EFFECTS OF HAND-ARM BIMANUAL INTENSIVE THERAPY ON SELF-EFFICACY, MOTIVATION, AND REAL-WORLD BIMANUAL PERFORMANCE IN CHILDREN WITH UNILATERAL CEREBRAL PALSY

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Unilateral cerebral palsy (UCP) is a neurodevelopmental disorder that causes deficits in the child's upper extremity motor control, which is essential for daily living activities. These motor control deficits are known to cause low self-esteem, low self-efficacy, and anxiety in social settings. It is also known that children with UCP may experience issues with appropriate emotional regulation when facing new challenges during motor performance tasks. However, the effects that low self-esteem, low self-efficacy, emotional regulation, and motivation have on real-world bimanual performance are still unknown. This study aims to evaluate whether hand-arm bimanual intensive therapy (HABIT) improves self-efficacy and motivation along with real-world bimanual hand use in children with UCP. We hypothesize that (1) self-efficacy levels, in addition to motivation, affected hand use, and perceptual hand use will increase through the child's participation in the intensive bimanual intervention, HABIT and that (2) children with UCP with higher levels of motivation and self-efficacy will have greater bimanual performance gains in a real-world environment following HABIT. Twenty-two children with unilateral cerebral palsy (UCP) underwent HABIT, 6-hours per day for 5 consecutive days. During HABIT, children participated in age appropriate, intensive, task-specific, structured bimanual activities. Children with UCP were administered questionnaires before, during, and after HABIT

to evaluate changes in perceptual hand use, affected hand use, self-efficacy, and motivation levels throughout the intervention. The Children's Hand-Use Experience Questionnaire and The Dimensions of Mastery Motivation Questionnaire were used to evaluate perceptual hand use and motivation levels pre- to post-intervention. Real-world bimanual performance was assessed using bilateral wrist-worn accelerometer data. Each child's responses were then recorded for further data analysis along with a self- efficacy and motivation survey that was administered during HABIT on intervention day four. A paired t-test was used to assess changes in all perceptual, motivation, and real-world bimanual performance measures. Mean improvement scores were calculated to measure improvements in self-efficacy during HABIT. A Pearson correlation analysis assessed the relationship between perceptual, self-efficacy, and real-world bimanual performance measures**.** Following HABIT, there was a significant improvement in the perception of hand use and hand use count ($p< 0.01$). There was a significant improvement in cognitive object persistence as well as gross motor persistence ($p<0.001$). Mean improvement scores from both parents and interventionists showed improvements in self-efficacy because of HABIT (parents = 7 ± 2.08, interventionists = 7 ± 1.01) on a 10-point Likert scale. There was also a significant increase in use ratio ($p= 0.04$). However, no correlation ($p >0.05$) was found between perceptual hand use, self-efficacy, motivation, and real-world bimanual performance. HABIT improves the perception of hand use, self-efficacy, as well as the affected arm use in real-world activities; however, improved perception of hand use in addition to increased hand use count and motivation do not directly correlate to improved real-world bimanual performance outcomes. Given the importance of hand-arm bimanual intensive therapy as an efficacious intervention in children with UCP, more research is needed to understand the relationship between the perception and action paradigm and the factors that influence real-world bimanual performance.

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CHAPTER 1– INTRODUCTION

Unilateral cerebral palsy (UCP) is a neurodevelopmental disorder that affects one out of one thousand births in the United States and is known as one of the most common childhood disabilities to date [34]. UCP is a disorder in which its outcomes impact a child's muscular control and motor function on one side of the body due to the trauma to one side of the brain[34]. Children with this disability often experience symptoms of weakness, loss of motor control, and spasticity in the affected upper and lower extremities impacting activities of daily living and participation in various leisure, social, and functional activities[30]. UCP has many causes and can be caused by factors such as injuries during labor and delivery, head trauma, stroke, brain tumors, hereditary conditions, hydrocephalus, or any bacterial infection such as meningitis[30].

With these symptoms that children with UCP experience and their effects on motor function, both in the upper and lower extremities, intensive physical therapy overtime has the ability to enhance a child's motor function and coordination abilities[5]. In previous studies, intensive physical therapy programs such as constraint-induced movement therapy (CIMT) and hand-arm bimanual intensive therapy (HABIT) have been used to help improve hand motor function and bimanual coordination in children with UCP[7]. Such interventions specifically focus on the upper extremity as hand function and bimanual coordination are instrumental in the success of daily living activities in children[7]. Bimanual coordination (BC) is a motor movement pattern that focuses on the movement of both upper limbs and that requires symmetrical movement patterns[1]. With the use of BC tasks during intensive therapies such as HABIT, therapeutic interventions such as these have been known to increase motor function and decrease the frequency of motor deviations to allow for increased efficiency in the function of daily living activities[1]. These interventions have been successful due to the style and nature of intensive therapy as it involves intensive hours of activities that improve fine and gross motor skills[27]. However, despite such intensive therapy interventions, it is still shown that completing bimanual tasks impacts a child's self-esteem, self-efficacy, motivation levels, and a child's perceptual response to such interventions[27]. This is found true in the literature as children with UCP are noted to have a reduced ability to perform daily living activities after an initial diagnosis[27]. Based on the literature that currently exists, there has been little to no research found indicating how adolescent self-efficacy levels and motivational factors are influenced by rehabilitation outcomes of the intensive physical therapy intervention itself in relation to real-world bimanual performance. In retrospect, programs such as HABIT or CIMT have the goal is to promote increased self-efficacy when completing daily tasks through childhood development and later in life[7].

However, with a lack of support in the literature regarding the importance of self-efficacy and motivation on rehabilitation outcomes in children with UCP, literature does show the importance of self-efficacy and motivation on other related performance outcomes. Bandura (1985) has supported these ideas as he identified an important model known as Bandura's Self-Efficacy Theory. Bandura (1985) defines self-efficacy as the belief in oneself to perform a certain behavior or activity. Upon identifying his theory, Bandura noted that self-efficacy, when identified in multiple treatment modalities, was known to promote behavior change, increase self-efficacy, and anxiety reduction. Based on Bandura's model, researchers have tested his theory amongst various other settings and noted that self-efficacy is an important determinant of performance outcomes[25].

In addition to Bandura's self-efficacy theory, motivation is also an important determinant of performance in literature. Motivation was first deemed as an important determinant of performance in the self-determination theory established by Deci and Richard Ryan (1985). The self-determination theory explains how motivational behaviors affect performance. Individuals more motivated to act are known to have better performance outcomes. This theory has been translated across multiple populations such as those in sport, in the psychological health realm, and those with intellectual disabilities in which the self-determination theory first originated. For example, in a study conducted by Miller et al., researchers noted that motivation has an influence on performance and that through the use of an intensive therapy intervention, motivation is improved and has the ability to improve performance in relation to daily living activities[23]. The self-determination theory has three components autonomy, competence, and connection or relatedness. These three components are implemented to improve performance and to decrease occurrences of anxiety and dissatisfaction with specific tasks[10].

Overall, it is known that self-efficacy and motivation have a positive relationship with performance. However, there is a gap in the literature stating whether hand-arm bimanual intensive therapy (HABIT) improves self-efficacy and motivation along with real-world bimanual hand use in children with UCP. It is important to identify how HABIT influences self-efficacy and motivation in relation to bimanual performance outcomes in a real-world environment to gain a better understanding of the perception and action paradigm involved in such interventions. Therefore, this study evaluated whether hand-arm bimanual intensive therapy (HABIT) improves self-efficacy and motivation along with real-world bimanual hand use in children with UCP.

Delimitations

Children diagnosed with unilateral cerebral palsy (UCP)

Between the ages of 6-16 years

Manual ability classification system (MACS) levels I-III

Ability to complete a stack of 3 cups in 1 minute

Mainstream in school

Potential Limitations and Assumptions

Intervention Delivery/Location

Participant Count

Absent Control Group

Study Participant Retention

Measure Reliability

Modified Questionnaires

CHAPTER 2 – LITERATURE REVIEW

Unilateral Cerebral Palsy (UCP)

Unilateral cerebral palsy (UCP) is a neurodevelopmental condition caused by lesions on the brain affecting the motor cortex which is the part of the brain associated with inter-limb movement [34]. UCP has a severe effect on inter-limb movement, and it is known for causing motor deficits that play a significant role in a child's life [32]. UCP can be a multi-factorial condition as its effects are often caused by experiences during labor and delivery but can also be caused by other related events such as a stroke, head trauma, or bacterial infections such as meningitis [32]. Due to these causes, lesions are formed on the brain that damage the motor cortex on the precentral gyrus and on the anterior paracentral lobule on the medial surface of the brain [32]. How the motor cortex works during the point in which it experiences those lesions present is that whichever side of the brain experiences this surface damage, the opposite limbs are affected as a result. The limbs largely affected are the upper arm and lower leg on the affected side. Once this damage to the motor cortex occurs, the condition is unfortunately permanent [32]. Currently there is no cure for this condition, however, this condition is known to not progress overtime. Since there is no cure, treatments for UCP are imperative in improving symptoms, motor function, and the quality of life [32]. Treatments for this condition include occupational therapy, stretching, and physical therapy [32]. Occupational therapy and physical therapy are among the most common treatment types in helping children increase their motor skills and complete daily living activities, essential for adequate quality of life[32]. One of the most common types of treatment/intervention in physical therapy is hand-arm bimanual intensive training (HABIT) [11].

