Reliability and Validity of the HASTe in Assessing Bilateral Sensory Function in Children with Hemiplegia

A Master’s Thesis

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The primary purposes of this study are: 1) to complete validation of the Haptic Active Sensation Test (HASTe) for use in children; 2) to extend the understanding of sensory and motor dysfunction in children with hemiplegic cerebral palsy in both hands; and 3) to examine the relationship between haptic sensation and motor function in hemiplegic cerebral palsy.

This study used a quasi-experimental cohort design, comparing six children, aged 6-10 years of age with hemiplegic cerebral palsy, to an age matched peer group (n=6) on motor and sensory tests in both hands. Tests were performed in a single day testing session, and included: grip strength, The Jebsen Taylor Test of Motor Function, two-point discrimination, the Nottingham method of stereognosis, and the HASTe. Data for the paretic/ non-dominant hand were combined with 6 additional subjects from a previous master’s thesis to increase statistical power.

Results found that the HASTe has good test-retest reliability (ICC=0.772), and excellent internal consistency (Cronbach’s Alpha= 0.871). A cut-off score of 12/18 was established, with sensitivity of .833 and specificity of .583. A Receiver Operating Characteristic Curve (ROC) was developed, with area underneath at 0.788. Using t-tests, the paretic hand was found to have statistically significant differences between groups (at p<0.05) for all scores except two-point discrimination of the thumb. The HASTe
correlated at a moderate rate with both stereognosis \( (r=0.428, p=0.037) \) and the Jebsen Taylor without writing \( (r=-0.509, p=0.011) \).

The HASTe is a valid and reliable tool in assessing haptic sensation in children. It identified a greater number of children as having a deficit on both the paretic and non-paretic hands compared to two point discrimination and stereognosis.
DEDICATION

This document is dedicated with much love to my family, especially my husband and wonderful children. They have encouraged me to persevere throughout this process, and shown endless patience and love while I worked to complete this project over the past 4 years. I hope that in the future, I can return this love and dedication to them by encouraging them to achieve each of their goals.
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TABLE OF CONTENTS

Abstract ....................................................................................................................... ii

Dedication .................................................................................................................. iv

Acknowledgments .................................................................................................... v

Vita ................................................................................................................................. vi

List of Tables ............................................................................................................. x

List of Figures ........................................................................................................... xi

Chapter 1: Introduction .......................................................................................... 1

1.1 Background of the Problem ................................................................. 1

1.2 Significance of the Problem .............................................................. 3

1.3 Purpose of the Study ............................................................................ 6

1.4 Objectives ................................................................................................. 7

1.5 Research Hypothesis ............................................................................. 7

1.6 Research Approach ............................................................................... 8

1.7 Limitations ............................................................................................... 9

1.8 Definition of Terms ............................................................................. 10

Chapter 2: Literature Review ............................................................................. 12
2.1 Neuroanatomy of the sensory/motor systems of the body..............12
2.2 Mechanisms of injury and deficits commonly found in hemiplegic cerebral palsy.................................................................14
2.3 Sensory impairment in children with cerebral palsy......................15
2.4 Tests of Sensory Function.................................................................20
2.5 Motor impairment........................................................................23
2.6 Relationship between sensory and motor function.......................26
2.7 MRI and hemiplegic cerebral palsy................................................27
2.8 HASTE as a tool to further evaluate sensory function...............28
2.9 Reliability and validity of other tests to be used in this study..........30

Chapter 3: Methods...........................................................................33
3.1 Introduction..................................................................................33
3.2 Design..........................................................................................33
3.3 Subjects.......................................................................................34
3.4 Testing procedures.......................................................................35
3.5 Analyzing Data............................................................................37

Chapter 4: Manuscript.......................................................................38
4.1 Introduction..................................................................................38
4.2 Purpose.......................................................................................40
4.3 Methods.......................................................................................41
4.4 Data Analysis..............................................................................43
4.5 Results.......................................................................................44
LIST OF TABLES

Table 1  Means and Standard Deviations Paretic/ Non-Dominant Hand.....................46
Table 2  Independent Samples t-Tests, Non Dominant Hand.....................................47
Table 3  Means and Standard Deviations Non Paretic/ Dominant Hand.......................48
Table 4  Independent Samples t-Tests for Dominant Hand.......................................49
Table 5  Correlations for Non-Dominant Hand, n=24................................................50
Table 6  Sensitivity/ Specificity of the HASTe...........................................................51
Table 7  Individual Scores for Dominant/ Non-Paretic Hand......................................58
Table 8  Frequency of Impairments of the Paretic Hand.............................................66
Table 9  Individual Scores for the Paretic Hand.........................................................110
Table 10 Motor/ Sensory Means and Standard Deviations Non-Dominat/ Paretic Hand,
This Study Only........................................................................................................112
Table 11 Independent Samples t-Tests for Non-Dominant Hand.................................114
Table 12 Correlations for Non-Dominant Hand, n=12.................................................116
LIST OF FIGURES

Figure 1. Haste ROC Curves For All Subjects Test 1……………………………………..52

Figure 2. Frequency of HASTe Scores ........................................................................53
CHAPTER 1: INTRODUCTION

1.1 Background of the problem

Cerebral Palsy is currently diagnosed in 1 out of every 278 children, and is considered a commonly diagnosed congenital disorder. It is the leading cause of childhood disability. Of children with spastic cerebral palsy, approximately 29-31% have hemiplegic cerebral palsy, with one side of the body primarily affected. Motor and sensory dysfunction is present in hemiplegic cerebral palsy due to the areas of the brain typically affected. The upper extremity is generally more involved than the lower extremity on the affected side of the body. Hemiplegic cerebral palsy can also have visual, behavioral, communication, and cognitive effects in some children. Children with hemiplegic CP have functional deficits of varying severity as a result of their impairments. Motor deficits on one side of the body are a primary diagnostic characteristic for hemiplegic cerebral palsy. Sensory deficit is typically classified in this population as lack of normal development of the somatosensory system and can result in deficits in identification of different forms of sensory modalities such as touch, the ability to detect position in space, and the ability to use the hand to identify objects (haptics). Although it is well known that there are both motor and sensory impairments associated with hemiplegic cerebral palsy, the prevalence of each varies among studies. Some studies have also shown deficits to the non-paretic hand of some
children with hemiplegia;\textsuperscript{6-8} this raises the question of whether a unilateral lesion can cause bilateral deficits or whether those children with bilateral deficits actually have a bilateral lesion. Improving functional abilities is of constant interest to both health care providers working with and children and families living with hemiplegic cerebral palsy. In order to achieve the highest functional outcomes, both motor and sensory deficits, as well as their intricate effect on each other, must be understood to allow for the best treatments to be developed and utilized for specific deficits.

This study will evaluate sensation and motor function in the paretic and non-paretic hands using some common tests, but also an active haptic sensation test. Motor function will also be assessed using both a strength test and a fine motor test, involving speed, for comparison to these sensory tests. Although a test of haptic sensation of this nature has not yet been published in children, Mays\textsuperscript{13} piloted a test of haptic sensation in children with hemiplegia and an age-matched control group. In her study, a haptic sensation test (the Hand Active Sensation Test, or HASTe),\textsuperscript{29} correlated with tests of two-point discrimination and stereognosis. Strength and fine motor function were also tested. The goal of this previous study was to evaluate the use of the HASTe as an appropriate and valid test for children and to compare it to other commonly used tests. Correlations were found between motor and sensory tests. This study found a statistically significant difference between the control and hemiplegia groups and demonstrated that the HASTe was valid and reliable in those tested.\textsuperscript{13} However, it had some limitations, namely that this study looked only at the paretic (or non-dominant) hand and was able to get only 6 subjects with hemiplegia to enroll, therefore, limiting its ability to obtain statistical
power. Thus, the current study will replicate the basic format of that original study. However, it will add testing of the non-paretic/dominant hands and explore lesion location, using MRI reports, to determine if deficits found in the non-paretic hand are linked to more global brain lesions than to a true unilateral lesion as would be expected with a hemiplegia diagnosis.\textsuperscript{14-16} This study will: further evaluate validity and reliability of the HASTe; explore the percentage of children showing a deficit in each hand using the HASTe as well as other commonly used sensory and motor tests by comparing the paretic hand of the group with hemiplegia to the non-dominant hand of controls and the non-paretic hand of the group with hemiplegia to the dominant hand of controls; evaluate the relationship of the HASTe to commonly used tests of sensory (two point discrimination, stereognosis) and motor function (strength and Jebsen-Taylor); and will use the MRI reports obtained to assist in explaining differences between those children with unilateral versus bilateral hand deficits. The data from the current study will be analyzed in combination with the previous master’s thesis to enhance statistical power by enlarging the study population.

1.2 Significance of the Problem

Motor and sensory impairment are prominent characteristics of hemiplegic cerebral palsy, primarily on one side of the body. Sensory loss in children with hemiplegic cerebral palsy has been recognized in the paretic hand in up to 96% of children tested.\textsuperscript{9} Recently, testing has also been done on the non-paretic side with results varying greatly between studies, depending on type of testing used.\textsuperscript{6,7,9} Motor
dysfunction is also present in nearly all children with hemiplegic cerebral palsy in the paretic hand \(^8,9,17-19\) and in up to 76% in the non-paretic hand.\(^8,18\) Given the high percentages of children experiencing both motor and sensory dysfunction in this population, significant attention to both sensation and movement, as well as the interaction between them, is critical for improving function in children with hemiplegia.

Evaluation and treatment of sensory dysfunction has not received the attention in the clinical setting that motor function has, although it has been more prominent in the literature in recent years. Prevalence of paretic upper extremity sensory loss varies by study from 50% to 96% in at least one sensory modality.\(^6,8,9,12,20\) Similarly, the non-paretic upper extremity has documented sensory deficit in at least one modality in up to 53% of children;\(^6,7\) however, several tests did not show any deficit in the non-paretic hand.\(^7,9,12\) Testing varies greatly and may impact the number of children identified as having a deficit on the non-paretic hand because they evaluate separate modalities such as touch perception,\(^6,9,21\) two point discrimination,\(^6,7,9,21-23\) object identification (stereognosis),\(^6,7,9,12,21,22\) and positional identification (proprioception).\(^7,8,11\) A comprehensive literature search identified two studies that looked at sensory discrimination using texture in children with hemiplegia,\(^6,12\) and both of these used a texture board with different width gratings rather than a match to sample task with objects held in the hand as is done for the HASTe. Both reported a deficit in the ability to detect texture accurately with both the paretic and non-paretic hand compared to controls, however the percentages of children with non-paretic hand deficits varied.\(^6,12\) Tests involving discrimination of touch (i.e. – stereognosis, 2 point discrimination, and
roughness discrimination) generally show more deficits than those involving perception of touch alone. In the 2006 Master’s thesis, the HASTe was used to evaluate the paretic hand and non-dominant hand, respectively, in children with hemiplegia and a peer control group, with 6 children in each group, and demonstrated a statistically significant difference between the paretic hand of the hemiplegic group and the non-dominant hand of controls. Yet, further testing is necessary to truly establish the reliability and validity of the HASTe and better characterize the role of sensory deficits on hand function in children with hemiplegic cerebral palsy.

Sensory feedback is known to be important for refining and improving motor performance. Children with hemiplegia typically have the most difficulty with grading force, coordination, and speed of tasks that require a lot of adjustment during the activity as compared to those that require strength alone. Sensation and the ability to gain feedback intrinsically from the hand have a role in the grading of force and fine motor control.

Anticipatory control, during grasp and lift, in children with hemiplegic cerebral palsy is found to be present and is best with familiar objects, but is impaired when compared to controls. Anticipatory control can be learned and refined through sensory feedback and experience with new objects. This provides evidence that sensory feedback and guidance is a vital component of improving performance of children with hemiplegia in functional activities that are important in daily life. Although sensory function is related to motor function, the relative impact of sensory dysfunction on movement in hemiplegia is still uncertain, since sensory dysfunction is highly
variable, dependent on the sensory test used, and often not examined. However, to best improve function, it is important to understand how sensation interacts with motor ability so that treatment approaches can be developed to improve both sensation and function.

In this study, information will be obtained regarding the sensory deficit in both the paretic as well as the non-paretic hand, using two-point discrimination, the Nottingham method of stereognosis, and the HASTe, which is a test requiring in-hand manipulation and discrimination of weight and texture of objects. Further, since multiple studies report bilateral deficits in children with hemiplegia,6-8,12 the non-paretic hand will be tested. Bilateral deficits raise the question of the mechanism(s) responsible for those deficits and whether a unilateral or bilateral brain lesion is present. Is there truly a sensorimotor deficit found in the non-paretic hand in those with an ipsilateral brain lesion, or do those with bilateral deficits in the hands also have bilateral involvement in the brain? It is known that in haptic exploration of objects, there is bilateral activation in the brain.27,28 In the studies that looked at sensation in the non-paretic hand in children with CP, however, no imaging was evaluated to establish if there is a bilateral or unilateral deficit in the brain. Therefore, this study will attempt to access brain MRI reports (if available) to assess if there is a unilateral or bilateral neurologic lesion associated with unilateral or bilateral sensorimotor deficits.

1.3 Purpose of this Study

This study aims to: 1) further establish the sensitivity and validity of the HASTe for use in children in conjunction with the previous master’s thesis;13 2) extend the
understanding of sensory and motor dysfunction in hemiplegic CP by characterizing the sensory and motor deficits in both hands; 3) examine the relationship between haptic sensation and motor dysfunction in hemiplegic CP; and 4) examine the relationship between neurological lesion (using previously performed MRI report) and impairment of the non-paretic hand in individual children.

1.4 Objectives:

1) To evaluate test-retest reliability and construct validity of the HASTe in children with hemiplegic cerebral palsy.

2) To evaluate sensory dysfunction of both hands across the domains of haptic function, two point discrimination, and stereognosis in hemiplegic cerebral palsy and controls and compare results of: the non-paretic hand to dominant hand of controls and the paretic hand to the non-dominant hand of controls.

3) To examine the relationship between sensory and motor function, using correlational analyses.

4) To compare neurologic lesion with the involvement of the “non-paretic” hand as a possible explanation for unilateral vs. bilateral deficits in individual children when MRI report is available.

1.5 Research Hypothesis

1) The HASTe will be a valid and reliable tool for assessing haptic sensation in 6-10 year olds with and without hemiplegia.
2) Sensory deficits will be found in both the paretic and non-paretic hand of children with hemiplegic cerebral palsy using the HASTe in a higher number of children than found using other sensory tests (two point discrimination, stereognosis of familiar objects).

3) Sensory deficit will be correlated with motor deficits as found using the Jebsen-Taylor test of motor function and grip strength.

4) Those children with hemiplegia that have bilateral deficits in the hands may show some bilateral deficit or a more global deficit on MRI.

1.6 Research Approach

This study is a prospective quasi-experimental design to evaluate sensorimotor function in children with hemiplegia and age matched controls in a single testing session and to establish HASTe test-retest reliability and concurrent validity. Sensorimotor testing of both hands included the HASTe; Jebsen Taylor Test of Motor Function; Jamar Dynamometer Grip Strength; Two-point Discrimination; and the Nottingham stereognosis test. Children recruited were between 6 and 10 years of age, had hemiplegic cerebral palsy, and were in regular education classes. Age-matched peers were recruited from a convenience sample for the control group. A sample of children were retested on the HASTe in the same day for test-retest reliability. MRI was obtained, if available, for evaluating the relationship between bilateral deficits and lesion location.
1.7 Limitations

This study limited recruitment of subjects to those between 6 and 10 years of age with hemiplegic cerebral palsy, who are in regular education and without active seizures or other medical diagnoses. Recruitment was from a convenience sample, and resulted in a limited pool of potential subjects.

Although it is recommended that children with cerebral palsy have MRI’s at this time, only three were available for evaluation, which limited any ability to compare the lesion findings with behavioral testing.

