Haptic Discrimination, Manual Dexterity and Academic Achievement in Nondisabled Preterm Children at School Age

THESIS

Presented in Partial Fulfillment of the Requirements for the Degree Master of Science in the Graduate School of The Ohio State University

By

Delphina J Christopher

Graduate Program in Allied Medical Professions

The Ohio State University

2010

Master's Examination Committee:

Deborah S Larsen, Advisor

Jill Heathcock

Jane Case-Smith
Abstract

Preterm (PT) children are at risk for sensorimotor impairments at school age, however little has been done with sensory discrimination in PT school aged children. **AIM:** To assess and compare haptic discrimination, manual dexterity and academic achievement in nondisabled PT and full term (FT) children. **METHODS:** Thirty-seven participants, 12 PT (6 males, 6 females, mean GA 32 weeks, mean age: 9.6 years); 25 FT (13 males, 12 females, mean age 9.9), assessed with 1) Hand Active Sensation Test (HASTe) for texture and weight discrimination, 2) Haptic Object Recognition Test (HORT) for shape discrimination, and 3) Nine-Hole Peg (NHP) for manual dexterity. The Ohio Achievement Test (OAT) reading and math scores were used to gauge academic achievement. **RESULTS:** Full term children had significantly higher mean HASTe accuracy scores \(p = .012\) and higher mean OAT reading scores \(p =0.041\); math scores approached significance \(p = .070\). No significant group differences for the HORT accuracy scores \(p = 0.158\) or NHP time scores \(p = 0.145\).**INTERPRETATION:** Nondisabled PT children did not perform as well as FT peers in haptic discrimination or reading achievement. The HASTe was able to discriminate between nondisabled preterm and full term children
Dedication

This document is dedicated to my family and friends who supported and encouraged me toward my goal of a master’s degree.
Acknowledgments

I would like to thank Dr. Deborah S. Larsen for her professional expertise and guidance. I truly appreciated her patience, support and encouragement all throughout the pursuit of my master’s degree and especially during the thesis process. I would also like to thank Dr. Jane Case-Smith and Dr. Jill Heathcock for their service, time and expertise as my thesis committee, and lastly, to Dr. Susan White for her assistance with my statistical analysis.
Vita

August 25, 1959……………………………………………………..born Southington, CT

June 1977……………………………………………………Southington High School, CT

May 1981…………………………………………………..B. S. in Physical Therapy, Quinnipiac University, CT

1981-1987……………………………………………………Physical therapist, Gaylord Hospital, CT

1993-1994 ___________________________Physical therapist, Mt. Carmel/Walnut Hills, OH

1994-2001………………Physical therapist, long term care and sub-acute rehabilitation, OH

2001-present…………….. Physical therapist, Columbus City Schools, Columbus, OH

2004- 2010….The Ohio State University Master of Science in Allied Medical Professions

…………………………..Advanced Clinical Practice in Neurologic Pediatric Rehabilitation

Member: ………………. Central Ohio Pediatric Physical Therapy Study Group

Member: ……………………………American Physical Therapy Association

…………………………………………….National & Ohio Chapters & Pediatric Section

Fields of Study

Major Field:  Allied Medical Professions
Table of Contents

Abstract ........................................................................................................ ii
Dedication ........................................................................................................ iii
Acknowledgments........................................................................................ iv
Vita...................................................................................................................... v
List of Tables ................................................................................................ viii
List of Figures ................................................................................................ ix
Appendix .......................................................................................................... x

CHAPTER 1: INTRODUCTION ........................................................................... 1
  Background of the Problem ................................................................. 1
  Significance of Problem ...................................................................... 2
  Problem Statement ................................................................................. 4
  Purpose of the Study .............................................................................. 5
  Research Questions and Hypothesis .................................................. 6
  Assumptions and Limitations .............................................................. 7

CHAPTER 2: LITERATURE REVIEW .............................................................. 9
  Normal sensorimotor control ............................................................. 9
  Sensorimotor impairments associated with preterm birth ................. 12
  Confounding variables of sensorimotor development ....................... 16
  Neuroanatomical Differences in the Preterm Brain ......................... 17
  Sensory, Motor and Cognitive Assessments ........................................ 19
    Motor Tests ........................................................................................ 19
    Sensory Tests .................................................................................... 22
    School Age Cognitive Testing .......................................................... 23

CHAPTER 3: METHODOLOGY ........................................................................ 26
  Research Design .................................................................................... 26
  Population and Sample Design ............................................................ 26
Instrumentation ......................................................................................................................... 27
Data Analysis ............................................................................................................................... 30
Summary ........................................................................................................................................ 31

CHAPTER 4: ARTICLE ................................................................................................................. 32
Abstract ......................................................................................................................................... 32
Introduction ................................................................................................................................. 33
Methods ......................................................................................................................................... 35
Participants ..................................................................................................................................... 35
Instrumentation ............................................................................................................................ 35
Statistical Methods and Results ................................................................................................. 36
Discussion ....................................................................................................................................... 38
Limitations ....................................................................................................................................... 43
Clinical Significance ...................................................................................................................... 44
Article References ......................................................................................................................... 52

CHAPTER 5: SUMMARY and CONCLUSIONS ........................................................................... 55
REFERENCES ................................................................................................................................. 61
List of Tables

Table 1. Descriptive Statistics of Groups ................................................................. 45
Table 2: Group Mean Statistics .................................................................................. 46
Table 3: Independent Samples T-Test ......................................................................... 47
Table 4: Pearson Product Moment Correlations ......................................................... 48
Table 5: Pearson Product Moment Correlations, Full Term ...................................... 49
Table 6: Pearson Product Moment Correlations, Preterm ......................................... 50
List of Figures

Figure 1: Test Instruments ........................................................................................................ 51
Appendix

Appendix A: Approval Letters, Recruitment, and Testing Materials…………………..68
CHAPTER 1: INTRODUCTION

Background of the Problem

Preterm births have increased by 30% since 1980. Each year approximately 500,000 children are born preterm at < 37 weeks gestation, and nearly two-thirds are born late preterm, between 32 and 36 weeks gestation. More preterm children are surviving, including those born at < 26 weeks and weighing < 1000 grams (2.2 pounds), thanks to improvements in neonatal medicine.

All preterm children are at a greater risk for neurodevelopmental impairments. The severity of their impairments vary and is often related to biological factors such as birth weight, gestational age and postnatal growth as well as environmental factors such as gender and socioeconomic status. Definitive outcomes are somewhat difficult to establish due to a variety of methodological problems. However, the general consensus is that severe disabilities such as cerebral palsy, significant developmental delay, hearing loss, and blindness occur in 10 to 20% of preterm children and are apparent within the first two years of life. Mild impairments noted prior to school age occur in 20 to 40% of PT children, and 40 to 60% of all preterm children are considered typically developing (nondisabled) at school age.
Significance of Problem

Follow up studies of the nondisabled into school age and beyond have become more common in the past decade. Multiple studies have discovered emerging developmental impairments in nondisabled preterm children with normal intelligence.\(^4\), \(^6\). \(^8\)\(^-\)\(^{15}\) It is not clear whether these problems reflect a maturational lag or a permanent disability.\(^4\) The spectrum of problems seen in these nondisabled preterm children are similar to those seen in the general population however the incidence is higher; 30-50\% of preterm children demonstrate impairments in two or more developmental domains versus 5-10\% of full term children.\(^7\), \(^9\), \(^{16}\)

Impairments have been found in multiple domains including: cognitive, motor, visual, perceptual, language, and behavior. Sensorimotor, visual motor and visual perceptual skills are commonly cited areas of concern. Sensorimotor and visual spatial impairments have been associated with cognitive impairments and academic difficulties.\(^9\), \(^{16}\) These children are also at greater risk for both specific and non-verbal learning disabilities\(^4\), motor coordination disorders\(^{16}\), attention deficit hyperactivity disorder\(^{11}\), and reduced academic achievement.\(^7\)\(^-\)\(^{16}\) Follow up of all preterm children, using a variety of developmental assessments, is recommended due to the heterogeneous presentation of impairments.\(^4\), \(^5\), \(^7\)\(^-\)\(^{13}\)

The assessment of haptic touch, as it relates to perceptual motor, visual motor and cognitive development, has largely been ignored in the preterm population. Haptic touch, also known as active touch, involves both cutaneous and kinesthetic exploration of the
world through touch and object manipulation. It is the primary way infants learn about the world around them and is considered the basic foundation for the organization and development of other perceptual systems. Infant development is a dynamic process that occurs in a multisensory environment. The dynamic processes that govern perceptual motor, visual motor, and cognitive development are interrelated throughout the developmental process. Selective attention and motivation toward perceptual motor experiences facilitate cognitive developments such as categorization, concept formation and language.

The neural foundations of the tactile sensory system, including haptic touch, are the first to be developed in utero and the most mature of the senses at birth. Preterm children are especially at risk for tactile sensory dysfunction for several reasons. As infants, preterm children have different initial experiences with active and passive touch in their first few months of life. They typically experience less qualitative touch that is considered positive and nurturing, and more harsh and painful touch that may be considered over stimulating and stressful. They may also have an altered responsiveness to touch, either a hyper or hypo-responsiveness, which can lead to difficulties with attachment to caregivers, and difficulties with oral or manual acquisition of sensory input. These factors may have long lasting effects into childhood.

From a neurological standpoint, central somatosensory structures, such as the dorsal medial lemniscal column and the somatosensory cortex, have higher metabolic demands and are more susceptible to hypoxic-ischemic insults, which are common in the preterm infant. Functional imaging studies of the preterm brain at birth and later in
childhood reveal persistent reduced volumes in multiple brain regions, including key cortical and sub-cortical somatosensory regions.\textsuperscript{26}

In summary, preterm children, including those who are considered to be typically developing, are at risk for multiple developmental impairments. The tactile sensory system of preterm children is especially vulnerable to dysfunction due to a number of biological and environmental reasons. Haptic touch is a developmental area that has largely been ignored in preterm population.

**Problem Statement**

Haptic touch may be impaired in non-disabled preterm children.\textsuperscript{19, 25} School aged children with impaired haptic touch may have subsequent perceptual motor impairments such as reduced manual dexterity.\textsuperscript{17, 18} Manual dexterity is needed for many activities of daily living at home and in school. Children with sensorimotor impairments are also more likely to have difficulty with academic achievement.\textsuperscript{4, 9-16} It is important to assess sensory function, especially haptic touch, in the preterm population and to understand its role in manual dexterity and academic achievement.
Purpose of the Study

The purpose of this study is to determine whether nondisabled preterm children 1) have impairments in haptic touch, specifically weight, texture and shape discrimination 2) have impairments with manual dexterity, and 3) have lower academic achievement in math or reading, when compared with their full term, non-disabled peers. It also seeks to determine 4) whether there is an association between haptic touch and manual dexterity, and 5) whether there is an association between haptic touch, manual dexterity and academic performance.

This study is unique in several aspects. First, it seeks to study only nondisabled preterm children with normal intelligence. The participation criteria will require subjects to be in good health and enrolled in regular education full time. Second, it seeks to determine if there are hidden sensory impairments in this population. Third, it seeks to determine if an association exists between sensory, motor, and/or academic achievement in this population.

For this study, haptic function will be measured using two new assessments 1) the Hand Active Sensation Test (HASTe) and 2) the Haptic Object Recognition Test (HORT). The HASTe involves intra-modal matching (haptic-haptic) of objects for weight and texture. The HORT involves inter-modal matching (vision-haptic) of objects for shape. Both assessments have demonstrated reliability and validity in identifying sensory impairment and for supporting the sensorimotor relationship.
Manual dexterity will be measured using the Nine-hole Peg Test (NHP). The NHP is a standardized, timed assessment of manual dexterity for adults and children. Academic achievement will be measured using the Ohio Achievement Test (OAT). It is a test that is linearly aligned with Ohio’s academic content standards for grade and subject. It will be used to correlate academic achievement with haptic function and manual dexterity.

**Research Questions and Hypothesis**

1) Do preterm children differ from term children in accuracy scores involving haptic function?
2) Do preterm and term children differ in time scores for manual dexterity?
3) What is the relationship between haptic function, manual dexterity and academic achievement in the preterm or term group?
4) Do gender, socioeconomic status, or gestational age, influence manual dexterity, haptic function, or academic achievement in preterm or term children?

My hypotheses are that preterm children when compared to their term peers will have:

5) Lower mean accuracy scores on haptic assessments.
6) Higher mean time scores for manual dexterity.

It is also hypothesized that there will be a:

- Positive relationship between haptic function and manual dexterity
• Positive relationship between haptic function, manual dexterity and academic performance

• Positive relationship between female gender, higher socioeconomic level, and haptic function and manual dexterity.

**Assumptions and Limitations**

Assumptions include:

1) Preterm children enrolled in regular education classes, who are not receiving special education services, are considered to have normal intelligence scores and will be considered nondisabled.