Protocol for Hand-Arm Bimanual Intensive Training (HABIT)

Hand-Arm Bimanual Intensive Training (HABIT) is a clinical intervention used to improve motor function in those with UCP who have severe motor deficits[7]. HABIT focuses on multiple areas of bimanual coordination tasks such as structured practice of skills that involve grasping and manipulating objects, creating functional activities for hand use involving bimanual coordination, and creating a child-friendly intervention protocol that keeps them well engaged while promoting the using of both hands simultaneously when completing a given task [7]. For the intervention style in a study conducted by Charles et al., researchers used HABIT for an intervention lasting 10 weekdays for 6 hours of functional tasks per day [7]. The HABIT intervention was conducted in a group setting that focused heavily on group involvement, social interaction, and peer support [7]. Although this type of intervention was applied in a group setting, children still had an interventionist assigned to them throughout their program duration to improve the child's gross and fine hand motor skills[7]. To help increase fine motor skills during the HABIT intervention, interventionists created tasks for the child to complete based on their individual need and created tasks that are engaging for the child using toys and other various objects [7]. Hand function and usage following HABIT were evaluated using accelerometry data and were measured both pre- and post-HABIT intervention to determine if there was a true benefit in improving real-world bimanual performance following the HABIT intervention [7]. Like the Charles et al. study, this research study evaluated changes pre- and post-HABIT intervention with measurements of accelerometry [7]. However, this study also assessed whether or not hand-arm bimanual intensive therapy (HABIT) improves self-efficacy and motivation along with real world bimanual hand use in children with UCP.

Benefits of Hand-Arm Bimanual Intensive Training (HABIT)

Hand-arm Bimanual Intensive Training (HABIT) has been shown to improve gross, fine motor skill and bimanual performance in children who have UCP[7]. Hand motor skill performance is enhanced by the use of this intervention through its outreach of involving activities that are both engaging and foster environments in which bimanual coordination is used. Research has shown that with the use of HABIT, children begin to obtain the hand motor skills needed to complete a task using bimanual coordination, and these skills are obtained and carried on with the child throughout their later years of motor development [7]. This is done so by the repetitive and skill-based practice of HABIT in a clinical setting. This type of skill-based practice is applicable to any setting which can only enhance the child's skills since these types of practices can be completed outside the clinical setting [7]. With the use of HABIT, it can be assumed that progress with hand motor function and bimanual performance can be improved over time [7].

Effects of HABIT in Children with UCP

In a study conducted by Bleyenheuft et al., researchers evaluated the effects of HABIT on children with UCP [5]. Bleyenheuft et al. found that through the use of HABIT on children with UCP, there was an increase in bimanual coordination use following intervention [5]. Researchers stated that children in their study showed to have a greater grasp on the motor movement pattern and were able to increase their abilities to complete the skill following the intervention [5]. This was due to the repetitive nature of the tasks as well as the nature of practice as most of these activities are relative to bimanual coordination and grasping and manipulation of a given object [5]. These movements help with temporal and spacial practice which is essential in obtaining a bilateral hand motor movement pattern necessary for hand-use in children with UCP[5].

Self-Efficacy

Self-efficacy (SE) is defined as the belief that oneself can perform a certain behavior or activity. Bandura (1985) mentions how SE can influence performance as this can be translated into various areas of one's abilities. SE, according to Bandura, can play an intricate role in one's behavioral change. Through HABIT, bimanual coordination is encouraged and the primary goal for HABIT is that bimanual hand use is maintained in a real-world environment. In agreement with Bandura's theory regarding SE, to promote behavior changes in a real-world environment, SE must be addressed and maintained. The main source of input from which SE is derived is through Performance. Performance is the direct result of the output we receive when performing an activity and is how we perceive our experiences to help form our behavior. Performance is the result of our mastery experiences. For example, when a child is performing an activity of daily living, such as tying their shoes, they utilize cognitive processes routed from mastery experiences to perform the task. The ability to perform this task correctly is based on previous mastery experiences. Hence, this factor is deemed important across all realms of performance[22].

To discuss further, the effects of SE have been studied extensively using different methods of testing in experimental settings such as in the laboratory, in sports performance, in the classroom, in health and wellness, etc[22]. Upon the conclusion of these different experimental designs, all analyses pointed to the sole conclusion that SE is a direct predictor of performance over any other type of factor behaviorally[22]. There are four domains that make up the reflection of SE in human behavior[19]. These four domains are mastery experiences, vicarious experiences, verbal persuasion, and feedback in physiological and affective states[22]. Mastery experiences are experiences in which an individual has been able to successfully complete a task that is difficult[22]. Vicarious experiences are experiences in which success is modeled through the observation of seeing others perform a given task[22]. Verbal persuasion is when individual belief is encouraged or discouraged from another individual. Feedback from our physiological and affective states is the feeling one may get when individual success is achieved[19]. Each of these factors play a significant role in SE in a real-world environment[22]. When negative SE, the hinderance of one's belief in their ability to perform an activity is present, it has been found that an individual's persistence (motivation to perform the given task) is minimal and attitudes towards performing that behavior in the future are indeed negative as well leading to deficient performance outcomes[22].

Due to the nature of HABIT, which involves the continued practice of bimanual hand use, it can be hypothesized that with continued practice using intensive therapeutic strategies, SE should increase according to the social cognitive theory. Feltz et al. supports Bandura's theory of continued practice in relation to performance as similar studies have been conducted evaluating SE along with collective efficacy amongst athletes. Those athletes that displayed continuous effort through practice and play, deemed to have higher SE levels which aided in their ability to be able to perform amongst outside pressures that may affect one who has lower SE[12]. In this study specifically, SE is measured in a survey administered to parents and interventionists in relation to a concept known as estimation of the other person's self-efficacy (EOSE) during the intervention.

EOSE is the degree to which a person believes his or her significant figure is confident in their own abilities[14]. In a study conducted by Habeeb et al 2020, researchers noted EOSE as another type of self-efficacy identified in the psychological framework of the self-efficacy concept[14]. EOSE, when evaluated was found to be deemed as an outcome of self-efficacy in relation to a coach to athlete relationship when subjects were interviewed[14]. Upon further evaluation through interviews with perceptions from both coaches and athletes, it was found that self-efficacy stemmed from the beliefs about the other person causing coaches to implement efficacy enhancing techniques that address goal setting and verbal feedback[14]. Therefore, this study evaluated EOSE in a clinical intervention known as HABIT to evaluate parents and interventionists beliefs of self-efficacy improvements in children participating in HABIT[14].

Motivation

Motivation (MO) is defined as the intrinsic force that drives our persistence during activities. Ryan and Deci (2000) describe the role of MO on performance and activity outcomes in the Self Determination Theory. The Self Determination Theory (SDT) is an approach to understanding human behavior and the psychological influences and processes that impact specific behaviors. Within the realms of the SDT, there are numerous factors that can create variable experiences in behaviors and reactions that tend to drive MO. MO can influence our learning experience, individual experiences, our well-being, and our self-esteem. Due to the nature of MO and how variable it can be amongst specific populations, the SDT encompasses all aspects that ultimately drive the learning process in settings in which learning is encouraged[10].

The psychological influences of MO that often effects our persistence when we are completing activities are autonomy, competence, and connection or relatedness. Autonomy is our ability to regulate oneself. Autonomy is responsible for our behavior regulation (in addition to competence and relatedness). Autonomy can be better described as the intrinsic force responsible for our choice in activities during the learning process and how we regulate ourselves in a learning environment when a task is given. Competence, an additional factor in the SDT, is described as our own SE or the belief we have in ourselves to complete a daily living activity.

Relatedness can be described as our connections to others and our feelings of belonging when performing an activity[10].

In a study conducted by Majnemer et al., researchers evaluated mastery motivation in adolescents with cerebral palsy[20]. Majnemer et al., evaluated MO through measures of fine and gross motor persistence using the aspects of the SDT established by Ryan and Deci (2000)[20]. In Majnemer et al.'s study, researchers noted the importance of motivation as a direct determinant of rehabilitation efforts that were specifically related to performance outcomes[20]. Rehabilitation efforts were noted to not only include the efforts by those administering therapy but also the type of environment they created in therapy and by creating activities that were both creative and meaningful to their patients in real-time[20]. In this study, researchers evaluated adolescents with UCP and found that those children with UCP were noted to have less persistence (motivation) than that of typically developing children in areas related to motor, cognitive, and social abilities[20]. When gross and fine motor persistence is lower in children with UCP, rehabilitation performance outcomes are often less improved due to example therapy interventions[20]. HABIT which aims to support not only bimanual hand use, but the success and function of daily living activities helps combat the constructs of MO by increasing autonomy, competence, and relatedness as its intervention strategy is applied in group play context[2]. It can be hypothesized that as children with UCP participate in intensive therapies that promote bimanual hand use, that overall MO should improve when all 3 compartments of mastery motivation have been addressed[20].

