2011

# A Constraint-Induced Movement Therapy Protocol for Children with Acquired Brain Injuries

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# A CONSTRAINT-INDUCED MOVEMENT THERAPY PROTOCOL FOR CHILDREN WITH ACQUIRED BRAIN INJURIES

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A Scholarly Project

Submitted to the Occupational Therapy Department

of the

University of North Dakota

in partial fulfillment of the requirements

for the degree of

Master's of Occupational Therapy

Grand Forks, North Dakota

May 2011

This Scholarly Project Paper, submitted by Amber Bath and Kortni Heckart in partial fulfillment of the requirement for the Degree of Master's of Occupational Therapy from the University of North Dakota, has been read by the Faculty Advisor under whom the work has been done and is hereby approved.

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**Department:** Occupational Therapy

**Degree:** Master's of Occupational Therapy

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TABLE OF CONTENTS

LIST OF FIGURES

ACKNOWLEDGEMENTS

The authors would like to extend a special thanks to Dr. Jan Stube, PhD, OTR, FAOTA, for her support, encouragement, and advisement during the development of this scholarly project.

The authors would also like to thank all of their family and friends for their continued support and encouragement throughout the past three years.

ABSTRACT

Acquired brain injury (ABI) includes any non-traumatic brain injuries such as stroke, cerebral palsy, and brain diseases such as cancer (Book, 2005). A child who sustains an acquired brain injury may experience profound impairments in motor performance, and significant deficits in sensory awareness and responsiveness, secondary to hemiplegia. (Taub et al., 2007, Taub, Ramey, DeLuca & Echols, 2004). Constraint Induced Movement Therapy (CIMT) is a intervention developed by Dr. Edward Taub for the secondary condition of hemiplegia affecting the adult stroke population. This intervention has also produced positive results in studies conducted with children (Taub et al., 2007). An extensive literature review revealed the need for further research to be completed using CIMT for pediatric diagnoses other than cerebral palsy. This manual was created to provide occupational therapists with an evidence-based protocol to guide the intervention process when using CIMT. The product includes an extensive literature review, an intervention protocol guide, and an evidence-based review to promote further research in occupational therapy and the pediatric population. The authors concluded that by creating this intervention protocol, children with ABI would be greatly benefited.

# CHAPTER I

# INTRODUCTION

Traumatic Brain injuries (TBI) do not affect only an individual's brain, but their whole system including physical, psychological, and social contexts. The side effects of TBIs can result in multiple deficits that may impair an individual's ability to perform tasks in activities of daily living (Yen & Wong, 2007). In the United States approximately 185 children out of every 100,000 will acquire a TBI each year (Yen & Wong, 2007). The most frequent causes of TBI among children are head trauma from car accidents, child abuse, and falls (Babikian et al., 2005.) Acquired brain injury (ABI) is another type of brain injury which includes any non-traumatic injury to the brain such as tumors, stroke, disorders of the metabolic system, and other degenerative conditions (Book, 2005.)

It has long been thought that a child's increased brain plasticity gave them a superior advantage in recovering from a brain injury. However, there are different theories suggesting otherwise. There are critical periods in a child's brain development; if any sort of interference occurs during this time of development, permanent disruption of the brains functional abilities may occur (Catroppa, Anderson, Morse, Haritou, & Rosenfeld, 2008). For example, there is a theory of *early vulnerability* in which it is believed that if the brain is damaged during a vital stage of development, irreversible damage may occur (Anderson et al., 2009). The brain's reorganizational ability is thought to be much stronger the younger the age of the child, and plasticity is superior in the developing brain (Johnston, 2009.) The theory of *early plasticity*, in which it is believed that the superior ability of a child's brain to reorganize itself gives a child's brain a unique advantage, supports this belief (Anderson et al., 2010).

As a result of ABIs, children often sustain hemiplegia and motor movement disorders. The purpose of this Constraint-Induced Movement Therapy Protocol for Children with Brain Injuries is to provide occupational therapists with an evidenced-based approach to carry out constraint-induced movement therapy (CIMT) intervention effectively for children, aged 7 months and older. CIMT has been found to be a promising intervention for substantially increasing the use of upper extremities affected by such neurologic injuries as stroke and traumatic brain injuries in adults (Taub, Ramey, Deluca, & Echols, 2004). However, the idea of introducing CIMT to the pediatric population is a relatively new concept. Children with a variety of conditions can widely benefit from the intervention of CIMT. The evidence supporting its use for children will be provided in chapters II and IV. In the pediatric population, CIMT may be a useful intervention with a variety of diseases, disorders, and illnesses, such as cerebral palsy, childhood strokes, hemiplegia, acquired brain injuries, and traumatic brain injuries. The overall goal of CIMT is to overcome a learned non-use behavior and improve functional use of the affected upper extremity (UE) by "forcing" use of the affected upper extremity (de Bode, Fritz, Weir-Haynes, & Mathern, 2009).

The role of the occupational therapist in the CIMT intervention process is to provide evidence-based intervention techniques using a variety of occupation-based activities that are meaningful to the child during this time of development. Occupational therapists focus on activities that an individual performs in their everyday life which have a specific important meaning to them and their functional performance (AOTA, 2008). The education of occupational therapists allows them to integrate occupations in to the therapeutic setting while addressing the cognitive and physical deficits of the child.

## Motor Leaning and Task Oriented Approach Frames

The Motor Learning theory is a multidisciplinary approach that is able to be easily applied to all types of movement anomalies. The framework incorporates psychology, behavioral sciences, neurology, medicine and allied health research which supports the proposal that a task-oriented approach directly correlates with motor learning (Cole & Tufano, 2008). Motor learning is defined as" the search for a task solution that emerges from an interaction of the individual with the task in the environment" (Shumway-Cook & Wooollacott, 2001, p. 1). Stedman's Medical Dictionary defines motor control as "the process of initiating, directing, and grading purposeful voluntary movement" (2005, p. 945). In order for a child to experience recovery of movement it is suggested that the occupational therapist have the child perform tasks in their natural environment (Cole & Tufano, 2008, p. 249).

According to Bear, Connors, and Paradiso (2007), nonassociative learning is defined as "the change in the behavioral response that occurs over time in response to a single type of stimulus." (Bear, Connors, & Paradiso, 2007, p. 763). There are two types of nonassociative learning: habituation, and sensitization. Habituation is defined as the diminished responsiveness which occurs from a repeat exposure to a non-noxious stimulus. For instance, in a therapy session, an occupational therapist may need to assist a client in becoming desensitized to stimuli that cause abnormal, or nonfunctional, motor movements. The second type of nonassociative learning, sensitization is defined as an increased response that follows an exposure to unpleasant or unsafe stimuli. For example, in a therapy session, a client may need assistance in increasing their sensitivity to unsafe situations in order to facilitate safe motor movements in different contexts (Cole & Tufano, 2008).

Another type of learning is associative learning which is how individuals form connections between events. Classical and instrumental conditioning form two sub-types of associative learning. Classical and operant conditioning allow the individual to associate one stimulus with another. This theory allows occupational therapists to better understand the process of reinforcing functional movements within the individual (Bear, Connors, & Paradiso, 2007; Cole & Tufano, 2008). Instrumental conditioning is when an individual learns to correlate a response with a rewarding stimulus (Bear, Connors, & Paradiso, 2007).

Two other types of learning are addressed by the Motor Learning and Task-Oriented approach. Procedural learning refers to tasks that do not require attention or conscious thought and develop through rote practice; in contrast, declarative learning requires conscious thought as well as mental practice, strategies, and/or sequencing (Cole & Tufano, 2008).

In order for this approach to be successful, it is important to match the tasks with the client's abilities and priorities. The therapist should begin with the tasks that the client can perform independently, and gradually move toward more difficult tasks that may require assistance. This motor approach has been used in treating adult survivors of stroke using CIMT (Cole & Tufano, 2008). This type of technique allows for task demands and environmental contexts to be changed as well as allows for muscle strengthening, stretching, supports, and splinting to be used in the motor learning process (Cole & Tufano, 2008). This framework also allows occupational therapist to use a holistic perspective, and maintain client-centeredness throughout the intervention process. Client-centeredness and a holistic viewpoint is encouraged in this frame of reference through the occupational therapist working with the client to identify personal goals, assisting the client with application to different contexts, and instructing the client on specific ways to accomplish meaningful tasks (Giuffrida & Rice, 2009).

## Key Terms

The following terminology was adapted from multiple resources that will be referred and referenced to later in this manual.

Traumatic Brain Injury (TBI)- An insult to the brain not of degenerative or congenital nature, but caused by an external physical force.

Acquired Brain Injury (ABI)- Any non-traumatic injury to the brain such as tumors, stroke, disorders of the metabolic system, and other degenerative conditions.

Constraint-induced Movement Therapy (CIMT)- An intervention used by therapists to constrain the unaffected upper extremity of an individual with hemiplegia to promote use the affect extremity.

Brain Plasticity- The brains ability to reorganize itself after injury such as stroke or other brain trauma.

Hemiplegia- Reduced muscle tone, decrease in reflexes, and paralysis on one side of the body.

Differentiation- The process by which parts of the body become specialized during development.

Cerebral Cortex- The part of the brain where the systems that control processing of sensations, learning, language, voluntary movement, cognition, and perception all come together.

Frontal Lobe- Front portion of the brain which controls voluntary movement and thinking.

Occipital Lobe- The lower hind portion of the brain which controls vision.

Temporal Lobe- The lower lateral portion of the brain that controls auditory sensation.