Haptic sensation using the HASTe was explored as part of this study. To determine validity as a measure of sensation, it was compared with stereognosis and two-point discrimination. A limitation of this method is that although the HASTe assesses sensation, it has been found in adults that the HASTe may assess a different aspect of sensation than other commonly used sensory tests, and may therefore identify those that were not identified on other sensory tests that require less discrimination. The HASTe also is a haptic exploration test involving matching, which has been found to activate multiple regions bilaterally in the brain, including motor, sensory, cognitive, and visual areas. The HASTe is of interest because it is a functional way of assessing sensation, however due to the complex nature of tasks involved (i.e. – manipulation, identifying object properties, comparing, and matching), it is difficult to fully isolate sensation compared to other activities that are involved such as matching and manipulation.
1.8 Definition of Terms

**Haptic Sensation** – The ability to use in-hand exploration to evaluate an object/ properties of an object.

**Hemiplegic Cerebral Palsy** – Classification of Cerebral Palsy, in which the upper and lower limb on one side of the body are affected.\(^{31}\)

**Non-Paretic Hand** – The hand of a child with hemiplegia that has the least motor involvement.

**Nottingham Test of Stereognosis** – A test of stereognosis, developed as part of a comprehensive Nottingham Sensory Assessment, in which 10 familiar objects are presented with vision occluded. Subjects are asked to identify the object or describe as many features of it as they can in 15 seconds. A scoring scale of 2 (normal), 1 (can identify some features of the object but not the object), or 0 (cannot identify the object in any manner) is used.\(^{32}\)

**Paretic Hand** – The hand of a child with hemiplegia that has more motor involvement and increased muscle tone.

**Sensitivity** – The ability of a test to identify actual positives correctly (true positives).

**Specificity** – The ability of a test to identify actual negatives correctly (true negatives).

**Stereognosis** – The ability to identify an object by touch alone, either via in-hand manipulation or touch.

**Two-Point Discrimination** – A test to determine at what distance a subject can correctly identify that 2 points are touching the skin vs. just a single point.
Haptics - The ability to use the hand for active touch to determine object characteristics (shape, texture, weight).
CHAPTER 2: LITERATURE REVIEW

2.1 Neuroanatomy of the sensory/motor systems of the body

In understanding the mechanism of injury and deficits found in the population that will be studied, it is important to first understand the physiology of the sensorimotor system. The neuron is the general nerve cell that is responsible for transferring information in the nervous system with neurotransmitters acting to allow communication between cells at synapses. Neuronal axons are covered by myelin to insulate them and allow the messages to be conveyed more efficiently. The 2 basic types of neurons that are of interest for this study are afferent neurons, which carry sensory information from the tissues and organs of the body into the central nervous system (sensory information), and efferent neurons, which carry information from the central nervous system back out to the body’s muscles, glands, and other tissues (motor neurons). There are also many interneurons connecting the systems.

Sensory receptors in the periphery of the body first detect an input from a specific type of stimulus. Mechanoreceptors and muscle spindle stretch receptors detect touch, pressure, posture, movement, and position. The signals then travel up through the dorsal column pathway in the spinal cord, synapsing and crossing over to the opposite side in the brainstem. After another synapse in the thalamus, sensation signals then travel to the cortex, where they go to the somatosensory cortex in the parietal lobe of the brain,
just posterior to the central sulcus and adjacent to the motor cortex. In basic “touch” sensation, this is where sensation is processed. However, in tasks requiring discrimination of distance, shape, etc, other parts of the brain in frontal, parietal, and/or occipital lobes are also active, with activation seen in both hemispheres, not just the contralateral side. In tasks requiring matching to previous experiences or recalling words, activation can also be expected in language and memory centers of the brain as well.

In motor function, a similar but opposite effect occurs, with a hierarchical structure controlling the movement. First, a command is created in the brain between multiple components of the motor system. Then, the primary motor cortex and the pre-motor area give rise to descending pathways going out to the periphery of the body to muscle fibers. The pathways carry the signal along the pyramidal tracts (lateral corticospinal tracts), crossing over to the opposite side in the brainstem, and continuing down the spinal cord to a motor neuron, in the ventral horn, to cause movement through activation of muscle fibers. The motor and sensory systems are heavily interconnected, both in the brain, and as they travel out to the periphery. Ascending pathways are acted upon by certain descending neurons, and ascending pathways interconnect with motor systems to cause changes in motor function based on the sensory input received. Some examples of this in the periphery are reciprocal inhibition (when sensory feedback synapses on a motor neuron to inhibit an antagonist muscle); tension monitoring systems (in which Golgi Tendon Organ afferent receptors are activated if too much tension is created in a muscle and synapses with a motor neuron to stop the muscle from contracting, therefore limiting
the tension); and the withdrawal reflex (when afferent input, usually pain, causes an immediate withdrawal from a painful stimuli even before the signal has reached the brain). In the cortex, these systems also work closely together, with motor patterns created based on constant input from the afferent systems, thus causing movements to be refined and made more efficient based on sensory feedback.

2.2 Mechanisms of injury and deficits commonly found in hemiplegic cerebral palsy

Cerebral Palsy (CP) is diagnosed in 2.5 to 3.3 per 1000 children, depending on how the statistic is calculated. Cerebral Palsy is considered a clinical diagnosis, with symptoms of movement disturbances, abnormal muscle tone, and hyper-reflexia. Studies report 84% to 90% of children diagnosed with CP will show a lesion in the brain on MRI. These injuries take place in utero or early in a child’s life, while the brain is still developing. 77% of young adults with CP report limitations in their daily functioning. Risk factors for developing CP include prenatal brain malformation, stroke or infection in utero, hypoxia, viral encephalitis, meningitis, trauma, low birth weight, and prematurity. Of children with cerebral palsy, approximately 31% have hemiplegia, or unilateral upper and lower extremity involvement. The majority of children with hemiplegic CP have a focal deficit in the brain, rather than more global deficits, and up to 40% have normal cognitive functioning. Of children with hemiplegia, the majority are able to ambulate; 96% without a device (Gross Motor Function Classification System, or GMFCS, level I or II). Co-morbidities that can occur with hemiplegic CP include intellectual disability, epilepsy, hearing loss, visual impairment,
and autism spectrum disorder.\textsuperscript{4} Seizures are common in hemiplegia, with up to 50 to 70\% of children with hemiplegia affected.\textsuperscript{2}

2.3 Sensory impairment in children with cerebral palsy

Sensory dysfunction in children with cerebral palsy has been documented in the literature as far back as the 1950’s and 1960’s using a variety of tests. Tests commonly used include light touch,\textsuperscript{6-9,10,17} stereognosis,\textsuperscript{6-9,12,17,21,22} static two point discrimination,\textsuperscript{6,9,10,17,21-23} moving 2 point discrimination,\textsuperscript{6,7} proprioception,\textsuperscript{7,8,11} kinesthesia,\textsuperscript{11} and more recently roughness discrimination.\textsuperscript{6,12} Nearly all studies reviewed enrolled children with milder impairment so that they had some use of the paretic hand for lift and grasp (exact requirements varied), and required that they follow basic instructions and have verbal and cognitive skills to complete the testing.\textsuperscript{6,7,9-12,23} The age range for these studies ranges from 4 up to adulthood (18 to 19 years of age),\textsuperscript{7} although many limited enrollment to starting at 5,\textsuperscript{9,6,8,21,22} 7,\textsuperscript{10} or 8\textsuperscript{6,17} years of age. This age limit is thought to have a dual purpose: 1) to allow children to be cognitively mature enough to understand instructions, and 2) to allow for relatively stable hand function. First, a level of cognitive maturity is necessary for children to be able to understand instructions. Children as young as 4-7 years of age are able to complete testing procedures for sensory and motor testing.\textsuperscript{9,20,21,36} At 4 years of age, 81\% of children with hemiplegia can follow instructions to complete stereognosis testing.\textsuperscript{20} Second, children’s hand development matures over time. In looking at the Quality of Upper Extremity Skills Test (QUEST), a test assessing the movement quality of children with spasticity to isolate movements at
the shoulder, elbow, and wrist, and grasp, 80% of typical children scored a 95/100 or greater at 4 years of age, while only 60% of 3 year olds and 40% of 2 year olds could achieve this score.\textsuperscript{37} On the same test, children with cerebral palsy were found to have maximum scores on the QUEST by 46 months of age.\textsuperscript{38} Norms are established on the Jebsen-Taylor test of hand function for children 6-19 years of age.\textsuperscript{39} In a study looking at grip in children with hemiplegia, changes in grip primarily occurred between 4 and 7 years of age, but by about 7 years of age, relatively few children showed significant changes in their grip patterns or spontaneous use.\textsuperscript{20} Therefore, for the purpose of this study, it is expected that by age 6 (the age for inclusion in this study), children will have sufficient hand function to complete the required testing. Age related “norms” for dynamometry and the Jebsen-Taylor test of motor function have been developed.

Less is known about the age at which sensory function is considered mature; however, children as young as 4-6 years of age have been tested in prior studies and were able to complete the testing with scores in the expected (i.e. “normal”) range for children in the control group.\textsuperscript{7,8,9} Studies suggest that early haptic sensation may be used for exploration in infancy;\textsuperscript{40} however, high level skills, such as integrating visual and haptic size information similar to an adult may not be present until 8-10 years of age.\textsuperscript{41} Thus, age 6 seems the right age for inclusion in this study to assure the ability to complete the sensory and motor tests.

Tests involving discrimination of objects (i.e. – stereognosis, 2 point discrimination, and roughness discrimination) generally show more deficits than those involving identification of light touch alone.\textsuperscript{6,7,9,17} In looking at the mechanisms for processing
touch versus discrimination of object characteristics, touch is processed primarily in the primary somatosensory cortex on the contralateral side; however, when additional tasks are added, such as detecting distance, recalling previous knowledge of objects, or comparing things to determine object properties, other areas of the brain are also activated bilaterally. 26-28,33 This may be an explanation for why different types of sensation are reported to be impaired at different rates, and why those tests involving more complex discrimination are more likely to be impaired than basic touch, especially on the non-paretic hand. Another possible explanation for bilateral impairment that will be explored is whether children with impairment on the non-paretic side may actually be part of the small group of those with hemiplegia (25 to 30%) who do not have the expected focal ischemic or hemorrhagic lesion isolated to one side of the brain, but rather have a bilateral component to their injury. Children with hemiplegia can have no abnormality, a structural abnormality, or periventricular white matter damage identified on MRI. 15 MRI reports will be obtained, where available, to further explore brain lesion and the involvement of the non-paretic hand in individual children.

**Paretic Hand Prevalence**

The paretic hand has consistently been noted to have sensory deficits when compared both to controls and to the non-paretic hand in children with hemiplegic cerebral palsy. 6-9,11,12,17,21,22 Prevalence of paretic upper extremity sensory loss varies by study from up to 96%, 9 to about 50% in at least one of the modalities tested. 8,20 However, the methods used, the tests administered, and the reporting are inconsistent among studies, and as shown below do affect the identification of those with sensory loss.
Stereognosis and two-point discrimination are currently the most commonly used tests for assessing sensation in this population. Findings are still highly variable between studies, with stereognosis impaired in 44% to 96% for the paretic hand, and two-point discrimination (at 3mm cut-off) impaired in 31% to 75%. The reported average distance detected correctly for 2 point discrimination on the paretic side is 5.43 mm compared to 3mm on the non-paretic hand. Proprioception and kinesthesia have also been found to be impaired on the paretic upper extremity compared to controls.

Overall, results of current sensory testing in patients with hemiplegia agree that as a group, the paretic hand in hemiplegic cerebral palsy is impaired in sensory function. Stereognosis and two-point discrimination are widely used, but there is not agreement as to which of these is more likely to be impaired. Yet, both are more likely to be impaired than light touch. Testing of haptic ability, using weight and texture discrimination, has not been published; however, in a pilot study in 2006, children with hemiplegic cerebral palsy and peers were tested with the HASTE and a difference was identified between the paretic hand and the non-dominant hand of controls.

Non-Paretic Hand Prevalence

The non-paretic hand of those with hemiplegic cerebral palsy has more recently been recognized to have both motor and sensory deficits when compared to controls; however, studies have reported mixed results as to the prevalence and types of deficits. In a recent study, up to 53% of children with hemiplegia showed some deficit on the non-paretic hand compared to controls. Depending on the type of tasks used, motor function was more frequently affected than sensory function, with dexterity
more affected than gross strength.\textsuperscript{6} Two-point discrimination was not impaired at a level that reached statistical significance in multiple studies;\textsuperscript{7,9,23,42} however a large recent study that focused on evaluating deficits in multiple sensory modalities in both hands found that static and moving two-point discrimination were impaired compared to controls.\textsuperscript{6} Identification of deficits in stereognosis has also varied greatly, depending on the type of test used, with fewer or no errors found when using only familiar objects in studies with small numbers of subjects;\textsuperscript{9,12,21} however, stereognosis of familiar objects was found to be impaired compared to controls in a large study (n=52).\textsuperscript{6} When using identification of shapes/letters, a deficit was reported in up to 33\% of subjects.\textsuperscript{7,8,12} Similarly, proprioception was impaired in up to 33\% of children for the non-paretic hand.\textsuperscript{7} Discrimination of texture (roughness) by touching different groove widths with the finger also detected deficits in the non-paretic hand compared to controls.\textsuperscript{6,12}

Overall, studies using discrimination tasks in the non-paretic hand when compared to touch identification tasks more frequently detected a deficit of sensation in the non-paretic hand.\textsuperscript{6,7,9} For example, certain tests of stereognosis and roughness discrimination were more likely to detect a deficit than light touch. Taking this one step further, when 3 different methods of stereognosis were compared on the non-paretic hand, only letter identification, a type of stereognosis, showed a deficit that met statistical significance, while geometric shapes and common object identification were comparable to controls.\textsuperscript{12} Authors concluded that the more complex the discrimination required for a sensory task, the more likely subjects were to show a deficit on the non-paretic hand compared to controls.\textsuperscript{12}
Since it has been shown that tasks requiring more complex discrimination tend to show a greater deficit, this study will compare the HASTe (assessing texture/weight discrimination) to two point discrimination and stereognosis, with the hypothesis that the HASTe may show a greater deficit in both hands than these commonly used tests due to the level of discrimination required.

2.4 Tests of Sensory Function

Testing procedures have varied, and may impact the identification of sensory deficits, which may be further impacted by the ability of children to perform the tests. Common tests used and methods found are highlighted here.

Light touch is one of the most basic sensations evaluated. It is generally tested using Semmes Weinstein monofilaments\textsuperscript{6-9,17} or touch from another blunt object.\textsuperscript{21} Light touch is generally understood by children, but as indicated above, is less likely to be impaired. It is not being used in this study, as other tests of sensation are felt to be better indicators of sensory deficit.

Two point discrimination has also been frequently used in the literature; however, methods varied from using 3mm, 5 mm, or 7mm as the “cut-off” score,\textsuperscript{7,9,21,22} to using several different distances to establish the minimal distance that each subject could detect.\textsuperscript{10,17,23} Three millimeters was consistently detected by typically developing children as young as 5 years of age and in the non-paretic hand of children with hemiplegia.\textsuperscript{6,9,17} Most studies reported that subjects (as young as 4–7 years of age) could complete the testing.\textsuperscript{6,9,23} Two-point discrimination was generally not impaired in the
non-paretic hand of children with mild hemiplegic cerebral palsy across studies at a level that reached statistical significance; however, Auld et al found both static and moving two-point discrimination were impaired in the hemiplegic group compared to control subjects.

Stereognosis is evaluated in several articles about children with hemiplegia; however, methods for assessing stereognosis vary between studies. Methods found include identification of: familiar objects, shapes, and/or letters, as well as standard tests such as the Manual Forms Perception Test. Identification of objects was the most commonly used method. Of studies that used both stereognosis and two-point discrimination, some studies found stereognosis more commonly impaired, but others found two-point discrimination more commonly impaired on the paretic hand.

A few studies attempted to address the multiple methods used for assessing stereognosis, and used shapes, letters, and/or common items to assess different levels of deficit. Most tests using stereognosis of familiar objects used common objects such as a key, pencil, spoon, button, coin, brush, doll, ball, eraser, wooden bead, and paper pellet. Authors of studies, using multiple methods of stereognosis assessment, indicate that identification of familiar objects was more easily understood by young children, yet may not identify higher level processing deficits that require greater discrimination and recall, such as identifying a letter, especially on the non-paretic side. Stereognosis is overall accepted amongst researchers as a good measure of discriminative sensory function. Both identifying familiar objects and identifying shapes (typically
using the Manual Forms Perception Test) have been successfully performed on children as young as 4-6 years of age.\textsuperscript{9,20}

Two studies found compared stereognosis scores to “roughness” discrimination, using different groove widths; the wider the width of the groove, the rougher the surface is perceived.\textsuperscript{6,12} Grated surfaces had different groove widths and were moved across the hand of the subject passively without vision; the higher groove widths were successful in differentiating between groups, but all children had errors at smaller groove widths.\textsuperscript{12} Deficits were found on both the paretic and non-paretic hands of children with hemiplegia.\textsuperscript{12} It is noted that children were able to successfully complete roughness discrimination testing.\textsuperscript{6,12} In a pilot study, children ages 6-10 years with hemiplegic cerebral palsy and controls were also able to complete the HASTe as a test of weight and texture discrimination, and those with hemiplegic CP showed impairment compared to control children, but only the paretic hand was tested.\textsuperscript{13}

Proprioception and kinesthesia have also been used in some studies of children with hemiplegia, with deficits noted in the paretic hand\textsuperscript{7,8,11} and at a lower percentage the non-paretic hand compared to controls.\textsuperscript{7} Most studies primarily assessed the fingers/hand of children with hemiplegia; however, one study looked at larger joints, using a limb positioning device to produce specific rotational movement in the upper and lower extremities of both the paretic and non-paretic sides. Proprioception errors were present, reaching statistical significance in the lower extremities compared to control children, but not in the upper extremity.\textsuperscript{11} However, kinesthesia was impaired compared to controls in the upper extremity, reaching statistical significance only on the paretic side.\textsuperscript{11} Authors
speculate that deficits in proprioception and kinesthesia may reveal a global
somatosensory deficit. Yet, they also question the secondary effect that spasticity and
motor deficits may have on sensation in relation to the feedback that the receptors such as
the muscle spindles, Golgi tendon organs, and other joint/skin receptors are able to
receive and accurately project.\textsuperscript{11} Spastic muscles may have changes that occur at the
muscle spindle level, making the muscle stiffer and resulting in different information
reception compared to a normal muscle. There also is a bias of the limb into internal
rotation as its resting position, which may result in errors occurring primarily in that
direction during testing without vision.\textsuperscript{11}

Tests described in this section were used across the literature in children both with
and without hemiplegia. It is noted that inconsistency amongst methods used, and
therefore, reported scores, affect the percentages of those reported with deficits. The
proposed study will use tests of stereognosis using familiar objects, two-point
discrimination, and the HASTe to assess sensory function of both hands in a control
group and children with hemiplegia. The HASTe will be tested for construct validity,
test-retest reliability, and its sensitivity further evaluated in children as well.