Effects of Self-Efficacy and Motivation on Rehabilitation Outcomes

In a study conducted by Craig et al., researchers evaluated the SE of children with UCP related to parental involvement during an intervention[8]. From this study researchers found that higher parental involvement is related to performance outcomes along with SE levels in children with UCP [8]. However, there is still little to no research found surrounding the SE levels of children with UCP and how levels of MO change pre- and post-intervention when aiming to master a motor skill during hand and arm bimanual intensive training (HABIT). One can hypothesize that pre- and post-intervention SE and MO levels would increase through hand and arm bimanual intensive training as more involvement would be expected to increase rehabilitation outcomes. However, more research is needed in this area to draw this conclusion.

Accelerometry Measures During HABIT

Accelerometry measures are known to evaluate the use of movement in both arms in children and adolescents with UCP in a real-world environment [9,13]. Accelerometry measures focus on the intermittent intervals established by stillness and vigorous movement of each arm [9]. During HABIT, accelerometry measures are used to evaluate the hand-arm use of pre- and post-intervention. By measuring accelerometry, hand and arm movements can be tracked to determine physical activity levels pre- and post- intervention and to determine the overall hand and arm use compared from one limb to another[13]. In a study conducted by Dawe et al., researchers used accelerometers to establish the validity of their use through hand and arm movement patterns in children with UCP [9]. Once this research study was completed, researchers established that accelerometry was a valid measure in determining upper limb movement in children with UCP [9]. Researchers also supported the fact that accelerometry can be used to develop innovative upper limb assessments to be used in a clinical setting for increased intervention on the affected limb in children with UCP [9]. In this study specifically, we evaluated HABIT and the relationship between this intensive therapy intervention and accelerometry data pre- and post-HABIT to determine the interventions impact on real-world bimanual performance.

Summary

Based on the support of literature in research surrounding the common belief that HABIT in children with UCP is beneficial, there is still little support surrounding what major impacts play a role on rehabilitation outcomes specifically in regard to SE and MO[20]. Not only has SE been shown to influence rehabilitation outcomes but also MO has been shown to increase positive effects on performance related to motor movement in related settings[20]. While there has been a great deal of research surrounding the positive benefits of hand-arm bimanual intensive therapy programs, there is still more work to be done in regard to how SE and MO can play a role in effecting those rehabilitation outcomes for the better and how they can be applied further in separate areas of research. This proposed study is designed to assess whether hand-arm bimanual intensive therapy (HABIT) improves SE and MO along with real-world bimanual hand use in children with UCP and to see if there are any distinct differences in SE and MO levels pre- and post- hand-arm bimanual intensive therapy (HABIT).

CHAPTER 3 – METHODS

Participants

Table 1. Demographic characteristics of the participants

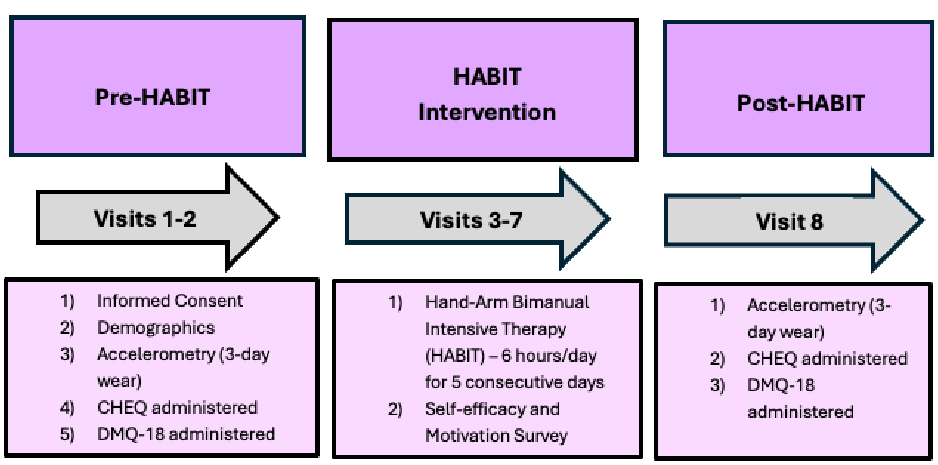
Characteristics	Participants Children with Unilateral Cerebral Palsy (*n* = 22)
Sex, *n* (%)	
Male	16 (62)
Females	6 (23)
Age, mean (SD)	10.27 (2.91) years
Side of hemiplegia, *n* (%)	
Left	12 (46)
Right	10 (39)
Race, *n* (%)	
Caucasian	17 (65)
African American	1 (4)
Asian	1 (4)
Hispanic/Latino	1 (4)
Multiracial	2 (8)
MACS Level, *n* (%)	
I	5 (19)
II	7 (27)
III	10 (39)

The sample for this study consisted of children who had been diagnosed with UCP and who were between the ages of 6-16 years old and whose mainstream was in school (n = 22). For the intervention, participants were required to be listed between levels I-III on the Manual Ability Classification System (MACS) and to be able to complete a cup stacking task that involves stacking 3 cups in 1 minute. This task excluded children who had any other developmental disabilities such as autism, attention deficit disorder, developmental coordination disorders, etc. Participants were also required to have no known cardiorespiratory, vascular, and metabolic disorders or neoplasm or hydrocephalus. In addition to the above exclusion criteria, participants in the study could not receive other adjunct therapies such as rTMS and tDCS or have seizures or be on anti-seizure medications. Table 1 displays the details of participant demographics.

Before the consent process, flyers were distributed to possible participants with study information and a QR code in which participants and their families were invited to participate. Upon scanning the QR code, parents of the children were then asked to complete an eligibility survey through Redcap to determine their eligibility for participation. The research staff and primary investigator then reviewed the responses from those who inquired to determine inclusion criteria. Following this determination, parents of the children who were then deemed eligible, were contacted by our research team to schedule an initial visit to administer the informed consent, demographics survey, as well as to complete the required questionnaires once consent was obtained. To obtain parental permission, the informed consent was thoroughly explained on-site by the primary investigator to both the parent and child in appropriate language to allow both the parent and child to ask any questions the primary investigator could answer.

Procedures

Figure 1. Schematics of the study timeline including the HABIT and assessment schedule.



In total, 22 participants with UCP completed the HABIT intervention, and the study consisted of 8 visits. For Visits 1-2, parents were provided with an informed consent and demographic details were obtained. On Visits 1-2, the participants were given accelerometers to wear for 3 days to obtain baseline hand use data, and questionnaires were also administered to the parents/child. The Children's Hand Use Experience Questionnaire (CHEQ) was given to assess hand-use activity and perceptual hand use when completing daily living activities. The Dimensions of Mastery Questionnaire (DMQ-18) was used to assess motivation through evaluation of behavior when completing an activity as well. Visits 3-7 consisted of participants completing the HABIT intervention and the self-efficacy and motivation survey was administered on the fourth day to parents and volunteers to evaluate improvements of SE and MO levels through the associated scale for perspectives of estimation of other's self-efficacy. On Visit 8, accelerometers were then re-administered to wear for 3 days to obtain post-HABIT hand use data. The CHEQ and DMQ-18 questionnaires were then re-administered to determine the effects of HABIT on these perceptual indicators of performance.

Measures

Hand and Arm Bimanual Intensive Therapy (HABIT)

HABIT is an intensive therapy program that is child-friendly and that focuses on the use of an intensive intervention that is specifically targeted at promoting bimanual coordination and functional use of the unaffected/affected upper extremities in children with UCP[7]. HABIT is based on the principle that through extensive practice of bimanual hand use, bimanual learning skills can be enhanced and can later be used and developed throughout a child's life[7]. This bimanual intensive therapy focuses on both fine and gross motor skills and the tasks associated with these skills are adapted to fit the child's needs based on their age in the use of contexts of play[7]. In this study, interventionists were trained to guide and continuously monitor each child under the supervision of licensed physical therapists and occupational therapists using a 1:4 ratio. Individual therapy goals were identified using the Canadian Occupational Performance Measure (COPM) and were later assessed using the Assisting Hand Assessment (AHA) based on the child's current upper extremity capabilities and their motor skillset. Activities were then tracked by the research staff over the 5-day duration of the intervention. Over the 5-day intervention, each day compromised of whole and part task activities. Task difficulty was manipulated for each child and recordings regarding affected hand use and its role in the given task were recorded. The affected hand was recorded as either the stabilizer, manipulator, or assistor and during HABIT, children were encouraged to use the affected and unaffected upper extremity in a coordinated manner. Positive reinforcement and knowledge of performance were provided to motivate and reinforce goal-directed activities.

Perceptual Hand Use

The Children's Hand Use Experience Questionnaire (CHEQ) is an assessment tool used to quantify hand-use specificity, time used to complete a given motor task compared to similar children the child's age, and how the child feels when completing the given motor task. There are 27 questions about perceptual hand-use and affected hand activity during given daily activities, and each sub-question is rated on a four-level scale[30]. Pre- and post-HABIT, this questionnaire was administered to monitor any changes in hand-use specificity and perceptual hand use. Research staff administered the questionnaire to either the parent or the child. Changes in perceptual hand use and hand use count were then analyzed to determine improvements in these factors. See *Appendix C* for the CHEQ.

