with the cutting edge orthosis and the brain triggered gadgets. OOTA Annual Conference, Youngstown, OH. October 27, 2007.

Hill Hermann, V. Rehabilitation Forum. OOTA Annual Conference, Youngstown, OH. October 27, 2007.

Hill Hermann, V. E-stim and OT: Let’s make friends with the cutting edge orthosis and the brain triggered gadgets. AOTA Annual Conference and Expo, St Louis, MO. April 23, 2007.

Hill Hermann, V. Building the Body of Knowledge for Practice. OOTA Cincinnati District- Invited presentation. February 8, 2007.

Hill Hermann, V. Neurological upper extremity, UMN, stroke and evidence based treatments. INHand and UE Education Group Clinical Practice Forum, Indianapolis, IN- Invited presentation. November 18, 2006.

Hill Hermann, V. Efficacy of Splinting for Lateral Epicondylitis.OOTA Annual Conference, Cincinnati, OH- Invited presentation. September 29-30, 2006.

Page, S. & Hill V. Changing their minds: Neuroplasticity and motor function in stroke patients. Northern District Kentucky Occupational Therapy Association meeting, Florence, KY- Invited presentation. May 25, 2006.

Hill, V. Efficacy of Splinting for Lateral Epicondylitis. AOTA Annual Conference and Expo, Charlotte, NC. April 29, 2006.

Hill, V. & Legros, J. Hand and UE Splinting Forum: Bioness H200. INHand Study Group, Indianapolis, IN- Invited presentation. April 22, 2006.

Fess, E. & Hill, V. Efficacy of Splinting for Lateral Epicondylitis. INHand Study Group, Indianapolis, IN- Invited presentation. June 4, 2005.

Boustani, M, Beitman, C, Moyers, P, Chase, C, Bowman, W, Emel, H, Hill, V, Jolly, S, & Stansberry, J. Curriculum design for systematic evidence review: connecting students to geriatric practice. Gerontological Society of America Annual Conference, San Diego, CA. October, 2003.

STUDENT RESEARCH PROJECTS:

Xavier University Sensation testing Jan 2010- May 2011

Primary Investigator, Tester Trainer, Clinical Tutor

Xavier University Sensation testing Jan 2010- Dec 2010
Primary Investigator, Tester Trainer, Clinical Tutor

University of Cincinnati Sensation testing/validity study Aug 2009- May 2010
Primary Investigator, Tester Trainer

University of Cincinnati Mentamove for gait case study Jan 2008- Dec 2008
Study Supervisor, Treatment Trainer

Xavier University Interactive Metronome pilot study Jan 2008- May 2009
Primary Investigator, Treatment Trainer, Clinical Tutor

Xavier University Ultraflex: bracing and e-stim case study Jan 2008- May 2009
Study Supervisor, Treatment Trainer. Clinical Tutor

Xavier University IM pilot study and Sensation testing/validity Jan 2008- June 2009
Primary Investigator, Treatment Trainer

Xavier University Ultraflex: bracing and e-stim case study Jan 2007- Dec 2009
Study Supervisor, Treatment Trainer, Clinical Tutor

Xavier University Coretx: feasibility study Jan 2007- June 2008
Study Supervisor, Treatment Trainer, Clinical Tutor

University of Kansas Chronometry April- Aug 2007
Clinical Tutor

University of Cincinnati Mentamove for gait case study Feb 2007- Aug 2007
Study Supervisor, Treatment Trainer

University of Cincinnati Bioness H200/ Botox Intensity case study Jan 2006- Aug 2006
Study Supervisor, Treatment Trainer

Xavier University Telerehab and Bioness H200 case study Jan 2006- Jan 2010
Study Supervisor, Treatment Trainer, Clinical Tutor
Xavier University Bioness H200 Intensity case study Jan 2006- Dec 2010
Study Supervisor, Treatment Trainer

University of Cincinnati Bioness H200 Intensity case study March 2006- Aug 2006
Study Supervisor, Treatment Trainer

GRANTS:
American Heart Association Great Rivers Affiliates Grant
Received June 2009- Closed June 2011
$120,000 for 2 years for the Robotic Arm (MYOMO) study

Interactive Metronome private grant funding
Received November 2007- Closed December 2008
$16,000 for 1 year for the Interactive Metronome study

PROFESSIONAL SERVICES:

Cincinnati District Chair, OOTA Cincinnati District Board	2009-2013
OTA-MOT Advisory Board Member, University of Cincinnati	2009-present
OTA Advisory Board Committee Member, Brown Mackie College	2009-2011
Editor, AOTA Physical Disabilities Special Interest Section Quarterly Newsletter	2008-2011
OTs in Action, OOTA Membership	2008-present
Rehab MSG Coordinator, OOTA Cincinnati District Board	2008-2009
Cincinnati District Chair, OOTA Cincinnati District Board	2007-2008
OTA Advisory Board Member, Cincinnati State Community College	2007-2013
Member, Medicaid Task Force for OOTA Board	2007-2008

