A Rhythmic Cueing in Martial Arts Protocol for the Motor Skills of Children with Autism: An Exploratory Pilot Study

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A RHYTHMIC CUEING IN MARTIAL ARTS PROTOCOL FOR THE MOTOR SKILLS OF CHILDREN WITH AUTISM: AN EXPLORATORY PILOT STUDY

By

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A RHYTHMIC CUEING IN MARTIAL ARTS PROTOCOL FOR THE MOTOR SKILLS OF CHILDREN WITH AUTISM: AN EXPLORATORY PILOT STUDY

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Movement differences are common in children with autism and may contribute to difficulties with social interaction. Previous research indicates that the motor skills of children with autism improved following martial arts programs and following rhythmic interventions. Further, listening to rhythmic cues primes the brain to perform a movement through providing information about the timing, range of movement, and muscle effort needed for each movement. Since rhythm and motor skills are processed in the same neural areas, adding rhythmic cues to martial arts may enhance motor execution. However, no studies to date have explored the integration of rhythm and martial arts. Thus, this study examined the combined effect of rhythmic cueing and martial arts on the gross motor skills of children with autism. In addition, this study sought to determine whether children with autism can learn martial arts movements.

Ten male children ages 7 to 12 years old and diagnosed with autism with no martial arts experience participated in the study. Each participant received eight, 30-minute martial arts sessions with rhythmic cueing over a 4-week period. Each session included reviewing and learning select martial arts movements (basic strikes, kicks, blocks, stances, and movement sequences) with rhythmic cues that were provided in the
form of pre-recorded percussion sounds. These sounds included: temporal cues that directed the timing of each movement, spatial cues that indicated the direction of movement, and force cues that facilitated the amount of muscle effort needed for each movement. Data were collected using the gross motor subtests from the Bruininks-Oseretsky Test of Motor Proficiency (2nd ed.) (Bruininks & Bruininks, 2005). Additionally, a Mastery of Martial Arts Test assessed participant’s ability to perform the 15 martial arts movements.

Results showed that following the protocol, participants exhibited statistically significant pre- to post-test improvements in bilateral coordination and body coordination skills (composite of bilateral coordination and balance). These differences also generated large effect sizes, thus indicating practical significance. All other gross motor sub-tests showed improvements at a non-significant level, with the exception of running speed and agility, which showed a non-significant decline. Furthermore, children demonstrated statistically significant pre- to post-test improvements in their performance of all 15 martial arts movements, which means they could and did learn the movements.

Though these findings are encouraging, without a comparison group, improvements in gross motor skills may or may not be associated with the rhythmic cues. Thus, future research should include both experimental and control conditions in which children with autism have opportunity to learn martial arts movements with and without rhythmic cues. Future music therapy research should strive to clarify the role of rhythmic cues and how the different musical elements in the cues affect motor outcomes. Furthermore, future research could build a social component into the protocol to determine whether improving motor coordination correlates with changes in social skills.
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Chapter 1

Introduction

Statement of the Problem

Autism Spectrum Disorder (ASD) is a prevalent developmental disorder in the United States that currently affects one in 59 children (Centers for Disease Control and Prevention, 2018). ASD is a neurological and developmental disorder characterized by impairments in communication and social interactions, repetitive, stereotypical behaviors, and motor differences (American Psychiatric Association [APA], 2013). Motor differences in ASD include hypotonia, apraxia, gross motor delay, and toe-walking (APA, 2013; Ming, Brimacombe, & Wagner, 2007). These differences can affect the development of motor skills, including problems with balance, clumsiness, poor postural control, delayed gross and fine motor coordination, and poor imitation skills (Bhat, Landa, & Galloway, 2011; Green et al., 2009; Whyatt & Craig, 2012).