Motivation

The Dimensions of Mastery Motivation Questionnaire (DMQ-18) is an assessment tool used to assess a child's ability to master their environment through an action or an activity[31]. In this study, the DMQ-18 questionnaire was used to assess motivation levels before and following the HABIT intervention[31]. Each question within this assessment related to motivation or persistence to daily tasks that a child may experience[31]. Each sub-question is rated on a five-level scale and each daily task related to social and gross motor skills[31]. This questionnaire consists of 41 questions total and is completed in-person either by the child or the child's parent/guardian[31]. Instructions for the questionnaire were given to the child and the guardian for ease in responsiveness and to limit any possible discrepancies in perception. Responses were then calculated to determine total motivation scores in the following domains: cognitive object persistence, gross motor persistence, social motor persistence with adults, social motor persistence with children, mastery pleasure, negative reactions related to frustration, anger, sadness, and shame, as well as general competence. *See Appendix D* for the DMQ-18.

Self-Efficacy and Motivation

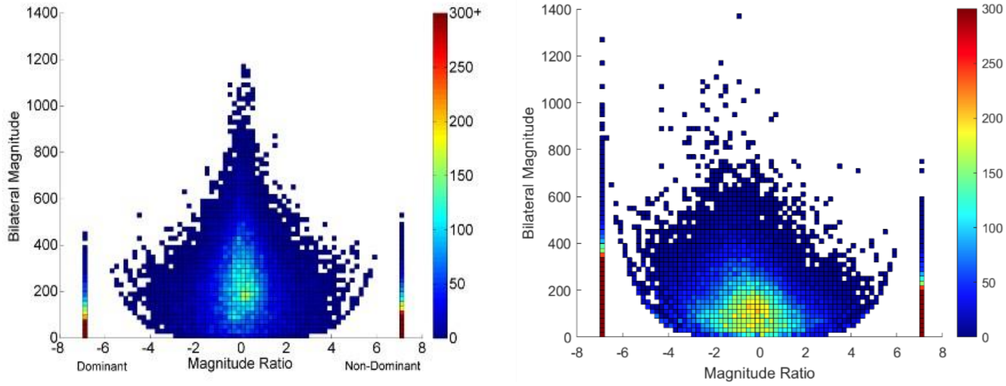
SE and MO were evaluated during HABIT to evaluate acute changes in each child's ability to perform given tasks and their motivation levels. During HABIT, a self-efficacy and motivation survey was directly administered via research staff to both parents and interventionists as it was believed that both parties could provide additional insight into the acute effects of HABIT on SE and MO through EOSE. Each question specifically relates to changes in behavior of each child during their participation in HABIT and it consists of 5 questions in which both parents and volunteers rate behavior changes related to SE and MO using a Likert-scale from 1-10 stating their level of agreement and/or disagreement with each statement provided.

Each question related to changes in affected hand use, improvements in SE related to affected hand use, MO to perform daily living activities, SE in social settings, as well as hand use changes. Please see *Appendix E* for the associated self-efficacy and motivation survey.

Accelerometry

Bimanual performance was measured using accelerometer data collected pre- and post-HABIT. Bimanual performance gains were measured with wrist-worn accelerometers (Actigraph GT9X, Pensacola, FL, USA) on both upper extremities. Children wore accelerometers three days pre- and post- the 30-hour HABIT to assess bimanual performance gains in a real-world environment. Five accelerometer derived variables use ratio (UR), magnitude ratio (MR), bilateral magnitude (BM), median acceleration (MA), and acceleration variability (AV) were used to assess bimanual performance gains and upper extremity capacity. UR indicates the hand use distribution between the unaffected and affected limb[13]. MR indicates the contribution of each extremity to a given task[13]. BM indicates the overall intensity of the movement in upper extremities[13]. MA indicates the speed or acceleration of the movement during the specific task in both extremities[13]. AV indicates the distribution of acceleration between both the affected and unaffected extremities during a given task[13]. Each accelerometer derived variable provided information about bimanual hand use pre- and post-HABIT. Figure 2 describes the previous variables mentioned in density plots by Gardas et al[13].

Figure 2. Representative examples of accelerometer derived density plots – As mentioned by Gardas et al., this is an accelerometer graphical representation of both upper extremities of (a) a typically normal developing child and (b) an age-matched child with right sided UCP.



(a) (b)

The density plots shown above represent second-by-second recordings of accelerations record over a 3-day time period pre-HABIT. The x-axis displays MR of both the dominant (unaffected) and non-dominant (affected) upper extremity hand use. The y-axis displays BM as mentioned above. In figure 2a, it can be recognized that the instances of hand use on both the non-dominant and dominant side are more symmetrical meaning that instances in which the typically normally developing child is using both hands is equal. However, in figure 2b, it can be recognized that the child is using their unaffected hand more than their affected hand which is displayed in unequal hand use distribution13[2]. This distribution an example of a density plot result from children who participate in HABIT[13].

To ensure accurate wear of these watches, clear written instructions were provided for wearing and using the accelerometers to both children and parents. Parents were instructed to have their child wear accelerometers during active hours while performing their daily routines. Children could remove the accelerometers for any water-related activities such as swimming or bathing. Parents were then instructed to return the accelerometer watches back to the laboratory staff on the date of their post-HABIT assessment. Once returned, accelerometer data was then processed through IBM SPSS Statistics, Version 29.0.1.0. for analysis.

Demographics

All demographic information was obtained during the consent process which occurred on the initial visit. The parents of each participant were asked to provide information regarding their age, date of birth, country of residence, school status, education level, and gender. In addition, parents of each participant were asked to state their child's dominant side (unaffected cortex), their own parental information (maternal and paternal date of birth and country of origin), languages that they are fully fluent in. Participants were also asked to state their CP predominant motor type, CP distribution, which extremities were more involved. Further questions regarding their treatment statuses related to strength and functional abilities were also required. Please see *Appendix B* for the demographics survey and open-ended questions.

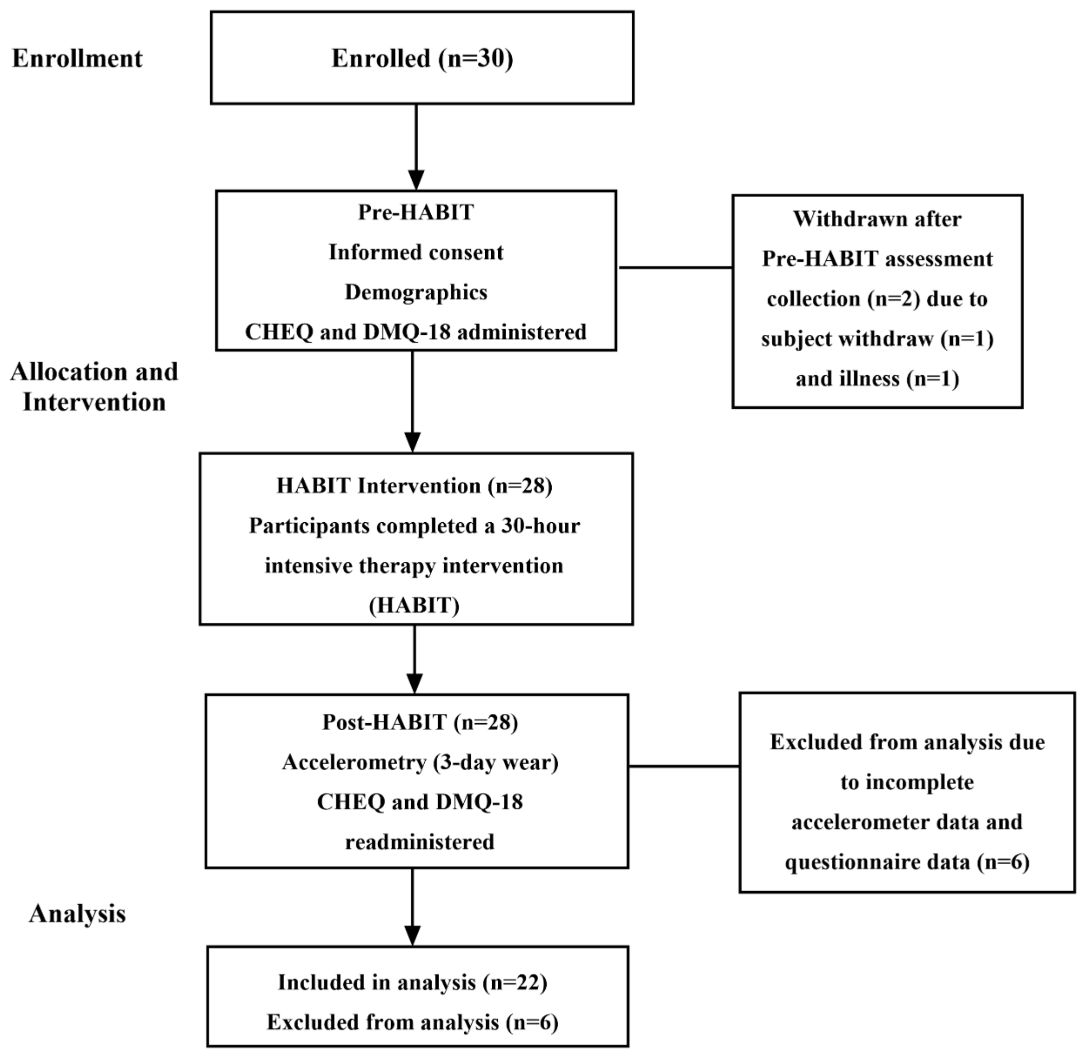
Data Analysis

All data analyses were conducted in IBM SPSS Statistics, Version 29.0.1.0. Categorical variables (i.e., gender, side of hemiplegia, race, and MACS level) were all reported as counts and percentages. Summary statistics (i.e., age, self-efficacy) were reported as means and standard deviations. Pearson correlation analyses were conducted to analyze the bivariate relationship between bimanual performance variables along with CHEQ derived variables (perceptual hand use and hand use count) and DMQ-18 derived variables pertaining to motivation (i.e., mastery motivation, gross motor persistence, etc.) and self-efficacy from pre- to post- intervention. Correlations were deemed significant if p-values were noted to be less than 0.05.