Parietal Lobe- The upper later portion of the brain which processes information about incoming sensations.

Computed Tomography (CT)- A non-invasive test using electromagnetic radiation to obtain a three dimensional view of the brain.

Magnetic Resonance Imaging (MRI)- A test that allows the specialist to obtain a detailed picture of the brain.

Learned non-use- A condition in which an individual stops using the affected limb because of several unsuccessful attempts.

Shaping- A behavior training method in which the end goal is approached in small steps.

## Summary of Chapters

Chapter I introduces the reader to TBI, ABI, brain organization, and CIMT. The chapter concludes with a list of key terms to guide the reader in understanding complex medical terminology. Chapter II is a review of literature divided in to four parts: neuroscience, CIMT, types of constraints, and assessments. The third chapter of the manual includes the methodology used for the development of the CIMT protocol. Chapter IV is the product for occupational therapists to implement the CIMT protocol. The product is entitled, "Constraint-induced Movement Therapy for Children with Acquired Brain Injuries" and includes sections encompassing: childhood brain development, constraint-induced movement therapy intervention, assessments, and a research evidence table using AOTA's critically appraised topic format. The last chapter of the manual is the summary of the literature, protocol, and suggestion for further evidence-based research by occupational therapists.

# CHAPTER II

## LITERATURE REVIEW

Traumatic brain injury (TBI) is a frequent cause of acquired childhood injury. In the United States alone, traumatic or acquired brain injury accounts to close to 50% of fatalities in children. The main age groups in which TBIs occur is under the age of five, and mid to late teenage years (Yen & Wong, 2007). In both of these age groups, there are periods in a child's development in which vital maturation of the brain occurs. If there is any sort of interference during these critical periods of development, permanent disruption of the brain’s functional abilities may occur including impairments including deficits in attention, memory, education, and adaptive issues (Catroppa, Anderson, Morse, Haritou, & Rosenfeld, 2008). The theory of *early vulnerability*, in which it is believed that if the brain is damaged during a vital stage of development irreversible damage may occur, supports this statement (Anderson, Jacobs, Spencer-Smith, Coleman, Anderson, Williams, Greenham, & Leventer, 2009). The most frequent causes of TBI in children is head trauma from car accidents, child abuse, and falls (Babikian, Freier, Tong, Nickerson, Wall, Holshouser, Burley, Riggs, & Ashwal, 2005). There is also a type of brain injury termed acquired brain injury (ABI) which includes any non-traumatic brain injuries such as stroke, cerebral palsy, and brain diseases such as cancer (Book, 2005). TBI and ABI may cause permanent impairments in motor performance, intelligence, and problem solving, and executive brain function.

The subject of brain plasticity in children has been the basis of much debate in the field of neuroscience in recent years. The term "brain plasticity" in simple terms, means that the human brain has the ability to reorganize itself after an injury such as a stroke, or other brain trauma. This term also refers to the brain's unique ability to learn and remember information, even after a traumatic event (Chapman, Max, Gamino, McGlothlin, & Cliff, 2002; Johnston, 2009). In children, it has long been thought that better functional outcomes occurred if a child sustained a brain injury earlier in childhood. The brain's reorganizational ability was thought to be much stronger the younger the age of the child, and plasticity was thought to be superior in the developing brain; therefore, children can make better progress when recovering from brain injuries than adults can (Johnston, 2009). The theory of *early plasticity*, in which it is believed that the superior ability of a child's brain to reorganize itself gives a child's brain a unique advantage, supports this belief (Anderson et al., 2009). However, there are many in neuroscience research who are now starting to dispute the idea that a child's increased brain plasticity always gives them an advantage in recovery from brain injury. Many times, children who have experienced an acquired brain injury or a traumatic brain injury, have no visible signs of impairment, but have extreme deficits in brain function (Forsythe, 2009).

Most research does point to the fact that children do have greater reorganizational ability in their brains than adults do, but it is still not clearly understood how much advantage this actually provides in a child's recovery (Anderson et al., 2009). There are new improvements in the measurements of functional recovery in children that are challenging the subjective and widespread beliefs regarding pediatric brain plasticity (Chapman, Max, Gamino, McGlothlin, & Cliff, 2002). For instance, shaken baby syndrome is one of the most common and most traumatic brain injuries that occur in infants. It is common knowledge that the bones in an infant skull are very flexible, not rigid as in adults; therefore, the circumstances required to cause a brain injury in an infant are much different than in an older person. A very young infant has a large head mass in comparison with its body; an infant also has underdeveloped neck muscles and a spinal column that is more prone to severe injury because of the arrangement of facet joints and the vertebral column. Computed Tomography (CT) scans of children, who have been subjected to shaking, reveal extreme swelling and brain death due to a decrease in oxygen to the brain because the infant stopped breathing. This type of injury minimizes the effect of the brain's ability to reorganize itself, and oftentimes, the brain cannot overcome this trauma (Geddes, Vowles, Hackshaw, Nickols, Scott, & Whitwell, 2001).

To look at this further, a 2005 study examined eighteen children between the ages of one and eighteen who had acquired head trauma. These children had deficits in many areas including intelligence, problem solving, educational performance, memory problems, and decreased attention and processing abilities. Magnetic Resonance Imaging (MRI) results revealed that there was a decrease in a certain neuronal markers, specifically N-acetyl and N-creatine which influenced recovery. This finding also determined that if a child had both risk factors which included younger age at injury and experiencing a more severe injury, they experienced poorer functional outcomes (Babikian et al., 2005).

There is a definite correlation between the age at the time of brain injury and functional outcomes in children. A study conducted by Anderson et al., (2009), examined one hundred and sixty-four children who had sustained a non-traumatic brain injury at different points in their childhood, and the researchers were able to determine the timing of the brain injury with MRI scans, brain biopsies, and medical history. The researchers concluded that they supported the "early vulnerability" theory, in which it is stated that a child's brain is more sensitive, therefore, significant impairments may occur. The results of this study did find that the age that a child sustained a brain injury before age two did play a significant role in poorer functional outcomes (Anderson et al., 2009).

The subject of brain plasticity was also explored by examining the connection between a child's age at the time of a brain injury and future neurological and psychiatric outcomes. Children included in a study by Max, Keatley, and Delis (2008), had suffered a stroke either before birth, or at some point during their childhood. The children were placed in two categories; "early" injuries which were acquired before age one, and "late" injuries which were acquired after age one. MRI brain scans were also obtained to determine the lesion size. The researchers examined aspects such as intelligence, language, visuospatial skills, memory, and executive functioning. This study did find that children, who acquire a brain injury prior to age one, do have significantly greater impairments psychiatrically and neurologically (Max, Bryce, Keatley, & Delis, 2010). These findings also support the "early vulnerability" theory.

Catroppa, Anderson, Morse, Haritou, and Rosenfeld (2008), stated that the highest indicator of positive adaptive and behavioral outcomes was a child's adaptive function prior to their brain injury. One hundred and nine children with a diagnosis of TBI were originally included in this study, with forty-eight children participating in the five year follow up. The children were evaluated in the first three months of TBI on intellectual abilities, and school skills. This study also found that children who experience a severe brain injury in early childhood between ages two to six years can have lasting global functioning impairments (Catroppa, Anderson, Morse, Haritou, & Rosenfeld, 2008).

There has been much information obtained from research regarding brain injury in adults. The mistake that is made all too often is transferring the adult model regarding brain injury to children. There is still little research on the effects of early childhood brain injury and all too often, the results of adult research are simply transferred into the treatment of children (Chapman, Max, Gamino, McGlothlin, & Cliff, 2002; Forsythe, 2009).

As stated by Yen & Wong, 2007:

> Children are not little adults. Their nervous systems at the time of injury are still not fully mature. They are still in the process of developing and acquiring new skills. Children must not only meet the challenges of recovery, but also ongoing

challenges of development and maturation. The impact of TBI on a child's ability to achieve developmental milestones has been found to be a critical factor in determining long-term outcome.

There is plenty of research involving animal subjects in regards to the treatment of TBI and ABI, however, it is often difficult to replicate these treatments when performing interventions with patients in a real world setting. Research regarding treatment of children with TBI or ABI, as well as brain plasticity in the pediatric population, is still very scarce when compared with the hundreds of research studies performed in adults.

## Constraint-Induced Movement Therapy

Constraint-Induced Movement Therapy (CIMT) has been found to be a promising treatment for substantially increasing the use of extremities affected by such neurologic injuries such as stroke and traumatic brain injuries in adults (Taub, Ramey, Deluca, & Echols, 2004). However, the idea of introducing CIMT to the pediatric population is a relatively new concept. Children with a variety of conditions can widely benefit from the intervention of CIMT. In the pediatric population CIMT may be a useful treatment for intervention with a variety of diseases, disorders, and illnesses, such as Cerebral Palsy, childhood strokes, hemiplegia, acquired brain injuries, and traumatic brain injuries.

- The most common disorders for which CIMT is used:

- Cerebral Palsy (CP) - CP is a motor disorder resulting from non-progressive lesion to the motor cortex during the early period of development (Martin, Burtner, Poole, & Phillips, 2008).
- Cerebral Vascular Accident (CVA) -Damage to the brain that occurs when the blood flow to the brain is disrupted (Ehrlich & Schroeder, 2005).
- Brain Trauma-Wound or injury to the brain (Ehrlich & Schroeder, 2005).
- Acquired Brain Injury (ABI) -Any non-traumatic injury to the brain such as tumors, stroke, disorders of the metabolic system, and other degenerative conditions (Book, 2005).
- Traumatic Brain Injury (TBI) - An insult to the brain not of degenerative or congenital nature, but cause by an external physical force (Reed, 2001).