2) The majority of children in the 3\textsuperscript{rd} grade are 9 years old, children in the 4\textsuperscript{th} grade are 10 years old, and children in the 5\textsuperscript{th} grade are 11 years old.

3) The Haptic Object Recognition Test is an appropriate and discriminative test of haptic function in children age 9 to 11.

Possible limitations include:

1) Attempts to control confounding variables will include the selection of similar characteristics for each group including: gender, age, and socioeconomic level, as all have been implicated in developmental performance.

2) Dependence on voluntary enrollment of subjects may result in fewer available subjects for participation and lower than expected group sizes. Attempts to control for this include: recruitment letters will be sent home to approximately
800 students in the 3rd through 5th grades in four Columbus City Elementary Schools.

3) Failure of parents to comply with requested demographic information may result in incomplete background data. Follow up with repeated requests, including explanations of the importance of complete information, will be used to obtain complete records for all participants.
CHAPTER 2: LITERATURE REVIEW

Normal sensorimotor control

The sensory system provides us with vital information about our body and its’ relationship to the world around us. In this section, we will focus on the sensation of touch that occurs with the hairless skin of the hand. The sensation of touch is the result of stimulation to a variety of highly specific mechanoreceptors located at various depths within our skin. There are approximately 17,000 tactile receptor units in the hand. Normal sensation in our hands is the result of the combined activity of four different types of mechanoreceptors. Receptor units can be either slow adapting with small receptive fields (Merkel cells), slow adapting with large receptive fields (Ruffini endings), fast adapting with small receptor fields (Meissner corpuscles), or fast adapting with large receptive fields (Pacinian corpuscles). Small receptive fields are used for sensing low frequency vibration, course textures, and patterns and shapes. Large receptive fields are responsible for high frequency vibration detection, fine texture perception, finger position, and the direction and force of object motion. There are also thermoreceptors that provide sensory information regarding warmth and cold.

Stimulation of distal mechanoreceptors results in activation of afferent primary sensory nerves that travel from the site of stimulation to the dorsal root ganglion in the
spinal cord, then ascends the dorsal-medial lemniscus column in the spinal cord and synapses with dorsal column nuclei in the medulla. Secondary sensory neurons decussate in the medulla and ascend to terminate in the contralateral ventroposterior thalamus. From the thalamus the sensory stimuli travel along tertiary sensory neurons that project to somatosensory areas in the cortex. There are several cortical areas concerned primarily with somatosensory function including the primary somatosensory cortex, the secondary somatosensory cortex, the granular insula and retroinsular cortex, and the posterior parietal cortex. Sensory impulses are processed in these areas prior to synapsing with the primary motor cortex where movement can be initiated or altered via stimulation to the efferent descending motor pathways.

This sensory motor loop provides the basic neural structural mechanism for sensorimotor control. The ability to accurately gather sensory information with our hands relies on the integrity and competency of every part of the sensorimotor processing loop. Haptic touch can be highly discriminating because it involves the combination of the passive sensation of touch (afferent and cutaneous input) with active exploration (efferent and kinesthetic output). The ability of our hands to perform adequate exploration relies on our hands’ ability to manually explore, free from constraint, in order to gather sensory information. Infants can only achieve a level of perception that is equivalent to their ability to manually explore. As an infant’s manual dexterity improves so does his ability to gather pertinent sensory information. Normal development relies on ongoing active exploration, repetition, and selection of solutions that are efficient and reliable. Haptic discrimination is guided by stereotypic manual explorations. For example, the weight of
an object is determined by the unsupported lifting of the object, shape is determined by hand enclosure and advances to in-hand manipulation and contour following of the object with fingertips, and texture is determined by a lateral motion over the surface of the object. Haptic touch facilitates perceptual motor learning through the dynamic interplay of perception and action.

In normal development, the infant gathers and processes information in a multisensory world. As such, the infant needs to be able to process incoming sensory input and respond appropriately. This involves selective attention toward certain incoming sensory information and exclusion or inattention to other stimuli. The dynamic processes that govern the cycles of action and perception in perceptual motor development are interrelated and mirrored in other perceptual developmental skills such as visual motor, visual perceptual and cognitive skills. Mental activities such as selective attention and motivation act as facilitators of the action and perception cycles. Perceptual motor and cognitive skill development have many similarities and are both essentially performatory. Experience (actions) and awareness (perceptions) result in learning, training effects, generalizations, and improved performances.

The visual cortex is involved in normal tactile perceptions. Vision plays a key role in manual exploration, grasping and manipulation. Cognitive and visual cues are used for predictive and feed-forward anticipatory actions, such as hand pre-shaping. For example, in order to lift an object; we must visually assess its weight and size, cognitively draw on previous experiences, and then pre-shape our hand while also calculating our grip and load force. The texture that is palpated on contact will provide us
additional information for adjustment of our grip force. Anatomically, multiple cortical and sub-cortical areas are responsible for skilled movement. The cerebellum and cerebral cortex work together and play a significant role in perception and execution of both cognitive and motor skills. Shared cortical processing of tactile and visual information facilitates visual motor and visual perceptual development.

In summary, sensorimotor development depends on an intact sensorimotor loop that can gather sensory input, process it, and provide feedback for the adjustment and refinement of movement. It is essential for motor learning. Haptic touch is an essential component of sensorimotor development because it involves both afferent sensory input (perception) and efferent motor exploration (action). The development of perceptual motor skills is similar to the development of visual motor, visual perceptual and cognitive skills because they share similar perception-action cycles and because they process information in multiple, shared cortical areas. Normal sensorimotor development involves ongoing dynamic interactions between the individual, his environment and his selective attention and motivation to task.

**Sensorimotor impairments associated with preterm birth**

Sensorimotor impairments associated with preterm birth (PT) can vary significantly in terms of severity. Severity is often inversely related to biological factors such as birth weight (BW), gestational age (GA), and postnatal growth; the youngest (lowest GA) and the smallest (lowest BW) infants often experience more significant
impairments. Environmental factors including male gender and lower socioeconomic status have also been associated with poorer outcomes. Definitive outcomes are somewhat difficult to establish due to a variety of methodological problems usually associated with experimental design. However, the general consensus is that severe disabilities such as cerebral palsy, significant developmental delay, hearing loss, and blindness occur in 10 to 20% of preterm children and are apparent within the first two years of life. Mild impairments, usually noted prior to school age, occur in 20 to 40% of PT children, and 40 to 60% of all preterm children are considered nondisabled and typically developing at school age.

Several follow up studies in the past decade have revealed that, of the 40-60% of nondisabled preterm children, a significant number have minor impairments in sensorimotor function and other developmental domains. These unknown, sometimes referred to as ‘hidden’, impairments appear to surface or worsen in later childhood. In addition to sensorimotor impairments, the other developmental domains commonly found to have minor impairments include cognitive (measures of IQ), visual perceptual, language, and behavior. Additionally, impairments in one or more developmental domains have been associated with below average academic achievement and school performance. In the nondisabled preterm child, it is not clear whether these impairments reflect true deficits and persistent problems or if they reflect maturational lags that will eventually catch up.

The spectrum of sensorimotor problems seen in nondisabled preterm children is similar to those seen in the general, nondisabled population, but with a higher incidence.
In follow up testing at school age, 30-50% of nondisabled preterm children demonstrated minor, multi-domain impairments versus 5-10% of children in the general population.  

Methodological issues related to the assessment and identification of sensorimotor impairment in both the preterm and term populations include the lack of a “gold standard” in developmental assessment, the use of a wide variety of assessment tools, and often, a lack of agreement as to what constitutes impairment. This has lead to problems in identifying, describing and reporting sensorimotor impairments for both the preterm and term population. Labels assigned to sensorimotor impairments are varied and include: perceptual motor dysfunction, hand eye coordination problems, evidence of soft neurological signs, clumsiness, minor neurological dysfunction, and developmental coordination disorder.

The specific sensorimotor assessments cited in the preterm literature are varied but test items typically include some combination of gross and fine motor assessment items such as: dexterity using finger tapping or pegboard, visual perceptual matching, visual motor design copying, ball skills, and static and dynamic balance. The PT studies that use neuropsychological testing include sensorimotor test items such as fingertip tapping, diadochokinesis, finger identification and imitating hand postures. In spite of the above mentioned difficulties, sensorimotor impairments commonly seen in preterm children include those related to fine motor control such as visual motor, eye-hand coordination, visual perceptual skills, and fine manual dexterity. Gross motor impairments in the preterm population are usually related to manual dexterity, eye-hand
coordination, and static and dynamic balance, postural control and abnormal reflexes.  

Functional limitations attributed to sensorimotor impairments in nondisabled preterm school aged children can be significant. Children may experience difficulty with activities of daily living such as handling eating utensils, managing fasteners and tying shoes. In school, difficulty may be seen with paper to pencil activities such as copying, letter formation, and writing speed. Gross motor impairments may appear as clumsiness in the classroom such as bumping into objects, difficulty walking in line, and difficulty maintaining a stable seated position. Gross motor impairments may limit playground abilities such as running, skipping, kicking a ball, bouncing and catching a ball, swinging, climbing, and riding a bicycle. Children with minor sensorimotor impairments may experience frustration and low self esteem related to their impairments that may lead to negative social and behavioral consequences.

To summarize, minor sensorimotor impairments are evident in a greater percentage of nondisabled preterm children versus term children. Nondisabled preterm children can have minor, but multiple impairments, that appear to surface or worsen later in childhood. These minor impairments are sometimes associated with learning disabilities and reduced academic achievement. If considered separately, these developmental impairments might appear inconsequential, but when considered together the cumulative effect can have significant functional, academic, and social consequences.
Confounding variables of sensorimotor development

Socioeconomic status, gender, and postnatal growth, all have been implicated in poorer outcomes for preterm children. Lower socioeconomic status has been associated with poorer outcomes for cognitive and motor development in preterm and term children.³⁻⁵, ¹⁴⁻¹⁶, ³⁸, ⁴¹, ⁴² Typical children from disadvantaged homes have higher incidences of fine and gross motor impairment, increased persistence of a primary reflexes and lower receptive language and reading skills than children from advantaged homes.³⁸, ⁴¹ Maternal social disadvantage, based on five risk factors including: age <19 years old, education < high school, unmarried status, minority status, and use of public assistance, has been associated with lower IQ scores in nondisabled preterm children.¹⁴ Preterm children reared in homes that were determined to be less stimulating for cognitive, social and physical development had a higher incidence of fine and gross motor impairment.¹⁴,¹⁵ And, extremely low birth weight (ELBW) children from disadvantaged homes tended to develop global intellectual impairment as opposed to ELBW children from middle class homes, who tended to have average intelligence but higher risk for learning disability.¹⁰,¹⁶

Preterm males are considered to have a higher risk of neurodevelopmental problems.¹⁰ Some preterm studies have demonstrated an association between male gender and an increased incidence of sensorimotor impairment.⁶, ¹⁰, ¹⁴, ¹⁶ Lastly, smaller than average postnatal growth and small head circumference have been associated with poor motor and cognitive performance at age 5 and 7.⁶, ¹⁴, ⁴², ⁴³
In summary, the potential confounding factors identified for this study include gender, socioeconomic status, and postnatal growth. Cognitive level is controlled for by enrollment in regular education classes.

**Neuroanatomical Differences in the Preterm Brain**

The etiology of neurodevelopmental impairment related to preterm birth, has not been clearly identified. However, a significant amount of growth occurs in the brain during the last two to three months of gestation.\(^{26, 44-52}\) In the past two decades, advanced imaging technology, such as 3- dimensional volumetric MRI’s, functional MRI’s (fMRI), and diffusion tensor imaging, have uncovered neuroanatomical differences between the preterm and term brain from birth through adolescence.\(^{25, 26, 44-52}\) Preterm birth has been shown to correlate with an increase in cerebrospinal fluid and white matter injury,\(^{14, 26, 45, 46}\) and decreases in total intracranial and regional brain volumes.\(^{26, 44-51}\) In addition to the gross structural abnormalities, changes at the cellular and synaptic level due to genetic alterations and hypoxic-ischemic insults have been proposed.\(^{25, 26}\) Preterm infants with significantly reduced cortical and sub-cortical volumes and increased CSF volume demonstrated moderate to severe neurodevelopmental disability at age one.\(^{46}\)

In a study of PT cerebellar volume, Limperopoulos\(^{47}\) found a significant increase in mean cerebellar volume (177\%) from 28 weeks gestational age (GA) to term equivalent. The increase in cerebellar volume was much greater than the increase of total mean brain volumes. Still, at term equivalent, these mean volumes remained significantly
less than full term infants. Anderson\textsuperscript{48} measured cerebellar vermis and corpus callosum (CC) length in PT infants several times between birth and term equivalent. Vermis length was strongly correlated to CC length. Reduced CC and cerebellar vermis length correlated with an increased risk of psychomotor delay and cerebral palsy at age two. Preterm birth has been associated with a variety of visual abnormalities. Reduced inferior occipital volumes correlated with impaired oculomotor control, i.e. saccadic movement, smooth pursuit, or strabismus in PT children at age two.\textsuperscript{49}

Rademaker\textsuperscript{50} measured cross-sectional areas of the CC in 7 to 8 year old preterm and term children. Preterm children had smaller mean cross sectional areas of the CC. Smaller CC correlated with poorer scores on standardized tests of gross, fine and visual motor skills. Children with cerebral palsy (CP) had the most significant decrease in CC areas. Peterson\textsuperscript{26} used fMRI in 8 year old children to compare the brain activity of term and preterm children while they listened to a children’s story and again when they listened to nonsensical speech. Term participants activated typical cortical language areas while the preterm participants used the same erroneous cortical activation patterns when listening to the story as when listening to the nonsensical speech. Preterm children with lower verbal IQ and less comprehension of the story utilized the erroneous activation pattern the most.