MSG Coordinator for Rehabilitation Services, OOTA State Board	2006-2008
NetWellness Occupational Therapist Consultant, Rehabilitation Section	2006-2010
Member, Hospital Research Committee, Christ Hospital	2005
Member, Nursing Research Council, Christ Hospital	2005
Chair, Therapy and Rehabilitation Research Committee, Christ Hospital	2004-2005

ACADEMIC SERVICES:

Member, Indiana University Alumni Association, IUPUI	2009-present
Member, Academic, Professional Women Association, UC	2009-2011
Member, Pi Theta Epsilon Honors Society, IUPUI	2003-2004
Student Representative Assembly Delegate, AOTA, IUPUI	2002
President, Occupational Therapy Class, IUPUI	2001-2004
Phi Eta Sigma Honors Society, IUPUI	200-2004
Member, Student Occupational Therapy Association, IUPUI	2000-2004

MEMBERSHIPS:

American Congress of Physical Medicine and Rehabilitation	2006-2012
Kentucky Occupational Therapy Association	2005-2010
Ohio Occupational Therapy Association	2004- present
Cincinnati Brest Cancer Awareness Society	2004- present
American Occupational Therapy Association	2003- present
World Federation of Occupational Therapy	2003- present
Indiana Occupational Therapy Association	2002- present

COMMUNITY SERVICES:

Team Leader, Guatemala Service Learning trip	2013
My Heart. My Life. Chair, Cincinnati American Heart Association	2012-2013
Guatemala Service Learning trip, Xavier University Occupational Therapy	2012
Chair, Steps for Stroke, American Heart Association Mini Heart	2011-2013
Member, ProKids	2011-2013
Member, Coming of Age for Cincinnati Development	2010-2012

Member, Cincinnati's Community Housing Accessibility Alliance	2011
Facilitator, Cincinnati Stroke Support Group	2010-2011
Member, Fundraising Team for Multiple Sclerosis Society	2010-2011
Volunteer, American Heart Association Heart Walk and Steps for Stroke	2011-2012
Team Leader, Stroke Support Group, AHA Heart Walk	2008-2012
Participate monthly, Dearborn County Stroke Support Group	2006
Participate monthly, Gateway Rehabilitation Hospital Stroke Support Group	2006

COMMUNITY PRESENTATIONS:

2012, April	Cincinnati Stroke Support Group
2008, Feb	Kentucky Occupational Therapy Association, Northern Kentucky
2008, Feb	Ohio Occupational Therapy Association, Columbus, OH
2007, Nov	University of Indianapolis, Physical Therapy Department, Indianapolis, IN
2007, Oct	University of Cincinnati, Gerontology Resident Program, Cincinnati, OH
2007, Sept	St Vincent's Hospital, Anderson, IN
2007, Sept	Ohio State University Medical Campus, Columbus, OH
2007, June	Public Health Services, Cincinnati, OH
2007, May	Mercy Hospital Mt. Airy, Cincinnati, OH
2007, April	St Vincent's Hospital, Indianapolis, IN
2007, Mar	Mercy Hospital Western Hills, Cincinnati, OH
2006, Nov	University of Indianapolis, Physical Therapy Department, Indianapolis, IN
2006, Nov	Gateway Rehabilitation Hospital, Florence, KY
2006, Oct	Drake in-patient therapists, Cincinnati, OH
2006, Oct	Drake out-patient therapists, Cincinnati, OH
2006, Sept	Mercy Western Hills, Cincinnati, OH
2006, July	The University Hospital, Cincinnati, OH
2006, June	The Christ Hospital, Cincinnati, OH
2006, May	The Jewish Hospital, Cincinnati, OH
2006, April	Deaconess Hospital, Cincinnati, OH
2006, March	Bethesda North, Cincinnati, OH
2006, Feb	Gateway Rehabilitation Hospital, Florence, KY

2006, Feb Health South, Florence, KY

AWARDS:

Commendation Award
American Occupational Therapy Association Apr 2010

Distinguished Alumna Award
IUPUI School of Health and Rehabilitation Sciences May 2009

Model Practice Award: Rehabilitation
Ohio Occupational Therapy Association Oct 2008

Model Practice Award: Research
Ohio Occupational Therapy Association Oct 2008

Service Award
Ohio Occupational Therapy Association Oct 2008

Affiliated Faculty of the Year Award
Xavier University Occupational Therapy Department Apr 2008

Commendation Award: Acute Care Fact Sheet
American Occupational Therapy Association Apr 2008

Carol D. Nathan Leadership Award
IUPUI Occupational Therapy Department Dec 2003

Top 100 Student Award
IUPUI May 2003