"The overall goal of CIMT is to overcome a learned non-use motor behavior and improve functional use of the affected upper extremity (UE) by "forcing" use of the affected upper extremity (de Bode, Fritz, Weir-Haynes, & Mathern, 2009, pg. 362)". Originally researched using monkeys, Dr. Edward Taub found that when constraining the affected limb for functional activities the monkeys overcame the learned "non-use" (Haung, Fetters, Hale, &Mcbride, 2009). Shaping techniques and repetitive techniques were later added to the approach which added to the constraint (Haung et al., 2009). CIMT has been reportedly used with a growing number of adults in the stroke population; it has been hypothesized that the constraint portion of CIMT improves the motor behavior and learned "non-use" (Glover, Mateer, Yoell, & Speed, 2002). According to

Glover et al., (2002), the results with the adult stroke population with secondary hemiplegia show a reason to believe that CIMT has benefits for children with developmental hemiplegia.

Children with hemiplegia have sensory-motor problems similar to those of adults with hemiplegia (Glover et al., 2002). According the Glover et al. (2002), children with hemiplegia often demonstrate early poverty of movement in the affected side; this is exemplified by fisting of the affected hand. Although care must be taken in applying adult outcomes of CIMT to a pediatric population, “forced use” alone results in improvement in chronically hemiperetic adults after a stroke (Willis, Morello, Davie, Rice, & Bennett, 2002). In addition to using forced use, adding intensive therapy and constraint induced movement therapy produces great movement (Willis et al., 2002). Given the efficacy of using CIMT with the adult stroke population there is reason to believe that benefit extends to children with hemiplegia, potentially because the brain plasticity of a child is expected to be greater.

“The consequences of major motor disabilities are profound for all aspects of a child’s quality of life; the deficits are not only seen in neuromotor function but in sensory awareness and responsiveness in their physical and social environment” (Taub et al., 2004). Children who have participated in CIMT as an intervention have had various forms of etiologies ranging from cerebral palsy, stroke, trauma, and cerebral hemispherectomys (de Bode et al., 2009). CIMT is commonly reported as a highly intensive intervention ranging from 60-126 hours of treatment (Sakzewski, Zivini, &

Boyd, 2009). According to Hoare et al., (2007), CIMT is most effective when the unaffected limb is constrained for 90% of the waking hours over a 2-3 week period. The research validates that depending on the individuals performing the intervention the constraint varies for time it is being used as a form of intervention for a child.

According to Gordon, Charles, and Wolf, (2005), there are two main principles of CIMT. The first principle is restraint of the child's less-involved upper extremity and secondly, intensive practice of the hemiplegic arm and hand using shaping. The use of CIMT as an intervention in young children with hemiparesis can lead to positive progressions in motoric function (Taub et al., 2004). Due to individuals receiving CIMT therapy for such an extensive amount of time, approximately six to eight weeks, it is imperative that their parents/guardians are aware and cooperative with the intervention process, because the therapist treating the child is unable to be present at all times.

According to Cope, Forst, Bibis, and Liu, (2008), the application of CIMT to the pediatric population has prompted concerns that the children may not developmentally be ready for the intense massed practice and restraint used in CIMT. However, recent studies have shown that children aged zero to eighteen months of age can benefit from CIMT. The concerns for the pediatric population receiving CIMT are that the restraint poses a safety risk, which may cause unnecessary frustration and stress for the child to use the affected arm, and may negatively affect the unaffected upper extremity due to constraint (Stanger & Oresic, 2003).

The neural basis of the brain reorganization following both developmental and acquired insults to sensorimotor cortices with results in hemiparesis is still not fully understood (de Bode, Weir-Haynes, and Mathern, 2009). CIMT is believed to alter the representation of the upper extremity within the primary motor cortex in adults, yet more research is needed in the pediatric population (de Bode et al., 2009).

## Constraints

The types of restraints that therapists use in CIMT vary depending on the research and protocol study that is being performed. In a critical review of CIMT or forced use, the beginnings of CIMT are discussed. CIMT began in research laboratories, and the subjects were primates, primarily monkeys. Researchers would surgically render one of the monkey's upper limbs hemiplegic by deafferentation. This simulated the effects of a brain injury, in which oftentimes, hemiplegia occurs. Hemiplegia ultimately causes sensory and movement dysfunction and causes an individual to have ineffective use of their impaired upper extremity. In the research setting, monkeys with surgically-induced hemiplegia, would not use their affected upper extremity unless the other extremity was restrained. It is felt that one of the reasons for the non-use was the result of many attempts to use the arm with no success. Shaping techniques, where a preferred motor action is performed in small and successive steps, was used with great success in these studies.

CIMT has been used extensively with adults after stroke, but was first introduced for children by Dr. Edward Taub and associates in 2007. Dr. Taub developed a set of procedures that were specifically designed to be used in children with brain injuries, specifically cerebral palsy, and were similar to those previously used in adults. These procedures were developed by Dr. Taub and associates for children eight months to eight years of age. There are three essentials steps that must be used when implementing CIMT training which include: rigorous training of the affected upper limb; extended restraint of the unaffected or less affected upper limb; and transfer of the skills learned in the clinical setting to real life situations. Dr. Taub used a fiberglass cast for upper extremity constraint which was held together by Velcro, and wrapped in an elastic bandage. Dr. Taub proposed having the child wear the cast on a twenty-four hour a day basis, which may prove difficult for effective compliance when the intervention is performed in the home setting (Taub, Griffin, Nick, Gammons, Uswatte, & Law, 2007).

In a 2006 report by Charles and Gordon, a type of training call Hand-Arm Bimanual Intensive Training (HABIT) is introduced. HABIT training involves the child being encouraged to used both hands in activities, and does not require the use of any type of restraint. Children will be involved in both functional and play activities that required the use of both hands for six hours per day on weekdays. The proposed activities include card games, video games, arts and crafts projects, and games that involve in-hand manipulation. HABIT training is drawn from the success of CIMT, but differs in the fact that no restraint is used, and it is considered more child-friendly because of this (Charles & Gordon, 2006). This protocol is considered to be one of the first functionally-based and intensive bimanual interventions for children and adults, and is expected to be successful in randomized, controlled trials (Charles & Gordon, 2006).

A 2005 study using modified CIMT conducted by Naylor and Bower, (2005), did not implement a restraint in the research protocol. A gentle manual restraint and verbal cuing were provided by the researchers in the clinic setting, and by the parents at home. The children in this study were aged twenty-one months to five years of age, and engaged in a variety of activities including performance in action songs, playing with dough, putting together puzzles, and playing computer games. Results were measured using the Quality of Upper Extremity Skills Test (QUEST), and it was shown that this treatment yielded promising results. The children who participated in this study exhibited improved upper extremity gross and fine motor function. This methodology of simply providing gentle manual restraint and verbal cuing is thought to be easier for children and parents to adhere too. It is tolerated well by the participants, and it is easy for parents to implement as a home program (Naylor & Bower, 2005).

CIMT is most often implemented with the use of a restraint on the unaffected arm and hand. A study conducted by Stearns, Burtner, Keenan, Qualls, and Phillips in 2009 involved the use of a removable bi-valve splint, or air cast that the child was required to wear four hours day during both therapy, and other activities. Several methods of measuring improvements were used including grip, pinch, nine-hole peg test, and the box and blocks test. Following the two week treatment session, the children were also assessed using electromyography.

In this study, pediatric subjects were between the ages of five and eight years. The subjects completed self-care activities such as eating, bathing, brushing their teeth and hair, and dressing, and play activities including drawing, painting, board games, and using scissors. Children who participated in this study did show considerable advancements in hand skills. The children did accept wearing the bi-valve cast well, and wore it for approximately eight to twelve hours a day (Stearns, Burtner, Keenan, Qualls, & Phillips, 2009).

A similar study conducted by Deluca, Echols, Law, and Ramey in 2005 also involved the use of a bi-valve cast which was removed weekly. The QUEST test was used for assessment, and examined four domains of motor function including dissociated movements, grasping, protective extension, and weight bearing. The children aged eight years or younger, performed activities while weight-bearing on the affected arm, as well as activities that encouraged in-hand manipulation, fine motor tasks, self-care activities, and grasping and reaching tasks. The children tolerated the restraint well, and showed positive improvements in the four domains of motor function assessed (Deluca, Echols, Law, & Ramey, 2007). Willis, Morello, Daviess, Rice, and Bennett 2002, also implemented the use of a cast in the CIMT treatment. In this study, several parents did request that their child not continue participation in the CIMT treatment because the child complained about wearing the cast. The children in this study were between the ages of one and eight years. The method of measurement in this study was the Pediatric Developmental Motor Scale, and functional use of the affected upper extremity was noted in all twenty-two of the children who participated in the study (Willis et al., 2002). A similar study conducted by Martin, Burtner, Poole, and Phillips (2008), also used a removable cast during the treatment period. The researchers used assessments which included the Canadian Occupational Performance Measure (COPM), the Melbourne Assessment of Unilateral Upper Limb Function, and the self-care scale of the Pediatric Evaluation of Disability Inventory (PEDI). The child, aged three, participated in activities for improving fine motor skills and activities of daily living. The child participated in four hours of therapy six days per week in the clinical setting, and two hours of therapy in the home setting (Martin, Burtner, Poole, & Phillips, 2008). Results from the study included the child showing improvements in activities and participation, and an increase in grip strength.