CHAPTER 4 – RESULTS

Sample Characteristics

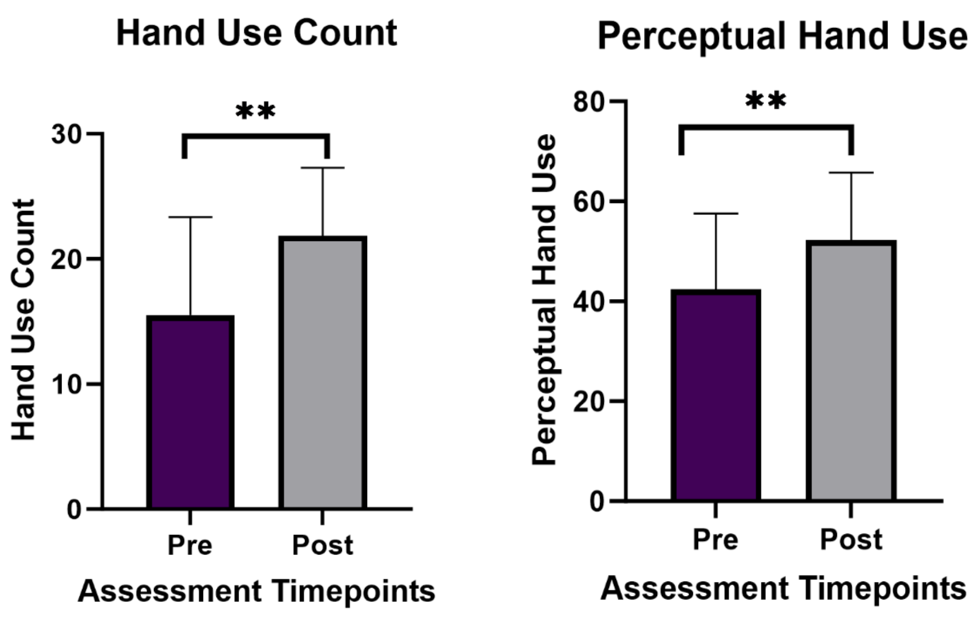
Figure 3. CONSORT Flow Chart



Thirty participants were enrolled, and twenty-eight participants completed the intensive therapy intervention. However, data was only analyzed for 22 participants due to incomplete accelerometer and questionnaire data. Figure 3 shows the CONSORT flow chart, describing the flow of participants through the study, including withdrawals and inclusion for analysis. The sample included 16 males (61.5%) and 6 females (23.1%) between the ages of 6 and 16 years old (M= 10.27, SD=2.91). Children who participated were classified using the MACS and were between levels I (n = 5, 19.2%), II (n=7, 26.9%), and III (n=10, 38.5%) on the MACS classification scale with either right (n=10, 38.5%) or left-sided (n=12, 46.2%) hemiplegia. Children either identified as White (n=17, 65.4%), African American (n=1, 3.8%), Asian (n=1, 3.8%), Hispanic/Latino (n=1, 3.8%), or Multiracial (n=2, 8.0%).

Pre and Post HABIT Differences in Hand Use Measures using the CHEQ

There was a significant improvement in hand use count (pre- 15.64±7.81, post- 20.91±6.03) and perceptual hand use (pre- 41.82±14.90, post- 51.45±13.69) from pre- to post-HABIT ($p<0.01$, Figure 3).



(a) (b)

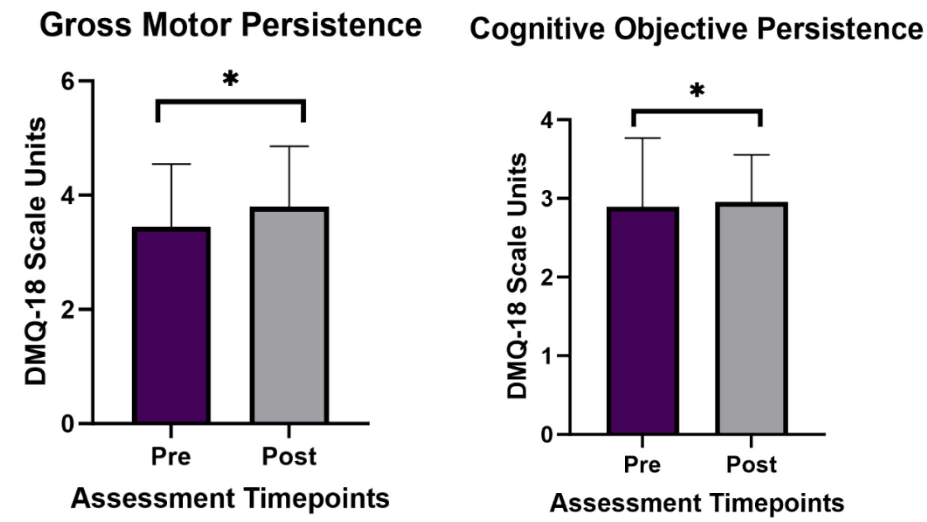
Figure 3. Comparison of differences in mean scores of hand use count and perceptual hand use from pre- and post-HABIT. Values are reported are means ± SD as determined by the

distribution of data during each assessment time point. Pre- refers to the baseline CHEQ assessment data obtained on Visit 1 to determine baseline perceptual hand use and hand use count. Post- refers to the immediate assessment of perceptual hand use and hand use count post-HABIT (Visit 8). There were significant improvements in hand use count (how often children are using their affected hand during a daily living activity) and perceptual hand use (how well the child/parent believe they are using their affected hand) pre- to post-HABIT as indicated by the p-value <0.01.

Time to complete daily living activities compared to peers as well as how bothersome the affected hand is during the completion of daily living activities were also collected from pre- to post-HABIT. However, there were no significant changes in time to complete these activities compared to peers (pre – 46.32 ± 13.4, post – 49.79 ± 10.5, p=.57) as well as no significant changes in how bothersome the affected hand is during the completion of daily living activities (pre – 61.32 ± 19.8, post – 63.84 ± 15.1, p=0.44).

Pre and Post HABIT Differences in Motivation Measures using the DMQ-18

There were significant improvements in the mastery motivation domains of cognitive objective persistence (COP) and gross motor persistence (GMP) from pre- to post-HABIT (p<.001, Figure 4).



(a) (b)

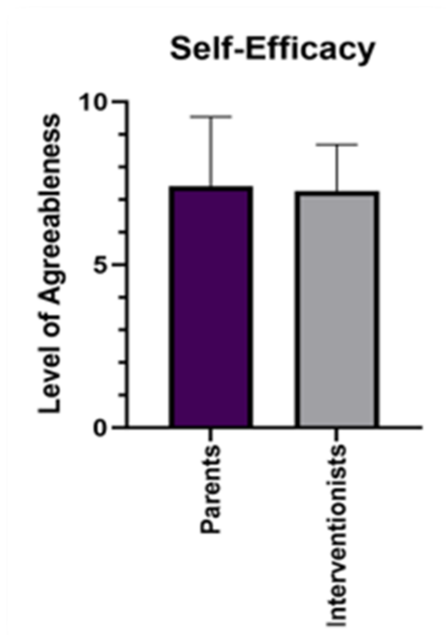
Figure 4. Comparison of differences in mean scores of gross motor persistence (GMP) and cognitive objective persistence (COP) from pre- and post-HABIT. Values reported are means ± SD as determined by the distribution of data during each assessment timepoint. Pre- refers to the baseline DMQ-18 data pertaining to mastery motivation. Post- refers to the immediate post- assessment data pertaining to the DMQ-18 on Visit 8. There were significant improvements in GMP (how motivated they are to complete a gross motor task) and cognitive objective persistence (how motivated the child believes they are when performing a task using bimanual hand use) pre- to post- as indicated by the p value ($p<0.001$).

Other mastery motivation factors: social motor persistence with adults, social motor persistence with children, mastery pleasure, negative reactions of frustration and anger, negative reactions of frustration and shame, and general competence were also collected from pre- to post-HABIT. However, there were no significant changes in social motor persistence with adults (pre – 3.94 ± 1.11, post – 3.83 ± .707, p=.44), social motor persistence with children (pre – 4.00

± 1.03, post – 4.06 ± .938, p=.24), mastery pleasure (pre – 4.39 ± .068, post – 4.22 ± .647, p=.21), negative reactions of frustration and anger (pre – 3.78 ± .647, post – 3.83 ± .707, p=.30), negative reactions of frustration and shame (pre – 3.44 ± .784, post – 3.28 ± .752, p=.38), and general competence (pre – 3.28 ± .752, post – 3.39 ± .698, p=.57).