Allin\textsuperscript{51} measured cross sectional areas of the CC in 15 and 19 year old VPT (<33 weeks GA) and term controls. While growth occurred in the CC’s of both populations, growth was more dramatic in the VPT group. It was suggested that the significant growth observed during adolescence, may be an indication of a delay in the maturational process.
In another study, Allin\textsuperscript{44} found that significant reduction in cerebellar volumes at age 14-15 was associated with cognitive, but not motor impairment in a preterm population.

In summary, advanced imaging technology such as 3-dimensional volumetric MRI’s, functional MRI’s (fMRI), and diffusion tensor imaging, has revealed significant differences in the brains of preterm and term children. Studies indicate that the presence of neuroanatomical differences in the preterm child can correlate with maturational delay and neurodevelopmental impairments.

**Sensory, Motor and Cognitive Assessments**

Sensory testing has been under reported in school aged preterm follow up studies. Motor testing is far more common. This section will provide descriptions of commonly used assessments reported in follow up studies of school aged preterm children. A single asterisk* will denote an assessment that was reported only once in this literature review. Two asterisk ** will denote an assessment that has been reported in multiple studies in this literature review. Following the review of commonly used assessments, the assessment tools chosen for this study will be described along with their supporting rationale.

**Motor Tests**

**Movement Assessment Battery for Children** (M-ABC, Henderson & Sugden, 1992): A standardized motor test with 5 age bands each with four motor sections: manual
dexterity, ball skills, static balance and dynamic balance. There are 2 items in each section for a total of 8 items. Controversy surrounds what constitutes impairment with this and other standardized tests in PT studies. All agree that -2 standard deviations (SD) from the mean indicates definite impairment, while others argue that scores between -1 and -2SD should also be considered impaired. Some studies report scores in both ranges.

**Pegboard test:** It is part of the M-ABC and is also used in some neuropsychological assessments.54

**Bruininks-Oseretsky Test of Motor Proficiency** (BOTMP, Bruininks RH, 1978): A norm referenced, standardized test of fine and gross motor skills for children 4½ to 14½ with 8 subtests including Response Speed, Visual Motor Control, Upper Limb Speed and Dexterity, Upper Limb Coordination, Bilateral Coordination, Balance, Running Speed and Agility, and Strength.


**Touwen's Examination of Minor Neurological Dysfunction** (Touwen BCL, 1979) A neurological assessment of muscle tone in various postures including standing, sitting and walking; abnormal reflexes, involuntary chorieform movements, coordination tests including finger to nose, fingertip opposition, rapid alternating forearms, tandem walking,
single leg stance, observation of abnormal fine manipulation, dysfunctions including VI or VII cranial nerve (rare), and/or presence of excessive amounts of associated movements.

**Test of Visual Motor Integration** (VMI, Beery and Buktenica, 1989, 1997): A test of visual and motor integration which involves copying 27 geometric forms with increasing complexity in a developmental sequence.

*Test of Visual-Perceptual Skills* (Non-Motor TVPS, Gardner, 1982). A test for children aged 4 to 13 that include seven subtests: visual discrimination, visual memory, visual-spatial relationships, visual closure, visual form constancy, visual sequential memory and visual figure ground.


*In-hand Manipulation Skill Test* (Exner, 1992): A two part, timed test of the dominant hand that includes 1) Rotation: A peg is picked up from a peg board, rotated 180 degrees in fingertips, and replaced back into the board and 2) Translation: an increasing number of pegs are picked up and held in the palm and then replaced in the pegboard.

**Sensory Tests**

**Finger Identification**: part of a battery called Sensory Integration and Praxis Test (SIPT, Ayres, 1989): A sensation test requiring the child to identify which finger is being touched without vision. Finger identification is sometimes done as part of a neuropsychological assessment.

*Stereognosis*: A test that consists of identifying common objects placed in hand without vision. *Graphesthesia*: the ability to reproduce designs that are drawn on the back of the hand. There was one study that reported using stereognosis and graphesthesia as part of a neurological assessment. The methods used to assess stereognosis and graphesthesia were not described.

The primary purpose of this study was to assess haptic discrimination in the nondisabled preterm school aged children. Tactile discrimination is typically assessed using a one dimensional, passive method such as two-point discrimination. A more active method of tactile discrimination involves haptic touch, commonly assessed with stereognosis. Because the participants in this study were all nondisabled, more dynamic assessments were sought to measure tactile haptic discrimination. Two relatively new assessments were chosen.

**The Hand Active Sensation Test (HASTe)** is an intra-modal (haptic-haptic) test of weight and texture discrimination. The HASTe is a valid assessment capable of discriminating haptic function in stroke survivors and children with cerebral palsy when compared with controls. It has demonstrated good internal consistency and reliability,
and has good correlation with well known gold standards of tactile discrimination including stereognosis, 2 point discrimination, and proprioception. 27, 29

**The Haptic Object Recognition Test (HORT)** 28 is a test of in-hand shape discrimination using 5 novel shapes as opposed to common objects. It is an inter-modal (vision-haptic) test of shape discrimination with good test-re-test reliability and validity for demonstrating change in elderly adults following a sensory training program. 28

The motor test chosen to measure manual dexterity in this study was the Nine Hole Peg Test.

**Nine Hole Peg Test** (NHP, Sammons, Preston and Roylan) is a standardized, timed assessment of manual dexterity for children and adults. The NHP was chosen for this study because a pegboard test is a fairly common test of manual dexterity and the NHP is norm referenced for children. A pegboard test is used to assess manual dexterity within the M-ABC (Henderson & Sugden, 1992) and is often used as part of a neuropsychological assessment for children.

**School Age Cognitive Testing**

Intelligence tests are the most often used measure of cognitive function in the preterm literature, although some studies have used academic achievement. 8, 10, 13 Intelligence tests are used to detect underlying causes of school failure in specific areas such as reading, arithmetic, language and writing. 54 They focus on the child’s ability to think, solve problems and reason. Intelligence tests are also used to diagnosis mental

Neuropsychological tests are used to measure brain–behavior function, especially as it relates to brain impairments that are the result of injury such as traumatic brain injury, tumors, near drowning, etc. In addition to identifying brain dysfunction due to injury, these tests have also been instrumental in identifying and understanding learning disabilities. Neuropsychological testing emphasizes motor, sensory, and perceptual skills in addition to traditional intelligence testing. These tests are capable of distinguishing between groups of children with brain injury, learning disability and children without disability. The theoretical concepts of executive function and nonverbal learning disability were derived from neuropsychological testing.

Tests of academic achievement measure how well a student has learned. They measure the product of learning versus the underlying process of learning. Achievement tests allow for comparisons between tests over time for an individual child, and for comparisons between children.

**Wechsler Intelligence Scale for Children-Revised** (WICS-R, Wechsler, 1989) A test used to measure intelligence quotients (IQ) that consists of two measures: Verbal IQ and Performance IQ. The Verbal subtests include: Information, Similarities, Arithmetic, Vocabulary, and Comprehension. The Performance subtests include: Picture Completion, Coding, Picture Arrangement, Block Design, and Object Assembly

**A Developmental Neuropsychological Assessment** (NEPSY, Korkman et al 1998). A neuropsychological battery used to evaluate attention/executive functions, language, sensorimotor function, visuospatial perception, memory and learning. The sensorimotor domain items include: fingertip tapping of simple and complex movements, imitating hand postures, and finger discrimination. Visuomotor precision involves drawing inside 3 consecutively narrower tracks. Visuospatial include design copying, visuospatial relationships, and directionality.

**The Ohio Achievement Test (OAT)** is a criterion-referenced achievement test that is linearly aligned with Ohio’s academic content standards for grade and subject, beginning in grade three. The OAT is administered each year to all public school students in grades three through eight. It has been determined to be a valid, reliable measure of academic achievement by the Ohio Department of Education, Office of Assessment. Raw scores are converted to scale scores which can be converted to standardized scores. The reading and mathematics sections of the OAT were chosen for this study to represent the participant’s academic performance.
CHAPTER 3: METHODOLOGY

Research Design

A casual comparative research approach was used to determine if there is a functional relationship between preterm birth, haptic sensation, manual dexterity, and/or academic performance. The two levels of the independent variables are: children born preterm (<37 weeks), and children born full term (>37 weeks). Dependent variables include: 1) Hand Active Sensation Test (HASTe) accuracy scores, 2) Haptic Object Recognition Test (HORT) accuracy scores, 3) Nine Hole Peg Test (NHP) time in seconds scores, and 4) the Ohio Achievement Test standardized scores for the reading and mathematics.

Population and Sample Design

Children enrolled in third, fourth and fifth grade at four elementary schools in the Columbus City School district were recruited for participation. A total of 730 recruitment letters were sent home. The letter briefly explained the research project and the criteria for participation: good physical health, enrollment in regular education, age 9, 10 or 11, and full term or preterm birth history.
Parents who expressed interest in enrolling their child (ren) were given a copy of The Ohio State University Parental Permission for Child’s Participation in Research, and a copy of the Parent Questionnaire. The researcher was available to answer questions and provide further explanation as needed. Children were also allowed to indicate their willingness to participate by responding to an age appropriate assent script. Participants were tested at their school, either before or after regular school hours. Testing included the HASTe, the HORT and the NHP. The tests were administered in a random order that was chosen by the participant. All three tests took approximately 30-40 minutes to complete. Scaled scores from the Reading and Math portions of the Ohio Achievement Test were obtained for the same school year (2009) that testing was completed. All testing and data collection was completed by a single researcher.

Instrumentation

For this study, haptic sensation was assessed using two tests, the HASTe\textsuperscript{27} and the HORT\textsuperscript{28}. The HASTe (Hand Active Sensation Test) was used to assess weight and texture discrimination in the dominant hand (the hand used for writing). The HASTe involves matching 9 target objects, which are small cylinders, weighing 6, 7, or 8 oz. that are covered in one of three textured materials: plastic, paper and Styrofoam. There are a total of 18 trials, with each target object matched twice, once for weight and once for texture, in a random order. The participant was allowed to see the objects prior to the start of testing. For this test, a small table top curtain was erected to block the view of the
test objects from the participant. The participant sat on one side of the table while the researcher and all of the test objects were on the other side. The participant was asked to place his dominant hand under the curtain. The researcher then presented the participant with a target object. The participant was allowed to manually explore the target object. Then, the participant was presented with three similar objects and asked to choose a match for the target object. Scoring is the number of accurate matches out of 18 trials. An accuracy score of 10 was determined to be the cut off for non-impaired function in children 6 ½ to 10 1/2 while an accuracy score of <10 suggests impairment. 29 The test was administered one time for each participant.

The HORT28 (Haptic Object Recognition Test) was used to assess shape discrimination in the dominant hand. Five different shapes, constructed from Lego™ blocks, measuring 1.5 x 2.7 x 4.7 cm, were displayed and labeled A through E. A 4” x4” box with a corresponding label was placed behind each shape. Prior to testing, the researcher allowed the participant to visually and manually explore the 5 displayed Lego shapes. The participant was then presented with a nylon drawstring bag that contained 17 matches to the displayed shapes. The participant was instructed to place the bag on his lap and reach into the bag with his dominant hand. The participant manually explored and matched the felt object with one of the displayed models. When a match was decided, the subject placed his selection into the box with the corresponding label. Visual confirmation of the selection was not allowed. The subjects were asked to complete the matching process as quickly but as carefully as possible. The accuracy score, the number of correct matches, was recorded.
Prior to this study, the HORT had only been used with elderly adults. To determine if the HORT was an appropriate test for children, a field test was conducted. In the reference article by Kalish, elderly adults, with an average age of 75, had an initial average accuracy score of 12.5 out of a possible 17. For the field test, seven children, aged 6 through 10, had an average accuracy score of 11.5; four children, aged 11-13, had an average accuracy score of 15; one 16 and one 19 year old had an average accuracy score of 15.5; and two middle aged adults, aged 49 and 55, had an average accuracy scores of 13.5. The field test participant’s accuracy scores were based on one trial of the HORT.