Motor differences in ASD may also contribute to impairments in social interactions, because sharing, gesturing, imitating, and playing with other children may be difficult without coordinated motor skills (Bhat et al., 2011). Children with ASD similarly have deficits in perception-action coupling as needed to produce coherent, controlled movements with speed and accuracy for goal-directed activities (Whyatt & Craig, 2012). These movements include playing ball with peers and performing social communication skills that involve pointing and gesturing to respond to the social cues of others. To improve and develop motor skills, children with ASD can participate in physical exercise programs (Sorensen & Zarrett, 2014; Sowa & Meulenbroek, 2012; Srinivasan, Pescatello, & Bhat, 2014). Programs such as jogging, cycling, aquatic
exercise, and martial arts are beneficial for improvements in motor skill areas, such as balance, increased speed of walking, and improved muscle strength.

Martial arts programs are a recreational physical activity that incorporate self-defense techniques, meditation, and movement training (Burke, Al-Adawi, Lee, & Audette, 2007; Paul, 2011). Styles of martial arts focus on different aspects of self-defense which influence the techniques and movement training. For example, judo is a Japanese martial art that focuses on throws and holds to take down the opponent to the ground, and taekwondo is a Korean martial art that emphasizes fast kicks and punches in full body contact. Aikido is a Japanese martial art that concentrates on deflecting, evading, and unbalancing an attacker (Burke et al., 2007). Regardless of program style, participants in martial arts develop a sense of community through sparring and practicing self-defense techniques with classmates. Balance, coordination, and body awareness improve through stretching, running, and learning and performing a kata, a sequence of offensive and defensive techniques that simulate an imaginary fight (Bell, Palace, Allen, & Nelson, 2016; Filingeri et al., 2012).

Children with ASD who have participated in individual lessons of 8- to 14-week martial arts programs showed significant decreases in repetitive stereotypy behaviors characteristic of the diagnosis (Bahrami, Movahedi, Marandi, & Abedi, 2012), as well as improved social behaviors (Movahedi, Bahrami, Marandi, & Abedi, 2013). In addition, children on the spectrum increased communication skills (Bahrami, Movahedi, Marandi, & Sorensen, 2016), and improved balance skills (Kim et al., 2016) following martial arts programs. When participating, these children may not always follow or respond to verbal instructions; thus, other strategies such as use of physical touch and prompts, and
repeating the child’s name may help improve compliance (Paul, 2011). Another strategy is the incorporation of music, specifically rhythm, to provide an auditory timing cue for enhanced execution of motor behavior (Hardy & LaGasse, 2013; Thaut, 2013).

An auditory rhythmic cue facilitates entrainment (or timing) of a motor behavior to rhythm. Children with ASD demonstrate the ability to process rhythm and tap in synchrony, indicating rhythm processing may be incorporated as an accommodation (Tryfron et al., 2012; Tryfon et al., 2017). For example, auditory rhythmic cuing assists with timing of motor coordination, helping to cue the initiation and completion of movements for a child with ASD (LaGasse & Hardy, 2013). Rhythm provides a temporal structure to anticipate and organize movements, as well as information to predict the pacing of movements (Hardy & LaGasse, 2013; Thaut, 2013). Furthermore, auditory rhythm and motor behaviors are processed in similar areas of the brain, including the premotor cortex, supplementary motor area, pre-supplementary motor area, basal ganglia, and cerebellum (Bengtsson et al., 2009; Penhune & Steele, 2012). Thus, an overlap exists in neural processing between both and provides preliminary justification for using rhythm as a stimulus to cue motor behaviors in children on the spectrum and improve motor skill functioning.

**Need for the Study**

Most research exploring how to improve motor skills in children with ASD is found in occupational therapy literature, with findings exploring a variety of exercise programs. Some research explores the use of music to address movements in children with ASD; however, outcomes from the combination of music and martial arts have not yet been published. Thus, this study has both theoretical and clinical contributions.
**Theoretical contributions.** While most current research on children with ASD focuses on social and communication skills, researchers now also call for examination of rhythm-based music and movement activities to address their motor skills (Kaur, Srinivasan, & Bhat, 2018; LaGasse & Hardy, 2013; Srinivasan & Bhat, 2013). The effect of using rhythmic cues to teach martial arts has not yet been published. Neither has the combined effects of rhythmic cues and martial arts on motor skills. Thus, the study fills a gap in current research literature as it explores the impact of rhythmic cues to guide martial arts movements on motor skills.