A study in 2008 conducted by Cope, Forst, Bibis, and Liu, emphasized the use of a non-removable cast which was worn for two weeks in a modified CIMT treatment protocol. One child, aged twelve months, participated in this study. Three assessments were used including the Peabody Developmental Motor Scales-2 (PDMS-2), parts of the Visual-Motor Integration subtests, the Toddler Amount of Use Test (TAUT) designed by Taub, and the Knox Parent Questionnaire. According to the researchers, the participant tolerated the cast well, and had no problems during the study (Cope, Forst, Bibis, & Liu, 2008). The child wore the cast during the two- week modified CIMT protocol; they participated in two sixty-minute sessions each week which included both occupational and physical therapy. Activities focused on the use of both hands and unilateral hand use, sensory interventions, activities that included weight-bearing and trunk strengthening, and movements that encouraged transition from sitting to standing (Cope, Forst, Bibis, & Liu, 2008). The results of this study included the child's parents noticing positive changes in the child's arm and hand function.

Another restraint that has been used in CIMT treatment is a fabric glove with a built in plastic splint. This type of glove allows the child to use the hand for support, but prevents them from using it during activities. In this study conducted by Eliasson, Krumlinde-Sundholm, Shaw, and Wang, (2005), the children only wore the glove for two hours per day instead of 90% of their waking hours as in Dr. Taub's original study conducted in 2007. The children who participated in this study were aged eighteen months to four years.  The Assisting Hand Assessment was used, and examines the effectiveness in which a child who has one-sided impairment uses their affected hand. The activities included were playing with dough, puzzles, computer games, finger games, sorting objects, and threading beads and buttons. Most children adapted well to wearing the restraining glove (Eliasson, Krumlinde-Sundholm, Shaw, & Wang, 2005). Specific results of this study included the children who participated in the CIMT therapy intervention improved the use of their affected upper extremity as compared to the control group.

A more child-friendly form of CIMT was developed by Charles, Wolf, Schneidner, and Gordon in 2006. The assessment used in this study was the Jebsen-Taylor test of hand function, as well as the fine motor subtests of the Bruininks-

Oseretsky. The restraint used in this study was a sling worn by the children aged four to eight years, for a six-hour treatment period. The children were expected to participate in activities at home using the involved extremity without restraining the uninvolved side for one hour, and the parents kept activity logs. The participants in this study showed improvements in hand function even without wearing the sling in the home program which is different from most previous research studies. The researchers felt that having this child-friendly approach encouraged compliance with the treatment (Charles, Wolf, Schneider, & Gordon, 2006).

In a 2010 Cochrane systematic review conducted by Hoare, Imms, Carey, and Wasiak, (2007), several assessments were used to measure outcomes of children engaged in CIMT. The QUEST test was used for measuring the quality of upper limb movement, a caregiver questionnaire called the Pediatric Evaluation of Disability Inventory, Pediatric Motor Activity Log, the Canadian Occupational Performance Measure, Goal Attainment Scaling, the Modified Ashworth Scale to measure muscle tone, and the Modified Tardieu Scale to measure spasticity. Restraints in the review included a bi-valved cast, a short arm cast, a Neoprene glove, and a sling. The activities chosen by the therapists included playing games that encouraged repetitive practice, both gross and fine motor skills, and activities of daily living (Hoare, Imms, Rawicki, & Carey, 2010). Specific results from the review included the participants showing improved use of their impaired upper extremity.

Similarly, a study conducted by Dickerson and Brown (2007), implemented the use of a custom-fabricated removable splint was implemented during the CIMT treatment. The child, aged two, wore the splint for the majority of his waking hours for twenty-one days. The child was able to remove his splint for bathing, sleeping, and short rest periods. The child participated in six hours of occupational therapy intervention. Activities included activities of daily living and play activities (Dickerson & Brown, 2007). The results of this study found that the child showed considerable improvements in functional use of his impaired right upper extremity.

The results of this exhaustive literature review yielded the conclusion that further research is needed in the pediatric population, specifically with acquired brain injuries. A protocol specifically developed for children with this diagnosis will result in further research and prove beneficial for the pediatric population experiencing ABIs and hemiplegia.

Introduction to CIMT Protocol Guide

Purpose and Rationale Statement: As stated previously there is limited research in the area of using CIMT as an intervention technique with the pediatric population, specifically with children diagnosed with brain injuries. The intention of this treatment protocol is to create universal guide to be used by occupational therapists as an intervention for children with hemiplegia due to traumatic or acquired brain injuries.

| Organization of Manual | | |
|---|---|---|
| **Chapter One** | Introduction | Preface to the use of CIMT with the pediatric population experiencing TBIs and hemiplegia. |
| **Chapter Two** | Literature Review | Overview of the research and results of using CIMT as an intervention with populations experiencing hemiplegia. |
| **Chapter Three** | Methodology | The approach the authors used to gather and review literature to form a treatment protocol for using CIMT in the TBIs in the pediatric population. |
| **Chapter Four** | Product | Neuroscience, Occupational Therapy, CIMT, Treatment Protocol, Assessments, Activities, Follow-Up, and Level of Evidence Table |
| **Chapter Five** | Summary | Concluding thoughts and hopes for the use of the treatment protocol to be implemented by therapists as well as further research to be conducted using the pediatric population. |

# CHAPTER III

# METHODOLOGY

From the review of literature, Constraint-Induced Movement Therapy (CIMT) is a promising intervention for children with acquired brain injuries (ABI). In the United States approximately 185 children out of every 100,000 will acquire a brain injury each year (Yen & Wong, 2007.) The goal of CIMT is to overcome a learned non-use behavior and improve functional use of the affected upper extremity (UE) by “forcing” use of the affected upper extremity (de Bode, Fritz, Weir-Haynes, & Mathern, 2009.) There is limited of research regarding CIMT with pediatric diagnoses other than Cerebral Palsy (CP). Often when treating children with hemiplegia the adult intervention protocols are applied to the child’s intervention.

Yen and Wong (2007) stated:

> Children are not little adults. Their nervous systems at the time of injury are not fully mature. They are still in the process of developing and acquiring new skills. Following injury, children must not only meet the challenges of recovery but also ongoing challenges of development and maturation (p.63).

The methodology used to gather information for the development of this CIMT intervention protocol for children with acquired brain injuries was an extensive literature review which revealed the need for its development, as well as personal communication with Joni Armstrong, OTR, CHT, who works specifically with the pediatric population. Information for the literature review was gathered using the following databases:

PubMed, CINAHL, SCOPUS, The *American Journal of Occupational Therapy*, and the Cochrane Library. Results from the literature gathered were compiled into an evidence table, using the American Occupational Therapy Association's format, and the information was used to compile the CIMT pediatric intervention protocol.

The CIMT intervention protocol was developed for use by occupational therapists in order to assist them in providing evidence-based intervention and promote further research for children with acquired brain injuries. The protocol uses the Motor Learning and Task Oriented Approach (Cole & Tufano, 2008), for occupational therapists to better assist children in regaining motor function in the hemiplegic upper extremity. This frame of reference allows the child to engage in tasks that are meaningful to them, while addressing motivation and encouraging the child to interact with the task and their environment.

The protocol contains information regarding the neurology and neuroanatomy of a child's brain development as well as information about what an occupational therapists role is in CIMT intervention. The figures of the brain located in the product were adapted using Microsoft Word 2010 clipart. The protocol gives a detailed explanation of what CIMT is and how the intervention works to rehabilitate children with hemiplegia. The overall goal of this protocol is to benefit children who have acquired brain injuries, and allow them to regain function with daily life skills. It is the hope of the authors that this intervention protocol be implemented by occupational therapists to facilitate intervention, and further clinical research for the pediatric population.

CHAPTER IV

PRODUCT

# Constraint-Induced Movement Therapy Protocol for Children with Acquired Brain Injuries



By: Amber Bath and Kortni Heckart

Table of Contents

## Introduction

Occupational therapists use the healing power of meaningful occupations as a form of intervention to establish or restore new behaviors and skills that have an impact on an individual's activities of daily living. The role of the occupational therapist is to focus on activities that an individual performs in their everyday life which have a specific and important meaning to them, and their functional performance (AOTA, 2008).

Occupation is an essential human function which is an important part of an individual's health and well-being. In the specific field of pediatrics, occupational therapists focus on the primary occupations that a child engages in throughout their day; these include play, school, and other activities of daily living (Case-Smith, 2005). Thorner, (1991) described the core constructs that an occupational therapist must develop to conduct effective interventions with each client. The core constructs are: (a) assessment of an individual's occupational performance, (b) analysis of the assessment to identify performance skills, (c) planning selected activities, (d) activity analysis, (e) adaptation of the activity, environment or individual's occupational behavior and (f) facilitation of the individual in acquiring and maintaining skills (Thorner, 1991).With development and implementation of these core constructs, the occupational therapist is able to access and use interventions and apply these to the pediatric population.

Occupational therapists view intervention from a holistic perspective; treating the whole person and not just the diagnosis. The education received in this profession assists the therapists to become skilled at grading activities within the person's own natural environment (Crepeau & Schell, 2009); occupational therapists receive education on performing effective intervention in pediatrics, as well as cognitive and physical dysfunction. This gives them the knowledge required to perform effective constraint-induced movement therapy. The following protocol has been specifically developed for occupational therapists treating children with acquired brain injuries. This protocol utilizes occupational therapy assessments and focuses on activities that are meaningful to the child's daily occupations. Enclosed in the manual is a variety of resources, and a step by step process for the therapist to follow when implementing constraint-induced movement therapy in the pediatric population.