The decision that the HORT was appropriate for use with children was made for several reasons. First, the field-tested children performed the test without hesitation or apparent anxiety. Second, the differences found in the average accuracy scores between the age groups were considered reasonable. Younger children did not perform as well as older children, middle aged adults did not perform as well as young adults, and middle aged adults performed better than elderly adults. Tactile discriminative abilities in adults decline with age and tactile discrimination in younger children is less mature than older children. The third reason for choosing the HORT was that it was easy to administer and easily transported. The test was administered one time for each participant. The accuracy score reflected the correct number of matches out of 17 trials.

The Nine-hole Peg Test (NHP) was used to assess manual dexterity. The test consists of a plastic pegboard with nine ¼” diameter pegs, which are held in a shallow depression adjacent to the pegboard and on the same side as the hand being tested. The
participant is asked to use his dominant hand to quickly insert the nine pegs one at a time into the pegboard and then remove them as quickly as possible one at a time. The time, in seconds, it takes to place all nine pegs into the board and remove them back into the shallow depression is timed and recorded. One practice trial was allowed prior to the recorded timed trial. Only the dominant hand was tested.

The Ohio Achievement Test (OAT) for reading and mathematics was chosen to reflect the participant’s academic performance. Scale scores were standardized for statistical comparison. Five of the 37 participants did not have OAT scores available for analysis due to their grade at the time of testing or because they were not residents of Ohio at the time of testing.

**Data Analysis**

The statistics used to accept or reject the null hypothesis were the Independent Sample T-Test, and the Pearson Product Moment Correlation.

Level of significance:

Alpha was set a priori at $p<0.05$.

SPSS for Windows, Chicago software was used for all statistical analysis.
Summary

This study evaluated sensory and motor function in nondisabled full and preterm 9-11 year old children. Testing for all participants included the HASTe, the HORT, and the NHP. Data gathered for all participants included accuracy scores for the HASTE and the HORT, time scores for the NHP and scale scores for the reading and math sections of the OAT.

Independent Samples t-test and Pearson Product Moment Correlations were utilized to answer the research questions. Alpha was set a priori at $p < 0.05$. 
CHAPTER 4: ARTICLE

Haptic Discrimination, Manual Dexterity, and Academic Achievement in Nondisabled Preterm Children at School Age

Abstract

Preterm (PT) children are at risk for sensorimotor impairments at school age, however little has been done with sensory discrimination in PT school aged children. **AIM:** To assess and compare haptic discrimination, manual dexterity and academic achievement in nondisabled PT and full term (FT) children. **METHODS:** Thirty-seven participants, 12 PT (6 males, 6 females, mean GA 32 weeks, mean age: 9.6 years); 25 FT (13 males, 12 females, mean age 9.9), assessed with 1) Hand Active Sensation Test (HASTe) for texture and weight discrimination, 2) Haptic Object Recognition Test (HORT) for shape discrimination, and 3) Nine-Hole Peg Test (NHP) for manual dexterity. The Ohio Achievement Test (OAT) reading and math scores were used to gauge academic achievement. **RESULTS:** Full term children had significantly higher mean HASTe accuracy scores ($p = .012$) and higher mean OAT reading scores ($p =0.041$); math scores approached significance ($p = .070$). No significant group differences for the HORT accuracy scores ($p = 0.158$) or NHP time scores ($p = 0.145$). **INTERPRETATION:** Nondisabled PT children did not perform as well as FT peers in haptic discrimination or
reading achievement. The HASTe was able to discriminate between nondisabled preterm and full term children.

**Introduction**

Preterm birth is on the rise in the United States and now accounts for 12% of all live births.\(^1\) Survival rates have improved for all preterm children including those born extremely preterm, at < 26 weeks, and those with extremely low birth weights, < 1000g.\(^2\) All preterm children are at higher risk for neurodevelopmental impairments, with the youngest and smallest at the greatest risk.\(^3\) A small percentage, 10-20% of these children, will present with severe disabilities within the first two years of life that may include cerebral palsy, significant hearing or vision impairment, significant cognitive or language impairments. Another 30-50% of preterm children will go on to exhibit minor developmental impairments, and 40-60% are considered to be nondisabled at school age.\(^4\)

Preterm birth results in an abrupt change in the normal growth and development of the infant. The impairments that follow can be quite varied and the underlying mechanisms responsible are not fully understood. In the past decade, numerous studies have assessed large groups of preterm children at school age, including nondisabled preterm children. These studies revealed that typically developing, nondisabled PT children can have minor impairments in one or more developmental domains and that these impairments can be associated with lower academic performance. Minor impairments in nondisabled PT children have been identified in one or more domains including: cognitive, motor, visual perceptual, language, social, emotional, and behavior.\(^5\)\(^6\)\(^7\) Individually, the impairments might appear inconsequential, but the
cumulative effect may be difficult for the child to compensate for, and can lead to significant functional and academic consequences.\textsuperscript{3,4}

Assessment of tactile sensory function of the preterm child has largely been ignored in the preterm literature even though preterm children are at risk for impairment to their sensory development.\textsuperscript{8,9} Preterm birth abruptly interrupts normal prenatal development. In the first few months of life, preterm infants may have different experiences with active and passive touch.\textsuperscript{10} They typically experience less qualitative touch that is positive and nurturing, and may experience more harsh and painful touch that may be considered over stimulating and stressful.\textsuperscript{10} The preterm infant may also have an altered responsiveness to touch, either under or over responsiveness, which can lead to difficulty with attachment to caregivers, and difficulty with oral or manual acquisition of sensory input. These factors can have long lasting effects into childhood.\textsuperscript{8,10}

Anatomical and physiological concerns also exist with regards to the tactile sensory function of the preterm child. When compared with other regions in the central nervous system, the somatosensory regions normally have very high metabolic demands in infants in the first 3 months of life.\textsuperscript{8} This puts the somatosensory areas at greater risk from hypoxic-ischemic insults that may result from respiratory and circulatory insufficiency. MRI studies of the preterm brain at birth, at term equivalent, and later in childhood reveal persistent reduced total brain volumes and reduced regional volumes in specific areas, including cortical and sub-cortical somatosensory structures.\textsuperscript{8,9,11,12}
Methods

A casual comparative research approach was used to: 1) haptic discrimination, 2) manual dexterity, and 3) academic achievement in nondisabled preterm and full term school aged children; and 4) to determine if there is a functional relationship between these variables.

Participants

Children enrolled in third, fourth and fifth grade at four elementary schools in the Columbus City School district were recruited for participation. Prior to recruitment permission was obtained from The Ohio State University Institutional Review Board, the Columbus City Schools district, and the principals at each elementary school. A total of 730 recruitment letters were sent home. The letter briefly explained the research project and outlined the criteria for participation: good physical health, enrollment in regular education, age 9, 10 or 11, and full term or preterm birth history.

Parents who expressed interest in enrolling their child (ren) were given a copy of The Ohio State University Parental Permission for Child’s Participation in Research, and a copy of the Parent Questionnaire. The researcher was available to answer questions and provide further explanation as needed. Children were also allowed to indicate their willingness to participate by responding to an age appropriate assent script.

Instrumentation

Haptic discrimination was assessed with: the Hand Active Sensation Test (HASTe),\textsuperscript{13} and the Haptic Object Recognition Test (HORT).\textsuperscript{14} Manual dexterity was assessed with the Nine-Hole Peg Test (NHP).\textsuperscript{15} All three tests were performed with the child’s
dominant hand; determined as the hand the child uses for writing. The tests were administered in a random order chosen by the participant. All three tests took approximately 30-40 minutes to complete. Scaled scores from the Reading and Math portions of the Ohio Achievement Test\textsuperscript{16} were obtained for all participants, except for five whose test scores were unavailable for the same school year (2009) that testing was completed. All recruiting, testing and data collection was completed by a single researcher.

Prior to this study, the HORT was field tested by this researcher to determine its’ appropriateness as an assessment for school aged children. The differences found in the field tests’ average accuracy scores between the age groups were considered reasonable. Older children performed better than younger children, young adults performed better than middle aged adults, and middle aged adults performed better than elderly adults. Adult tactile discrimination declines with age\textsuperscript{14} and tactile discrimination ability in younger children is less mature than that of older children\textsuperscript{17}.

Please see Figure I for complete description of Test Instruments.

**Statistical Methods and Results**

The statistical tools used to answer the research questions were the Independent Samples T-Test, and the Pearson Product Moment Correlation. Level of significance: Alpha was set a priori at $p<0.05$. Statistical analysis was performed using SPSS for Windows\textsuperscript{18}.

The independent variables were the two levels of term: preterm (PT) and full term (FT). The dependent variables were: accuracy scores for the HASTe\textsuperscript{13} and the HORT\textsuperscript{14}. 

36
time scores for the NHP\textsuperscript{15}, and standardized scores from the reading and mathematics sections of the Ohio Achievement Test (OAT)\textsuperscript{16}.

The PT and FT groups were very similar in terms of age, gender, socioeconomic background and racial diversity. There were 25 full term participants (13 male, 12 female) and 12 preterm participants (6 male, 6 female). The mean age of the FT group was 9.9 years; the PT group was 9.6 years. The female PT group was moderately preterm\textsuperscript{2} with a mean gestational age of 32.6 weeks and had a moderately low\textsuperscript{2} mean birth weight of 1780 grams. The male PT group had a very preterm\textsuperscript{2} mean gestational age of 31.8 weeks and a moderately low\textsuperscript{2} mean BW of 2069 grams. There was a fairly even distribution of race and socioeconomic status. (Table 1)

Mean scores for both groups were obtained for the HASTe, the HORT, the NHP, and standardized OAT reading and math scores. (Table 2) Group mean score analysis for significance was done using the Independent Samples T-Test. Significant group differences were found between the FT and the PT group for HASTe accuracy scores ($t = 2.65$, $df = 17.84$, $p = 0.012$) and for OAT reading scores ($t = 2.168$, $df = 22.62$, $p = 0.041$). The FT group had higher mean HASTE accuracy and higher standardized reading scores. The math scores approached significance ($t = 1.884$, $df = 28.20$, $p = 0.070$). No significant group differences were found for the HORT accuracy scores ($t = 1.45$, $df = 22.95$, $p = 0.158$) or the NHP time scores ($t = -1.55$, $df = 12.67$, $p = 0.145$). (Table 3)

Pearson product correlation coefficient analyses were done for all dependent variables. Correlations were carried out for participants’ scores as a whole and for the
groups individually. There were no significant correlations between the dependent variables in either case. (Tables 4, 5, 6)

**Discussion**

The primary purpose of this study was to assess and compare haptic discrimination in the nondisabled PT and FT children. Based on the results of the Independent Samples T-Test, there was a significant difference between the preterm and the full term group with the HASTe, assessment ($p = 0.012$), but not with the HORT assessment ($p = 0.158$).

For the HASTe, the FT groups mean accuracy score was 11.64 with a range of 8-15. The PT group mean accuracy score was 9.83 with a range of 7-13. Only 3 out of 25 FT participants scored $< 10$, but 6 out of 12 PT participants scored $< 10$. A score of $< 10$ suggests impairment\(^\text{19}\). For the HORT, the FT groups mean accuracy score was 9.60 with a range of 3-15. The PT group mean accuracy score was 7.67 with a range of 3-13. In the FT group, 12 out of 25 scored $< 10$, while 9 out 12 PT participants scored $< 10$. The wide range of accuracy scores in both groups for the HORT resulted in inconclusive results.

Both groups of participants performed better with the HASTe than they did with the HORT. Although both tests sought to assess haptic discrimination, the structure and concurrent demands of these two assessments are quite different. For example, because the HASTe is interactive, it was apparent to the researcher, soon after starting, when the participant needed additional clarification of the directions. With the HORT, once the directions were given, the participant proceeded to sort the shapes
uninterrupted to completion. If the participant did not fully understand the directions, it was not apparent until the end when the matches were sorted.

Also, the level of active manipulation required to perform the HORT and the HASTe were quite different. The Lego™ shapes used in HORT assessment required precise in-hand manipulation and finger-tip contour following for accurate shape discrimination. In contrast, because the HASTe objects were much larger, accurate discrimination of weight required the participant to fully grasp the object to perform unsupported holding, or apply a light, lateral motion over the surface to discriminate texture. In addition to the more challenging in-hand manipulation, the HORT also required visual perceptual ability in order to successfully match the felt object with the visually displayed model.