Differences in SE and MO using the Self-Efficacy and Motivation Survey

Average rated self-efficacy improvements were noted for both parents and interventionists. There were improvements in self-efficacy noted for both parents and interventionists (parents- 7±2.08, interventionists - 7±1.01, Figure 5).



(a)

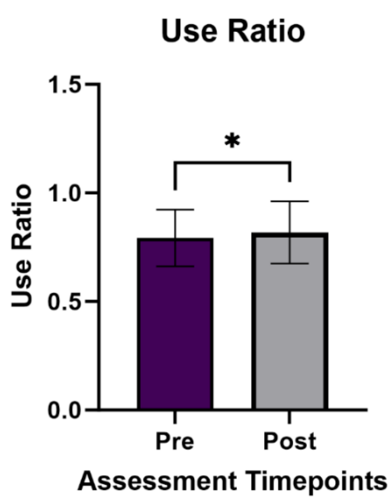
Figure 5. Comparison of differences in mean scores related to improvements of self-efficacy between both parents and interventionists. Values are reported are means ± SD as determined by the distribution of data obtained from intervention day four. Level of agreeableness reported by both parents and interventionists on day four indicates their

agreeableness with the statement “My child’s confidence in using their affected hand has improved since participating in HABIT.”

Other self-efficacy and motivation survey questions were collected on day four of the intervention. Additional improvements were found in levels of agreeableness in both parents and volunteers related to changes observed in affected hand use since participating in HABIT (parents - 8±2.09 , interventionists- 8±1.01), motivation to perform daily living activities since participating in HABIT (parents - 8±2.13 , interventionists- 6±1.47), overall confidence in social settings has improved since participating in HABIT (parents - 7±2.49, interventionists- 7±1.81), and bimanual hand use while completing daily living activities since participating in HABIT (parents- 8±2.13 , interventionists-8±1.11).

Pre- and Post- Differences in Upper Extremity Bimanual Performance Measures

There was a significant improvement in UR from pre- to post-HABIT ($p<0.01$, Figure 6). This improvement indicates that 30-hour HABIT enhanced children’s bimanual symmetry in both upper extremities.



(a)

Figure 6. Comparison of differences in mean scores of the accelerometer derived variable use ratio (UR) from pre- and post-HABIT. Values are reported are means ± SD as determined by the distribution of data during each assessment timepoint. Pre- refers to the accelerometer 3-day wear prior to HABIT. Post- refers to the immediate timepoint of the 3-day accelerometer wear post-HABIT. There were significant improvements in UR (the contribution of the affected upper extremity relative to the less affected upper extremity) pre- to post-HABIT as indicated by the p value (p=0.04).

Other accelerometer derived variables BM, MR, MA, and AV were collected pre – to post-HABIT. However, there were no significant changes in BM (pre- 108.5 ± 37.1, post – 119.2 ± 36.2, p = .460), MR (pre - -.90± 1.06, post - -.83 ± .70, p = .538), MA (pre – 29.89 ± 18.01, post – 33.2 ± 20.04, p = .669), AV (pre- 75. 6 ± 23.39, post – 78.7 ± 17.83, p = .458).

Correlation between SE, MO, and Perceptual Hand Use on Real-World Bimanual Performance

Pearson correlations for all the main variables (self-efficacy, motivation, and perceptual hand use) were performed. There were no significant correlations found between perceptual hand use, motivation, self-efficacy, and real-world bimanual performance (p>0.05). This indicates that there was no significant relationship between perceptual hand use, self-efficacy, and motivation on real-world bimanual performance gains.

CHAPTER 5 – DISCUSSION

Key Findings

The purpose of this study was to (1) evaluate if SE and MO levels will improve in children with UCP who participate in the intensive physical therapy intervention known as HABIT and to examine (2) if children with UCP who participate in HABIT and who have higher levels of MO and SE will have greater bimanual performance gains in a real-world environment compared to those children who have lower SE and MO levels following the duration of HABIT. Based on past research, we know that SE and MO influence performance (Bandura, 1985, Ryan and Deci 2000). We hypothesized that (1) SE levels, in addition to MO will increase through the child's participation in the intensive physical therapy intervention known as HABIT and that (2) children with UCP who participate in HABIT and who have higher levels of MO and SE will have greater bimanual performance gains in a real-world environment compared to those children who have lower SE and MO levels following the duration of HABIT.

Hypothesis 1 was supported due to significant improvements found in perceptual hand use, affected hand use count, and motivation in relation to real-world performance. Hypothesis 2 was not supported as there was no significant correlation found between self-efficacy and motivation in relation to real-world bimanual performance gains in children with UCP who participated in HABIT. However, there were significant improvements in two domains of mastery motivation (cognitive persistence and gross motor persistence). Perceptual hand use and hand use count showed to be significantly improved from pre-to post intervention alongside the accelerometer derived variable of UR. In addition, it was found that both parents and interventionists observed improvements in their child's self-efficacy related to affected hand use during HABIT. Based on these findings, it can be noted that improvements in perceptual hand use and hand count do not directly correlate with improvements of bimanual performance in a real-world environment. In addition, it is important to note that SE and MO are predictors of performance and the impacts of HABIT on SE and MO are not significant.

Rationale

These findings have been supported by the literature, as researchers have noted that perceptual hand use gains do not translate to real-world bimanual performance and that retention of hand use is limited following intensive therapy interventions such as HABIT[1,20]. However, the findings related to SE and MO are contraindicated in the literature as SE and MO are considered predictors of performance[14,22,20]. Further indicating that SE and MO should be correlated with improvements in bimanual performance using accelerometer data. However, SE and MO have not been measured during HABIT in a rehabilitation setting that focuses on appropriate, task-specific, intensive therapy for children with UCP.

In a study conducted by Gardas et al., researchers noted that accelerometers are useful tools in examining bimanual performance gains of activities in a real-world environment[13]. Unlike the Gardas et al study, where researchers saw bimanual performance gains in all accelerometer derived variables (UR, BM, MR, MA, and AV), UR is the only variable found to be significant in terms of improvements in hand use from pre to post[13]. Inconsistencies from the results found could be due to proper wear discrepancies as the literature supports that all accelerometer derived variables should be improved in a real-world environment pre- and post-HABIT[13]. An example of improper wear would be the wear of such accelerometers during activities not typical of a child's daily routine or wear that captures specific timelines in which low activity is recorded in both upper extremities.

Strengths, Limitations, Delimitations

Meaningful and applicable research methods that were used in this study are considered strengths as real-world bimanual performance measures have not been tested previously in correlation with perceptual hand use, SE, and MO. Accelerometry data has been used to measure hand capacity and function. By using this type of data collection method, in addition to questionnaires, it was a meaningful, applicable, and practical way to measure the direct effects that these psychological aspects have on bimanual performance. By using accelerometers, we can track hand capacity in a real-world environment to determine daily hand use and function.

Additionally, another strength of this study was the use of valid and reliable test measures in regard to perceptual hand use, affected hand use count, and motivation. Valid and reliable test measures are those established in research and proven to be successful in remaining resistant to bias, commonly associated with unreliable measures of psychological factors and influences. By using valid and reliable test measures, these measures can be used by researchers repeatedly and should provide the same result when such conditions have been met. The CHEQ and the DMQ-18 are questionnaires tested by researchers specifically in this population which strengthens the outcomes of these measured when correlated with performance variables. Such as the study conducted by Miller et al. in which researchers found that the DMQ-18 accurately captured motivation during functional activities in children with UCP[23].

Limitations of this research study included a small sample size due to non-response implications and incorrect completion of the questionnaires administered. Due to the small sample size, it can be determined that the results of this study may not be applicable to a much larger sample size if completed in an identical manner. In addition, another limitation of this study was the modification of the self-efficacy and motivation survey was there has not been a scale tested in relation to SE for this specific population. To measure SE in this population, an adapted measure was created specifically looking at the agreement and or disagreement with the statements above instead of incorporating SE and MO related to daily living activities or activities that are considered important to the children in the intensive therapy intervention.

Lastly, delimitations of this study included the inclusion criteria related to those diagnosed with UCP. This is a delimitation because this study targeted only this specific population and the results of this study cannot be utilized in populations that are similar and are not within the guidelines of those children who participated. This means the results of this study should be recognized and applied to this specific study population only. In addition, another delimitation of this study was that the intensive therapy intervention was administered in Eastern North Carolina at an academic research institute. This intensive therapy intervention's outcomes may be a result of the interventions and therapists who worked with each child. In addition, such findings in this research study may not be applicable to other populations in different areas due to differences in culture, healthcare, and other factors that may influence perceptual hand use, self-efficacy, and performance.

Application

The research findings established in this study are most significant to children with UCP who a participating in an intensive therapy intervention. If those researchers and clinicians who are interested in practical clinical application for such scales related to perceptual hand use, SE, and MO wanted to focus on intervention strategies that would improve these factors to increase bimanual hand use in a real-world environment they may want to consider ways to best fit the needs of their patients with this type of disability. In a previous study conducted by researchers, SE and MO were most improved when daily living activities that the child was completing were more personable to them[1,2]. Meaning that aspects of Bandura's self-efficacy theory and the SDT theory were addressed appropriately amongst the rehabilitation provided by clinicians.