Additionally, this study contributes to the body of knowledge and furthers the understanding of how rhythmic cues impact movement. Although evidence is well-established in regard to rhythmic cues in gait training (Hurt, Rice, McIntosh, & Thaut, 1998; Thaut, McIntosh, & Rice, 1997; Thaut et al., 1996), this current study is unique in exploring the combination of rhythm and movement for individuals with neurologically-based motor differences beyond gait. Implications include the enhancement of motor execution through auditory rhythmic stimuli, combined with martial arts movements.

**Clinical contributions.** If rhythmic cueing can help children with ASD learn and execute martial arts movements, they may experience improvements in their motor skills. For children with ASD, behavioral difficulties at home or school may be due to struggles with motor planning, initiation, and inhibition (LaGasse & Hardy, 2013). With improved motor skills, a child may have better social interactions because sensory integration and motor output are required for prosocial skills (LaGasse & Hardy, 2013; Srinivasan & Bhat, 2013). Improvement in social interactions may be with peers, siblings, or parents; thus, families and friends of children with ASD may also benefit from this study.
Parents may need to adjust expectations for their child’s abilities and development when they learn he or she has ASD (Martinez-Pedraza & Carter, 2009). As part of the adjustment, parents may have concerns about how their child will make friends, learn in school, or which therapies are most beneficial. Children have enrolled in music therapy to address their social and communication skills. Through adding a martial arts program to the rhythmic aspect of music therapy, a child may make gains in motor skills, which may relieve some parents’ concerns for their child’s physical development. They can also better support their child’s progress and help them practice motor skills at home (Srinivasan & Bhat, 2013).

In addition to children with ASD and their families, music therapists who work with children with ASD will benefit from this study. The findings can inform therapeutic interventions using the Neurologic Music Therapy technique of Patterned Sensory Enhancement (Thaut, 2014) to help children with ASD address motor skills. Music therapists may be able to incorporate knowledge of different types of exercise, such as martial arts, that may benefit children with ASD and develop an individualized music movement-based program to address motor behaviors.

**Purpose of the Study**

The purpose of this study was to examine the effect of rhythmic cueing in martial arts on motor skills of children with ASD, in particular gross motor coordination, bilateral coordination of upper and lower extremities, static and dynamic balance, running speed and hopping agility, and sustained strength. In addition, this study investigated how well children with ASD could learn martial arts movements.
Chapter 2

Review of Related Literature

This chapter reviews research literature on the motor skills of children, motor differences and neuropathology of ASD, physical activity programs for children with ASD, and martial arts programs for adults and children with ASD. Additionally, the chapter includes literature related to the central nervous system structures involved in rhythm perception as well as regulation of motor skills. Finally, the chapter provides information on rhythmic entrainment of children with ASD, music and movement programs, the use of music in martial arts, and the effect of Patterned Sensory Enhancement on motor skills in clinical populations.

Motor Skills of Children

According to physical education standards (SHAPE America, 2013), individuals by age 7 demonstrate competency in balance skills and movement patterns. For example, children in kindergarten can maintain balance while performing sliding skills, meaning the ability to step with one foot on the floor and then the other foot slides on the floor to a point next to the lead foot. In addition, children in kindergarten can stay still momentarily when balancing on different bases of support and are able to form wide and narrow body shapes while maintaining balance. In first grade, children know how to move to designated rhythms in their self-space and general space, are able to transfer weight, and demonstrate twisting, bending, and stretching actions. By second grade, children can combine balance and weight transfers into three-part sequences, such as in dance or gymnastics; they also can combine locomotor skills (i.e. sliding, skipping, hopping) with a rhythm in a general space.
Table 1