In addition to the haptic and visual perceptual demands of the HORT and the HASTe, consideration must also be given to the cognitive demands of these assessments. The cognitive skills that are required to perform well on these assessments are higher level cognitive skills known as executive function. Executive function involves developing a plan or a strategy to accomplish a task efficiently and consistently. It involves focused attention, the ability to inhibit competing stimuli, and the ability to avoid impulsive responses. Both the HASTe and the HORT require a certain amount of executive function skills for successful performance. For example, the HASTe requires sustained attention to task; there are 18 trials that take approximately 15 minutes to complete. The HASTe also requires working memory. Once the participant examines the test object for weight and texture, he must remember what he felt in order to match it to
one of three possible choices. He then needs to decide if he knows the correct match or if he needs to feel the objects again. Impulsive responses could result in lower accuracy scores. Likewise, the HORT requires the same executive functions as described for the HASTE, and in addition, it requires a plan to visually identify the differences between the shapes and a strategy to haptically explore the objects in order to detect those differences. Again, impulsive responses would probably result in lower accuracy scores. It’s possible that the haptic and cognitive demands of the HORT exceed the demands of the HASTE. The HORT may be too challenging for children in this age range. The wide range of accuracy scores might be attributed to the level of difficulty of this assessment.

Lastly, in this study, only one trial of the HORT was conducted to obtain the accuracy score versus what was described in Kalish’s introduction to the HORT.\textsuperscript{14} He determined the accuracy score by taking the average of 3 consecutive trials. We planned only one trial of the HORT for this study to reduce the amount of time the children were subjected to testing.

The second objective of this study was to assess and compare the difference between nondisabled PT children and FT children with respect to manual dexterity. Statistical analysis of the group means failed to identify a significant difference ($p = 0.145$), with equal variances not assumed. However, further analyses of NHP raw scores indicated a more defined difference between the two groups. There was a higher variability of scores in the PT group compared to the FT group. The mean score for the PT group was 22.53$\pm$1.2 seconds; range: 16.81-32.65; a 15.8 second span. The mean score for the FT group was 20.54$\pm$.33 seconds; range: 16.0 – 23.6; a 7.6 second span.
Additionally, although the means for both groups did not fall above the normal ranges for their age and sex, 50% of the PT group had time scores above the normal range for their age and sex, and only 25% of the FT group had time scores above the normal range. 15 Testing both hands with the NHP may have yielded more definitive results. Studies have shown that children with perceptual motor and/or tactile discrimination impairment perform significantly worse with their non-dominant hand when compared to children with normal perceptual motor and tactual abilities. 37, 58, 59

The final objective of this study was to determine if there was a functional relationship between haptic function, manual dexterity and academic achievement in the preterm or term group. This study mirrors much of the literature with regards to dependent variables and term status.3-7 Most PT studies identify significant differences in the mean scores between preterm and term groups for various dependent variables, such as cognitive, motor, perceptual, or academic performance but do not typically demonstrate a correlation among these dependent variables. Historically, the primary concern has been how demographic variables (i.e. gender, socioeconomic status, and maternal education); and perinatal characteristics, (i.e. birth weight, gestational age, pre- and postnatal growth, medical complications, interventions, imaging studies, etc). factor into overall outcome. In school age studies, demographic and perinatal characteristics are factored with cognitive function. Studies that seek to correlate visual, perceptual, and motor assessments with cognitive function are not as common and when motor or perceptual impairments are identified they are usually considered only as additional impairments to the child’s primary cognitive impairment.
This study is unique because it measured and compared haptic discrimination and manual dexterity as stand-alone dependent variables. In this study, we failed to demonstrate a clear association between haptic discrimination and manual dexterity, as expected to support the sensory-motor loop. We were able to demonstrate a significant mean group effect for haptic discrimination, but we were unable to demonstrate an equally significant mean group effect for manual dexterity. This apparent contradiction could be due to a couple of reasons. First, it could be our choice of assessments. While, the HASTe was sensitive enough to identify a significant difference between the PT and term groups, the HORT and the NHP were not able to demonstrate clear differences. As discussed previously, the HORT assessment of haptic function may have been too difficult to render clear results. On the other hand, the NHP may not have been challenging enough to identify a difference in manual dexterity between these two groups of nondisabled children. The NHP was chosen because, as stated previously, a pegboard test has been used in school age preterm studies as part of a neuropsychological battery and it is used in the manual dexterity subtest of the M-ABC, higher age bands. However, the NHP may be more appropriate as an evaluative tool of manual dexterity for individuals with known impairment because there are age norms, and it has face, content, and criterion validity, but not discriminative validity. It’s possible that using a different assessment may have resulted in different manual dexterity findings. This particular pegboard assessment, while it requires speed and agility, does not simulate the exploratory or in-hand manipulative skills that are consistent with successful high level manual tactual performance. A grooved pegboard test or Exner’s In-hand manipulation
test may have been more challenging and able to discriminate differences between these two unimpaired groups. To our knowledge, this is the first study where the HASTe was able to discriminate significant haptic differences between two groups of individuals with no known neurological diagnosis. Therefore, this study further supports the discriminative validity of the HASTe.

**Limitations**

Limitations to this study included a significantly smaller than expected number of preterm participants. After recruitment began, it was discovered that there were 730 students enrolled in the 3rd - 5th grade at the four targeted elementary schools which was lower than previously estimated. Also, the majority of children in 3rd – 5th grade are 8-10 years old and not 9-11 years old as assumed. Therefore, the majority of eligible children were only in 4th and 5th grade, thereby reducing the recruitment pool by one-third. Together, these two factors significantly limited the number of nondisabled preterm children available for recruitment in this study. A greater number of preterm participants may have yielded clearer results with some findings such as the OAT math scores.

The sample of children enrolled in this study, was a convenience sample of voluntary participants who responded to recruitment efforts, and not randomly selected. Results are limited to a small geographical area, approximately 6-8 square miles, in central Ohio with fairly homogeneous lower socioeconomic status.

Methodological problems may have also limited the findings of this study. Conducting one trial of the HORT versus 3 trials may have contributed to the inconclusive results. Our choice of a manual dexterity assessment, one that appeared to
favor speed and agility over in-hand manipulation, and/or failure to test both hands with
the NHP may have also limited our findings with manual dexterity.

**Clinical Significance**

PT children are at increased risk for sensory impairment \(^8\textsuperscript{-10}\) In this study, we were able to demonstrate that nondisabled preterm children, enrolled in regular education, can have significant differences in haptic discrimination and academic achievement when compared to their FT peers. Studies show that PT children with sensorimotor impairments are more likely to have learning disabilities \(^3\textsuperscript{-7}\), even when IQ is within normal limits. Sensorimotor impairments have been associated with decreased handwriting speed and legibility \(^20\); and visuospatial and sensorimotor function has been associated with cognitive function. \(^7\)

Assessments used for the nondisabled PT population should be chosen carefully. The assessments should be sufficiently challenging, but also age appropriate. Additional studies are needed to focus on the impact of PT birth on sensory function, including haptic discrimination and its relationship to the sensorimotor and functional impairments. Also, studies of haptic discrimination, at various ages, could reveal important clues in understanding the maturational changes that occur in PT and FT children. Lastly, this study found the HASTe to be a valid assessment for the nondisabled PT population and may be appropriate for future studies of this group.
<table>
<thead>
<tr>
<th></th>
<th>FT Group</th>
<th>PT Group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Males</td>
<td>13</td>
<td>6</td>
</tr>
<tr>
<td>Females</td>
<td>12</td>
<td>6</td>
</tr>
<tr>
<td>Mean Age (years)</td>
<td>9.9</td>
<td>9.6</td>
</tr>
<tr>
<td>% African American</td>
<td>48</td>
<td>41</td>
</tr>
<tr>
<td>% Caucasian</td>
<td>44</td>
<td>50</td>
</tr>
<tr>
<td>% Hispanic</td>
<td>&lt;2</td>
<td>&lt;1</td>
</tr>
<tr>
<td>% Free/Reduced Lunch</td>
<td>72</td>
<td>58</td>
</tr>
</tbody>
</table>

FT= full term, PT= preterm, GA= gestational age, BW= birth weight, g= grams

Table 1: Descriptive Statistics of Groups
NHP= Nine Hole Peg test, HORT= Haptic Object Recognition Test, HASTe= Hand Active Sensation test, OAT = Ohio Achievement Test, *Note: Standardized Score derived using a z-score conversion from OAT Statistical Summary. 25 (Subtracted mean from scale score and divide by standard deviation); N= lower d/t lack of test results for some participants. N= number of participants, FT= full term, PT= preterm

Table 2: Group Mean Statistics

<table>
<thead>
<tr>
<th></th>
<th>FT/PT</th>
<th>N</th>
<th>Mean</th>
<th>Std. Deviation +/-</th>
<th>Std. Error Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>NHP time, sec</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FT</td>
<td>25</td>
<td>20.54</td>
<td>1.68</td>
<td>0.33</td>
<td></td>
</tr>
<tr>
<td>PT</td>
<td>12</td>
<td>22.53</td>
<td>4.27</td>
<td>1.23</td>
<td></td>
</tr>
<tr>
<td><strong>HORT accuracy scores</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FT</td>
<td>25</td>
<td>9.60</td>
<td>3.91</td>
<td>0.78</td>
<td></td>
</tr>
<tr>
<td>PT</td>
<td>12</td>
<td>7.67</td>
<td>3.70</td>
<td>1.06</td>
<td></td>
</tr>
<tr>
<td><strong>HASTe accuracy scores</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FT</td>
<td>25</td>
<td>11.64</td>
<td>1.77</td>
<td>0.35</td>
<td></td>
</tr>
<tr>
<td>PT</td>
<td>12</td>
<td>9.83</td>
<td>2.25</td>
<td>0.64</td>
<td></td>
</tr>
<tr>
<td><em><em>Standardized Reading</em> OAT</em>*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FT</td>
<td>22</td>
<td>-0.054</td>
<td>1.100</td>
<td>0.234</td>
<td></td>
</tr>
<tr>
<td>PT</td>
<td>10</td>
<td>-0.822</td>
<td>0.840</td>
<td>0.265</td>
<td></td>
</tr>
<tr>
<td><em><em>Standardized Math</em> OAT</em>*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FT</td>
<td>22</td>
<td>-0.060</td>
<td>1.138</td>
<td>0.242</td>
<td></td>
</tr>
<tr>
<td>PT</td>
<td>10</td>
<td>-0.658</td>
<td>.647</td>
<td>0.204</td>
<td></td>
</tr>
<tr>
<td>Test</td>
<td>Levene's Test for Equality of Variances</td>
<td>T-Test for Equality of Means</td>
<td>Sign. (2-tailed)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>--------------</td>
<td>----------------------------------------</td>
<td>-----------------------------</td>
<td>-----------------</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>$F$</td>
<td>Sig</td>
<td>$t$</td>
<td>df</td>
<td></td>
</tr>
<tr>
<td>NHP</td>
<td>Equal variances assumed</td>
<td>9.76</td>
<td>0.004</td>
<td>-2.04</td>
<td>35</td>
</tr>
<tr>
<td></td>
<td>Equal variances not assumed</td>
<td></td>
<td>-1.55</td>
<td>12.67</td>
<td>0.145</td>
</tr>
<tr>
<td>HORT</td>
<td>Equal variances assumed</td>
<td>0.02</td>
<td>0.884</td>
<td>1.43</td>
<td>35</td>
</tr>
<tr>
<td></td>
<td>Equal variances not assumed</td>
<td></td>
<td>22.95</td>
<td>0.158</td>
<td></td>
</tr>
<tr>
<td>HASTe</td>
<td>Equal variances assumed</td>
<td>1.10</td>
<td>0.3</td>
<td>2.65</td>
<td>35</td>
</tr>
<tr>
<td></td>
<td>Equal variances not assumed</td>
<td></td>
<td>2.44</td>
<td>17.84</td>
<td><strong>0.025</strong>*</td>
</tr>
<tr>
<td>OAT Read</td>
<td>Equal variances assumed</td>
<td>1.91</td>
<td>0.177</td>
<td>1.95</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td>Equal variances not assumed</td>
<td></td>
<td>2.16</td>
<td>22.62</td>
<td><strong>0.041</strong>*</td>
</tr>
<tr>
<td>OAT Math</td>
<td>Equal variances assumed</td>
<td>3.12</td>
<td>0.087</td>
<td>1.54</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td>Equal variances not assumed</td>
<td></td>
<td>1.88</td>
<td>28.20</td>
<td>0.07</td>
</tr>
</tbody>
</table>

NHP= Nine Hole Peg Test, HORT= Haptic Object Recognition Test, HASTe= Hand Active Sensation Test, OAT = Ohio Achievement Test

**Table 3: Independent Samples T-Test**

*Significant @ $p< 0.05$
### Table 4: Pearson Product Moment Correlations, Accumulative