2.5 Motor impairment

Motor deficits are well recognized and frequently addressed in therapies and
literature in children with cerebral palsy. Sensory and motor function are very closely
intertwined in the central nervous system.\textsuperscript{26} Sensory feedback contributes to the refining
and learning of motor tasks in those without deficits.\textsuperscript{26} Those with cerebral palsy have
also been shown to have anticipatory control with familiar objects and are capable of using practice repetitions (i.e. – feedback from prior experience with the properties of an object such as weight, size, and texture of an object) to develop better anticipatory control with new objects.\textsuperscript{10}

There seems to be agreement among those looking at motor function that the higher the demands of the task (increased speed, more precise, increased difficulty), the more noticeable the deficits in both the paretic and non-paretic hands compared to controls.\textsuperscript{10,18}

Prevalence of motor deficit is well documented in children with hemiplegia, with impairment in the paretic hand in nearly all of children tested and in up to 76% in the non-paretic hand, with speed and coordination more impaired than strength alone for both sides.\textsuperscript{8,9} In tests involving speed and dexterity (Jebsen Taylor Test of Motor function, Purdue Peg Test, Pick up Test, Box and Block Test), 80 to nearly 100% of subjects were found to have impairment of the paretic hand\textsuperscript{8,17,23,43} with up to 10 times slower performance compared to controls. Strength, using a dynamometer, was impaired in 0-34% on the non-paretic side and up to 80% in the paretic hand.\textsuperscript{7,8} Similarly, other studies show that a statistically significant deficit exists between the paretic hand and controls in grip strength, pinch strength, and grasp pattern.\textsuperscript{7}

By contrast, in timed studies or those requiring more coordination, deficits were more likely to be identified, with slower speed and poorer accuracy of movements noted.\textsuperscript{8,10,18} Grasp control and then release, using both familiar and unfamiliar objects, with different demands such as speed and weight modified between lifts\textsuperscript{10,18} found children with cerebral palsy to perform slower than controls with the paretic hand. This
difference was more pronounced when asked to perform quickly rather than at comfortable pace.\textsuperscript{10,18} Release was also impaired and affected by speed.\textsuperscript{18} The Pick Up Test (a test of speed and coordination to pick up and move objects with and without vision present) identified a deficit in the non-paretic hand in 8\% of children compared to controls.\textsuperscript{9} When vision was occluded, significant involvement in the paretic hand was found in 40\% of those tested, with just over ¼ of the children being unable to perform the Pick Up Test at all without vision, indicating a significant reliance on vision and significant limitations in the ability to feel the objects and grasp them, based on touch alone.\textsuperscript{9} The paretic hand was found to use the same grip force for an object, regardless of the weight of that object, where as the non-paretic hand was able to grade and change the forces used, depending on the weight of the object.\textsuperscript{23} This indicates that impairment of the paretic hand’s ability to lift was not necessarily related to strength but to a sensory component limiting the ability to grade pressure in order to perform as efficiently and smoothly as the non-paretic hand. Also of note, in a bimanual lifting task, both hands actually slowed down compared to even the paretic hand’s unilateral lift time when asked to work together. Therefore, they were not more efficient when trying to use a “helper” hand compared to lifting with just one hand.\textsuperscript{23}

In the current study, strength and manual dexterity will be tested and compared to the HASTE sensory test, as well as 2-point discrimination and stereognosis for both hands to provide a more complete analysis of sensorimotor hand function. It is expected that this will generate useful information regarding the link between motor and sensory function,
especially since sensory function will be tested in a more active way that requires manipulation.

2.6 Relationship between sensory and motor function

There have been several studies attempting to look at the correlation between sensory and motor function in children with cerebral palsy in recent years. Results of these are mixed and difficult to interpret, as studies look at a variety of measures including: 1) strength of grip and/or pinch;\textsuperscript{7,8,17} 2) motor dexterity/ speed, using the Jebsen Taylor Test of Hand Function, Purdue Peg Test, Box and Block Test, and Pick-up Test;\textsuperscript{8,9,17,23,43} 3) lifting ability / grasp control (unilateral and bilateral);\textsuperscript{7,10,18,20,23,43} 4) functional measures using the QUEST, Assisting Hand Assessment (AHA), or Peabody Developmental Motor Scales;\textsuperscript{23,38} and 6) bilateral coordination.\textsuperscript{8,9,17,42} Sensory tests used were typically light touch, stereognosis, or two-point discrimination.\textsuperscript{8,9,17,19}

The majority of studies show a correlation between motor and sensory function at a moderate rate.\textsuperscript{8,9,17,19} with some exceptions.\textsuperscript{7} In those exceptions, there was a trend of greater motor deficit with greater sensory deficit; however, it was not statistically significant.\textsuperscript{7} The majority of studies found that motor function was equally or more affected than sensory function.\textsuperscript{8,9}

Most studies found a moderate correlation between at least some sensory tests and motor function tests.\textsuperscript{8,9,17,19} Grip/ pinch strength was moderately correlated to two-point discrimination and stereognosis (with Manual Form Perception Test).\textsuperscript{17} Manual dexterity correlated moderately with light touch, two-point discrimination, and stereognosis.\textsuperscript{9,19}
The highest correlations found with motor tests were with two-point discrimination (r values of .60 to .68)\textsuperscript{9,17} and stereognosis (r values of .49 to .65).\textsuperscript{8,9,19} It is noted that when both stereognosis of familiar objects and stereognosis of forms were used, stereognosis of familiar objects was more highly correlated with motor function.\textsuperscript{9}

Several authors recommended a combination of tests for explaining function. Gordon & Duff (1999) cited two-point discrimination, pinch strength, and spasticity rating as their “best combination” of tests for evaluating hand function.\textsuperscript{17} Krumlinde-Sundholm (2003) preferred two point discrimination, stereognosis of familiar objects, and Pick Up Test with vision occluded as their preferred combination.\textsuperscript{9}

The findings from these previous studies that examined correlations of sensory and motor function impacted the choosing of sensory and motor tests for the current study. In choosing sensory tests, consideration was given to those that tend to correlate best with motor function, as our ultimate interest is in function. Motor tests were chosen that represent both gross strength, and a fine motor/coordination test involving speed, as these motor tests assess very different aspects of motor function. Both have been used in previous studies frequently.

2.7 MRI and hemiplegic cerebral palsy

Magnetic Resonance Imaging (MRI) is now the imaging method of choice and recommended in all children diagnosed with cerebral palsy, unless they have previous perinatal imaging that is adequate for establishing the etiology of their cerebral palsy.\textsuperscript{16} The majority of children with cerebral palsy (greater than 70%) in developed countries
now have MRI’s (or other perinatal imaging) performed as part of their diagnostic procedure, usually within the first few years of life.\textsuperscript{14,44} Some studies caution that MRI performed too early (in the first 6-12 months) may not be as accurate due to incomplete myelination.\textsuperscript{14,35} Between 84 to 89\% of children with spastic cerebral palsy showed lesions on an MRI.\textsuperscript{14,16,35} Surprisingly, up to 96\% of children with hemiplegia had an abnormality on their MRI,\textsuperscript{16} of which 67-76\% showed a focal ischemic or hemorrhagic lesion in the brain on one side.\textsuperscript{14,15} This finding leaves approximately 25 to 30\% of those with a hemiplegia diagnosis who have either a normal MRI or other finding on an MRI, such as a structural abnormality or periventricular white matter damage.\textsuperscript{15} Also, it is noted that, especially in children with milder cerebral palsy, the skill and background of those reading the MRI does make a difference. Horridge et al \textsuperscript{44} report that approximately 60\% of MRI’s that were reported as “normal” locally were found to have abnormalities when examined by a specialist.\textsuperscript{44}

Generally speaking, MRI is considered the “gold standard” for confirming brain abnormalities in children with hemiplegia, and over the past 5-6 years, it has been recommended that all children with cerebral palsy receive an MRI, if they haven’t been previously imaged during the neonatal period.\textsuperscript{16} Therefore, MRI reports will be obtained for this study, if available, and the type of lesion recorded for use in data comparisons.

2.8 HASTe as a tool to further evaluate sensory function

The HASTe was first developed to be a more precise measure of haptic hand function, following stroke. Validation of the HASTe involved testing both hands in
subjects with hemiplegia and a control group with comparison to 2 point discrimination and the Wrist Position Sense Test, a test of wrist proprioception. The HASTe incorporates discrimination of weight and texture because of the influence these properties have on grip and lift function. The shape of the test objects was chosen to mimic a small juice container, a commonly lifted object in daily life. The HASTe did discriminate between stroke survivors and controls, indicating that it is a valid tool for evaluating hand function in stroke. It also was noted that this test was challenging enough that there was some variability even amongst controls, allowing for sensation to be assessed along a continuum. The cut-off score that distinguished between controls and experimental groups was 13. The HASTe also showed sensory impairment in 66% of survivors who had tested normally on the Wrist Position Sense Test and two-point discrimination, showing it to be a more sensitive tool than those commonly used tests. Test-retest reliability was found to be strong (ICC= .77), and internal consistency was found to be strong as well, with Chronbach coefficient alpha level of .82.

The authors concluded that this test provided more sensitive information about hand sensation/ function than other standard tests of sensory function, and that it is a valid and reliable tool in adults post-stroke.

There are no published studies that look at in-hand manipulation to discern the weight and textures of objects in children. Mays compared the use of the HASTe in children with hemiplegic cerebral palsy and controls. Results indicated that children with hemiplegic cerebral palsy were able to perform the HASTe, and that scores differentiated
those with cerebral palsy and controls (paretic hand vs. non-dominant hand). This study will replicate that study with a larger group of children and will include testing of the non- paretic hand to allow for comparisons to be made between the non- paretic hand and the dominant hand of controls as well.

2.9 Reliability and validity of other tests to be used in this study

Two-point discrimination

Two-point discrimination is a commonly used test amongst children with cerebral palsy. It was originally developed and validated as a test for peripheral nerve injury, however has since been commonly used in central nervous system injury as well. Reliability was established in patients with peripheral nerve injury, in children using a simple “paperclip” test, and in children with hemiplegic cerebral palsy. Inter-rater reliability (ICC =0.92) and test-retest reliability (ICC = 0.81) were found to be high in children with hemiplegic cerebral palsy. Two-point discrimination has been found to be impaired in children with hemiplegia in the paretic hand, and generally not in the non- paretic hand; however, one larger study did find a deficit in the non- paretic hand compared to controls.

Nottingham Test of Stereognosis

The Nottingham Sensory Assessment has moderate to good interrater reliability, (kappa values ranged from 0.40 to 1.0) with the scores for the non- paretic hand more reliable than scores for the paretic hand for adult patients post-stroke. In children with hemiplegic cerebral palsy, stereognosis of familiar objects was found to have high inter-
rater reliability (ICC= 0.78) and high test-test reliability (ICC= 0.86). This test presents a “standardized” way of assessing stereognosis of familiar objects in a manner that is easily available and repeatable.

**Jebsen Taylor Test of Hand Function**

The Jebsen Taylor Test of Hand Function was first established in adults in 1969. In this study, the 7 items used in the Jebsen Taylor test were established as: writing a short sentence; turning over cards; picking up small objects; stacking checkers; simulated eating; moving empty large cans; moving weighted large cans. Normal subjects were tested to establish norms, divided out by age, with older adults performing slower than younger adults. Reliability was established using Pearson product-moment correlations, with r-values of 0.60 to 0.99 for individual tests, statistically significant to p <0.01. There was no significant practice effect for re-testing.

Age norms have been established for typical children ages 6-19 years with the writing item omitted for younger children. Test-retest reliability was established (r= 0.83) on children with stable hand disorders. Total test-retest reliability was .97 for the dominant hand and .98 for the non-dominant hand. It is noted that correlations in children are even higher than those in adults. This test has been used in multiple research studies as a test of unilateral hand function.

**Grip Strength**

The Jamar dynamometer was used for a study to establish grip strength normative values in children. Typical children, age 6 to 19 were tested. Children as young as 6 years old were able to follow instructions for testing. Standard positioning was used of:
seated with shoulder adducted and neutrally rotated, elbow in 90 degrees of flexion, wrist in a neutral position. Scores were divided out by age, gender, and hand dominance. They found that there was a difference in strength by age and gender but not by hand dominance. Three trials were performed, and the average of three trials was used.

In 2006, a study was performed to establish validity and reproducibility of Jamar dynamometry in typical children age 4 to 11 years old. They found that the dynamometer was a valid test of hand function and had good test-retest reliability (ICC = 0.96 to 0.97) for both hands. A 2010 study also established high interrater (ICC = 0.92) and test-retest reliability (ICC = 0.81) in children with hemiplegic cerebral palsy.

These tests will be used in comparison with the HASTe in the current study. It will be determined whether the HASTe can serve as a more sensitive tool in assessing hand sensory function and will correlate equally or better with motor function of children in hemiplegic cerebral palsy.
CHAPTER 3: METHODS

3.1 Introduction

The literature is currently incomplete with regard to the best methods for assessing sensory function and its relationship to motor function. This study attempted to add to the current literature by: 1) further establishing the sensitivity and validity of the HASTe for use in children in conjunction with the previous master’s thesis;\textsuperscript{13} 2) extending the understanding of sensory and motor dysfunction in hemiplegic CP by characterizing the sensory and motor deficits in both hands; 3) examining the relationship between haptic sensation and motor dysfunction in hemiplegic CP; and 4) examining the relationship between neurological lesion (using previously performed MRI report) and impairment of the non-paretic hand in individual children.

Testing procedures were also designed to be similar to an unpublished Master’s Thesis performed in 2006\textsuperscript{13} to replicate the testing with a greater number of subjects and include the non-paretic hand. This study was approved by The Ohio State University Biomedical Institutional Review Board.

3.2 Design

The design is a quasi-experimental cohort design, comparing children with hemiparesis to an age matched peer group. Both groups were administered the same tests
to both hands in a 1 day testing session. Results were compared for the paretic hand of
the experimental group to the non-dominant hand of controls. The non-paretic hand of
the experimental group was compared to the dominant hand for controls. A sample, of
approximately half of the children, was re-tested using the HASTe within the same day to
establish test-retest reliability, trying to minimize risk of an actual change in the subject
by using a very short time frame between testing sessions. All HASTe re-testing
occurred with 1-2 hours between test 1 and test 2. The same therapist (researcher)
performed all testing procedures. A risk of this design is that the tester is not blinded to
group membership.

3.3 Subjects

Subjects were a convenience sample, with age between 6 and 10 years. Inclusion
criteria for the hemiplegic group were: 1) hemiplegia as a result of Infantile Hemiplegic
Cerebral Palsy; 2) the ability to grasp/lift a small can unimanually and elevate the
involved upper extremity above the shoulder; and 3) to be able to follow verbal
instructions at an age-appropriate level. Children were excluded from this study if they:
1) had another neurologic, genetic diagnosis, or uncontrolled seizures, 2) had moderate or
greater cognitive deficits (determined by supports needed in school), 3) could not attend
to testing (have attention deficits that prevent child from attending to a task for 20
minutes or greater without a break).

The control group was chosen from a convenience sample to be age matched to the
experimental group. Control subjects were also excluded if they had a neurological
diagnosis or uncontrolled seizure activity. They also had to be able to follow instructions and sit to attend to a task. All subjects were in regular education classes, and their cognitive status was screened by parent questionnaire, administered over the phone. For the hemiplegic group the phone interview also obtained: age, medical diagnosis, age at time of injury, assistance needed in the classroom, any known vision/ hearing deficits, ability to answer questions and follow instructions, additional neurologic or medical diagnoses, and if the child had an MRI in the past. For control children, a similar screening tool was used. The questions included: age, any medical or behavioral diagnosis, need for any additional assistance or support in school, and any deficits in hearing or vision (See addendum ). Prior to testing, informed consent was obtained from parents, along with verbal assent from the children in the study. HIPAA Authorization was obtained as well.