Based on evaluating the child's interest and goals, clinicians could then determine the appropriate motivators and cues to provide the child when learning a fine or gross motor skill that promoted bimanual hand use. Upon this evaluation, clinicians could exclude or include those motivators and cues for the skill to be performed successfully. For example, if a clinician is providing therapy to a child, they may provide the child with an option on the choice of activity to do. Upon providing specific verbal cues and finding out what types of motivators help the child perform the behavior, the therapist may use that to their advantage by ensuring the success is maintained throughout therapy. Upon providing essential feedback, and multiple attempts to try the given task, the child will then rely on some mastery experience, the vicarious experience they receive from the clinician, etc. By relying on these factors related to self-efficacy and motivation, the child may then learn the skill and will be more willing to perform the skill in their individual environment. With the performance now increased, retention of bimanual hand use will hopefully be maintained while preserving the child's efficacy and promoting motor persistence.

Future Research

As suggested by this study, future research needs to be conducted to better understand how psychological factors such as SE, MO, and perceptual hand use play a role in rehabilitation outcomes for children with unilateral cerebral palsy. In future research, investigators should use a highly tested scale to measure baseline SE values to measure the direct impacts of SE because of the intensive therapy intervention. In this study, a self-efficacy and motivation survey was administered to interventionists and parents of the participants instead of the participants themselves. To better understand SE in this population, a structured scale should be used, and such scales should address efficacy in the performance of daily living activities in a real-world environment and should be administered directly to the child in a way that is understandable in regard to their individual belief in their performance of such activities. SE has been addressed in the literature as a predictor of performance, instead self-efficacy was addressed as an influencer of performance [19].

In addition to creating a uniform SE scale for this population, future researchers should focus on administering such questionnaires in a much more realistic rehabilitation environment for those children with UCP. Children with UCP are often seeing occupational therapists and physical therapists in a clinical setting (outpatient clinic) or in a home-exercise setting [7]. To truly measure real-world bimanual performance and the impacts that SE has on rehabilitation outcomes, clinicians administer these types of questionnaires in a real-world environment. In this study, children with UCP participated in a hand-arm bimanual intensive therapy intervention that lasted 6 hours a day for 5 days. Typically, children with UCP are not receiving this high dosage of therapy in their daily life. For more research, clinical application methods should be considered for proper retention outcomes regarding real-world bimanual performance.

Additionally, specific characteristics should be addressed when evaluating perceptual hand use, SE, and MO levels. In addition to focusing on those children who have neurodevelopmental disabilities, future researchers should focus on specific population characteristics when considering each of these performance influencing factors. For example, socioeconomic status, age, gender, grade level, and current MACS level should be considered when evaluating perceptual hand use, SE, and MO levels. Differences in each of these factors may be influential towards measures of bimanual performance. In this study, these specific population characteristics were not considered as factors that may influence performance outcomes in correlation to the specific psychological factors measured. One can extrapolate that MACS levels, grade level, gender levels, age, and socioeconomic status may play a role in the levels measured in a rehabilitation setting.

Conclusion

To further understand how HABIT influences SE and MO and real-world bimanual performance outcomes in children with UCP, more psychological and performance-based research is needed in this area, specifically in those with neurodevelopmental disabilities. Based on previous research SE and MO have been linked to performance outcomes in all realms of study[22,14]. Factors surrounding SE such as performance outcomes, psychological feedback, verbal persuasion, and vicarious experiences all play a role in our ability to perform an activity, even those of daily living [22]. As such displayed in previous studies such as the study conducted by Habeeb et al. 2020, in which the factors of self-efficacy were evaluated in the sports performance realm relating to the coach and athlete relationship in which perceptions of one's belief in the other’s capabilities were strongly correlated with performance[14].

In addition to the psychological factors established in Bandura’s self-efficacy theory, the SDT and the factors pertaining to autonomy, competence, and relatedness all work together interchangeably to affect fine and gross motor persistence in this specific population [29]. In retrospect, the findings in this study are supported by the literature as perceived hand use and increases in hand use count do not translate into improved real-world bimanual performance. However, there is still a lack of knowledge and scaling in regard to how SE and MO can be measured in this population and how specific guidance and feedback can be utilized to improve the effectiveness of the rehabilitation that is provided to those children with UCP as more research needs to be done in this area to better understand the perception and action paradigm involved in real-world bimanual performance.

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APPENDIX A: IRB APPROVAL LETTER

EAST CAROLINA UNIVERSITY
University & Medical Center Institutional Review Board
Willis Building · Mail Stop 682
600 Moye Boulevard · Greenville, NC 27834
Office **252-744-2914** · Fax **252-744-2284** ·
rede.ecu.edu/umcirb/

Notification of Continuing Review Approval

From: Biomedical IRB
To: Swati Surkar
CC:

Swati Surkar
Date: 10/12/2023
Re: CR00010244
UMCIRB 21-001913
Remote Ischemic Conditioning, bimanual skill learning, and corticospinal excitability

I am pleased to inform you that at the convened meeting on 10/11/2023 at 12:15 PM of the Biomedical IRB, this research study underwent a continuing review and the committee voted to approve the study. Approval of the study and the consent form(s) is for the period of 10/11/2023 to 10/10/2024.

The Biomedical IRB deemed this study Greater than Minimal Risk .

As the Principal Investigator you are explicitly responsible for the conduct of all aspects of this study and must adhere to all reporting requirements for the study. Your responsibilities include but are not limited to:

1. Ensuring changes to the approved research (including the UMCIRB approved consent document) are only initiated with UMCIRB review and approval except when necessary to eliminate an apparent immediate hazard to the participant. All changes (e.g. a change in procedure, number of participants, personnel, study locations, new recruitment materials, study instruments, etc.) must be prospectively reviewed and approved by the UMCIRB before they are implemented;

2. Ensuring that only valid versions of the UMCIRB approved, date-stamped informed consent document(s) are used for obtaining informed consent (consent documents with the IRB approval date stamp are found under the Documents tab in the ePIRATE study workspace);

3. Promptly reporting to the UMCIRB all unanticipated problems involving risks to participants and others;

4. Applying for continuing review and receive approval of continuation of the study prior to the study's current expiration date. Application for continuing review should be submitted no less than 30 days prior to the expiration date. Lapses in approval (i.e. study expiration) should be avoided to protect the safety and welfare of enrolled participants and liability to the University; and

APPENDIX B: Demographics Survey

Subject ID		
Date of Assessment		
DOB	**Country of birth**	
Country of residence		
Age (Years. Months)		
Gender		Male Female Other
Dominant Side		Right Left Both
Maternal DOB	**Country of origin**	
Paternal DOB	**Country of origin**	
Languages fully fluent (choose all that apply)		English Spanish American sign language Chinese languages French German Other, specify
CP predominant motor type		Spasticity Dyskinetic-dystonia Dyskinetic-Choreoathetosis

	Ataxia Hypotonia
CP distribution	Hemiplegia Monoplegia Diplegia Triplegia Quadriplegia
More involved extremity	Right Left Both
Timing of injury/ abnormality	Prenatal Perinatal Postnatal Unknown
Predominant Brain Pattern	Maldevelopments Predominant white matter injury Predominant grey matter injury Miscellaneous Normal
Ethnicity	Non-Hispanic or Latino Hispanic And Latino Prefer not to answer
Race	White African American Asian American Indian/ Alaska native Native Hawaiian/ Pacific Islander Other, specify

School status	Going to school On vacation from school (between grades) Neither Unknown
Education level	Less than 1st grade 1^{st} to 8^{th} grade 8^{th} to 12^{th} grade $>12^{th}$ grade
Number of years of education	
Primary caregiver of the child	Self Parent or legal guardian Sibling Home aid Long term care Other, specify
Parents education	Never attended/ Kindergarten only High school Vocational/ Technical College Associates degree Bachelor’s Master’s Doctoral
Number of people the child is living with	

Persons living with (list all the relations)	
Rehabilitation	
Rehabilitation Status	Yes No
Physical Therapy	Yes No
PT Frequency	Less than or equal to 2 times per week Once a week 2-5 times per week More than 5 times a week
Strength Training Status	Yes No
Strength Training Frequency	Less than or equal to 2 times per week Once a week 2-5 times per week More than 5 times a week
Functional Training Status	Yes No
Functional Training Frequency	Less than or equal to 2 times per week Once a week 2-5 times per week

	More than 5 times a week
Home exercise Status	Yes No
Home exercise Frequency	Less than or equal to 2 times per week
	Once a week
	2-5 times per week
	More than 5 times a week

Height (meters)	
Weight (pounds)	
Weight (kgs)	
BMI	
Diagnosis	
Extremity used for RLIC	
GMFCS level	
Group Assignment	
Have you ever been diagnosed with peripheral vascular disease?	Yes No
Have you ever been diagnosed with heart problems?	Yes