<table>
<thead>
<tr>
<th></th>
<th>NHP</th>
<th>HORT</th>
<th>HASTe</th>
<th>OAT STD Math</th>
<th>OAT STD Read</th>
</tr>
</thead>
<tbody>
<tr>
<td>NHP</td>
<td>Pearson Correlation</td>
<td>1</td>
<td>-.215</td>
<td>-.209</td>
<td>.075</td>
</tr>
<tr>
<td></td>
<td>Sig. (2-tailed)</td>
<td>.202</td>
<td>.215</td>
<td>.682</td>
<td>.724</td>
</tr>
<tr>
<td></td>
<td>N</td>
<td>37</td>
<td>37</td>
<td>32</td>
<td>32</td>
</tr>
<tr>
<td>HORT</td>
<td>Pearson Correlation</td>
<td>1</td>
<td>.221</td>
<td>.016</td>
<td>.144</td>
</tr>
<tr>
<td></td>
<td>Sig. (2-tailed)</td>
<td>.189</td>
<td>.930</td>
<td>.431</td>
<td></td>
</tr>
<tr>
<td></td>
<td>N</td>
<td>37</td>
<td>32</td>
<td>32</td>
<td></td>
</tr>
<tr>
<td>HASTe</td>
<td>Pearson Correlation</td>
<td>1</td>
<td>.074</td>
<td>.155</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sig. (2-tailed)</td>
<td>.687</td>
<td>.396</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>N</td>
<td>32</td>
<td>32</td>
<td></td>
<td></td>
</tr>
<tr>
<td>OAT STD Math</td>
<td>Pearson Correlation</td>
<td>1</td>
<td>.752**</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sig. (2-tailed)</td>
<td>.000</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>N</td>
<td>32</td>
<td>32</td>
<td></td>
<td></td>
</tr>
<tr>
<td>OAT STD Read</td>
<td>Pearson Correlation</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sig. (2-tailed)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>N</td>
<td>32</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

NHP= Nine Hole Peg Test, HORT= Haptic Object Recognition Test, HASTe= Hand Active Sensation Test, OAT STD = Ohio Achievement Test Standardized Scores

Significant @ $p < 0.05$
<table>
<thead>
<tr>
<th></th>
<th>NHP</th>
<th>HASTe</th>
<th>HORT</th>
<th>OAT STD Read</th>
<th>OAT STD Math</th>
</tr>
</thead>
<tbody>
<tr>
<td>NHP</td>
<td>Pearson Correlation</td>
<td>1</td>
<td>-.373</td>
<td>.010</td>
<td>.251</td>
</tr>
<tr>
<td></td>
<td>Sig. (2-tailed)</td>
<td>.066</td>
<td>.961</td>
<td>.260</td>
<td>.140</td>
</tr>
<tr>
<td></td>
<td>N</td>
<td>25</td>
<td>25</td>
<td>22</td>
<td>22</td>
</tr>
<tr>
<td>HASTe</td>
<td>Pearson Correlation</td>
<td></td>
<td></td>
<td>1</td>
<td>.308</td>
</tr>
<tr>
<td></td>
<td>Sig. (2-tailed)</td>
<td></td>
<td></td>
<td>.134</td>
<td>.554</td>
</tr>
<tr>
<td></td>
<td>N</td>
<td>25</td>
<td>25</td>
<td>22</td>
<td>22</td>
</tr>
<tr>
<td>HORT</td>
<td>Pearson Correlation</td>
<td></td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Sig. (2-tailed)</td>
<td></td>
<td></td>
<td></td>
<td>.170</td>
</tr>
<tr>
<td></td>
<td>N</td>
<td>25</td>
<td>22</td>
<td>22</td>
<td>22</td>
</tr>
<tr>
<td>OAT STD Read</td>
<td>Pearson Correlation</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sig. (2-tailed)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>N</td>
<td>22</td>
<td>22</td>
<td></td>
<td>22</td>
</tr>
<tr>
<td>OAT STD Math</td>
<td>Pearson Correlation</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sig. (2-tailed)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>N</td>
<td>22</td>
<td></td>
<td></td>
<td>22</td>
</tr>
</tbody>
</table>

NHP= Nine Hole Peg Test, HORT= Haptic Object Recognition Test, HASTe= Hand Active Sensation Test, OAT STD = Ohio Achievement Test Standardized Scores

**Table 5: Pearson Product Moment Correlations, Full Term**

*Significant @ $p < 0.05$
<table>
<thead>
<tr>
<th></th>
<th>NHP</th>
<th>HASTe</th>
<th>HORT</th>
<th>OAT STD Read</th>
<th>OAT STD Math</th>
</tr>
</thead>
<tbody>
<tr>
<td>NHP</td>
<td>Pearson Correlation</td>
<td>1</td>
<td>.098</td>
<td>-.332</td>
<td>-.180</td>
</tr>
<tr>
<td></td>
<td>Sig. (2-tailed)</td>
<td></td>
<td>.761</td>
<td>.291</td>
<td>.619</td>
</tr>
<tr>
<td></td>
<td>N</td>
<td>12</td>
<td>12</td>
<td>12</td>
<td>10</td>
</tr>
<tr>
<td>HASTe</td>
<td>Pearson Correlation</td>
<td>1</td>
<td>-.160</td>
<td>-.234</td>
<td>.013</td>
</tr>
<tr>
<td></td>
<td>Sig. (2-tailed)</td>
<td></td>
<td>.619</td>
<td>.515</td>
<td>.972</td>
</tr>
<tr>
<td></td>
<td>N</td>
<td>12</td>
<td>12</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>HORT</td>
<td>Pearson Correlation</td>
<td>1</td>
<td>-.348</td>
<td>-.399</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sig. (2-tailed)</td>
<td></td>
<td>.325</td>
<td>.253</td>
<td></td>
</tr>
<tr>
<td></td>
<td>N</td>
<td>12</td>
<td>10</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>OAT STD Read</td>
<td>Pearson Correlation</td>
<td>1</td>
<td>.688*</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sig. (2-tailed)</td>
<td></td>
<td></td>
<td>.028</td>
<td></td>
</tr>
<tr>
<td></td>
<td>N</td>
<td>10</td>
<td>10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>OAT STD Math</td>
<td>Pearson Correlation</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sig. (2-tailed)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>N</td>
<td>10</td>
<td>10</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

NHP= Nine Hole Peg Test, HORT= Haptic Object Recognition Test, HASTe= Hand Active Sensation Test, OAT (STD) = Ohio Achievement Test Standardized Scores

**Table 6: Pearson Product Moment Correlations, Preterm**

*Significant @ $p < 0.05$
The Hand Active Sensation Test (HASTe) is a test of weight and texture discrimination. It is a valid sensory assessment that has been able to discriminate haptic touch in stroke survivors and children with cerebral palsy. The HASTe is also a reliable assessment that has shown high correlation with well known gold standard measures of sensory function. The HASTe involves matching 9 target objects, which are small cylinders, weighing 6, 7, or 8 oz. and that are covered in one of three textured materials: plastic, paper and Styrofoam. There are a total of 18 trials with each target object matched twice, once for weight and once for texture. Scoring is the number of accurate matches out of 18 trials. An accuracy score of 10 was determined to be the cut off for non-impaired function in children. An accuracy score of 9 or below suggests impairment.

The Haptic Object Recognition Test (HORT) is a test of shape discrimination using 5 novel shapes as opposed to common objects. It is a reliable assessment with good test-retest reliability and validity for demonstrating change in elderly adults following a sensory training program. Five different shapes, constructed from Lego blocks are displayed and matched without visual confirmation. The subjects are asked to complete the matching process as quickly but as carefully as possible. The number of correct matches is recorded.

Nine Hole Peg Test (Sammons, Preston and Roylan) is a standardized, timed assessment of manual dexterity for children and adults. The test consists of a plastic pegboard with 9 pegs. The participant is asked to insert the nine pegs one at a time into the pegboard and then remove them one at a time as quickly as possible. The time it takes to place all nine pegs into the board and move them back into the shallow depression is timed and recorded.

The Ohio Achievement Test (OAT) is a criterion-referenced achievement test linearly aligned with Ohio’s academic content standards for grade and subject, beginning in grade three. Raw scores are converted to scale scores which can be converted to standardized scores.

Figure 1: Test Instruments


**Article References**


5. Whitfield, Grunau, Holsti. Extremely premature (< 800g) schoolchildren: multiple areas of hidden disability. Archives of Disease in Childhood 1997; 77: F85-F90


14. Kalish, Tegenthoff, Dinse. *Improvement of sensorimotor functions in old age by passive sensory stimulation*. Clinical Interventions in Aging; on line 5-8-2008:1-18


18. SPSS for Windows, Rel. 12.01.2008. Chicago; SPSS Inc.


www.ode.state.oh.us/GD/Templates/Pages/ODE/ODEDetail
CHAPTER 5: SUMMARY and CONCLUSIONS

This was the first study to assess haptic discrimination in a nondisabled preterm population and FT control group. Our group of preterm children were, on average, considered moderately PT (GA= 32 to 36 weeks) with moderately low birth weight (1500 to 2499 g or 3.3 to 5.4 pounds). The purpose of this study was to determine whether nondisabled preterm children differ from their full term peers in 1) haptic discrimination, specifically weight, texture and shape, 2) manual dexterity, and 3) academic achievement. It also sought to determine 4) whether there is an association between haptic function, manual dexterity and/or academic performance. In this study, we have been able to demonstrate that nondisabled preterm children can have significant differences in haptic discrimination and academic achievement when compared to a full term control group.

Haptic discrimination was assessed using the HASTe, for texture and weight discrimination, and the HORT for shape discrimination. The PT group had a significantly lower mean accuracy score for the HASTe ($p = .012$) when compared to the FT control group. The FT group accuracy scores averaged 11.64 while the PT group accuracy scores averaged 9.83. For children, HASTe accuracy scores that range from 10-18 are considered non-impaired, while scores that range from 0-9 suggest impairment. The PT group fell within the range that suggests impairment. The HASTe was able to discriminate haptic function between nondisabled PT and FT children.
Unfortunately, the results for the HORT were inconclusive. A wide range in raw accuracy scores for both groups interfered with identifying any significant mean difference. The widespread inconsistency of HORT accuracy scores may have been due to: 1) our use of one trial versus three, 2) confusion with directions, 3) the HORT’s need for more precise in-hand manipulation coupled with visual perceptual demands, or 4) a high level of cognitive demands such as strategy formation, problem solving and impulse control, that is needed to perform well on this assessment. The HORT may be too challenging for children in this age range.

We believe future studies involving haptic discrimination should consider using the HORT as an assessment tool. It is a challenging assessment of shape discrimination via visual-haptic matching. Future studies could determine accuracy score cut offs and age norms which would be beneficial in identifying impairment in high functioning groups such as the nondisabled preterm population. Future studies should also consider using completion time scores for the HORT and/or testing both hands as performance indicators. More inefficient manual dexterity and greater variability in tactual performance accuracy has been found between the dominant and the non-dominant hand in children with perceptual motor and learning difficulties.37, 58, 59

Manual dexterity was assessed using the NHP.30 A statistical comparison of group means was not significant (p = 0.145) when equal variance was not assumed. There was a lot of variability in the time scores for the NHP, PT > FT. The NHP has been shown to have face, content and criterion validity but not discriminative validity.57 The manual dexterity construct measured by the NHP appears to be speed, however the
manual skills required for accurate haptic discrimination involves more deliberate manipulative dexterity, but not necessarily speed. Future studies of individuals without an apparent disability, such as the non-disabled preterm population, should consider a more challenging assessment of manual dexterity that emphasizes more in-hand manipulation instead of manual speed. For future studies that choose to use the NHP, we would recommend assessment of both hands. Studies have shown that children with perceptual motor and/or tactile discrimination impairment perform significantly worse with their non-dominant hand when compared to children with normal perceptual motor and tactual abilities.\textsuperscript{37, 58, 59}

Academic performance was measured using the reading and math scores from the OAT.\textsuperscript{31} The PT group had significantly lower mean reading achievement scores compared to the FT group ($p=.041$). The math OAT scores came close to significant, PT $< FT$ group ($p=.070$). Studies of non-disabled PT students, with normal IQ, report varying degrees of difficulty with both reading and math with almost equal incidence. It has been suggested that learning disabilities in the PT population are complex and often complicated by impairments in other domains.\textsuperscript{4, 5, 7, 9, 10, 12, 13, 14, 16, 59}

This study did not demonstrate an association between the dependent variables of sensory, motor or academic performance. This is similar to what is reported in the existing PT literature. Studies often report significant group mean differences between non-disabled PT and FT groups, but most studies, with few exceptions, do not report correlations between the impairments.\textsuperscript{12, 16, 53, 39}
A heterogeneous array of impairments often co-exists in the nondisabled preterm child. The etiology of these impairments is not known. Some researchers have inadvertently implicated sensory function and sensory discrimination as a potential primary deficit that may lead to other impairments. For example, Peterson measured regional and total brain volumes in preterm infants and discusses normal cerebral blood flow in infants. He notes a higher resting metabolic rate in the cortical sensory areas compared to other areas at birth and throughout the first three months of life; but he also describes problems with cerebral blood flow in PT infants, especially those on mechanical ventilation, along with a predisposition to ischemic and hypoxic events. He correlated these findings with later impairments in auditory processing and verbal IQ.