# Development of the Child's Brain

## Development of the Child's Brain

Youth is a time of expansion, discovery, and increasing knowledge for most children. However, for the child who has an acquired or traumatic brain injury, the experience can be quite different. In order to provide appropriate and effective intervention for these children, it is imperative that the occupational therapist acquire knowledge on pediatric brain development, the effects of brain injury, and ways to assist the child in improving their occupational performance.

The human brain is an intricate structure, with two distinct divisions called the central nervous system (CNS) which is composed of the brain and the spinal cord, and the peripheral nervous system (PNS) which is composed of the spinal nerves that control the skin, as well as visceral nerves which control internal organs, glands, and blood vessels (Bear, Connors, & Paradiso, 2007). The maturation of a child's brain starts from a single cell; the brain and nervous system eventually contain over 100 billion neurons. The embryo begins as a flat, disk-like structure which eventually moves together and fuses to become the neural tube from which the entire central nervous system develops. As the neural tube continues to expand, the neural crest develops and eventually forms the peripheral nervous system (Bear, Connors, & Paradiso, 2007). The precise development of the neural tube is critical in the configuration of the nervous system and occurs during the first three weeks after conception. At this point in gestation, many women are unaware that they are even pregnant.

As the infant continues to develop in the uterus, other types of brain development are occurring. An embryo develops in a cephalocaudal pattern, that is, the greatest amount of growth occurs at the head and gradually spreads towards other parts of the body. During this time, the brain is also experiencing a significant increase in the number of synapses, with the maximum amount of synaptic connections being formed within the first two years of a child's life (Santrock, 2007). This being said, any disruption in the brain during the first two years of life can have detrimental results.

During the development of the fetus in the mother's womb, differentiation occurs and the brain structures become more complex and specialized (Bear, Connors, & Paradiso, 2007). The first brain structure to undergo this process is the forebrain, which is the location for perception, consciousness, cognitive ability, and actions that are voluntary or intentional (See Figure 1). The achievement of this process depends on the development of the synapses that are produced with the central nervous system (Bear, Connors, & Paradiso, 2007). The cerebral cortex eventually develops from the forebrain, and is an extraordinary brain structure where the systems of sensation, perceptions, voluntary movement, learning, speech, and cognitive processing come together.

During the differentiation process, the midbrain develops very little in comparison with the forebrain. The midbrain serves as a channel for information that passes from the spinal cord to the forebrain and from the forebrain to the spinal cord (Bears, Connors, & Paradiso, 2007). One of the essential structures that passes through the midbrain is the corticospinal tract, which takes part in a fundamental role in the control of voluntary movement. Any type of interruption to this tract produces loss of voluntary movement on the one side or both sides of the individual’s body. There are tracts that receive information directly from the eyes and control the eyes movement; there are also tracts that obtain auditory information and pass through the midbrain (Bears, Connors, & Paradiso, 2007).

The hindbrain includes three imperative structures; the cerebellum, the medulla oblongata, and the Pons. The purpose of the cerebellum is to acquire information from the spinal cord and the Pons in relation to movement. In fact, the cerebellum’s most important function is to serve as the body's movement control center (Bears, Connors, & Paradiso, 2007). If an individual sustains an injury to this portion of the brain, the result is uncontrolled movements. The medulla oblongata contains neurons that execute essential motor and sensory functions. The medulla's neurons bring sensory information from the auditory system, as well as information regarding the senses of touch and taste. Motor signals from the spinal cord to the thalamus are relayed in the medulla, as well as the motor neurons that control the muscles of the tongue (Bears, Connors, & Paradiso, 2007).

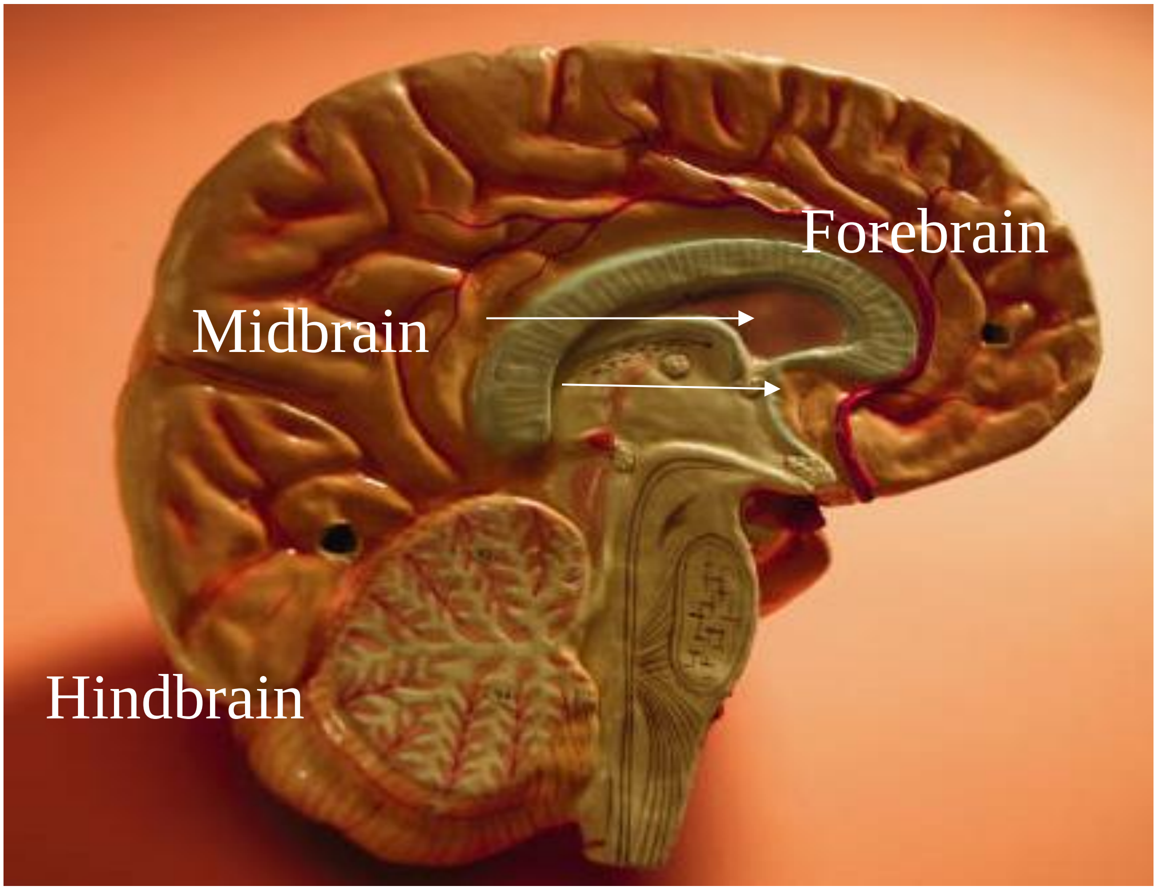



Figure 1

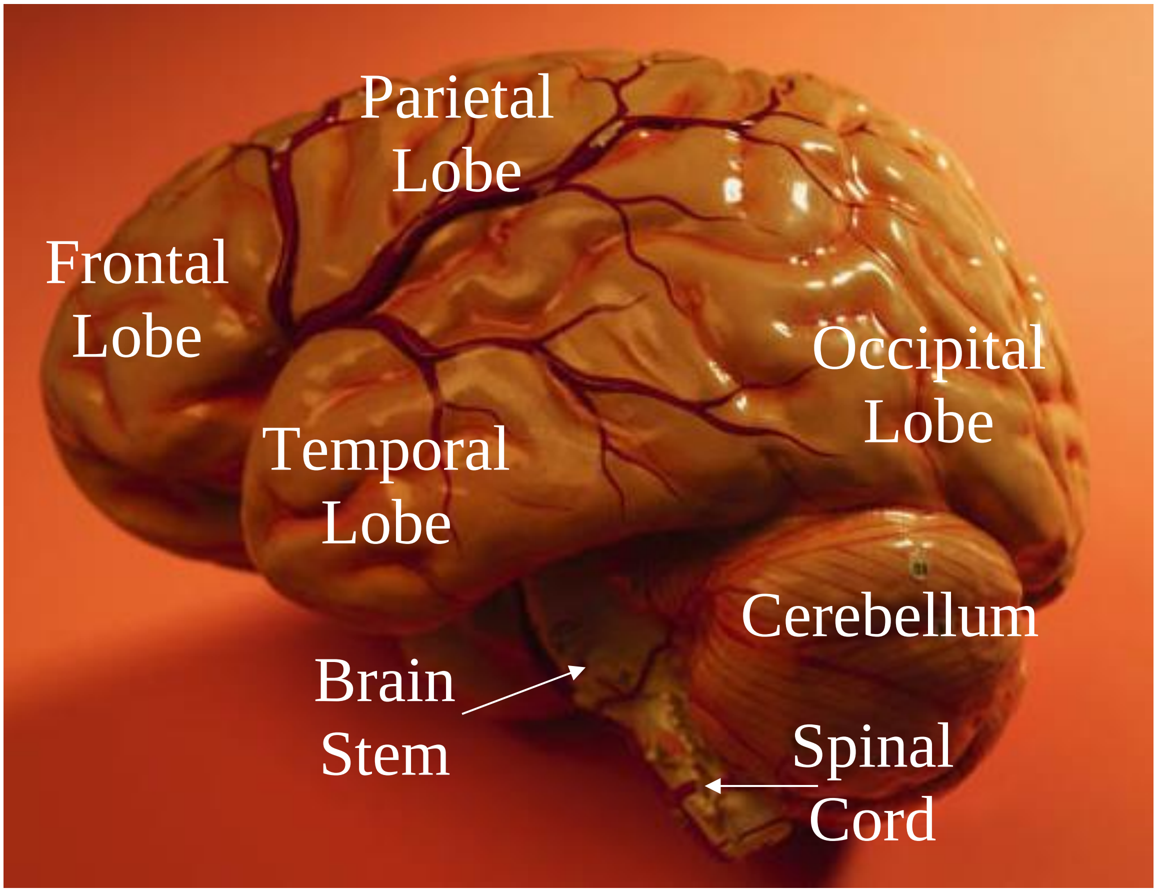

Parietal
Lobe
Frontal
Lobe
Occipital
Lobe
Temporal
Lobe
Cerebellum
Brain
Stem
Spinal
Cord