*Motor Skills of TD Children and Motor Differences of Children with ASD*

<table>
<thead>
<tr>
<th>Age in years</th>
<th>Motor Skills in Typically-developing Children</th>
<th>Motor Differences in Children with ASD</th>
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</thead>
<tbody>
<tr>
<td>7</td>
<td>Large motor control that is more finely tuned</td>
<td>Difficulty in imitating gestures or performing gestures to verbal command (5 to 18 years old; Dewey et al., 2007)</td>
</tr>
<tr>
<td></td>
<td>Balances on either foot</td>
<td>Difficulty with balance (7 to 10 years old; Whyatt &amp; Craig, 2012)</td>
</tr>
<tr>
<td></td>
<td>Throws and catches smaller balls</td>
<td>Difficulty with ball skills (7 to 10 years old; Whyatt &amp; Craig, 2012)</td>
</tr>
<tr>
<td>8</td>
<td>Significant improvement in agility, balance, speed, strength</td>
<td>Difficulty with balance and slow speed of repetitive timed movements (6 to 17 years old; Jansiewicz et al., 2006)</td>
</tr>
<tr>
<td></td>
<td>Good eye-hand coordination</td>
<td>Inefficient eye-hand coordination (4 to 8 years old; Crippa, Forti, Perego, &amp; Molteni, 2013)</td>
</tr>
<tr>
<td>9 and 10</td>
<td>Throws a ball with accuracy</td>
<td>Difficulty with throwing and catching a ball (9 to 10 years old; Green et al., 2009)</td>
</tr>
<tr>
<td></td>
<td>Uses arms, legs, hands, and feet with ease and improved precision</td>
<td>Poor praxis performance of limb motor function (hand pronation-supination, alternating heel to toe tapping) (8 to 14 years old; Dziuk et al., 2007)</td>
</tr>
<tr>
<td>11 and 12</td>
<td>Movements are smoother and more coordinated</td>
<td>Demonstrate spatial errors when performing gestures or imitating gestures (8 to 12 years old; Mostofsky et al., 2006)</td>
</tr>
<tr>
<td></td>
<td>Perfected all fundamental gross motor skills</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Improved strength: run faster, throw balls farther, jump higher</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Kick or bat balls more accurately</td>
<td></td>
</tr>
</tbody>
</table>

*Note.* Developmental milestones of typically developing children from Allen & Marotz (2010).

Developmental milestones for children’s motor skills provide further information (Allen & Marotz, 2010). Children at age 5 are able to balance on either foot for 10
seconds. By age 6, children develop greater control of their large motor skills, executing more deliberate movements with some clumsiness. Table 1 provides a comparison of motor skills of typically-developing (TD) children and motor differences of children with ASD between 7 and 12 years of age. The fundamental gross motor skills for this age range include dynamic and static balance, and the locomotor skills of running, leaping, galloping, sliding, hopping, skipping, and horizontal and vertical jumping and landing (SHAPE America, 2013). Fundamental gross motor skills also involve manipulative ball skills of striking, catching, dribbling with hands and/or feet, overhand and underhand throwing, passing with hands and/or feet, kicking, and volleying.

**Motor Differences of ASD**

Researchers have reported multiple motor movements that seem different in children with ASD. For instance, children with ASD have difficulty coordinating arm and hand movements to reach and grasp objects (Mari et al., 2003), and difficulty with ball skills of catching and throwing (Green et al., 2009; Whyatt & Craig, 2012). Individuals with ASD have also demonstrated inconsistent timing during bimanual rhythmic coordination tasks (Isenhower et al., 2012). Likewise, they have difficulty planning and executing movement sequences to demonstrate gestures and movements with and without objects on verbal command (Dewey, Cantell, & Crawford, 2007; Dziuk et al., 2007; Mostofsky et al., 2006; Salowitz et al., 2013). Children with ASD have difficulty with bilateral coordination of upper extremities and lower extremities when executing movements independently and when imitating an adult (Kaur et al., 2013).