Weiss discusses the infant’s primary reliance on sensory input and the importance of normal quantitative and qualitative sensory experiences to the infant’s physical, emotional and behavioral health and development. She suggests disruptions to normal quantitative and qualitative sensory experiences in the preterm infant may result in psychological disorders such as attachment disorders and later emotional and behavioral problems in children.

Dr. Byron Rourke has done extensive research using neuropsychological instruments, including the Tactual Performance Test (a test of haptic discrimination) and the Grooved Pegboard on children with learning disabilities. He discusses the extremely heterogeneous nature of children with learning disabilities including those children with no apparent neurological disease or impairment. He theorizes a specific
learning disability; the nonverbal learning disability (NLD)\(^{59}\) that he hypothesizes is related primarily to developmental white matter injury and right hemispheric dysfunction. He defines the origins of NLD as “significant primary deficits in some dimension of tactile perception, visual perception, complex psychomotor skills, and in dealing with novel circumstances.”\(^{59}\) He goes on to say that “these primary deficits lead to secondary deficits in (both) tactile and visual attention and significant limitations in exploratory behavior.”\(^{59}\) According to Rourke, the functional implications of this include graphomotor problems with slow, inefficient, and frustrating pencil to paper work. He, therefore, is attributing a specific learning disability, NLD, to an array of tactile perceptual deficits. Neuropsychological testing is not as common as traditional IQ testing in PT studies, nor are specific learning disabilities usually described, but similarities of NLD and PT impairments have been mentioned.\(^{4}\)

Lastly, based on the work of Jean Ayres’ sensory integration theory comes the term “somatodyspraxia”.\(^{55}\)”Somatodyspraxia is (a movement disorder) characterized by poor planning of both anticipatory, feedforward-dependent movements and actions that depend on sensory feedback.”\(^{55}\) The sensory feedback refers to the product of higher level processing of tactile, vestibular and proprioceptive information. Key to the conveyance and the processing of tactile information is the dorsal column medial lemniscal system. She is careful to say that not all individuals with dyspraxia have sensory integrative dysfunction, but that somatodyspraxia describes a type of dyspraxia that has its origins in sensory dysfunction. Clinical observations often associated with somatodyspraxia include: “inadequate supine flexion, difficulty with sequential finger touching, impaired
ability to perform slow, controlled movements, and impaired haptic exploration and in-hand manipulation”. 55

The above mentioned studies and hypotheses regarding sensory impairments are important because they provide the theoretical basis to support the hypothesis of this study. The hypothesis of this study was that nondisabled preterm children would not perform as well as their FT peers in accuracy scores of haptic discrimination. This study, along with the above mentioned studies, highlights the importance of assessing and understanding haptic discrimination in the nondisabled preterm population. Additional studies are needed that focus on the impact of PT birth on sensory function, including haptic discrimination, and its relationship to the sensorimotor and functional impairments in the PT child at home and at school. Also, studies of haptic discrimination, at various ages, could reveal important clues in understanding the maturational changes that occur in PT and FT children. Lastly, this study found the HASTe to be a valid assessment for the nondisabled PT population and may be appropriate for future studies of this group.
REFERENCES


8. Grunau, Whitfield, Fay. *Psychosocial and academic characteristics of extremely low birth weight (< or =800g) adolescents who are free of major impairment compared with term-born control subjects.* Pediatrics 2004; 114 (6): e725-732


10. Whitfield, Grunau, Holsti. *Extremely premature (< 800g) schoolchildren: multiple areas of hidden disability.* Archives of Disease in Childhood 1997; 77: F85-F90


15. Goyen and Lui. *Longitudinal motor development of “apparently normal” high risk infants at 18 months, 3 years and 5 years.* Early Human Development 2002; 70: 103-115


28. Kalish, Tegenthoff, Dinse. Improvement of sensorimotor functions in old age by passive sensory stimulation. Clinical Interventions in Aging; on line 5-8-2008:1-18


30. Poole, Burtner, Torres. Measuring Dexterity in Children Using the Nine-hole Peg Test. 2005; 18:348-351


34. Temple, Williams, Bateman. A Test Battery to Assess Intrasensory and Intersensory Development of Young Children. Perceptual and Motor Skills 1979; 48:643-659


43. Cooke, Foulder-Hughes. *Growth impairment in the very preterm and cognitive and motor performance at 7 years.* Archives of Diseases in Childhood 2003; 88: 482-487

44. Allin, Matsumoto, Santhouse, Nosarti, AlAsady, Stewart, Rifkin, Murray. *Cognitive and motor function and the size of the cerebellum in adolescents born very pre-term.* Brain 2001; 124: 60-66


65


56. SPSS for Windows, Rel. 12.01.2008. Chicago; SPSS Inc.


Appendix A:
Permission Letters, Recruitment, and Testing Materials
July 6, 2009

Protocol Number: 2009BM138
Protocol Title: SENSORY AND MOTOR FUNCTION IN TYPICALLY DEVELOPING SCHOOL AGED CHILDREN WITH A HISTORY OF PRETERM BIRTH, Deborah Larsen, School of Allied Medical Professions
Type of Review: Initial Review—Expedited
IRB Staff Contact: Jacob E. Stoddard
Phone: 614-292-0526
Email: stoddard.13@osu.edu

Dear Dr. Ahijevych,

The Behavioral and Social Sciences IRB APPROVED BY EXPEDITED REVIEW the above referenced research. The Board was able to provide expedited approval under 45 CFR 46.110(b)(1) because the research presents minimal risk to subjects and qualifies under the expedited review category(s) listed below.

Date of IRB Approval: June 28, 2009
Date of IRB Approval Expiration: May 26, 2010
Expedited Review Category: 4, 7

In addition, the protocol has been approved for the inclusion of children (permission of one parent sufficient).

Note: Submit a letter of support from Columbus Public Schools as well as signed letters from principals of schools where research will be conducted via amendment prior to beginning research activities at specific locations.

If applicable, informed consent (and HIPAA research authorization) must be obtained from subjects or their legally authorized representatives and documented prior to research involvement. The IRB-approved consent form and process must be used. Changes in the research (e.g., recruitment procedures, advertisements, enrollment numbers, etc.) or informed consent process must be approved by the IRB before they are implemented (except where necessary to eliminate apparent immediate hazards to subjects).

This approval is valid for one year from the date of IRB review when approval is granted or modifications are required. The approval will no longer be in effect on the date listed above as the IRB expiration date. A Continuing Review application must be approved within this interval to avoid expiration of IRB approval and cessation of all research activities. A final report must be provided to the IRB and all records relating to the research (including signed consent forms) must be retained and available for audit for at least 3 years after the research has ended.

It is the responsibility of all investigators and research staff to promptly report to the IRB any serious, unexpected and related adverse events and potential unanticipated problems involving risks to subjects or others.

This approval is issued under The Ohio State University’s OHRP Federalwide Assurance #00006378.

All forms and procedures can be found on the ORRP website – www.orrp.osu.edu. Please feel free to contact the IRB staff contact listed above with any questions or concerns.

Shari R. Speer, PhD, Chair
Behavioral and Social Sciences Institutional Review Board
August 10, 2009

Don Cramer
The Ohio State University
College of Education
110 Arps Hall
1945 North High Street
Columbus, OH 43210-1172

Dear Mr. Cramer,

The Research Proposal Review Committee of Columbus City Schools has reviewed and approved the research proposal, *Sensory and motor function in typically developing school-aged children with a history of pre-term birth* by Delphina Christopher. In any communications to parents, including recruitment materials, Ms. Christopher must include the following statement: “The Columbus City School District does not endorse participation in the study.”

I am enclosing a letter of introduction. The letter of introduction should be given to administrators when soliciting participation/subjects for the study. Ms. Christopher must get the permission of building principals or designee, get their signed consent (see letter of introduction), and fax it to the Department of Evaluation Services, Columbus City Schools at 365-5160, before contacting any potential subjects at that school. The letter may be reproduced as needed in order to get signed consent from all administrators involved.

If you have any questions or concerns, please contact my office.

Sincerely,

Saundra G. Brennan, Ed.D.
Director, Evaluation Services
August 10, 2009

Dear Administrator:

This letter serves as an introduction to Delphina Christopher graduate student from the Ohio State University. Her proposed research: Sensory and motor function in typically developing school-aged children with a history of pre-term birth has been reviewed and approved by the Research Proposal Review Committee. In any communications to parents, including recruitment materials, Ms. Christopher must include the following statement: "The Columbus City School District does not endorse participation in the study."

This letter does not obligate you to participate in the study. Rather, it is an introduction and official notification that Ms. Christopher has followed established procedures and has been granted permission to solicit subjects to participate in the study.

If you agree to allow the researcher to conduct research in your building, please sign below. The researcher must then fax this letter to the Department of Evaluation Services at 365-5160. This must be completed before the researcher contacts any potential subjects or distributes any materials in your building. If you have any questions or concerns, please call my office.

Sincerely,

Saundra G. Brennan
Director, Evaluation Services

[Signatures]

Principal's Signature Date

Deborah D. H. Chisolm 9/18/09

[Printed Name]
August 10, 2009

Dear Administrator:

This letter serves as an introduction to Delphina Christopher graduate student from the Ohio State University. Her proposed research: *Sensory and motor function in typically developing school-aged children with a history of pre-term birth* has been reviewed and approved by the Research Proposal Review Committee. In any communications to parents, including recruitment materials, Ms. Christopher must include the following statement: “The Columbus City School District does not endorse participation in the study.”

**This letter does not obligate you to participate in the study.** Rather, it is an introduction and official notification that Ms. Christopher has followed established procedures and has been granted permission to solicit subjects to participate in the study.

If you agree to allow the researcher to conduct research in your building, please sign below. The researcher must then fax this letter to the Department of Evaluation Services at 365-5160. This must be completed before the researcher contacts any potential subjects or distributes any materials in your building. If you have any questions or concerns, please call my office.

Sincerely,

Saundra G. Brennan, Ed.D.
Director, Evaluation Services

Principal's Signature

Principal's Name
August 10, 2009

Dear Administrator:

This letter serves as an introduction to Delphina Christopher graduate student from the Ohio State University. Her proposed research: Sensory and motor function in typically developing school-aged children with a history of pre-term birth has been reviewed and approved by the Research Proposal Review Committee. In any communications to parents, including recruitment materials, Ms. Christopher must include the following statement: "The Columbus City School District does not endorse participation in the study."

This letter does not obligate you to participate in the study. Rather, it is an introduction and official notification that Ms. Christopher has followed established procedures and has been granted permission to solicit subjects to participate in the study.

If you agree to allow the researcher to conduct research in your building, please sign below. The researcher must then fax this letter to the Department of Evaluation Services at 365-5160. This must be completed before the researcher contacts any potential subjects or distributes any materials in your building. If you have any questions or concerns, please call my office.

Sincerely,

Saundra G. Brennan
Director, Evaluation Services

Principal's Signature: Karen Williams
Principal's Name: Maize ES
Date: 9-11-09
August 10, 2009

Dear Administrator:

This letter serves as an introduction to Delphina Christopher graduate student from the Ohio State University. Her proposed research: Sensory and motor function in typically developing school-aged children with a history of pre-term birth has been reviewed and approved by the Research Proposal Review Committee. In any communications to parents, including recruitment materials, Ms. Christopher must include the following statement: "The Columbus City School District does not endorse participation in the study."

This letter does not obligate you to participate in the study. Rather, it is an introduction and official notification that Ms. Christopher has followed established procedures and has been granted permission to solicit subjects to participate in the study.

If you agree to allow the researcher to conduct research in your building, please sign below. The researcher must then fax this letter to the Department of Evaluation Services at 365-5160. This must be completed before the researcher contacts any potential subjects or distributes any materials in your building. If you have any questions or concerns, please call my office.

Sincerely,

Saundra G. Brennan

Director, Evaluation Services

Rhonna R. McKibbin 9-11-09
Principal’s Signature  Date

Rhonna R. McKibbin Forest Park ES
Principal’s Name
Hello. My name is Del Christopher. I am working on my thesis requirement for a Master of Science Degree in Physical Therapy at The Ohio State University with Deborah S. Larsen, PhD. I am also employed by Columbus City Schools as a physical therapist.