Data from our participants were combined with data from a previous study with the same inclusion/ exclusion criteria and that performed the same tests, to increase the number per group for the non-dominant hand only, with the exception of two-point discrimination due to differences in testing procedures.

3.4 Testing procedures

In a single day testing session, the following tests were administered to each subject to both hands: two-point discrimination, stereognosis of familiar objects using the Nottingham Test of Stereognosis, the Jebsen Taylor Test of Hand Function, Grip Strength (using Jamar Dynamometer), and the HASTE. Order was varied across subjects. Order
of hand testing was chosen randomly to avoid “learning” between hands, however, with stereognosis, the non-dominant hand was performed first, in case the subjects could recall the objects since the same objects were used for both hands.

- **Two-point discrimination** was administered using a DiskCriminator, to both the index finger and thumb for static testing only. The published protocol was used, with children needing to answer 2/3 correctly for a given distance to get credit for that distance.\(^{49}\) Score is the distance at which they correctly identified two points in at least 2/3 attempts.

- **Nottingham Method of Stereognosis** was administered using 10 objects (a comb, a paper clip, a pencil, a key, a sponge, a coin, a cup, a toothbrush, scissors, and a bottle of glue). Scoring is as follows: 2 points for a correct answer; 1 point for describing characteristics without naming, and 0 points for neither naming or describing the object.\(^{32}\)

- **The Jebsen Taylor Test of Hand Function** was assessed according to published procedures,\(^{39,46}\) with subjects assigned a score of 180 seconds if they were unable to complete the item in that time frame. Score recorded was the time required to complete each task.

- **Jamar Dynamometer** testing was administered with subjects seated and positioned with elbow in 90 deg of flexion and wrist between 0 and 30 degrees of flexion per protocol.\(^{47}\) Subjects were instructed to squeeze the dynamometer as hard as they could, with 3 trials per hand on left and right hands. Fifteen seconds were allowed between trials, and the average of the 3 trials was used for data analysis.\(^{47}\)
The Hand Active Sensation Test (HASTe) was administered using procedures as published in adult stroke literature and repeated in a Master’s thesis with children with hemiplegia. One hand at a time was used to manipulate 3 objects, all of the same shape and size with vision occluded by a curtain. The subject is given a target object that he or she matched to 1 of the 3 objects. The objects varied in either weight or texture, but not both. The weights are 6, 7, or 8 ounces. Textures mimic paper, plastic, and Styrofoam. All are shaped like a small juice can to be a functional shape/size for grasping.

3.5 Analyzing Data

Data were analyzed using SPSS. The following tests were utilized: 1) Cronbach’s Alpha / ICC for reliability of HASTe, 2) ROC curves for sensitivity and specificity of HASTe; 3) ANOVA for group differences, and 4) Spearman Correlations for comparison of sensory and motor tests. For t-tests, Levene’s Test was first run on data to determine equal or unequal variances, and then the correct output was used for analysis based on these results.
CHAPTER 4: MANUSCRIPT

4.1 Introduction

Cerebral Palsy is the leading cause of childhood disability.\textsuperscript{1,2} Of children with spastic cerebral palsy, approximately 29-31\% have hemiplegic cerebral palsy.\textsuperscript{2,3} Motor and sensory deficits are common on the paretic side in children with hemiplegic cerebral palsy, and the upper extremity is generally more involved than the lower extremity.\textsuperscript{2}

Although it is well known that there are both motor and sensory impairments associated with hemiplegic cerebral palsy on the paretic side, the prevalence of each varies between studies, with nearly all children showing a motor deficit, and 50-96\% of children showing a sensory deficit, depending on the study and testing procedures used.\textsuperscript{6,8,9,12,20} Sensory and motor function is very closely intertwined in the central nervous system.\textsuperscript{26} Sensory feedback contributes to the refining and learning of motor tasks.\textsuperscript{26} Motor and sensory tasks generally correlate with each other at a moderate rate, with stereognosis and two-point discrimination commonly showing a correlation with motor function.\textsuperscript{8,9,17,19}

More recently, some studies have also found a deficit in the non-paretic side in children with hemiplegic cerebral palsy, in up to approximately 50\% of children for sensory deficits,\textsuperscript{6-8,12} and up to 76\% of children with motor deficits.\textsuperscript{8,9} It has been noted that these deficits tend to be present in tasks involving more complex sensory
discrimination\textsuperscript{6,7,12} and motor tasks requiring more speed and coordination.\textsuperscript{8} It is unclear why there is a functional deficit on the non-paretic side. It has been hypothesized that a portion of children with hemiplegia may have a bilateral deficit in the brain, especially since there is noted variability in MRI reports among children with similar diagnoses.\textsuperscript{14,15} Another possibility is that children have deficits on tasks requiring more discrimination because these tasks have been shown to elicit a bilateral response on fMRI,\textsuperscript{26-28,33} and therefore may show bilateral hand deficit even with a unilateral lesion in the brain. When asked to determine distance, shape, or other discriminative properties of sensation, the frontal, parietal, and/or occipital lobes are active, with activation seen in both hemispheres.\textsuperscript{26,33} This study intends to explore this further.

Haptic exploration of texture and weight is something that has been explored in adults post-stroke\textsuperscript{25,29} but is not yet published in children with cerebral palsy. The Haptic Active Sensation Test (HASTe) is a test that was first developed to be a more precise measure of haptic hand function, following stroke.\textsuperscript{29} The test incorporates discrimination of weight and texture because of the influence these properties have on grip and lift function. The shape of the test objects was chosen to mimic a small juice container, a commonly lifted object in daily life, with objects varying in weight or texture, but not both. In adult stroke survivors, this test was found to have strong test-retest reliability (ICC= .77) and internal consistency (Cronbach coefficient alpha level = 0.82).\textsuperscript{29} This test was noted to be more sensitive for identifying sensory deficits than commonly used tests in adult stroke survivors. It was effective in discriminating between groups, with a cut-
off score of 13 established in adults. This test has not yet been published in children, but was piloted on children with hemiplegia in a master’s thesis.

In the current study, the HASTe was compared to commonly used sensory tests (two-point discrimination and stereognosis of familiar objects) to see if it is a more sensitive tool for identifying deficits in children than currently used tests. Test-re-test reliability was also explored. Data were combined with the previous study to increase statistical power.

In addition to the HASTe, this study further explored sensory and motor dysfunction in hemiplegic cerebral palsy on both the paretic and non-paretic hands, using two additional commonly used sensory tests: two-point discrimination and stereognosis using the Nottingham method. Strength, using a handheld dynamometer, and motor function, using the Jebsen Taylor test of motor function were also evaluated. Finally, MRI reports were explored, when available, to attempt to explain the relationship between non-paretic hand dysfunction and brain lesion location, as reported on an MRI.

4.2 Purpose

This study aims to: 1) complete the validation of the HASTe for use in children in conjunction with the previous master’s thesis; 2) extend the understanding of sensory and motor dysfunction in hemiplegic CP by characterizing the sensory and motor deficits in both hands; 3) examine the relationship between haptic sensation and motor dysfunction in hemiplegic CP; and 4) examine the relationship between neurological lesion (using previously performed MRI report) and impairment of the non-paretic hand.
4.3 Methods

Six subjects with hemiplegic cerebral palsy, and 6 age matched controls were recruited from a convenience sample. Researchers used contacts from pediatric physical therapy groups using fliers and e-mail. Inclusion criteria for the hemiplegic group were: 1) hemiplegia as a result of Infantile Hemiplegic Cerebral Palsy; 2) the ability to grasp/lift a small can unimanually and elevate the involved upper extremity above the shoulder, and 3) be able to follow verbal instructions. Subjects were excluded if they had an additional neurological diagnosis or uncontrolled seizure activity, or were unable to follow instructions or attend to testing. All children were able to walk independently and were in regular education classes.

An age-matched typically developing peer was recruited for each subject through a convenience sample. All were within 6 months of age of the “matched” child. Five of the six control subjects had no medical diagnosis. One subject did have a diagnosis of Attention Deficit Hyperactivity Disorder (ADHD), however with medication, is functioning at an age-appropriate level in school. All children were in regular education. The actual age range for subjects in the hemiplegic group: 8 years 3 months to 10 years 7 months (average age= 9.15 years). The actual age range for the control group is: 8 years 5 months to 10 years 2 months (average age= 9.25 years). This compares to the means from the previous study from which data will be used, with a mean of 8.13 years for the hemiplegic group, and 8.06 years for the control group.
Approval for this study was obtained from The Ohio State University Institutional Review Board.

**Testing Procedures**

In a single day testing session, the following tests were administered to each subject to both hands: two-point discrimination, stereognosis of familiar objects using the Nottingham Test of Stereognosis, the Jebsen Taylor Test of Hand Function; grip strength (using Jamar Dynamometer), and the HASTe. Order was varied across subjects. Order of hand testing was chosen randomly to avoid “learning” between hands; however, with stereognosis, the non-dominant hand was always performed first in case the subjects could recall the objects, since the same objects were used for both hands.

- **Two-point discrimination** was administered using a DiskCriminator, to both the index finger and thumb for static testing only. The published protocol was used, with children needing to answer 2/3 correctly for a given distance to get credit for that distance. Score is the distance at which a child correctly identified two points.

- **Nottingham Method of Stereognosis** was administered using 10 objects (a comb, a paper clip, a pencil, a key, a sponge, a coin, a cup, a toothbrush, scissors, and a bottle of glue). Scoring is as follows: 2 points for a correct answer; 1 point for describing characteristics without naming, and 0 points for neither naming or describing the object.

- **The Jebsen Taylor Test of Hand Function** was assessed according to published procedures, with subjects assigned a score of 180 seconds if they are unable to complete the item in that time frame. Items include: writing, flipping cards, picking up common
objects, simulated feeding, stacking 4 checkers, moving light objects (cans), and moving heavy objects (cans). Score recorded is time it takes to complete each task.

- **Jamar Dynamometer** testing was administered with subjects seated and positioned per protocol. Dynamometer was adjusted to fit their hand. Subjects were instructed to squeeze the dynamometer as hard as they could, with 3 trials on each hand. Fifteen seconds was allowed between trials, and the average of the 3 trials was used for data analysis.

- **The Hand Active Sensation Test (HASTe)** was administered using procedures as published in adult stroke literature and repeated in a Master’s thesis with children with hemiplegia. One hand at a time was used to manipulate a target object. They then were asked to hold 3 similar objects, all of the same shape and size with vision occluded. The subject was asked to match 1 of the 3 objects to the target object. The objects vary in either weight or texture, but not both. The weights are 6, 7, or 8 ounces. Textures mimic paper, plastic, and Styrofoam. All are shaped like a small juice can to be a functional shape/ size for grasping.

4.4 Data Analysis

Data were analyzed using SPSS. The following tests were utilized: 1) Cronbach’s Alpha / ICC for test-retest reliability of HASTe, 2) ROC curves for sensitivity and specificity of HASTe; 3) ANOVA for group differences, and 4) Spearman Correlations for comparison of sensory and motor tests. For t-tests, Levene’s Test was first run on data to determine equal or unequal variances, and then the correct output was
used for analysis based on these results. If $p < 0.05$, then equal variances were not assumed for the output of group analyses. If $p > 0.05$, then equal variances were assumed for t-test comparisons.

4.5 Results

This chapter contains results from the testing of subjects both with hemiplegia and an age-matched control group. The outcomes are presented in written and table format. The statistical analysis provides comparisons between the groups to determine if the research hypotheses can be accepted. Data for the non-dominant or paretic hand were combined and run with 6 additional subjects per group from a previous Master’s Thesis to increase statistical power, for a total of 12 subjects per group. It was determined using t-tests that there was no statistically significant difference between the group of 6 from this study, and the group from the previous study; therefore it was assumed that groups are similar enough to be combined for purposes of data analysis. Data were not available for the dominant (non-paretic) hand from the previous study, so that data included 6 subjects per group for the non-paretic hand. Two-point discrimination for the non-dominant hand is also reported with this study only, as the method for reporting two-point discrimination in the previous study differs from what was used in this study.

Group means and standard deviations are presented in Table 1 and t-test results are in Table 2 for the comparison of the hemiplegic paretic and non-dominant hand of the controls. Grip strength, the Jebsen-Taylor (both with and without writing), stereognosis of objects, and the HASTe all showed a statistically significant difference between
groups at p <0.05. Two-point discrimination with 6 per group reached statistical significance for the index finger, but not for the thumb at p<0.05.

Tables 3 and 4 show the data collected for the dominant/ non-paretic hand. The control group scored better than the group with hemiplegia as a group in every test with the exception of Two-Point Discrimination for the thumb; however, none of the tests reached statistical significance with this small sample size. It is noted that there is a large amount of variability in the scores for the hemiplegic group on all tests.

Correlations were run between all sensory and motor tests, using Spearman’s Rho, to analyze both the ordinal and nominal data collected. Table 5 shows correlational data for each area using the combined data (total n=24), with the exception of two-point discrimination data. Two point discrimination correlations can only be run with n=12, as data were not able to be combined with previous study due to reporting differences. Correlations were generally found at a moderate to high level between motor and sensory tests, with the exception of two-point discrimination of the thumb, which did not correlate with any other tests. Two-point discrimination of the index finger correlated moderately with strength (r=-0.724, p= 0.008), and stereognosis (r=-0.691, p=0.013). Stereognosis correlated significantly with strength, the Jebsen Taylor, two-point discrimination (index finger), and the HASTe. The HASTe was found to correlate at a moderate level with the Jebsen Taylor (without writing, r=-0.509), and Stereognosis (r=0.428). The HASTe did not correlate with two-point discrimination or strength.
Table 1

Means And Standard Deviations Paretic/ Non-Dominant Hand

<table>
<thead>
<tr>
<th></th>
<th>Hemiplegic Group</th>
<th>Control Group</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean (standard deviation)</td>
<td>Mean (standard deviation)</td>
</tr>
<tr>
<td><strong>Grip Strength (lbs)</strong> **</td>
<td>5.60 (5.85)****</td>
<td>22.20 (9.86)****</td>
</tr>
<tr>
<td><strong>Jebsen Taylor with writing (seconds)</strong></td>
<td>362.54 (231.95)**</td>
<td>133.23 (45.41)**</td>
</tr>
<tr>
<td><strong>Jebsen Taylor, writing omitted (seconds)</strong></td>
<td>245.37 (208.21)**</td>
<td>51.24 (24.83)**</td>
</tr>
<tr>
<td><strong>Stereognosis</strong></td>
<td>15.92 (3.42)**</td>
<td>19.42 (1.44)**</td>
</tr>
<tr>
<td><strong>Two Point Disc. Thumb</strong></td>
<td>3.50 (0.837)</td>
<td>2.67 (0.516)</td>
</tr>
<tr>
<td>(reported with 6 per group)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Two Point Disc. Index Finger</strong></td>
<td>2.83 (0.408)*</td>
<td>2.17 (0.408)*</td>
</tr>
<tr>
<td>(reported with 6 per group)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>HASTe</strong></td>
<td>9.00 (3.045)*</td>
<td>12.00 (2.66)*</td>
</tr>
</tbody>
</table>

**= p <0.01, *= p < 0.05

All data is reported with both studies, 12 children per group with the exception of two-point discrimination. Two point discrimination data is reported with 6 children per group.
Table 2

**Independent Samples t-Tests, Non-Dominant Hand**

<table>
<thead>
<tr>
<th></th>
<th>n= 24</th>
<th>t-test</th>
<th>Degrees of freedom (df)</th>
<th>Significance -2 tailed (p)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grip Strength</td>
<td>-5.015</td>
<td>17.894</td>
<td></td>
<td>0.00**</td>
</tr>
<tr>
<td>Jebsen Taylor (with writing)</td>
<td>3.361</td>
<td>11.842</td>
<td></td>
<td>0.006**</td>
</tr>
<tr>
<td>Jebsen Taylor (writing omitted)</td>
<td>3.207</td>
<td>11.313</td>
<td></td>
<td>0.008**</td>
</tr>
<tr>
<td>Stereognosis</td>
<td>-3.263</td>
<td>14.791</td>
<td></td>
<td>0.005**</td>
</tr>
<tr>
<td>Two Point Disc. – Thumb (n=12)</td>
<td>2.076</td>
<td>10</td>
<td></td>
<td>0.065</td>
</tr>
<tr>
<td>Two Point Disc. - Index Finger (n=12)</td>
<td>2.828</td>
<td>10</td>
<td></td>
<td>0.018*</td>
</tr>
<tr>
<td>HASTe</td>
<td>-2.569</td>
<td>22</td>
<td></td>
<td>0.018*</td>
</tr>
</tbody>
</table>