Figure 2

The brain is composed of four lobes: the frontal lobe which is crucial for voluntary movement and thinking; the occipital lobe which controls vision; the temporal lobe which is vital for hearing; and the parietal lobe which processes information regarding the body's sensations (See Figure 2). The frontal lobe is the most immature in an infant, and as the infant grows, this lobe continues to develop (Santrock, 2007). If an infant acquires a brain injury during any point of brain development, typical progression of the frontal lobe may not occur. Acquired brain injury (ABI), which includes any non-traumatic brain injury, may cause permanent impairments in motor performance, intelligence, problem-solving, and complex brain function (Santrock, 2007).

Children may acquire many different types of brain injuries. A brain injury may be diffuse, focal, or possibly, both. A diffuse brain injury occurs when a motor vehicle accident or fall causes acceleration, deceleration, and/or rotation of the child's brain inside their skull (Rogers, 2005). The cerebral portion of the brain may rotate around the brainstem, resulting in stretch or traumatic force. This type of brain injury may cause decreased speed of the child's mental processing and intense difficulty with tasks or activities that require divided attention. Abstract reasoning, problem solving ability, executive functioning, and planning may also be adversely affected (Rogers, 2005). A focal brain injury results from bruising, lacerations, hematoma's inside the brain, and damage to cranial nerves. Focal brain lesions occur when the child's brain hits the skull which causes a scraping of the brain across the uneven boney protrusions. This type of injury may affect the child's emotion, memory, motivation, and result in hemiparesis and increased impulsivity.

The subject of brain plasticity in children has been the basis of much debate in the field of neuroscience in recent years. The term "brain plasticity" in simple terms, means that the human brain has the ability to reorganize itself; this term also refers to the brain's unique ability to learn and remember information, even after a traumatic event (Chapman, Max, Gamino, McGlothlin, & Cliff, 2002; Johnston, 2009). In children, it has long been thought that better functional outcomes occurred if a child sustained a brain injury earlier in childhood. The brains reorganizational ability is much stronger the younger the age of the child, and plasticity is superior in the developing brain. However, this is not always to the child’s advantage (Johnston, 2009).

The theory of *early plasticity*, in which it is believed that the superior ability of a child's brain to reorganize itself gives a child's brain a unique advantage, supports this belief (Anderson et al., 2010). However, there are many in neuroscience research who are now starting to dispute the idea that a child's increased brain plasticity gives them an advantage in recovery from brain injury. Many times, children who have experienced an acquired brain injury or a traumatic brain injury, have no visible signs of impairment, but have extreme deficits in brain function (Forsythe, 2009). It is also indicated that despite the increased brain plasticity children, secondary deficits may exist after a brain injury that cannot be overcome. These deficits can cause a reduction in the child’s ability to attain comprehension of new skills, and acquire knowledge. These children may also experience difficulties in academic performance (Anderson et. al, 2010). Many individuals in the area of neuroscience support the "*early vulnerability*" theory in which it is stated that a child's brain is more sensitive at a younger age, and therefore, is more vulnerable to disease and trauma (Anderson et al., 2010). Children who acquire a brain injury prior to age one do have significantly greater impairments psychiatrically and neurologically (Max, Bryce, Keatley, & Delis, 2010).

Most research does verify the fact that children do have greater reorganizational ability in their brains than adults do, but it is still not clearly understood how much advantage this actually provides in a child's recovery (Anderson et al., 2010). There are new improvements in the measurements of functional recovery in children that are challenging the subjective and widespread belief of the benefits of pediatric brain plasticity (Chapman, Max, Gamino, McGlothlin, & Cliff, 2002). For instance, ‘shaken baby syndrome’ is one of the most common and most traumatic brain injuries that occur in infants. It is common knowledge that the bones in an infant skull are very flexible, (i.e. not rigid as in adults); therefore, the circumstances required to cause a brain injury in an infant are much different than in an older person. A very young infant has a large head mass in comparison with its body; an infant also has underdeveloped neck muscles and a spinal column that is more prone to severe injury because of the arrangement of facet joints and the vertebral column. Computed Tomography (CT) scans of children, who have been subjected to shaking reveal extreme swelling and brain death due to a decrease in oxygen to the brain because the infant stopped breathing. This type of injury minimizes the effect of the brain's ability to reorganize itself, and oftentimes, the brain cannot overcome this trauma (Geddes et al., 2001).

Many in neuroscience research are now starting to dispute the idea that a child's increased brain plasticity gives them an advantage in recovery from brain injury. Many times, children who have experienced an acquired brain injury or a traumatic brain injury, have no visible signs of impairment, but have extreme deficits in brain function (Forsythe, 2009).

# Pediatric Constraint-Induced Movement Therapy Treatment Protocol Guide

## Constraint-Induced Movement Therapy

Constraint-Induced Movement therapy (CIMT) was originally researched by Dr. Edward Taub using primates who had surgical intervention to render them hemiplegic (Taub, Griffin, Nick, Gammons, Uswatte, & Law, 2007). Originally developed for adult clients after stroke with hemiplegia, CIMT has also proven to be a promising intervention for children who have experienced hemiplegia as the result of an acquired or traumatic brain injury. Acquired brain injuries often leave children with a permanent diminution in upper extremity function which inhibits them from performing required tasks of everyday living (Taub et al., 2007). Dr. Taub and associates illustrated the correlation between the brain’s plasticity and intervention results using CIMT in adult stroke clients. Due to the positive results shown in the studies in adult stroke clients, it was determined that CIMT would have significant results in children (Taub et al., 2007).

In Dr. Taub's original study, primates who had one upper limb surgically rendered hemiplegic tried to use the affected upper extremity at first, but stopped after several attempts. The primates become efficient at doing everyday tasks with the unaffected upper extremity. This behavior is termed "learned non-use", which means that the monkeys "realized" that using the affected upper limb was not effective and simply stopped trying (Glover, Mateer, Yoell, & Speed, 2002). This behavior proves true in humans as well. After an individual has a stroke or other acquired brain injury, one upper extremity is often rendered hemiplegic, and the person learns to "get by" with using the unaffected upper extremity.

For children with an acquired brain injury, the consequences of major motor disability are profound for all aspects of a child's quality of life. The deficits are not only seen in neuromotor function, but also in sensory awareness and responsiveness in their physical and social environments (Taub et al., 2004). Children with hemiplegia often demonstrate decreased functional ability in the affected side. Using the techniques of CIMT, which include "*shaping"* and "*forced use"*, occupational therapists are able to encourage the child to use their affected upper extremity, and increase functional use of the impaired limb. *Shaping* exercises are tasks that progressively increase in difficulty, therefore preventing increased frustration during the intervention process (Karman, Maryles, Baker, Simpser, & Berger-Gross, 2003). *Forced use* involves using a restraint on the affected upper extremity during unstructured activities (Charles & Gordon, 2005).

In CIMT, there are three basic intervention techniques that are followed including: intense training of the affected upper extremity, extended restraint of the unaffected limb, and the ability to transfer the intervention into the child's natural environment (Taub et al., 2007). The last technique is extremely important for the intervention to be considered successful. According to Hoare et al. (2007), CIMT is most effective when the unaffected limb is constrained for 90% of the child's waking hours over a two to three week time period. This is the same time period that is outlined in Taub's original study.

During the course of the CIMT intervention, the child performs a variety of activities, and the therapist is able to grade the difficulty of the tasks throughout the intervention period. Both fine and gross motor tasks are accomplished through the use of activities of daily living, leisure interests, and play. By using these activities, the child is able to be interested and find meaning in the functional tasks being performed. Recreational and educationally relevant matter may be used to facilitate the intervention throughout the intervention period. The use of computers, games, crafts, sports, and other activities that are of interest to the child, may facilitate the intervention process due to the level of interest and meaningfulness (Karman et al., 2003). The desired outcome of CIMT is to decrease undesirable "learned disuse" motor function and increase the use of the affected upper limb by encouraging, through constraint, the use of the affected upper extremity (de Bode, Fritz, Weir-Haynes, & Mathern, 2009).

In starting CIMT intervention, it is important for the occupational therapist to perform sensory assessments of the child's impaired upper extremity to determine whether the intervention will likely have a positive outcome. If the child has sensation in their hemiplegic upper extremity, it is more likely the CIMT intervention process will be successful. J. Armstrong (personal communication, November 8, 2010). Assessments will be discussed further in this protocol guide.