	No
Have you ever been diagnosed with diabetes?	Yes No
Which type?	Yes No
Do you have peripheral neuropathy?	Yes No
Where is your peripheral Neuropathy	Hands Feet Hands and Feet
Do you take medications for your diabetes?	Oral Injectables Other None
Oral medications	
Injectables	
Other diabetes medications	
Have you ever been diagnosed with a genetic disorder?	Yes No If yes, specify the type

	No known single gene disorder Mendelian Mitochondrial Other, specify
Have you ever been diagnosed with ADD/ ADHD?	Yes No
Have you ever been diagnosed with autism?	Yes No
Have you ever been diagnosed with developmental coordination disorder?	Yes No
Have you ever been diagnosed with hydrocephalous?	Yes No
Do you have any metal implant that will contraindicate MRI?	Yes No
Did you have BOTOX in the affected extremities in the last 6 months?	Yes No
Are you receiving any adjuvant therapy such as rTMS or tDCS?	Yes No
Are you able to hold/ grasp and release a cup?	Yes No
Have you ever been diagnosed with sleep apnea?	Yes No
Do you use a CPAP machine at night?	Yes No
Have you ever been diagnosed with neurological problems?	Yes

	No
Did you have a stroke?	Yes No
If yes, when?	
Do you have a recent or have you ever had a lower limb injury that would prevent your ability to do balance training?	Yes No
Have been ever been diagnosed with vestibular or balance problems?	Yes No
Have you ever been diagnosed with seizures? ***If yes, at what age?** **Are you currently on seizure medication?** **If yes, since, when are you on seizure medication?** **Name of the medications and dose**	Yes No Yes No

Are seizures under control with medication?

When was the last seizure episode?

Have you ever been diagnosed with muscle or bone problems?	Yes No
Have you ever been diagnosed with arthritis?	Yes No
Do you have any other conditions?	Yes No
What other health conditions do you have?	Yes No

Exclusion met!

Prenatal and Postnatal history

Developmental History

APPENDIX C: CHILDREN'S HAND USE EXPERIENCE QUESTIONNAIRE (CHEQ)

(©Karolinska Institutet, 2011)

	Two hands	Use hand *	Time required **	Feeling ***
Pull up track suit trousers	Yes	4	3	4
Remove a straw from the front of a juice box and insert it. (Refers to the whole process, including taking off the wrapping of the straw)	Yes	4	4	4
Put on socks	One hand	1	4	4
Eat out of a small container of yoghurt	Yes	4	4	4
Spread out glue on paper using a glue stick	Yes	4	4	4
Cut out a picture using scissors	Yes	3	3	4
Butter a slice of soft bread	Yes	3	3	4
Open a small box (for example a box of mints)	Yes	4	3	4
Put toothpaste on a toothbrush	Yes	3	4	4
Cut up a pancake (or other food easy to cut up) on the plate	Yes	3	3	4
Remove the wrapping from a piece of candy	Yes	4	3	4
Open the zipper on a small bag (e.g. pencil case or purse)	Yes	4	4	4
Handle playing-cards (Refers to the whole process; holding, selecting and placing cards in the hand while playing)	Yes	3	3	4
Pick money out of a purse or wallet	Yes	3	3	3
Carry a tray (for example in the canteen)	Yes	4	4	4
Pull up the zipper of a jacket	Yes	4	4	4
Button up the trousers	Yes	3	2	3
Open a plastic box with a lid (for example an ice-cream box)	Yes	4	4	4
Screw off the cap of a small, unopened softdrink bottle.	Yes	4	4	4
Remove the wrapping from an ice-cream	Yes	4	4	4
Cut on a chopping board (for example fruit, vegetables, bread)	Yes	3	3	4
Peel an orange	Yes	3	3	4
Open a bag (for example a bag of crisps)	Yes	3	4	4
Take off the protective plastic backing of a Elastoplast	Yes	4	3	4
Cut meat (or other food hard to cut up) on a plate	Yes	2	2	2
Open up a box of milk or juice	Yes	4	4	4
Tie shoelaces	Yes	3	3	3

** How do you think the child's hand works?   Bad / not used, 1------2------3------4,Good*

*** How much time does your child need to do the whole task, compared to peers?   Considerably longer, 1------2------3------4,Equally long*

**** Is your child bothered by his/her reduced hand/arm function during this activity?   It bothers him/her a lot, 1------2------3------4,It does not bother him/her at all*

APPENDIX D: DIMENSIONS OF MASTERY MOTIVATION QUESTIONNAIRE (DMQ-18) (Morgan et al., 2019)

School-Age Motivation Questionnaire
(by adult)

Child's ID_______________ Age ________ (years)   Circle one: Male Female   Today's Date __________

Rater's Relationship to Child: Mother_____ Father _____ Teacher _____ Other (please specify) __________

Please CIRCLE the number that best indicates how typical each statement is of this child's recent behavior. Children vary; most are motivated to do some things but not others. Note that some of the questions may not be typical of a child his or her age, so it is okay to use a "not like this child" rating. Please try to answer all questions even if you are not sure.

		NOT AT ALL LIKE THIS CHILD				EXACTLY LIKE THIS CHILD
1.	Works on a new problem until he or she can do it	1	2	3	4	5
2.	Is pleased with self when finishes something challenging	1	2	3	4	5
3.	Tries to do well at athletic games	1	2	3	4	5
4.	Solves problems quickly	1	2	3	4	5
5.	Seems sad or ashamed when he or she doesn't accomplish a goal	1	2	3	4	5
6.	Tries hard to make other children feel better if they seem sad	1	2	3	4	5
7.	Tries to say and do things that keep other children interested	1	2	3	4	5
8.	Often discusses things with adults	1	2	3	4	5
9.	Gets frustrated when not able to complete a challenging task	1	2	3	4	5
10.	Is very good at doing most things	1	2	3	4	5
11.	Gets excited when he or she is successful	1	2	3	4	5
12.	Tries to do well in physical activities even when they are challenging	1	2	3	4	5
13.	Gets frustrated when does not do well at something	1	2	3	4	5
14.	Completes school work, even if it takes a long time	1	2	3	4	5
15.	Tries hard to interest adults in his or her activities	1	2	3	4	5
16.	Protests after failing at something tried hard to do	1	2	3	4	5
17.	Tries to figure out all the steps needed to solve a problem	1	2	3	4	5
18.	Gets excited when he or she figures something out	1	2	3	4	5
19.	Tries to get adults to see his or her point of view	1	2	3	4	5
20.	Does things that are difficult for kids his or her age	1	2	3	4	5
21.	Is pleased when solves a problem after working hard at it	1	2	3	4	5
22.	Tries hard to get adults to understand him or her	1	2	3	4	5

OVER PLEASE

SURVEY CONTINUES TO NEXT PAGE

		NOT AT ALL LIKE THIS CHILD				EXACTLY LIKE THIS CHILD
23.	Works for a long time trying to do something challenging	1	2	3	4	5
24.	Won't look people in the eye when tries but cannot do something	1	2	3	4	5
25.	Tries hard to understand other children	1	2	3	4	5
26.	Repeats sports skills until he or she can do them better	1	2	3	4	5
27.	Does most things better than other kids his or her age	1	2	3	4	5
28.	Tries hard to make friends with other kids	1	2	3	4	5
29.	Will work for a long time trying to solve a problem for school	1	2	3	4	5
30.	Smiles when succeeds at something he or she tried hard to do	1	2	3	4	5
31.	Understands things well	1	2	3	4	5
32.	Tries to get included when other kids are doing something	1	2	3	4	5
33.	Tries to find out what adults like and don't like	1	2	3	4	5
34.	Looks away when tries but cannot do something	1	2	3	4	5
35.	Tries to keep things going for a long time when playing with other kids	1	2	3	4	5
36.	Tries hard to get better at sports	1	2	3	4	5
37.	Tries hard to understand the feelings of adults	1	2	3	4	5
38.	Tries hard to improve his or her ball-game skills	1	2	3	4	5
39.	Withdraws after trying but not succeeding	1	2	3	4	5
40.	Prefers to try challenging problems instead of easy ones	1	2	3	4	5
41.	Gets angry if cannot do something after trying hard	1	2	3	4	5

APPENDIX E: SELF-EFFICACY AND MOTIVATION QUESTIONNAIRE

Child's ID: ________ Relationship to the Child: __________ Today's Date: _________

HABIT – Confidence and Motivation Survey

Please indicate your agreement or disagreement with the following statements by circling your response using the following the scale.

1. I have seen a change in my change in my child's affected hand use since participating in HABIT.

1 2 3 4 5 6 7 8 9 10

Strongly Disagree Neutral Strongly Agree

2. My child's confidence in using their affected hand has improved since participating in HABIT.

1 2 3 4 5 6 7 8 9 10

Strongly Disagree Neutral Strongly Agree

3. My child is more motivated to perform daily activities since participating in HABIT.

1 2 3 4 5 6 7 8 9 10

Strongly Disagree Neutral Strongly Agree

4. My child's overall confidence in social settings has improved since participating in HABIT.

1 2 3 4 5 6 7 8 9 10

Strongly Disagree Neutral Strongly Agree

5. My child is starting to try and use both hands now when completing daily activities since participating in HABIT.

1 2 3 4 5 6 7 8 9 10

Strongly Disagree Neutral Strongly Agree