I am looking for students for my research project and I am hoping you can help me. I would like to evaluate children’s sense of touch and their hand dexterity. The activities I have planned should be easy and fun for kids, and take only 30 to 45 minutes.

I would like to evaluate the children at school, either before or after school. The criteria for participation include:

- Ages 9, 10, 11
- Born pre-term (before 37 weeks) or full-term (37 weeks to 40 weeks+)
- Be in good health
- Be enrolled in regular education

The Columbus City School District does not endorse participation in the study. Your child’s participation is completely voluntary, but would be very much appreciated. All personal information will be confidential.

If you have any questions, and if you are interested in enrolling your child in this study, please contact me. Thank you.

Del Christopher, PT
(614) 833-9679 (Home)
(614) 477-3300 (Cell)
Email: christopher.55@osu.edu
Yes ____ I would like my child to take part in this research project.

**Student Information**

Name: ___________________ Date of Birth: ___/___/___  M/F

Grade: 3rd/ 4th/ 5th     Full term / Preterm
1) Does your child qualify for Free or Reduced Lunch?  Y/ N
2) Is your child in good health?  Y/ N
   List any areas concern:_____________________________________
3) Growth rate since birth according to most recent doctor visits:
   Below Average/ Average/ Above Average

**Parent Information**

Mother Name: _______________ Father's Name_________________
Best way to reach you? Phone #'s___________________________
   _______________________________________________________
Email ___________________________ Other:_________________

1) Mothers' highest level of school completed:
   Some High School_______
   Graduated High School_____
   Some College____________
   Graduated College_________
   Highest Degree____________

2) Household Income per year
   < $20,000______________
   $ 20,000 to $40,000_____
   $40,000 to 60,000 _______
   $ 60,000 to 80,000 _______
   $80,000 to 100,000_______
   > $100,000______________

**Additional Information: Preterm Students Only**

Name: ___________________ Date of Birth: _____________
1) Number of weeks at birth: _____________
2) Weight at birth: ________________
3) Number of Days in the hospital at birth: ___________
   Medical complications?:_________________________________
   _______________________________________________________
4) Was your child enrolled in a special needs preschool?  Y/ N
5) Has he/she ever had an IEP (Individualized Education Plan)?  Y/ N

Parent Signature: __________________Date: ___________
The Ohio State University Parental Permission For Child’s Participation in Research

IRB Protocol #: 2009B0135

Study Title: SENSORY AND MOTOR FUNCTION IN TYPICALLY DEVELOPING SCHOOL AGED CHILDREN WITH A HISTORY OF PRETERM BIRTH

Researcher: Deborah Larsen, PhD,

Sponsor: School of Allied Medical Professions

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.

Your child’s participation is voluntary.

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. If you permit your child to participate, you will be asked to sign this form and will receive a copy of the form.

Purpose:

This study is being done to determine whether children born preterm have sensory (ability to feel objects with their hands), fine motor dexterity (ability to write, manage buttons and other clothing fasteners, cut with scissors and others), and academic skills (scores on the Ohio Achievement Test) similar to children not born prematurely.

Procedures/Tasks:

The plan is for 60 children, between the ages of 9 and 11, to participate in this study; 30 preterm children and 30 full term children.

You will be asked to provide information regarding your child’s birth, medical history, and development. You will be asked to provide answers to personal information regarding your level of education and your income. You will also be asked to sign a consent form for permission to review educational records related to the Ohio Achievement Test. The Ohio Achievement Test is given annually by Columbus City Schools for students in the 3rd through 8th grades.

Your child will participate in 3 assessments: one for fine motor dexterity, called the Nine-hole Peg Test, and two for sensory function (ability to feel objects with the hand) called the HASTE and the HORT. The 3 tests should take between 30-45 minutes. The Nine-hole Peg Test involves removing and inserting nine 1/4” pegs into a peg board. The HASTE involves grasping, lifting and comparing small cylinders that are similar in size and weight to small juice cans. There will be three different weights and three different textures that the children will be asked to match using the hand that they write with, but without looking at their hand. They will be able to see everything else in their surroundings, but their hand will be hidden behind a small table top curtain. The HORT involves matching five small shapes made from Lego blocks. Five different shapes will be in view on a table in front of the child. A total of 17 matches will be in a bag held in the child’s lap. The child needs to reach inside the bag and find matches to the shapes on display.

Your child’s scores on the Ohio Achievement Test will be obtained from the School and reviewed. Your child will only need to participate in one 30-45 minute testing session. After all children are tested and the data analyzed, results will be shared with you and your child if requested.

Duration:
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.

Risks and Benefits:

Risks: Your child may experience mild fatigue during or after the assessments.
Benefits: You and your child will learn a little about their sensory and movement skills.

Confidentiality:

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;
- The Ohio State University Institutional Review Board or Office of Responsible Research Practices;
- The sponsor, if any, or agency (including the Food and Drug Administration for FDA-regulated research) supporting the study.

Incentives:
No incentives will be provided.

Participant Rights:

You or your child may refuse to participate in this study without penalty or loss of benefits to which you are otherwise entitled. If you or your child is a student or employee at Ohio State, your decision will not affect your grades or employment status.

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.

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.

Contacts and Questions:

For questions, concerns, or complaints about the study you may contact Delphina Christopher @ 614 477-3300 or, Deborah Larsen @ 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 @ 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

AM/PM

Relationship to the subject

Date and time

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

AM/PM

Date and time
Age Appropriate Assent Script

“Hi! My name is Mrs. Christopher. I’m trying to find out how well children can use their hands to feel objects, and how well your hands can feel when things are the same or different.

I have three tests I would like for you to try. One test will see if you can match five Lego shapes, and the other test will see if you can match cylinders by their weight or texture. You can’t use your eyes for either test. I want to see if you can tell when they are the same shape, weight or texture by just feeling them.

The weight and texture objects will be behind this curtain so you can’t see them but can feel them with your hand. The Lego shapes will be in this bag, so you’re reaching in to feel the shapes but you can’t see them.

The last test I want you to try is this Peg Board Test. I want to see how fast you can put them into the peg board and then take them back out.

I’m going to use my stopwatch to time you with all of these tests to see how long it takes you. I want you to try to do things quickly, but also carefully, so don’t rush.

Is this something you would like to try?”
HASTe**

Indications:
- Tests haptic sensation, specifically the ability to compare differences in texture and weight.

Procedure:
- Place curtain on tabletop
- Subject places dominant hand under the curtain
- Follow the scoring sheet exactly for all trials regarding the cylinder tested and the three choices. The score sheet is read from left to right, top to bottom.

Instructions:
“**This test is a matching test to measure how well you can use your hand to feel the weight and texture of objects.** You will use the hand that you write with. All of the objects are small cylinders that are the same shape and size. (Show one of the objects). The objects will differ in either the texture, which is the feel of the object, or in the weight of the object. You will be asked to first feel the target object and then feel three other objects. You will be asked to find the one that matches the target object. You are allowed to feel the target object and the three possible choices as many times as you’d like until you find the “match”. Tell me when you have found the match and we will move on to the next trial. There are 18 trials. I cannot tell you if you got them right or not. Just do your best.”

Normative available pediatric data:*  
0-9: Impaired  
10-18: Non-impaired

* Mays. Reliability and Validity of the HASTE in Children with Hemiparesis. Master’s Thesis. The Ohio State University 2006

** Williams, Basso, Case-Smith, Nichols-Larsen. Development of the Hand Active Sensation Test: Reliability and Validity. Archives of Physical Medicine & Rehabilitation 2006; 87:1471-1477
HASTe: Weight and Texture Discrimination Test

Subject Number: _____________

Trial Date: ________________    Trial Duration: ________________

Tested Extremity:  R    L    Hand Dominance:    R    L

For each Trial circle subject’s choice:

<table>
<thead>
<tr>
<th>T1</th>
<th>1</th>
<th>4</th>
<th>7</th>
<th>9</th>
<th>7</th>
<th>8</th>
<th>T3</th>
<th>6</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>4</td>
<td></td>
<td></td>
<td>7</td>
<td></td>
<td></td>
<td>6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T4</td>
<td>2</td>
<td>5</td>
<td>8</td>
<td>T5</td>
<td>1</td>
<td>3</td>
<td>2</td>
<td>T6</td>
<td>9</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>5</td>
<td></td>
<td></td>
<td>2</td>
<td></td>
<td></td>
<td>6</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T2</td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>T8</td>
<td>7</td>
<td>9</td>
<td>8</td>
<td>T9</td>
<td>8</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td>9</td>
<td></td>
<td></td>
<td>8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>T10</td>
<td>6</td>
<td>9</td>
<td>3</td>
<td>T11</td>
<td>1</td>
<td>3</td>
<td>2</td>
<td>T12</td>
<td>8</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td></td>
<td></td>
<td>1</td>
<td></td>
<td></td>
<td>2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T13</td>
<td>3</td>
<td>9</td>
<td>6</td>
<td>T14</td>
<td>8</td>
<td>9</td>
<td>7</td>
<td>T15</td>
<td>7</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>9</td>
<td></td>
<td></td>
<td></td>
<td>8</td>
<td></td>
<td></td>
<td>7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>T16</td>
<td>6</td>
<td>4</td>
<td>5</td>
<td>T17</td>
<td>4</td>
<td>6</td>
<td>5</td>
<td>T18</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

Accuracy Score: _______/18
**Haptic Object Recognition Test (HORT)**

**Purpose:**

**Procedure:**
- Child is seated at a table with 5 different Lego shapes in front of him that are labeled A through E. Behind the shapes are corresponding boxes labeled A-E.
- The child is allowed to manually and visually explore the objects for a few minutes prior to the test.
- Start the stop watch when he puts his hand into the bag and stop the watch when he states he is taking out the last shape and places it in the box.
- Measure time of entire test and accuracy score.

**Instructions:**

“This is a matching test to see how well you can feel the shape of an object with your hand and match it with one that you see. You will use the hand that you write with. Inside this bag are 17 shapes. They all match one of the shapes that are in front of you on the table. Your job is to feel each object and decide which shape it matches. You are not allowed to look inside the bag. When you decide which shape it matches, take the shape out of the bag and place it in the box behind the shape that you feel it matches. Don’t look at your choice; just place it in the box that is behind the object that you think it matches. I will time you with a stop watch. Please do this quickly, but also carefully. When you are taking the last shape out of the bag, let me know so that I can stop the stopwatch.”

Once the test is complete, ask the child if he used any strategies that helped him match the objects.

--Kalish, Tegenthoff, Dinse. Improvement of sensorimotor functions in old age by passive sensory stimulation. Clinical Interventions in Aging; on line 5-8-2008:1-18
9-Hole Peg **

Indications:
- Fine motor coordination, eye/hand coordination, ability to follow simple directions

Procedure:
- Place horizontally with rounded side next to the hand to be tested.
- Start stop watch as soon as person touches the first peg. Stop stopwatch as soon as last peg hits container.

Practice:
This will be a practice test. Pick up the pegs one at a time using the hand you write with only. Place the pegs in the holes until all 9 holes are filled; then remove all of them on at a time. The pegs can be placed in the holes in any order. This is a practice test. Are you ready? Begin!

Actual:
This will be the actual test. Pick up the pegs one at a time using the hand to be tested only, the hand you write with. Place them in the holes until all nine holes are filled. Then remove them one at a time. The pegs can be placed in the holes in any order. I am going to time you with my stopwatch to see how long it takes you to complete this task. Are you ready? Begin.

** Sammons Preston, A Patterson Medical Company
W68 N158 Evergreen Blvd., P.O. Box 886
Cedarburg, WI 53012, USA

Norms*

<table>
<thead>
<tr>
<th>Age Range (yrs)</th>
<th>Mean Completion Time (s) M/F</th>
<th>SD M/F</th>
</tr>
</thead>
<tbody>
<tr>
<td>4-5</td>
<td>29.8/30.2</td>
<td>3.8 / 6.3</td>
</tr>
<tr>
<td>6-7</td>
<td>25.5/22.5</td>
<td>6.0/2.3</td>
</tr>
<tr>
<td>8-9</td>
<td>19.9/18.7</td>
<td>3.9/1.9</td>
</tr>
<tr>
<td>10-11</td>
<td>18.9/16.7</td>
<td>4.1/3.4</td>
</tr>
<tr>
<td>12-13</td>
<td>18.0/17.1</td>
<td>2.5/1.8</td>
</tr>
<tr>
<td>14-15</td>
<td>18.0/16.8</td>
<td>2.7/2.4</td>
</tr>
<tr>
<td>16-17</td>
<td>16.9/15.8</td>
<td>2.0/1.9</td>
</tr>
<tr>
<td>18-19</td>
<td>16.1/16.1</td>
<td>1.6/2.1</td>
</tr>
</tbody>
</table>

* Poole, Burtner, Torres. Measuring Dexterity in Children Using the Nine-hole Peg Test. 2005; 18:348-351