** = p <0.01, *= p < 0.05

All data is reported with both studies, 12 children per group with the exception of two-point discrimination. Two point discrimination data is reported with 6 children per group.
<table>
<thead>
<tr>
<th>n= 6 subjects per group</th>
<th>Hemiplegic Group</th>
<th>Control Group</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n= 6</td>
<td>n= 6</td>
</tr>
<tr>
<td></td>
<td><strong>Mean (standard deviation)</strong></td>
<td><strong>Mean (standard deviation)</strong></td>
</tr>
<tr>
<td>Grip Strength (lbs)</td>
<td>29.47 (12.71)</td>
<td>32.22 (5.87)</td>
</tr>
<tr>
<td>Jebsen Taylor, with</td>
<td>77.79 (24.20)</td>
<td>72.18 (16.92)</td>
</tr>
<tr>
<td>writing (seconds)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jebsen Taylor, writing</td>
<td>43.16 (16.96)</td>
<td>32.19 (1.90)</td>
</tr>
<tr>
<td>omitted (seconds)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stereognosis</td>
<td>19.83 (0.41)</td>
<td>20.00 (0.00)</td>
</tr>
<tr>
<td>Two Point Disc. –</td>
<td>2.67 (0.52)</td>
<td>3.00 (0.00)</td>
</tr>
<tr>
<td>Thumb</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Two Point Disc. Index</td>
<td>2.50 (0.55)</td>
<td>2.17 (0.41)</td>
</tr>
<tr>
<td>Finger</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HASTe</td>
<td>11.00 (2.10)</td>
<td>12.00 (2.76)</td>
</tr>
</tbody>
</table>

No differences between groups were statistically significant at p<0.05
Table 4

Independent Samples t-Tests For Dominant Hand

<table>
<thead>
<tr>
<th></th>
<th>t-test</th>
<th>Degrees of freedom (df)</th>
<th>Significance -2 tailed (p)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grip Strength</td>
<td>-0.482</td>
<td>10</td>
<td>0.640</td>
</tr>
<tr>
<td>Jebsen Taylor (with writing)</td>
<td>0.466</td>
<td>10</td>
<td>0.651</td>
</tr>
<tr>
<td>Jebsen Taylor (writing omitted)</td>
<td>1.574</td>
<td>5.126</td>
<td>0.175</td>
</tr>
<tr>
<td>Stereognosis</td>
<td>-1.000</td>
<td>5.00</td>
<td>0.363</td>
</tr>
<tr>
<td>Two Point Disc. – Thumb</td>
<td>-1.581</td>
<td>5.00</td>
<td>0.175</td>
</tr>
<tr>
<td>Two Point Disc. - Index Finger</td>
<td>1.195</td>
<td>10</td>
<td>0.260</td>
</tr>
<tr>
<td>HASTe</td>
<td>-0.707</td>
<td>10</td>
<td>0.496</td>
</tr>
</tbody>
</table>

No scores on the dominant hand reached statistical significance with group size of 6 at p<0.05
<table>
<thead>
<tr>
<th>n= 24</th>
<th>Grip Strength</th>
<th>Jebsen Taylor with writing</th>
<th>Jebsen Taylor, without writing</th>
<th>Stereognosis</th>
<th>HASTe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grip Strength</td>
<td>XX</td>
<td>-0.767**</td>
<td>-0.835**</td>
<td>0.540**</td>
<td>0.280</td>
</tr>
<tr>
<td>Jebsen Taylor, with writing</td>
<td>-0.767**</td>
<td>XX</td>
<td>0.910**</td>
<td>-0.733**</td>
<td>-0.346</td>
</tr>
<tr>
<td>Jebsen Taylor, writing omitted</td>
<td>-0.835**</td>
<td>0.910**</td>
<td>XX</td>
<td>-0.727**</td>
<td>-0.509*</td>
</tr>
<tr>
<td>Stereognosis</td>
<td>0.540**</td>
<td>-0.733**</td>
<td>-0.727**</td>
<td>XX</td>
<td>0.428*</td>
</tr>
<tr>
<td>HASTe</td>
<td>0.280</td>
<td>-0.346</td>
<td>-0.509*</td>
<td>0.428*</td>
<td>XX</td>
</tr>
</tbody>
</table>

** Indicates statistical significance at p<0.01; * Indicates statistical significance at p<0.05.

All data reported is with combined studies, n=24. Two point discrimination is not included in this chart, as data cannot be combined to have n=24. See below for two-point discrimination correlations.

Reliability and Validity of the HASTe

Test-Retest reliability for the HASTe was performed for the combined data, with good test-retest reliability (ICC 0.772). Internal consistency was good/excellent, with Cronbach’s Alpha score of 0.871. Sensitivity and specificity were run on the HASTe to determine a “cut off” score that best differentiates the two groups. A cut-off score of 12
(meaning 12 and above would be “normal”, and 11 and below would be “impaired”) gave the best combination of sensitivity and specificity, with a sensitivity of 0.833, and specificity of 0.583 using all subjects, test 1 only scores (See Table 6). Receiver Operating Characteristic (ROC) curves (Figure 1) were calculated using test and re-test data for both studies to assist in determining the effectiveness with which the HASTe separates subjects into the two groups,\textsuperscript{50} with area underneath the curve calculated at 0.788 (see Figure 1).\textsuperscript{51}

**Table 6**

### Sensitivity/ Specificity Of The HASTe

<table>
<thead>
<tr>
<th>Cutoff Score</th>
<th>Sensitivity</th>
<th>Specificity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Both groups, both tests</td>
<td>Both groups, test 1</td>
</tr>
<tr>
<td>9</td>
<td>0.474</td>
<td>0.417</td>
</tr>
<tr>
<td>10</td>
<td>0.579</td>
<td>0.583</td>
</tr>
<tr>
<td>11</td>
<td>0.789</td>
<td>0.750</td>
</tr>
<tr>
<td>12</td>
<td>0.895</td>
<td>0.833</td>
</tr>
<tr>
<td>13</td>
<td>0.895</td>
<td>0.833</td>
</tr>
<tr>
<td>14</td>
<td>0.895</td>
<td>0.833</td>
</tr>
</tbody>
</table>

Cutoff score of 12 divides the scores into <12 in the “impaired” group, 12 and over in the “typical” group.
Haste Receiver Operating Characteristic (ROC) Curves For All Subjects Test 1

Figure 1

Sensitivity = True Positive Rate

Specificity = False Positive Rate

Area: 0.788
MRI reports, if available, were obtained to explore the relationship between lesion location and results; however, MRIs were obtained for only 3 of the 6 subjects in the hemiplegic group (children 2, 4, and 6). The other 3 subjects either had not had an MRI, or the results were not available. On 2 of the MRI reports obtained, there is unilateral damage noted, on the contralateral side to their hemiparesis, at and around the periventricular white matter. No midline shift or deficit on the ipsilateral side to their weakness is noted.

In the third MRI, for child 6, a bilateral abnormality is noted, with increased T2 and FLAIR signal noted in the bilateral deep cerebral white matter along the centrum
semiovale in the parietal and occipital lobes related to a remote ischemic insult and areas of gliosis. This is more prominent on the right side compared to the left. This child has a diagnosis of left hemiplegia. This child was noted to have decreased scores on the dominant hand compared to the mean for strength (14.66 lbs, group mean = 29.47 lbs); the Jebsen-Taylor (99.12 seconds, group mean = 77.80 seconds); Stereognosis (score of 19/20; however, she was the only child to miss a point with the dominant hand); and on the HASTE, she scored a 10 with her dominant hand (group mean is 11), compared to a score of 11 with her paretic hand.

4.6 Discussion

The first purpose was to establish scoring criteria, as well as test-retest reliability for the HASTE. Test-retest reliability was found to be good/excellent, with Cronbach’s Alpha of 0.871, and ICC of .772 for single measures. This is comparable to what was found when this test was evaluated in adults, where the ICC was reported at 0.77. The cut-off score of 12 determined by ROC curves is lower than the score of 13 that was established in adults. This indicates that children may not have mature haptic sensation by elementary school. While other sensory tests (stereognosis; two-point discrimination) have indicated in the literature than children in this age range can score as well as adults, the HASTE does not appear to allow children to score the same as adults. This test does require much more discrimination between objects, including matching, and therefore likely requires activation of more areas of the brain than simple touch tests, or the ability to discriminate weight/texture may develop at a later age than object
identification or touch discrimination. Most studies found on the process used for haptic exploration of weight/texture has been in adults. One study involving integration of haptic exploration of size with visual information indicated that children did not test at adult levels until 8-10 years of age, and may indicate that some children in this age range have more mature haptic sensation than others. It was noted that all children indicated that they understood the testing, and appeared to be answering to the best of their ability on the tests. There was also good test-re-test reliability, indicating that each child did answer consistently. The HASTe shows more fluctuation in scoring in children with hemiplegia than was found for adults; however even in adults, it was noted that this test was very sensitive, and identified deficits even when more commonly used sensory tests were normal. When looking at individual scores for children, it was noted that children who scored higher on their initial test tended to also score higher on their dominant hand, and their re-test as well, and were outliers across all tests for their group. This is evidence that the test is assessing haptic sensation accurately, and that haptic sensation may actually have fluctuations even among normal subjects.

**Paretic Hand**

For the paretic hand, this study confirmed what many other studies have found: that there is consistent impairment in the paretic hand of children with hemiplegia compared to controls for both sensory and motor function. It is noted that 12/12 children scored below published norms for both grip strength and 11/12 on the Jebsen Taylor Test of Hand Function. The child that is reported as not being impaired on the Jebsen Taylor had “borderline” impairment, at approximately 2 SD’s from the mean; however,
the rest were even greater than 2 SD’s from the published means.\textsuperscript{47,39} Regarding sensory function, 9/12 children showed impairment on stereognosis testing (score of less than 20); and 2/6 children (reported on this study only) had a two point discrimination score over 3 mm. On the HASTe, using <12 as the cut-off, 10/12 children showed a deficit. All children tested showed a deficit in motor function. The child that scored “normally” on motor function had borderline levels of deficit, especially with regard to strength. Sensory deficit prevalence ranged from 33% to 83%. It is noted that the tests of sensory function requiring increased discrimination were more likely to show a deficit than two-point discrimination, again confirming the current literature.\textsuperscript{6,7,12,17}

**Non- paretic hand**

Results on the non-paretic hand did not reach statistical significance, with a limited number of subjects; however, a trend was noted that the mean scores of the control group were better than the hemiplegic group in every area (Grip Strength, Jebsen Taylor, Stereognosis, Two Point Discrimination of the Index Finger, and HASTe), with the exception of Two-Point Discrimination of the Thumb (see Table 3 for means of the dominant hand of both groups). When looking at the data for individual subjects for each test (presented in Table 7), it was noted that there was much more variability between scores for the hemiplegic group than for controls, with higher standard deviations for the hemiplegic group on nearly all tests. It was also noted that some subjects seemed to score similarly to controls, while others showed scores well below the mean of the control group (see Table 7 for individual scores for the non- paretic hand). With regard to
strength, three of the six children scored well below the mean of the control group. One child in the hemiplegic group scored well above the mean with his non-paretic hand, pulling the mean for the group higher than it would have otherwise been. Looking at the same information for the Jebsen Taylor, two of the six children had much higher times than the control group did (53 and 73 seconds without writing compared to a control group mean of 32 seconds), while the other four children scored at a similar level to the controls.

Similar differences are present, but not quite as obvious, in looking at sensory function. Only one child had impaired stereognosis, and no children had a two-point discrimination score over 3mm. Using the established cut-off score for the HASTe, five of the six children had impairment on the non-paretic hand. It should be noted that three of the six control children scored below a 12 as well. One child had impaired scores across the board on all tests except two-point discrimination (impairment in strength, the Jebsen Taylor, stereognosis, and the HASTe). One other child scored at an impaired level on strength, the Jebsen Taylor, and the HASTe (with normal scores on stereognosis and two-point discrimination). Even without reaching statistical significance, it appears that some children with hemiplegia trended toward an impairment in both motor and sensory function on the non-paretic hand compared to controls.
Table 7

<table>
<thead>
<tr>
<th></th>
<th>Grip Strength</th>
<th>Jebsen no writing</th>
<th>Two-Point Discrimination</th>
<th>Stereognosis</th>
<th>HASTe</th>
</tr>
</thead>
<tbody>
<tr>
<td>CONTROL (SD)</td>
<td>32.22 (5.87)</td>
<td>32.19 (1.90)</td>
<td>Th=3.00 (0.00)</td>
<td>20.00 (0.00)</td>
<td>12.00</td>
</tr>
<tr>
<td>GROUP MEAN (SD)</td>
<td></td>
<td></td>
<td>Ind=2.17 (0.41)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Child 1</td>
<td>20.5 lbs</td>
<td>35.19 sec</td>
<td>3/3</td>
<td>20</td>
<td>11</td>
</tr>
<tr>
<td>Child 2</td>
<td>32.33 lbs</td>
<td>30.6 sec</td>
<td>3/3</td>
<td>20</td>
<td>15</td>
</tr>
<tr>
<td>Child 3</td>
<td>24.33 lbs</td>
<td>53.72 sec</td>
<td>2/2</td>
<td>20</td>
<td>10</td>
</tr>
<tr>
<td>Child 4</td>
<td>50.67 lbs</td>
<td>31.3 sec</td>
<td>3/3</td>
<td>20</td>
<td>9</td>
</tr>
<tr>
<td>Child 5</td>
<td>34.33 lbs</td>
<td>35.02 sec</td>
<td>2/2</td>
<td>20</td>
<td>11</td>
</tr>
<tr>
<td>Child 6</td>
<td>14.67 lbs</td>
<td>73.13 sec</td>
<td>3/3</td>
<td>19</td>
<td>10</td>
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</table>

Correlations were run between all tests to further evaluate the relationship between motor and sensory function, especially to establish this relationship with the HASTe (see Table 5). The HASTe correlated at a moderate rate ($r=0.428$) with Stereognosis and the Jebsen Taylor test of motor function ($r=0.509$). The HASTe did not correlate at a significant level with grip strength or two-point discrimination. The HASTe does appear to be a valid method for assessing haptic sensation, as it correlated...
with stereognosis at a moderate rate. However, the fact that it does not correlate more highly suggests that the two tests are assessing different aspects of sensation. Two-point discrimination (index finger only) did correlate with stereognosis, but not with the HASTe. Two-point discrimination has been found to correlate with stereognosis in some studies,\textsuperscript{6,9} but not in others.\textsuperscript{17} It is noted that two-point discrimination is a less complex method of assessing sensation compared to the other sensory tests used, and that different areas of the brain are recruited for object recognition\textsuperscript{28} and matching tasks\textsuperscript{27} specifically. Therefore, it is worthwhile to assess sensation utilizing different methods rather than only one method exclusively, as different areas of the brain are involved depending on the type of sensation and amount of discrimination necessary.\textsuperscript{26,33}

The HASTe was found to correlate with both stereognosis, and hand function, using the Jebsen-Taylor, indicating that it is an effective tool for assessing the hand and information gained is unique compared to other available tests; thus it may be another key piece of the puzzle in regard to function.

MRI review showed two of the three children with available reports had unilateral damage on their MRI and showed normal scores on all tests with their non-paretic hand compared to controls with the exception of one of these children scoring a 9 on the HASTe. The third child had some bilateral abnormality on her MRI and showed scores below a normal range on the non-paretic hand for all motor and sensory tests with the exception of two-point discrimination. Since there were not MRI’s available for the other three children, these trends could not be confirmed for them. Yet, the question remains: why do some children demonstrate bilateral deficits and some don’t. While MRI is now
recommended for all children with cerebral palsy, children are still typically diagnosed based on clinical presentation and fit into a pre-existing framework that most closely resembles their symptoms. Therefore, MRI results can differ, even amongst children with a diagnosis of hemiplegic cerebral palsy. This is an area that researchers may wish to explore further with a larger sample size in the future.

4.7 Conclusions

Children with hemiplegic cerebral palsy have deficits in both motor and sensory function in the paretic hand. Some children appear to have a deficit in the non-paretic hand as well, while others do not. MRI analysis may explain a portion of this difference, and it is recommended that this be explored further with a larger population.