In Dr. Taub's original protocol in 2004, children aged 7-96 months were placed in a plaster bi-valve cast for 21 consecutive days. The children were assessed prior to the intervention and 3 weeks after the CIMT intervention was completed (Taub, Ramey, Deluca, & Echols, 2004). Through an extensive search of the literature, the authors concluded that although Dr. Taub's protocol was highly effective in gaining results, a removable splint is the most child-friendly constraint to be used for this CIMT protocol.

The authors of this protocol feel that a custom fabricated, easily removable splint is safest and most child-friendly method of restraint feasible. The recommended splint for this protocol is a resting hand splint with the child in 35° of wrist extension, and slight finger flexion to prevent the splint from sliding. Fabricating a bi-valve splint with thermoplastic material on the volar aspect of the hand and forearm, and a thin, perforated splinting material on the dorsal aspect of the hand and forearm is recommended to make the splint as lightweight as possible. It is also recommended to use Velcro straps with the ends meeting at the top. J. Armstrong (personal communication, November 8, 2010). The therapist and caregivers will remove the splint every six hours to inspect the limb for skin breakdown, and modifications will be made to the splint as deemed necessary. The child will have the opportunity to individualize their custom splint with hopes to encourage compliance during the course of intervention.

Once the constraint is fabricated for the child, the child will wear the splint for 90% of their waking hours for twenty-one days while completing tasks and activities at home, in the educational setting, and in out-patient occupational therapy. The child will see the occupational therapist in the out-patient setting three times per week for one hour. The following information in this protocol details assessments and activities that will be used to complete the CIMT intervention process.

# Assessments

## Assessments

The child should be assessed by the occupational therapist at the beginning of CIMT to develop a baseline for intervention. After the CIMT intervention has been concluded the child should be re-tested to examine functional outcomes. A follow-up assessment should be completed six months post-intervention to observe any progress or regression the child may have developed.

For the purpose of this CIMT protocol guide, four key assessments have been selected by the authors as valid and reliable resources for measuring strength and function before, during, and after the child's intervention with CIMT.

The Pediatric Motor Activity Log (PMAL), allows the parent to rate their child with twenty-two arm and hand function tasks rating the quality of movement of the affected limb. Examples of tasks included in this assessment are donning and doffing shoes and socks, dressing, eating, and manipulating small objects. Parents can rate their children in terms of frequency and quality of movement of the child's affected limb on a 0-5 scale. Information for this assessment can be located in the appendices of the research study conducted by Taub, Ramey, Deluca, & Echols, (2004).

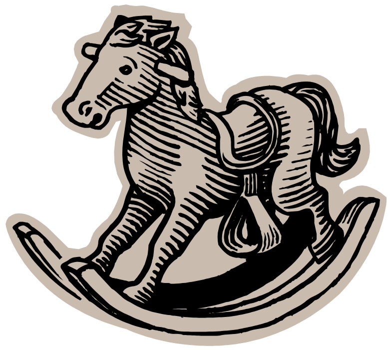
The Quality of Upper Extremity Skills Test (QUEST) was developed in 1992 by Carol DeMatteo, Mary Law, Dianne Russell, Nancy Pollock, Peter Rosenbaum, and Stephen Walter. This test is a performance-based checklist designed to evaluate the individual's upper extremity function within the context of their environment, and measure the quality and effectiveness of the therapeutic intervention used. Originally this assessment was developed as a measure for treating children with cerebral palsy from eighteen months to eight years of age with neuromotor dysfunction and spasticity. The results of this assessment are expressed as a total score and percentage. Information regarding the QUEST assessment can be located on the McMaster University website under CanChild, Centre for Childhood Disability Research.

The third assessment outlined for this intervention protocol is the Jebsen-Taylor Hand Function test. This test was originally developed in 1969 by Robert Jebsen, Neil Taylor, Roberta Trieschmann, Martha Trotter, and Linda Howard. It is a standardized performance test which is designed to assess the use of an individual's hands in everyday activity. The assessment is used standardized for children aged 5 years plus. This test provides the administrator with a way to assess effective areas of intervention. The assessment consists of seven manual tasks which are designed to simulate functional everyday activities that individuals may perform in their daily life. Information regarding the Jebsen-Taylor Hand Function assessment can be located through Sammons Preston Rolyan, Inc.

The fourth assessment is the Dynamometer. The dynamometer is an assessment tool that measures the strength of a person's grasp in pounds or kilograms. The hand grip dynamometer is an excellent measure of an individual's hand strength, and has normative data available for quick and easy referencing. Information regarding normative data for children's grip strength can be located in the research study by Hager-Ross and Rosblad, (2002).

The pinch meter test is a quick and simple measure that looks at the amount of pressure an individual is able to exert in three types of pinches. The three types of pinches measured are the tip pinch, the lateral pinch, and palmer pinch. Occupational therapists can find normative data for 6 to 19 year olds in the research study by Mathiowetz, Wiemer, and Federman (1986).

# Occupations for OT Intervention

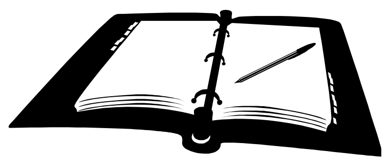


Occupations for OT Intervention

| Activities of Daily Living | Play | Leisure or School-based | Instrumental Activities of Daily Living | Sensory Activities |
|---|---|---|---|---|
| **Dressing** | Board Games | Handwriting | Meal Preparation and Cleanup (making light snack for self) | Lotion Massage |
| **Personal Hygiene and Grooming** | Card Games | Drawing | Care of pets (feed, water, groom, and play) | Textured Bean Bags, Moon Sand ™, Cotton Balls, Rice, Thera-putty™ |

| | | | | |
|---|---|---|---|---|
| **Bathing** | Playing with Play Dough ™ | Social Activities with Peers | Household cleanup (picking up toys, making bed, clearing table, helping with dishes) | Weight Bearing with the affected upper extremity using different textures |
| **Toilet Hygiene** | Sports | | Home maintenance ( outdoor activities with adults) | |
| **Eating** | Role Playing | | | |
| **Feeding** | Fine Motor: Lego's™, Lincoln Logs™, dressing dolls, age-appropriate model cars and motorcycles. Gross Motor: playground activities with supervision, assisted upper extremity weight-bearing activities | | | |
| **Functional Mobility** | Computer and Video Games | | | |

# Occupational Therapy Follow-Up Protocol



The follow-up protocol consists of re-assessing the child 3 weeks and six months post-intervention. According to Dr. Taub's original protocol the children were re-assessed 21 days post intervention (Taub, Ramey, Deluca, & Echols, 2004). The authors of this protocol feel that the child should also be re-assessed 6 months post-intervention to evaluate if a repeated course of CIMT is considered necessary. If a repeated course of CIMT is implemented, the same assessment instruments as previously used in the protocol will be used to maintain reliability, and allow the occupational therapists to see whether progress has been made. Research suggests that a second intervention with CIMT results in further advancement and enhanced functional status of the involved upper extremity (Charles & Gordon, 2007).

# Evidence-Based Research

Levels of Evidence Table on Constraint-Induced Movement Therapy Intervention Protocol

Focused Question: What is the evidence for the use of Constraint-Induced Movement Therapy (CIMT) in children with acquired brain injuries using occupational therapy interventions?

Clinical Scenario:

Traumatic brain injury (TBI) is a frequent cause of acquired childhood injury. In the United States alone, traumatic or acquired brain injury accounts to close to 50% of fatalities in children. The main age groups in which TBI's occur is under the age of 5, and mid to late teenage years (Yen & Wong, 2007). In both of these age groups, there are periods in a child's development in which vital maturation of the brain occurs. If there is any sort of interference during these critical periods of development, permanent disruption of the brains functional abilities may occur (Catroppa, Anderson, Morse, Haritou, & Rosenfeld, 2008).

Constraint-Induced Movement Therapy has been found to be a promising intervention for substantially increasing the use of extremities affected by such neurologic injuries such as stroke and traumatic brain injuries in adults (Taub, Ramey, Deluca, & Echols, 2004). However, children with a variety of conditions can also benefit from the intervention of CIMT. In the pediatric population CIMT maybe a useful intervention for intervention with a variety of diseases, disorder's, and illnesses, such as cerebral palsy, childhood strokes, hemiplegia, acquired brain injuries, and traumatic brain injuries. The overall goal of CIMT is to overcome a learned non-use behavior and improve functional use of the affected upper extremity (UE) by "forcing" use of the affected upper extremity (de Bode, Fritz, Weir-Haynes, & Mathern, 2009). According to Glover, Mateer, Yoell and Speed, ( 2002), children with hemiplegia often demonstrate early poverty of movement in the affected side; this may be exemplified by fisting of the affected hand (Willis, Morello, Davie, Rice, & Bennett, 2002).

Through the use of CIMT children can gain an increased amount of upper extremity range of movement and strength. With the cooperation of the parents or guardians, children with acquired brain injuries have the ability to make significant improvements in upper extremity function.