In the clinic setting, sensory function is often not assessed, and when it is, usually it involves only light touch. While this study did not assess light touch, our findings regarding two-point discrimination indicate that using only a perception method of assessing sensation may be inadequate, and miss a large percentage of children who may have sensation deficits in other areas. There are differences in the number of children showing deficits depending on the types of sensation tested, and therefore, it is worth not only assessing sensation, but assessing it using multiple methods (i.e. – Stereognosis and the HASTe). Given the relationship between stereognosis, the HASTe, and hand motor function, ignoring sensation in the clinical setting may ignore a key piece of the puzzle with regard to function. Sensory function is rarely addressed in a treatment plan or goals in a clinical setting, although feedback from the hand is recognized to play a part in
movement and developing motor patterns.\textsuperscript{10,26} It is recommended that sensory tests, especially those like the HASTe and stereognosis, be used in the clinic setting for evaluation of all children with hemiparesis, and addressed as part of a treatment plan for the paretic hand, as well as the non-paretic hand, in those with impairment.
CHAPTER 5: DISCUSSION

5.1 Review of Purpose

There were 4 primary purposes for this study. They were: 1) to establish the sensitivity and test-retest reliability of the HASTe in children with hemiplegic cerebral palsy, 2) to characterize the sensory function for this group of children with both the paretic and non-paretic hand, 3) to more thoroughly evaluate the relationship between sensory and motor function using a comprehensive set of measures, and 4) to compare MRI results when available with performance of the non-paretic hand.

5.2 Discussion of Results

The first purpose was to establish scoring criteria, as well as test-retest reliability for the HASTe. Test-retest reliability was found to be good/excellent, with Cronbach’s Alpha of 0.871, and ICC of .772 for single measures. This is comparable to what was found when this test was evaluated in adults, where the ICC was reported at 0.77.29

Validity of identifying differences between groups was also evaluated, with attempts made to establish what a “normal” score is for children. The HASTe score with the best accuracy for discriminating between the hemiplegic group and control group was 12. At this score, the sensitivity for all scores available (both studies, test1 only) was 0.833, and specificity was 0.583. Area under the ROC curve was 0.788, demonstrating a much better than chance difference between groups. The cut-off score between groups

62
with adult stroke survivors is higher, at 13. The sensitivity was reported for adults at
0.857 and specificity at 1 for this score using average of test 1 and test 2 scores.29

The HASTe shows more fluctuation in scoring in children with hemiplegia than
was found for adults;29 however even in adults, it was noted that this test was very
sensitive and identified deficits even when more commonly used sensory tests were
normal.29 When looking at individual scores for children, it was noted that children who
scored higher on their initial test tended to also score higher on their dominant hand, and
their re-test as well. For example, child 2 in the hemiplegic group had poor strength
scores (1 lb average); however, he had better sensation scores than the mean on all
sensory tests. He scored a 14 on the HASTE on his paretic hand and a 15 on his non-
paretic or dominant hand. He also scored a 19/20 on stereognosis on his paretic hand and
a 20/20 on his dominant hand, indicating good sensation despite a significant motor
deficit, which suggests that this was a pure motor deficit.

Not every child in the control group scored above the 12 cut-off. Of the twelve
children reported on, five of them scored below the cut-off of 12 on the non-dominant
hand. Of the six typically developing children tested by this researcher, only one child,
number 2 in the control group, scored below a 12 on all three tests issued to her. She
scored an 8 and a 10 in her two tests on her non-dominant hand, and scored a 10 on her
dominant hand, indicating that this child has relatively consistent (but low) scores for
texture and weight discrimination across all of her tests. All 3 of her scores would fall
into the impaired range for the cut-off score determined, yet she had normal functioning
of her hand and scored normally on two-point discrimination and stereognosis. It is not
known if her haptic sensation is not as mature yet as some other subjects, if she lacks the ability to detect texture and/or weight, or if she is simply an outlier. Age alone did not appear to be a factor, as this child was 9 years old; however, one study that evaluated the integration of haptic and visual information indicated that children may not perform higher level integration skills at adult levels until 8-10 years of age, so it is possible that children are still developing skills regarding haptic sensation and interpreting that information during the ages of inclusion in this study. It is noted that children did appear to understand the testing procedure with the HASTe at initial testing, as they did not improve their scores significantly from the initial test to the 2nd test (with the opposite hand) or the 3rd test (for those who did re-testing). Two other children did have an 8 or 9 on one of their scores, but did have at least one score above the cut-off.

The second purpose of this study was to characterize the sensory function for this group of children with both the paretic and non-paretic hand. For the non-dominant, or paretic hand, there was a statistically significant difference (p< 0.05) found between the groups for Grip Strength, The Jebsen-Taylor (both with and without writing), Stereognosis, and the HASTe when combined with the children from the previous study for 12 children per group. With the data from 12 children per group, this study confirmed what many other studies have found, that there is consistent impairment in the paretic hand of children with hemiplegia compared to controls for both sensory and motor function (See Table 8). Two-point discrimination was evaluated for the paretic hand with 6 children per group. It was found that there was a statistically significant difference
between the hemiplegic and control group in two-point discrimination of the index finger, but not for the thumb. It is noted that 12/12 children scored below published norms for grip strength; 47 and 11/12 tested below published norms on the Jebsen Taylor Test of Hand Function. 39 The child that tested comparably to control children had “borderline” scores, right at 2 standard deviations from the mean. Regarding sensory function, 9/12 children showed impairment on stereognosis testing (did not achieve a score of 20); and 2/6 children had a two-point discrimination over 3 mm. On the HASTe, using <12 as the cut-off, 10/12 children had a deficit. All children showed motor deficit. Prevalence of sensory deficit ranged from 33% to 83% in a single test. It is noted that the tests of sensory function requiring increased discrimination were more likely to show a deficit than two-point discrimination, again confirming the current literature. 6,7,12,17 These results generally confirm the current literature, which shows that a high number of children with hemiplegia have a deficit in sensation and nearly all have a deficit in motor function compared to controls. 6,8,9,17,18 With regard to sensory function, different children showed deficits on different tests, indicating that the sensory tests provide different information from each other (i.e. touch vs. discriminative properties).
Table 8

<table>
<thead>
<tr>
<th></th>
<th>Strength</th>
<th>Jebsen Taylor, no writing</th>
<th>Stereognosis</th>
<th>Two point Disc.</th>
<th>HASTe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paretic Hand</td>
<td>12/12</td>
<td>11/12</td>
<td>9/12</td>
<td>2/6</td>
<td>10/12</td>
</tr>
</tbody>
</table>

For the dominant, or non-paretic hand, no tests reached a statistically significant difference between the 2 groups. This data included 6 subjects per group, as the previous study did not test the dominant or non-paretic hand. There was, however, a trend noted when looking at the means of the control group scoring better than the hemiplegic group in every area (Grip Strength, Jebsen Taylor, Stereognosis, Two Point Discrimination of the Index Finger, and HASTe), with the exception of Two-point Discrimination of the Thumb, which were comparable (2.67 mm for the hemiplegic group compared to 3 mm for controls). See Table 3 for means of the dominant hand of both groups. Research findings are mixed regarding the prevalence of sensory impairment; however 2 of the larger studies that were found (n=50 and n=52 in the hemiplegic groups) found impairment at a statistically significant level in both touch and discriminative sensation. However, findings regarding the percentage of children with these deficits and the type of deficit found vary. When data for individual subjects for each test were examined, greater variability between scores for the hemiplegic group than for controls was
observed, with higher standard deviations for the hemiplegic group on nearly all tests. It was also noted that some subjects seemed to score similar to controls, while others showed scores well below the mean of the control group. With regard to strength, three of the six children scored well below the mean of the control group. Conversely, one child in the hemiplegic group scored well above the mean with his non-paretic hand, pulling the mean for the group higher than it would have otherwise been. Looking at the same information for the Jebsen Taylor, two of the six children had much higher times than the control group did (53 and 73 seconds without writing compared to a control group mean of 32 seconds), while the other four children scored at comparable level to the controls. The two children with longer scores on the Jebsen Taylor also had impaired strength on the non-dominant hand.

The differences are even less clear with sensory function for the non-paretic hand. Only one child had impaired stereognosis, and no children had a deficit in two-point discrimination, using 3mm as a cut-off score. Using 12 and above as a “normal” score, five of the six children had impairment on the HASTe (however, three of the control group children tested below a 12 as well). Notably, of those with non-paretic hand impairment, one child had an impaired score on strength, the Jebsen Taylor, stereognosis, and the HASTe while another scored at an impaired level on strength, the Jebsen Taylor, and the HASTe (with normal scores on stereognosis and two-point discrimination). Even without reaching statistical significance, it appears that children with hemiplegia trended toward an impairment in both motor function and strength compared to controls. These individual analyses illustrate that some, but not all, children with hemiplegia appear to
have a deficit on the non-paretic hand. Findings from larger studies report normal sensory functioning in approximately half of the children tested.\textsuperscript{6,8} It is recommended that when evaluating children with hemiplegia in a clinical setting that sensory, as well as motor function, be assessed in both hands and that a comprehensive treatment plan be developed to address all deficits that may be limiting function.

The third purpose of this study was to more thoroughly evaluate the relationship between sensory and motor function. The correlations found between all tests are presented in Table 5 (with the exception of two-point discrimination). See Chapter 4 narrative for reporting of two-point discrimination correlations. Motor function was evaluated both with Grip strength and Jebsen Taylor test of hand function (with and without writing), and were correlated with each other at a very high rate, as expected, since they are both assessing an aspect of motor function of the hand. This shows that children with deficits in strength also tended to have deficits in the speed and coordination required for the Jebsen Taylor.

The HASTe correlated at a moderate rate ($r=0.428$) with Stereognosis; however, it did not correlate with two-point discrimination of either the thumb or index finger. The HASTe does appear to be a valid method for assessing haptic sensation, as it correlated with stereognosis at a moderate rate. However, the fact that it does not correlate more highly tells us that the two tests are assessing different aspects of sensation and that each may provide different information. Two-point discrimination of the index finger only correlated with stereognosis at a moderate rate. Two-point discrimination has been found to correlate with stereognosis in some studies\textsuperscript{6,9} but not in others.\textsuperscript{17} Only 2/6 children in
the hemiplegic group scored below 3mm with the thumb, and no children did with the index finger. Yet, children who tested normally on two-point discrimination showed deficits on the other tests used. It is noted that two-point discrimination requires very little discrimination compared to the other sensory tests used, and that different areas of the brain are recruited for object recognition and matching tasks specifically. Therefore, it is worthwhile to assess sensation using different methods rather than only one method exclusively, as different areas of the brain are involved, depending on the type of sensation and amount of discrimination necessary.

Sensory and motor tests were found to correlate with each other at a moderate to high rate, when looking at the HASTe and stereognosis. Two-point discrimination of the thumb did not correlate with any other tests. However, two point discrimination of the index finger did correlate with strength, but not with the Jebsen Taylor. In the literature, two-point is reported to correlate at a substantial rate with certain motor tests in some studies, however, not with all tests of motor function. In Gordon and Duff 1999, two-point discrimination correlated with pinch strength only but did not correlate with manual dexterity. In contrast to two-point discrimination, in this study, the HASTe correlated with the Jebsen Taylor at a substantial rate (r=0.509), however, did not correlate at a significant level with grip strength. The HASTe correlation with the Jebsen Taylor indicates that haptic sensation is related to hand function. Stereognosis correlated with both grip strength and the Jebsen Taylor test of hand function at a moderate and very high rate, respectively. This is consistent with findings from most previous studies for the relationship of stereognosis with motor function. The HASTe was found to correlate
with both sensation, using stereognosis, and hand function, using the Jebsen-Taylor, indicating that it is an effective tool for assessing the hand and information gained is unique compared to other available tests; thus, it may be another piece of the puzzle in regard to function.

The final purpose of this study was to compare MRI results when available with performance of the non-paretic hand. Three of the six children in this study had MRI’s that were available to the researcher. Two of those children showed unilateral damage on the contralateral side to their hemiparesis, primarily at and around the periventricular white matter. The third child was found to have some bilateral abnormalities; however, there was more damage on the contralateral side to her hemiparesis. The 2 children with unilateral damage on their MRI’s showed normal scores on all tests with their non-paretic hand compared to controls with the exception of one of these children scoring a 9 on the HASTe. The child who had some bilateral deficit on her MRI showed scores below the normal range on the dominant hand for all motor and sensory tests with the exception of two-point discrimination. Since MRI’s were not available for the other three children, these trends could not be confirmed for them. However, this does make for an interesting discussion of why some children may show deficits on the dominant hand and some may not. While MRI is now recommended for all children with cerebral palsy,¹⁶ children are still typically diagnosed based on clinical presentation and fit into a pre-existing framework that most closely resembles their symptoms.¹⁴,34,35 This is an area that researchers may wish to explore further with a larger sample size in the future. However, it is also important that therapists examine the function of both hands in children with
hemiplegia so that an appropriate treatment program can be developed to treat impairments of both hands.

5.3 Limitations

The primary and most obvious limitation of this study was the small sample size of hemiplegic subjects. This was remedied in part by combining paretic hand data with data from the same tests with same inclusion/exclusion criteria from a previous study. However, this data was not available for the dominant hand, as this was added to be unique to this study. Therefore, while some trends were noted for the dominant hand scores, none of the group differences for the dominant hand reached statistical significance. Along with a small sample size, in order to make sure that all children could understand the testing and complete it appropriately, the criteria for this study were very specific, and limited to children only with mild hemiplegia and needing no supports in school. This is not necessarily typical of all children with hemiplegic cerebral palsy.

Another limitation of this study was that the sample recruited was a convenience sample of children recommended by therapists in the area. This generally meant that all of the children who participated in this study were known to or currently seeing physical therapists in their area. This may have resulted in a unique population from the general population of children with hemiplegia, as many children with hemiplegia are not still in therapy at elementary school age. It also may have limited recruitment of children with hemiplegia, as those who are not in the therapy community were excluded unintentionally. All subjects who participated were 8, 9, or 10 years old, despite the age
range being 6-10 years of age. Having no 6 or 7 year olds may cause issues in two areas. First of all, the data may differ from the previous master’s thesis, as there were no younger subjects in this study. To evaluate this as a possible limitation, t-tests were run to see if the groups from this study and the previous master’s thesis were statistically “different” or “the same”. T-tests did not reach statistical significant differences between groups, indicating that the data are similar to each other. Therefore, we did combine them into one larger group, assuming based on t-test results, that groups are the similar to each other. Also, even though the intent was to be able to generalize results to elementary school age children, only children in the upper age range of this group participated, therefore limiting the ability to generalize results to the intended age group.

The same therapist/researcher performed all data collection, and was not blinded as to group. Therefore, there could be an unintentional bias in testing. Also, participation criteria were evaluated per parent report, based on a phone conversation with the researcher. Children were included based on parent report that they were in regular education and had no other medical diagnoses. There was no follow up to confirm accuracy. One control group child did have ADHD, and was on medication. He was allowed to participate, as he was able to meet the inclusion criteria of being able to attend to testing, and having no neurologic diagnosis. He did complete all testing without difficulty, and even had the highest scores of the control group on the HASTe, however it is not known what affect his diagnosis or medication may have had on the testing.

Another limitation related to data analysis is the limited number of MRI’s that were available to the researcher (3/6). When looking at the dominant/non-paretic hand
especially, it was noted that there were some trends in certain children showing deficits in sensation/motor function, while others tested at or very near the mean of the control groups or published norms. One child, who showed deficits on the non-paretic hand, did have an MRI report indicating some bilateral damage, although significantly greater on the contralateral side to her paretic hand. The other child that consistently showed deficits on her non-paretic hand did not have an MRI available for comparison. The 2 other children that had MRI’s that indicated only unilateral damage on the report showed a deficit only on the HASTe, but on no other tests with their non-paretic hand. Again, this may be due to different areas of activation in the brain for haptic sensation, and specifically for matching tasks, compared to other types of sensation.\textsuperscript{27,28} This information was interesting, however due to the limited number of MRI’s obtained, no consistent trend was found.

5.4 Implications

This study confirmed results found in other studies that children with hemiplegia have deficits in their paretic hand in both movement and sensation compared to controls,\textsuperscript{6,7,9} with motor deficits in 100\% of children in this study, and sensory deficit on at least one test in 83\% of children without the HASTe, and 92\% with the HASTe. With a group size of 12, all motor and sensory tests administered, reached statistical significance using a \textit{p} value of <0.05. With a group size of 6, two point discrimination of the index finger, but not the thumb, reached statistical significance using a \textit{p} value of <0.05. There was not a statistically significant difference between the control and
hemiplegic groups in the dominant/ non-paretic hands; however, there were some
differences, especially when looking at individual scores rather than group means. This
fits with the mixed results presented in previous studies,\textsuperscript{6,7,9,12} and leads this researcher to
believe that there are some children with deficits in their non-paretic hand, while others
do not have deficits.

Establishing the reliability and validity of the HASTe in children was a primary
purpose of this study. The HASTe was shown to be a reliable (ICC= 0.77 for single
measures), and have good internal consistency (Cronbach’s Alpha= 0.871) with children,
as was previously shown with adults.\textsuperscript{29} The HASTe was correlated with stereognosis at a
moderate rate, indicating both that the HASTe does have concurrent validity with other
tests using in-hand manipulation to assess sensation, but also since it is only at a
moderate rate, that the HASTe may give some information regarding sensation of the
hand that is not available in other studies. There was fluctuation in scores both amongst
hemiplegic children and controls, however, children who tended to score higher on the
HASTe tended to do so for all testing sessions completed, and those who tested lower
also tended to test lower on all testing sessions. The HASTe was found in adults to
assess sensation along more of a continuum than other sensory tests, allowing for
fluctuation even amongst normal subjects.\textsuperscript{29} It also did this for children. Although the
cut-off score between groups was not quite as clear-cut for children as it was for adults,
the HASTe did show that a score of 12 can be considered “normal” in children, with a
sensitivity of 0.833 and a specificity of 0.583, and area under the receiver operating
characteristic curve (ROC) of .788. This indicates some overlap between groups in
scores, primarily with scores of 8, 9, and 10 having overlap between the 2 groups. Since the majority of children are in the same age range, but at a still relatively young age, it may be that children’s haptic sensation develops at a different rate, and some children have developed this skill faster than others. Researching this in a larger group so that scores can evaluated for an age effect and test what age haptic sensation appears to be mature in children is recommended. Overall, however, the HASTE was able to be performed in children ages 8-10, both with and without hemiplegia, and provided information regarding sensation that was both along a continuum, and not necessarily reflected in other sensory measures used.

5.5 Recommendations for Future Research

From this study, it seems beneficial to continue to explore: 1) the HASTE in typical children on a larger scale to further evaluate the best cut-off score, if an age-effect is present, and at what age haptic texture/weight discrimination appears to be mature; 2) the occurrence of deficit in the non-paretic hand of children on a larger scale with both motor and sensory tests; and 3) MRI lesion analysis to determine what percentage of children do have deficits on their dominant side, and if this relates consistently to MRI results.

The HASTE was shown to be a reliable and valid tool for assessing children, however, with some overlap noted between the groups. It is hypothesized that there may be some children who have a more mature sensory system with regard to haptic sensation than others at this age range. It was noted in the previous study, using the HASTE in
children, that haptic sensation did not appear to be mature by 10 years of age. However, it is not known at what age it is mature, especially with regards to weight and texture. Many motor tests report different “norms” for hand speed/coordination and strength for different ages even into the teenage years.39,47 Less is known regarding haptic sensation maturity, so further research is needed.

The second area needing further exploration is the prevalence and cause of deficits on the non-paretic hand of children with hemiplegia. It has been demonstrated in a variety of studies6-9,12 that there is a percentage of children with deficits in their dominant, or non-paretic hand. Based on the results of this study, it is felt that there are deficits in a percentage of children, but others have normal functioning of the hand, even when looking at a variety of different methods of testing. Group analysis is not effective at identifying these on a small scale, as the differences are smaller and may not be present in all (or even necessarily a majority) of children in the group. Due to the lower percentage of children with deficits, in order to find differences between groups for the dominant hand, a study needs to plan to utilize a larger sample size.

The third area which requires further exploration is comparison of MRI reports to non-paretic hand deficits. There were some interesting findings in this study, however nothing was able to be linked consistently due to the insufficient number of subjects and MRI reports. Follow up to this preliminary data is recommended to complete this comparison between brain lesion type/location and non-paretic hand deficit in sensorimotor function on a larger scale.
This study was able to demonstrate that using the HASTe in children can be an effective tool, providing information regarding sensation along a continuum that is not necessarily available with other tests. It also was able to serve as a pilot study for building some interesting areas for discussion regarding the dominant/ non-paretic hand and MRI comparison to deficits. Hopefully these areas will continue to be explored, using this information to help build future research questions.
REFERENCES


APPENDIX A

INTAKE QUESTIONNAIRE
Intake Questionnaire
(To be completed by phone with parent)

Child’s Name:______________________  Child’s DOB/ Age:____________________

Parent’s Name:_______________________  Contact Phone for Parent:_______________

- How old is your child?____________________
- What is your child’s primary medical diagnosis?

- When did your child’s injury occur (if known)?
- Is your child in mainstreamed classes in school?
  If so, do they need any additional help from an aide or other person in the classroom to complete their school work?

- Can your child follow verbal directions and answer questions like other children their age?

- Does your child have any deficits in vision or hearing?

- Does your child have any other neurologic or medical diagnosis such as Autism, Down syndrome, ADHD, etc?

- Has your child had an MRI of their brain?

Appointment time/ place:_______________________________
APPENDIX B

PARENT RECRUITMENT LETTER
Hello!

My name is Stephanie Taranto. I am working on my thesis requirement for a Master of Science Degree in Physical Therapy at The Ohio State University with my advisor, Deborah Larsen, PhD. I am also employed by Children’s Rehab Center as a physical therapist.

I am looking for children to participate in my research study. The study will look at children ages 6-10 years old with congenital hemiplegia and age-matched peers without hemiplegia. The children in this study will complete a variety of tests to assess the motor and sensory function of both hands, including strength, coordination/speed, touch (one vs. two points), identifying different objects with hands only without using vision, and matching a small can that is exactly the same as the target object. I will also be requesting a copy of your child’s most recent MRI if they have had one. Testing will take about 1.5 hours. A small sample of children will be asked to complete a second testing session within a week after the first.

I will evaluate the child at Children’s Rehab Center in Howland, or at their home school if approved by administration, or at your home.

The criteria for participation include:

- 6-10 years old
- Diagnosis of Hemiplegia (one side of the body affected)
- Generally in good health with no other diagnoses
- In regular education classes in school

Your child’s participation in this study is completely voluntary. Your decision will not affect your current or future relationship with The Ohio State University or Children’s Rehab Center. All personal information and individual data/test results will be confidential.

I would be glad to answer any questions you may have. If you have questions or are interested in enrolling your child in this study, please contact me.

Thank you!

Stephanie Taranto, PT
372 S. Briarcliff Drive
Canfield, OH 44406
614-440-0409
Stephanie.taranto42@gmail.com
APPENDIX C

THERAPIST RECRUITMENT LETTER
Re: Reliability and validity of the HASTe as a tool to assess sensation bilaterally in children with hemiplegia

Hello. My name is Stephanie Taranto, and I am currently working on my Master’s thesis at The Ohio State University under Dr. Deborah Larsen. I am also a member of the pediatric physical therapy group in the area, and work at Children’s Rehab Center. I am looking for participants for my research project, and I was hoping that you could help.

To complete this project, I need to recruit up to 20 subjects with congenital hemiplegia (one sided weakness as a result of an injury occurring prior to, during, or immediately after birth) and 20 age matched peers, age 6-10 years of age. The children will complete 2 motor tests and 3 sensory tests with both hands as part of the testing: Strength using a dynamometer; coordination/ speed using the Jebsen Taylor Test of Motor Function; Two-point discrimination; Stereognosis (identifying different familiar objects); and the HASTe (Haptic Active Sensation Test), a newer test that has children “match” an object to a target object based on either weight or texture. I will also try to obtain a copy of their MRI if they have one. Criteria are as follows:

- 6-10 years old
- Hemiplegic Cerebral Palsy
- Regular education (normal cognition)
- No other diagnoses
- I will also need 20 age matched peers, so if you have or know of typically developing children in this age range, please pass this information along to them as well.

If you have children on your caseload or that you know that may be interested in this study, I am hoping that you will talk to their parent or guardian to see if they would be willing to participate in this study. If you have a child in mind, you can refer them for participation by:

1. Give the parent my contact information or the attached parent flyer so that they can contact me to have their child participate.

Thank you for your help on this matter to allow me to complete my thesis! Please feel free to contact me with any questions.

Contact information:

Stephanie Taranto, PT
372 S. Briarcliff Drive
Canfield, OH 44406
Stephanie.taranto42@gmail.com
614-440-0409
APPENDIX D

AUTHORIZATION TO USE PERSONAL HEALTH INFORMATION IN RESEARCH
Title of the Study: Reliability and validity of the HASTe as a tool to assess sensation bilaterally in children with hemiplegia

OSU Protocol Number: 2012H0041

Principal Investigator: Deborah S. Larsen, PT, PhD

Subject Name__________________________________________________________

Before researchers use or share any health information about you as part of this study, The Ohio State University is required to obtain your authorization. This helps explain to you how this information will be used or shared with others involved in the study.

- The Ohio State University and its hospitals, clinics, health-care providers and researchers are required to protect the privacy of your health information.
- You should have received a Notice of Privacy Practices when you received health care services here. If not, let us know and a copy will be given to you. Please carefully review this information. Ask if you have any questions or do not understand any parts of this notice.
- If you agree to take part in this study your health information will be used and shared with others involved in this study. Also, any new health information about you that comes from tests or other parts of this study will be shared with those involved in this study.
- Health information about you that will be used or shared with others involved in this study may include your research record and any health care records at the Ohio State University. For example, this may include your medical records, x-ray or laboratory results. Psychotherapy notes in your health records (if any) will not, however, be shared or used. Use of these notes requires a separate, signed authorization.

Please read the information carefully before signing this form. Please ask if you have any questions about this authorization, the University’s Notice of Privacy Practices or the study before signing this form.

Initials/Date: _______________

Page 1 of 3
Those Who May Use, Share And Receive Your Information As Part Of This Study

• Researchers and staff at The Ohio State University will use, share and receive your personal health information for this research study. Authorized Ohio State University staff not involved in the study may be aware that you are participating in a research study and have access to your information. If this study is related to your medical care, your study-related information may be placed in your permanent hospital, clinic or physician’s office records.

• Those who oversee the study will have access to your information, including:
  - Members and staff of the Ohio State University’s Institutional Review Boards, including the Western Institutional Review Board
  - The Office for Responsible Research Practices
  - University data safety monitoring committees
  - The Ohio State University Research Foundation

• Your health information may also be shared with federal and state agencies that have oversight of the study or to whom access is required under the law. These may include:
  - The Food and Drug Administration
  - The Office for Human Research Protections
  - The National Institutes of Health
  - The Ohio Department of Human Services

These researchers, companies and/or organization(s) outside of The Ohio State University may also use, share and receive your health information in connection with this study:

• Health care facilities, research site(s), researchers, health care providers, or study monitors involved in this study: School of Health and Rehabilitation Sciences, Stephanie Taranto, PT

The information that is shared with those listed above may no longer be protected by federal privacy rules.

Authorization Period

This authorization will not expire unless you change your mind and revoke it in writing. There is no set date at which your information will be destroyed or no longer used. This is because the information used and created during the study may be analyzed for many years, and it is not possible to know when this will be complete.

Signing the Authorization

• You have the right to refuse to sign this authorization. Your health care outside of the study, payment for your health care, and your health care benefits will not be affected if you choose not to sign this form.

You will not be able to take part in this study and will not receive any study treatments if you do not sign this form.

Initials/Date________
• If you sign this authorization, you may change your mind at any time. Researchers may continue to use information collected up until the time that you formally changed your mind. If you change your mind, your authorization must be revoked in writing. To revoke your authorization, please write to:

Deborah S. Larsen, PhD
453 W. 10th Ave.
Columbus, OH 43210

or HIPAA Privacy Manager, The Ohio State University Medical Center, 140 Doan Hall, 410 W. Tenth Ave., Columbus, OH 43210.

• Signing this authorization also means that you will not be able to see or copy your study-related information until the study is completed. This includes any portion of your medical records that describes study treatment.

Contacts for Questions

• If you have any questions relating to your privacy rights, please contact HIPAA Privacy Manager, The Ohio State University Medical Center, 140 Doan Hall, 410 W. 10th Ave., Columbus, OH 43210 (Phone: 614-293-4477).

• If you have any questions relating to the research, please contact Deborah S. Larsen, 106 Atwell Hall, 453 W. 10th Ave., Columbus, OH 43210 (Phone: 614-292-5645).

Signature

I have read (or someone has read to me) this form and have been able to ask questions. All of my questions about this form have been answered to my satisfaction. By signing below, I permit Deborah Larsen and the others listed on this form to use and share my personal health information for this study. I will be given a copy of this signed form.

Signature________________________________________________________
(Subject or Legally Authorized Representative)

Name _____________________________________________________________
(Print name above)
(If legal representative, also print relationship to subject.)

Date___________ Time __________ AM / PM
Study Title: Reliability and validity of the HASTe as a tool to assess sensation bilaterally in children with hemiplegia

Principal Investigator: Deborah S Larsen, PhD, PT

Sponsor: School of Health and Rehabilitation Sciences, The Ohio State University

- This is a parental permission form for research participation. It contains important information about this study and what to expect if you permit your child to participate. Please consider the information carefully. Feel free to discuss the study with your friends and family and to ask questions before making your decision whether or not to permit your child to participate.

- Your child’s participation is voluntary. You or your child may refuse participation in this study. If your child takes part in the study, you or your child may decide to leave the study at any time. No matter what decision you make, there will be no penalty to your child and neither you nor your child will lose any of your usual benefits. Your decision will not affect your future relationship with The Ohio State University, or with your current therapist. If you or your child is a student or employee at Ohio State, your decision will not affect your grades or employment status.

- Your child may or may not benefit as a result of participating in this study. Also, as explained below, your child’s participation may result in unintended or harmful effects for him or her that may be minor or may be serious depending on the nature of the research.

- You and your child will be provided with any new information that develops during the study that may affect your decision whether or not to continue to participate. If you permit your child to participate, you will be asked to sign this form and will receive a copy of the form. You are being asked to consider permitting your child to participate in this study for the reasons explained below.

1. Why is this study being done?
This study is being done in order to assess the movement and sensation ability in both hands of children with hemiplegia as a result of cerebral palsy. The results of this testing will be used to 1) determine if a new test better characterizes sensory ability than commonly used tests; 2) to evaluate sensory and motor ability of children with hemiplegia compared to children without hemiplegia; 3) to compare sensory function to motor function to see what kind of impact sensory loss has on movement of the hand, and 4) to compare a picture of your child’s brain called an MRI (Magnetic Resonance Imaging), if your child has had one, to results of testing. An MRI is a scan of the brain that a doctor may have ordered in the past. If your child has not had a brain MRI, this will not be required for participation in this study. This study will help us get a better picture of the sensory and motor function of children with hemiplegia.

2. How many people will take part in this study?

40 children will participate in this study, 20 with hemiplegia, and 20 without hemiplegia.

3. What will happen if my child takes part in this study?

If your child participates in the study and has hemiplegia, you will first be asked to fill out a questionnaire about their diagnosis, any other medical conditions or diagnoses that they have, which hand they use to write with, and the supports they need in school (to help assess their ability to follow directions and concentrate for the duration of the study).

If your child participates in this study and does not have hemiplegia, you will be asked if your child has any medical or behavioral diagnosis, or needs any supports in school in order to determine eligibility for this study. You will be asked which hand your child writes with.

If you choose to move forward, and your child fits the criteria for the study (for either the group with or without hemiplegia), they will then be scheduled for a testing session of approximately 90 minutes in length. At that testing session, your child will complete the following tests with both hands:

1) HASTe (Haptic Active Sensation Test) – during this test, your child will be given a “target” object and then asked to choose from 3 different objects, one of which is the same as the “target” object using only the hand being tested; vision of the objects will be blocked by a curtain. The child’s goal is to match either the weight or texture of the “target object” to one of the 3 objects to the target object. The objects are all the same size and shape (like a small juice can).

2) The Jebsen-Taylor Test of Motor Function- This test assesses motor coordination and speed. All items are timed, and if the child cannot complete the item within 180 seconds, the testing is stopped and 181 is recorded. The items for this test are: 1) Writing (omitted for 6 year olds), 2) flipping over 3x5 cards, 3) Picking up
small common objects and placing them in a container, 4) simulated feeding by picking objects up on a spoon and placing them in a container, 5) stacking checkers, 6) picking up large light objects (empty 1 pound coffee cans), and 7) picking up large heavy objects (full 1 pound coffee cans).

3) Dynamometry – This is a test of grip strength. Your child will be asked to squeeze a metal “handle” device called a dynamometer as hard as they can while keeping their arm still and in a certain position 3 times with each hand. When the child squeezes this device, it will record how hard they are able to squeeze, and this will determine how much grip strength they have in the hand being tested. The average of the 3 scores will be recorded.

4) Two-point discrimination- This is a test of sensation. Your child will be asked to identify if there is 1 or two points touching their skin without using their vision, using one point and different widths between the two points to determine what distance apart the points have to be for them to identify 2 touches rather than 1.

5) Stereognosis- This is a sensation test in which your child will be asked to identify common objects using 1 hand (will be done with one hand, then the other hand). They will not be allowed to look during testing. There will be 6 familiar objects for the child to identify. They will have 15 seconds to explore and name the object, and a 30 second break before the next object is presented.

Most children will receive only 1 testing session. If your child becomes fatigued, they can complete the remaining tests after a break or in a second testing session. Some children will be asked to complete a second testing session of 30 minutes using the HASTe only to establish how well the test can obtain consistent scores on the same child in a different testing session (with a short period of time in between to minimize the risk of actual changes in the child’s function). This is known as the “reliability” of the test.

4. How long will my child be in the study?

There will be 1 or 2 testing sessions. The second testing session will be scheduled within 1 week after the first testing session. There is no long-term follow up needed after these testing sessions.