## Summary of Key Findings:

Summary of levels: I, II, III, IV, and V

Neuroscience Interventions
Eleven studies categorized as research for Neuroscience approaches:

**Seven Level III Studies**

| Author | Year |
|---|---|
| **Anderson, Catroppa, Morse, Haritou, & Rosenfeld** | 2005 |
| **Anderson, Jacobs, Spencer-Smith, Coleman, Anderson, Williams, Greenham, & Leventer** | 2010 |
| **Anderson, Morse, Catroppa, Haritou & Rosenfeld** | 2004 |
| **Babikian, Freier, Tong, Nickerson, Wall, Holshouser, Burley, Riggs, & Ashwal** | 2005 |
| **Catroppa, Anderson, Morse, Haritou, & Rosenfeld** | 2008 |
| **Chapman, Max, Gamino, McGlothlin, & Cliff** | 2003 |
| **Max, Bruce, Keatley, Delis** | 2008 |

**One Level IV Studies**

| Author | Year |
|---|---|
| **Geddes, Vowles, Hackshaw, Nickols, Scott, & Whitwell** | 2001 |

**Three Level V Studies**

| Author | Year |
|---|---|
| **Forsyth** | 2009 |
| **Johnston** | 2009 |
| **Yen & Wong** | 2007 |

The level III studies examined the outcomes of brain injuries in the pediatric population using Magnetic Resonance Imaging (MRI) as well as the relationship between the severity of the injury and a child's functional recovery. The level IV study examined the effects of head injuries in children, specifically with shaken baby syndrome. The level V studies examined the effectiveness of rehabilitation with children after brain injuries, *Participants* included: Individuals from less than one year of age to sixteen years of age. The diagnosis included where Cerebral Palsy, Shaken Baby syndrome, stroke, and trauma.

*Interventions* included: Using story recall, intelligence testing, verbal learning testing, processing speed testing, and visual spatial testing.

*Outcomes* measures included: Standard cognitive and language measures, neurobehavioral measures.

*Results:* Each study found that there is a relationship between the age of injury and functional outcomes in children. The younger the child's age at the time of the insult to the brain the poorer the outcomes.

Constraint-Induced Movement Therapy

Fifteen studies categorized Constraint-Induced Movement Therapy approaches:

Four Level I Studies

| Author | Year |
|---|---|
| **Charles & Gordon** | 2005 |
| **Hoare & Carey** | 2007 |
| **Huang, Fetters, Hale, & McBride** | 2009 |
| **Taub, Griffin, Nick, Gammons, Uswatte, & Law** | 2007 |

Three Level II Studies

| Author | Year |
|---|---|
| **Charles & Gordon** | 2007 |
| **DeLuca, Echols, Law, & Ramey** | 2005 |
| **Taub, Ramey, DeLuca, & Echols** | 2004 |

Four Level III Studies

| Author | Year |
|---|---|

| | |
|---|---|
| **Glover, Mateer, Yoell, & Speed** | 2002 |
| **Karman, Maryles, Baker, Simper, Berger-Gross** | 2003 |
| **Stearns, Burtner, Keenan, Qualls, & Phillips** | 2009 |
| **Willis, Morello, Davie, Rice, & Bennett** | 2002 |

One Level IV Studies

| Author | Year |
|---|---|
| **Dickerson & Brown** | 2007 |

Three Level V Studies

| Author | Year |
|---|---|
| **De Bode, Fritz, Weir-Haynes, & Mathern** | 2009 |
| **Martin, Burtner, Poole, & Phillips** | 2008 |
| **Stanger & Oresic** | 2003 |

The level I studies examined CIMT and forced use intervention in pediatric populations through systematic reviews. The level II studies examined the results of repeated courses of CIMT and intensive CIMT intervention through randomized, controlled trials. The level III studies examined the effectiveness of CIMT intervention in children with cerebral palsy and acquired brain injuries. The level four study examined the effectiveness of CIMT intervention with one child who had decreased arm movement. The level V studies examined pediatric CIMT in children with acquired brain injuries such as Cerebral Palsy, brain tumors, and congenital injuries.

*Participants* included: Children from birth to seventeen years of age. The diagnosis ranged from Cerebral Palsy, hemiparesis, brain tumor, stroke, and head trauma.

*Interventions* included: Activities of daily living, leisure, play, fine as well as gross motor upper extremity tasks. Testing included Quality of Upper Extremity Test (QUEST), Peabody Developmental Motor Skills-Fine, Emerging Behavior Scale (EBS), Toddler Arm Use Test (TAUT), Jebsen- Taylor Test of Hand Function, Bruinincks-Oseretsky Test of Motor Proficiency, the Caregiver Function Use Survey, the Pediatric Motor activity log, Nine Hole Peg test, Pinch Meter, and Box and Blocks.

*Outcomes* measures included: Upper extremity range of motion, strength, grip, pinch, and dexterity.

*Results:* Each of the 15 studies found positive results with CIMT being used as an intervention for brain injury. However, due to the length of time the restraint had to be worn compliance was sometimes reported to be difficult.

Modified Forms of CIMT Intervention
Seven studies categorized the modified forms of CIMT approaches:

Two Level II Studies

| Author | Year |
|---|---|
| **Charles, Wolf, Schneider, & Gordon** | 2006 |
| **Hoare, Imms, Rawicki, & Carey** | 2010 |

Two Level III Studies

| Author | Year |
|---|---|
| **Eliasson, Krumlinde-Sundholm, Shaw, & Wang** | 2005 |
| **Naylor & Bower** | 2005 |

Three Level V Studies

| Author | Year |
|---|---|
| **Charles & Gordon** | 2006 |
| **Cope, Forst, Bibis, & Liu** | 2008 |
| **Gordon, Charles, & Wolf** | 2005 |

The level II randomized controlled trials examined outcomes of using modified CIMT interventions for children with Cerebral Palsy. The level III studies examined using an adapted model of CIMT in children with Cerebral Palsy. The Level V studies examined using child friendly forms of CIMT in children with hemiplegia and Cerebral Palsy.

*Participants* ranged: Ages from one year to 8 years old. The diagnoses were Cerebral Palsy and hemiplegia.
*Interventions* used: Botulinum toxin –A, activities of daily living, computer gaming, finger games, and bi-manual tasks. The evalution testing included the QUEST test, Jebsen- Taylor Test of Hand Function, Bruinincks-Oseretsky Test of Motor Proficiency

Pediatric Evaluation of Disability Inventory, Canadian Occupational Performance Measure, Goal Attainment Scaling, Modified Ashworth Scale, and Modified Tardieu Scale.

*Outcome* measures included: Evaluated movement and functional limitations, environmental functional limitations, impairment, and strength.

*Results:* The studies included evidence that using modified child friendly form of CIMT results in positive improvement in children with upper extremity impairments.

## Bottom Line for Occupational Therapy Practice

In reviewing the research in children with Cerebral Palsy and Acquired Brain injuries using Constraint-Induced Movement Therapy as a intervention, positive outcomes have been reported through the use of randomized controlled trials, systematic reviews, case reports, and modified forms of CIMT. However, this review of the literature also indicated the need for further research to be completed in the occupational therapy practice as well as children with acquired brain injuries other than Cerebral Palsy.

## Review of Process

Inclusion Criteria

- Highest levels of evidence
- Pediatrics aged zero to eighteen years
- The use of CIMT as a intervention
- Brain injuries

Exclusion Criteria

- Individuals over the age of 18
- Children without acquired brain injuries
- No qualitative research
- No non-peer reviewed research

**Search Strategy**

| Categories | Key Terms Searched |
|---|---|
| **Client Population** | Pediatrics, acquired brain injuries, traumatic brain injuries, children, modified CIMT, brain plasticity, Cerebral Palsy, Stroke, Brain Tumor, Trauma |
| **Interventions** | Constraint-Induced Movement Therapy, occupational therapy, Forced use, Modified CIMT, Child friendly CIMT |

| Databases and Sites Searched |
|---|
| **PubMed** |
| **Cochrane Reviews** |
| **CINAHL** |
| **SCOPUS** |
| **American Journal of Occupational Therapy (AJOT)** |
| |

Results of Research

| Level of Evidence | Study Design/Method | Number of Articles |
|---|---|---|
| **I** | **Systematic Reviews** | **4** |
| **II** | **Randomized Controlled Trials** | **5** |
| **III** | **Non-randomized, pre test and post-test** | **13** |
| **IV** | **Non-experimental** | **2** |
| **V** | **Case Reports and Expert Opinions which include narrative reports.** | **9** |
| **Total** | | **33** |

Limitations

- Most of the studies have a small sample size
- There is a for more researchers that are occupational therapists
- There is a need for more randomized controlled trials
- There is a limited amount of pre-test and post-test studies
- Most of the studies evaluated Cerebral Palsy (CP) as the main diagnosis

# CHAPTER V

## SUMMARY

The overall purpose of this manual is to provide an evidence-based intervention protocol for occupational therapists to implement when using CIMT as an intervention for children with traumatic brain injuries. After an exhaustive review of the literature, it was found by the authors that there was limited research in the area of CIMT with the pediatric population with acquired brain injuries. The researchers decided that by creating a protocol that could be easily implemented by occupational therapists, children with acquired brain injuries would be greatly benefited.

The limitations of this scholarly project included a lack of studies with high levels of evidence, a need for more research to be completed using CIMT with diagnoses other then pediatric stroke and cerebral palsy, and a lack of occupational therapy driven research. It is the hope of the authors that this intervention protocol be implemented in the following ways:

- Implemented by licensed, practicing occupational therapists in treating children with acquired brain injuries.
- To carry out a research study using children with acquired brain injuries to increase occupational therapy driven research.

To conclude this scholarly project, research has shown that CIMT can be a very valuable intervention when implemented appropriately. This includes using evidence-based research and implementing CIMT according the protocol designated by the authors. It is the hope of the authors that this protocol be implemented by occupational therapists when performing CIMT with children who have acquired brain injuries. In the future it is the goal of the authors to carry out a research study using this protocol as a guide to intervention.

# CHATPER VI.

## APPENDIX A

UNIVERSITY OF UND NORTH DAKOTA

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