5. Can my child stop being in the study?

Your child may leave the study at any time. If you or your child decides to stop participation in the study, there will be no penalty and neither you nor your child will lose any benefits to which you are otherwise entitled. Your decision will not affect your future relationship with The Ohio State University.

6. What risks, side effects or discomforts can my child expect from being in the study?
The risks to your child are minimal, and involve mainly fatigue or frustration involved with the items they are being asked to perform. Your child will be monitored, and if they are becoming too frustrated or tired, they will be allowed breaks. If your child is unable to complete the testing, they have the option of completing it in another session. You may withdraw your child from the study at any time. Information may be discovered regarding your child’s motor or sensory function that you were not aware of previously. This information will be given to you after the testing.

7. What benefits can my child expect from being in the study?

The benefits to your child directly are minimal, and include gaining information about their motor and sensory function that is more detailed than what is usually performed as part of a typical physical or occupational therapy evaluation. If desired, you may have this information after the testing.

8. What other choices does my child have if he/she does not take part in the study?

You or your child may choose not to participate without penalty or loss of benefits to which you are otherwise entitled.

9. Will my child’s study-related information be kept private?

Efforts will be made to keep your child’s study-related information confidential. However, there may be circumstances where this information must be released. For example, personal information regarding your child’s participation in this study may be disclosed if required by state law.

Also, your child’s records may be reviewed by the following groups (as applicable to the research):

- Office for Human Research Protections or other federal, state, or international regulatory agencies;
- U.S. Food and Drug Administration;
- The Ohio State University Institutional Review Board or Office of Responsible Research Practices;
- The sponsor supporting the study, their agents or study monitors; and
- Your insurance company (if charges are billed to insurance).
If this study is related to your child’s medical care, your child’s study-related information may be placed in their permanent hospital, clinic, or physician’s office records. Authorized Ohio State University staff not involved in the study may be aware that your child is participating in a research study and have access to your child’s information.

You may also be asked to sign a separate Health Insurance Portability and Accountability Act (HIPAA) research authorization form if the study involves the use of your child’s protected health information.

10. What are the costs of taking part in this study?

There are no costs to taking part in this study, other than getting transportation to the testing session if necessary. Attempts will be made to schedule testing conveniently for you.

11. Will I or my child be paid for taking part in this study?

By law, payments to subjects are considered taxable income. There is no payment available for participation in this study.

12. What happens if my child is injured because he/she took part in this study?

If your child suffers an injury from participating in this study, you should notify the researcher immediately, who will determine if your child should obtain medical treatment at The Ohio State University Medical Center or a hospital of your choice.

The cost for this treatment will be billed to you or your medical or hospital insurance. The Ohio State University has no funds set aside for the payment of health care expenses for this study.

13. What are my child’s rights if he/she takes part in this study?

If you and your child choose to participate in the study, you may discontinue participation at any time without penalty or loss of benefits. By signing this form,
you do not give up any personal legal rights your child may have as a participant in this study.

You and your child will be provided with any new information that develops during the course of the research that may affect your decision whether or not to continue participation in the study.

You or your child may refuse to participate in this study without penalty or loss of benefits to which you are otherwise entitled.

An Institutional Review Board responsible for human subjects research at The Ohio State University reviewed this research project and found it to be acceptable, according to applicable state and federal regulations and University policies designed to protect the rights and welfare of participants in research.

14. Who can answer my questions about the study?

For questions, concerns, or complaints about the study you may contact
Stephanie Taranto, PT at 614-440-0409, or Deborah Larsen, PhD, PT at 614-292-5645.

For questions about your child’s rights as a participant in this study or to discuss other study-related concerns or complaints with someone who is not part of the research team, you may contact Ms. Sandra Meadows in the Office of Responsible Research Practices at 1-800-678-6251.

If your child is injured as a result of participating in this study or for questions about a study-related injury, you may contact Deborah Larsen, PhD at 614-292-5645.
Signing the parental permission form

I have read (or someone has read to me) this form and I am aware that I am being asked to provide permission for my child to participate in a research study. I have had the opportunity to ask questions and have had them answered to my satisfaction. I voluntarily agree to permit my child to participate in this study.

I am not giving up any legal rights by signing this form. I will be given a copy of this form.

Printed name of subject

Printed name of person authorized to provide permission for subject

Signature of person authorized to provide permission for subject

Relationship to the subject

Date and time

AM/PM

Investigator/Research Staff

I have explained the research to the participant or his/her representative before requesting the signature(s) above. There are no blanks in this document. A copy of this form has been given to the participant or his/her representative.

Printed name of person obtaining consent

Signature of person obtaining consent

Date and time

AM/PM

Witness(es) - May be left blank if not required by the IRB

Printed name of witness

Signature of witness

Date and time

AM/PM

Printed name of witness

Signature of witness

Date and time

AM/PM
APPENDIX F

TESTING DATA FORM
Reliability and Validity of the HASTE as a tool to assess sensation bilaterally in children with hemiplegia

Testing Data Form

<table>
<thead>
<tr>
<th>Name:</th>
<th>Today’s Date:</th>
<th>Date of Birth:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (Yr, M, Day):</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group (Exp or Control):</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hemiplegic Hand: Left Right N/A</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dominant Hand: Left Right</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gender: M F</td>
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<td></td>
</tr>
</tbody>
</table>

Has Child had an MRI? Yes No
Control Group (N/A) (skip to testing)
What was the date of the child’s most recent MRI?
What Dr./ Facility should we contact for a copy?

Dynamometry:
RIGHT HAND

<table>
<thead>
<tr>
<th>Trial 1</th>
<th>Trial 2</th>
<th>Trial 3</th>
<th>Average of 3</th>
</tr>
</thead>
</table>

LEFT HAND

<table>
<thead>
<tr>
<th>Trial 1</th>
<th>Trial 2</th>
<th>Trial 3</th>
<th>Average of 3</th>
</tr>
</thead>
</table>

Jebsen Taylor Test of Motor Function (time in seconds, maximum of 180)

<table>
<thead>
<tr>
<th>Test Item</th>
<th>Right Hand Time (Max 180)</th>
<th>Left Hand Time (Max 180)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Writing (age 7 and older)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flipping over cards</td>
<td></td>
<td></td>
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<tr>
<td>Common Objects</td>
<td></td>
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<tr>
<td>Simulated feeding</td>
<td></td>
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<tr>
<td>Checkers</td>
<td></td>
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<tr>
<td>Light objects</td>
<td></td>
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<tr>
<td>Heavy objects</td>
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<tr>
<td>TOTAL TIME</td>
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</tbody>
</table>

Stereognosis (Score of 0, can’t identify object, can’t name object; Score of 1, Identify properties of object, but cannot name object; Score of 2, Names object)

<table>
<thead>
<tr>
<th>Item Tested</th>
<th>Order</th>
<th>Right Hand Score</th>
<th>Left Hand Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Comb</td>
<td></td>
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<tr>
<td>Paperclip</td>
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<tr>
<td>Pencil</td>
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<td>Key</td>
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<td>Sponge</td>
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<tr>
<td>Coin</td>
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<td>Cup</td>
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<tr>
<td>Toothbrush</td>
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<tr>
<td>Scissors</td>
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<tr>
<td>Glue Bottle</td>
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<td>TOTAL</td>
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Two-Point Discrimination (Thumb tested first, start at 6 mm, and go up/down depending on if they answer right or wrong. Score recorded is the closest distance at which they identified 2 points correctly 2/3x)

<table>
<thead>
<tr>
<th>RIGHT</th>
<th>Thumb</th>
<th>LEFT</th>
<th>Index finger</th>
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</thead>
<tbody>
<tr>
<td>Thumb</td>
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<tr>
<td>Index finger</td>
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</table>

HASTe

<table>
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<th>RIGHT HAND</th>
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TOTAL CORRECT:_______  TOTAL CORRECT:_______

Testing session 2:
ONLY COMPLETE THE COLUMN FOR THE NON-DOMINANT OR HEMIPARETIC HAND

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<th>RIGHT HAND</th>
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**TOTAL CORRECT:**_________ **TOTAL CORRECT:**_________
The Ohio State University  
School of Allied Medical Professions  

Stephanie Taranto, PT

Re: ____________________________
Date: __________________________

Dr. ____________________________.

I am requesting a copy of the most recent MRI report for ____________________________.
DOB __________. This information is being requested to complete a portion of my Master
of Science thesis in Physical Therapy, under the supervision of Deborah S. Larsen, PhD,
Director of the School of Allied Medical Professions at The Ohio State University. My
study includes the comparison of MRI results to performance on motor and sensory tests
with the paretic and non-paretic hands of children diagnosed with hemiplegia. This
request has been approved by the parent, both with the signing of their consent form for
this study, and their signature below.

Please fax or email a copy of this report to:

Stephanie Taranto, PT
372 S. Briarcliff Drive
Canfield, OH 44406
Stephanie.taranto42@gmail.com
Fax: 330-856-2107, Attn: Stephanie Taranto

Thank you for your time,

Stephanie R. Taranto, PT

Signature  Date

I approve the release of the most recent MRI report for the above named child. I am
the parent or legal guardian of this child, and have given my permission for this portion
of my child’s medical information to be released to Stephanie R. Taranto, PT for the
purpose of this study.
APPENDIX H

INDIVIDUAL SCORES FOR THE PARETIC HAND
Table 9

**Individual Scores for the Paretic Hand**

<table>
<thead>
<tr>
<th></th>
<th>Grip Strength (lbs)</th>
<th>Jebsen Taylor without Writing (sec)</th>
<th>Two-Point Discrimination Thumb/ Index</th>
<th>Stereognosis</th>
<th>HASTe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Child 1</td>
<td>19.17</td>
<td>57.14</td>
<td>3/3</td>
<td>20</td>
<td>7</td>
</tr>
<tr>
<td>Child 2</td>
<td>1.00</td>
<td>107.14</td>
<td>3/3</td>
<td>19</td>
<td>14</td>
</tr>
<tr>
<td>Child 3</td>
<td>5.33</td>
<td>164.05</td>
<td>5/3</td>
<td>14</td>
<td>9</td>
</tr>
<tr>
<td>Child 4</td>
<td>3.33</td>
<td>222.80</td>
<td>3/3</td>
<td>17</td>
<td>10</td>
</tr>
<tr>
<td>Child 5</td>
<td>3.67</td>
<td>92.88</td>
<td>4/2</td>
<td>20</td>
<td>10</td>
</tr>
<tr>
<td>Child 6</td>
<td>2.67</td>
<td>602.32</td>
<td>3/3</td>
<td>14</td>
<td>11</td>
</tr>
</tbody>
</table>

*Raw scores are presented for the paretic hand of each child for those tested as part of this Master’s Thesis only.*
APPENDIX I

MOTOR/ SENSORY MEANS AND STANDARD DEVIATIONS NON-DOMINANT/PARETIC HAND, THIS STUDY ONLY
Table 10

Motor/ Sensory Means and Standard Deviations Non-Dominant/Paretic Hand, This Study Only

<table>
<thead>
<tr>
<th>n= 6 subjects per group</th>
<th>Hemiplegic Group</th>
<th>Control Group</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean (standard deviation)</td>
<td>Mean (standard deviation)</td>
</tr>
<tr>
<td>Grip Strength (lbs) **</td>
<td>5.86 (6.67) **</td>
<td>29.72(6.26)**</td>
</tr>
<tr>
<td>Jebsen Taylor with writing (seconds)</td>
<td>308.59 (243.07)</td>
<td>112.45 (31.07)</td>
</tr>
<tr>
<td>Jebsen Taylor, writing omitted (seconds)</td>
<td>207.72 (201.90)</td>
<td>36.26 (2.82)</td>
</tr>
<tr>
<td>Stereognosis</td>
<td>17.33 (2.81)</td>
<td>20.00 (0.00)</td>
</tr>
<tr>
<td>Two Point Disc. Thumb</td>
<td>3.50 (0.837)</td>
<td>2.67 (0.516)</td>
</tr>
<tr>
<td>Two Point Disc. Index Finger-*</td>
<td>2.83 (0.408)*</td>
<td>2.17 (0.408)*</td>
</tr>
<tr>
<td>HASTe</td>
<td>10.17 (2.32)</td>
<td>12.50 (3.15)</td>
</tr>
</tbody>
</table>

**= p <0.01, *= p< 0.05
APPENDIX J

INDEPENDENT SAMPLES T-TEST FOR NON-DOMINANT HAND
Table 11

Independent Samples t-Test for Non-Dominant Hand

<table>
<thead>
<tr>
<th>n= 6 per group</th>
<th>t-test</th>
<th>Degrees of freedom (df)</th>
<th>Significance -2 tailed (p)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grip Strength</td>
<td>-6.392**</td>
<td>10</td>
<td>0.001**</td>
</tr>
<tr>
<td>Jebsen Taylor (with writing)</td>
<td>1.961</td>
<td>10</td>
<td>0.078</td>
</tr>
<tr>
<td>Jebsen Taylor (writing omitted)</td>
<td>2.080</td>
<td>5.002</td>
<td>0.092</td>
</tr>
<tr>
<td>Stereognosis</td>
<td>-2.329</td>
<td>5</td>
<td>0.067</td>
</tr>
<tr>
<td>Two Point Disc. – Thumb</td>
<td>2.076</td>
<td>10</td>
<td>0.065</td>
</tr>
<tr>
<td>Two Point Disc. - Index Finger</td>
<td>2.828*</td>
<td>10</td>
<td>0.018*</td>
</tr>
<tr>
<td>HASTe</td>
<td>-1.463</td>
<td>10</td>
<td>0.174</td>
</tr>
</tbody>
</table>

**= p <0.01, *= p< 0.05
APPENDIX K

CORRELATIONS FOR NON-DOMINANT HAND, n=12
Table 12

**Correlations for Non-Dominant Hand, n=12**

Spearman’s Rho

<table>
<thead>
<tr>
<th>n= 12</th>
<th>Grip Strength</th>
<th>Jebsen Taylor with writing</th>
<th>Jebsen Taylor, writing omitted</th>
<th>Stereognosis</th>
<th>Two-Point Discrimination, Thumb</th>
<th>Two-Point Discrimination, Index finger</th>
<th>HASTe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grip Strength</td>
<td>XX</td>
<td>-0.650* (p=0.22)</td>
<td>-0.720** (p=0.008)</td>
<td>-0.717** (p=0.009)</td>
<td>-0.496 (p=0.101)</td>
<td>-0.724** (p=0.008)</td>
<td>0.240 (p=0.452)</td>
</tr>
<tr>
<td>Jebsen Taylor, with writing</td>
<td>-0.650* (p=0.022)</td>
<td>XX (p=0.000)</td>
<td>0.937** (p=0.001)</td>
<td>-0.826** (p=0.001)</td>
<td>0.259 (p=0.417)</td>
<td>0.386 (p=0.215)</td>
<td>-0.120 (p=0.710)</td>
</tr>
<tr>
<td>Jebsen Taylor, no writing</td>
<td>-0.720** (p=0.008)</td>
<td>0.937** (p=0.001)</td>
<td>XX (p=0.001)</td>
<td>-0.826** (p=0.001)</td>
<td>0.300 (p=0.343)</td>
<td>0.531 (p=0.076)</td>
<td>-0.223 (p=0.487)</td>
</tr>
<tr>
<td>Stereognosis</td>
<td>0.717** (p=0.009)</td>
<td>-0.826** (p=0.001)</td>
<td>-0.826** (p=0.001)</td>
<td>XX (p=0.019)</td>
<td>-0.383 (p=0.219)</td>
<td>-0.691* (p=0.013)</td>
<td>0.095 (p=0.769)</td>
</tr>
<tr>
<td>Two Point Disc. – Thumb</td>
<td>-0.496 (p=0.101)</td>
<td>0.259 (p=0.417)</td>
<td>0.300 (p=0.343)</td>
<td>-0.383 (p=0.219)</td>
<td>XX (p=0.316)</td>
<td>0.317 (p=0.316)</td>
<td>-0.198 (p=0.537)</td>
</tr>
<tr>
<td>Two Point Disc. – Index Finger</td>
<td>-0.724** (p=0.008)</td>
<td>0.386 (p=0.215)</td>
<td>0.531 (p=0.076)</td>
<td>-0.691* (p=0.013)</td>
<td>0.317 (p=0.316)</td>
<td>XX (p=0.316)</td>
<td>-0.195 (p=0.543)</td>
</tr>
<tr>
<td>HASTe</td>
<td>0.240 (p=0.452)</td>
<td>-0.120 (p=0.710)</td>
<td>-0.223 (p=0.487)</td>
<td>0.095 (p=0.769)</td>
<td>-0.198 (p=0.537)</td>
<td>-0.195 (p=0.543)</td>
<td>XX</td>
</tr>
</tbody>
</table>

Correlation data and p value for subjects tested as part of this study only, 6 subjects per group on the non-dominant hand.