Children on the spectrum have difficulty adjusting posture while standing with eyes closed (Minshew, Sung, Jones, & Furman, 2004), and difficulty with standing and
hopping balance in general (Jansiewicz et al., 2006; Whyatt & Craig, 2012). Moreover, children with ASD display difficulty with jumping side-to-side and jumping forward while maintaining balance. In the same fashion, they have difficulty with diadochokinesis, which is rotating a hand quickly from pronation to supination (Freitag, Kleser, Schneider, & von Gontard, 2007; Jansiewicz et al., 2006). Neurological variations may possibly explain these motor differences in ASD.

**Neuropathology of Motor Differences of ASD**

To clarify, this study will address only the neurological differences related to movement in ASD. Research findings on the neuroanatomy of autism are inconsistent because of the broad spectrum of ASD, varying research methodologies, and the research questions that contribute to current knowledge (Amaral, Schumann, & Nordahl, 2008). Thus, a general conclusion of the neural structures related to movement differences in ASD cannot be made due to the inconsistent outcomes; however, differences have been found that may account for some of the demonstrated movement differences. Overall, these motor challenges affect activities of daily living and social interactions for children with ASD.

The motor cortex of children with ASD does not show activity when watching other individuals complete sequential arm movements, suggesting a deficit of the mirror neuron system (Fabbri-Destro, Cattaneo, Boria, & Rizzolatti, 2009). This system is involved in understanding the intention of a motor action and the ability to imitate an action; a finding which implies children with ASD have difficulty with imitation. In addition, decreased connectivity in the cerebellum and increased activity in the supplementary motor area during a finger tapping task suggests impairments in motor
execution for children on the spectrum (Mostofsky et al., 2009). Increased activity in the ipsilateral anterior cerebellum and decreased activity in contralateral and posterior cerebellum during a motor task also indicate poor motor coordination in individuals with ASD (Allen, Muller, & Courchesne, 2004). Moreover, decreased connectivity between the basal ganglia and the cerebral cortex may account for stereotypy behaviors (Turner et al., 2006).

Physical Programs for Children with ASD

To address these motor and social differences, as well as physical fitness, different physical activity programs ranging from 10 to 60 weeks have been designed for children with ASD. Through swimming programs, children with ASD learned aquatic skills, decreased antisocial behaviors (Pan, 2011), and improved fitness (Fragala-Pinkham, Haley, & O’Neil, 2008; Fragala-Pinkham, Haley, & O’Neil, 2011; Pan, 2010; Pan, 2011; Rogers, Hemmeter, & Wolery, 2010; Yilmaz, Yanardag, Birkan, & Bumin, 2004). Through walking, jogging, and snowshoe programs, children with ASD improved aerobic fitness, and increased speed of walking and distance walked (Kern et al., 1982; Pitetti, Rendoff, Grover, & Beets, 2007; Todd & Reid, 2006). In addition, they decreased in self-stimulatory behaviors, increased in appropriate ball play of catching and throwing a ball, and increased in academic responding (Kern et al., 1982).

Similarly, through stationary and mobile bicycling programs, children with ASD improved muscular strength and aerobic fitness (Lochbaum & Crews, 2003), improved walk time (Hayakawa & Kobayashi, 2011), and increased sustained physical activity by learning self-regulation skills of self-monitoring (Todd, Reid & Butler-Kisber, 2010). In aerobic exercise programs, children with ASD improved cardiorespiratory fitness and
abdominal strength, significantly increased on-task behavior, and reduced negative behaviors (Magnusson, Cobham, & McLeod, 2012). In addition, children with ASD improved muscle strength and walking efficiency in an aerobic program of activities completed with music (Fragala-Pinkham, Haley, Rabin, & Kharasch, 2005). The researchers did not specify type of music or if music had an effect on the motor outcome of the participants.

Through interventions involving interaction with robots, TD children and children with ASD improved bilateral coordination skills (Kaur, Gifford, Marsh, & Bhat, 2013) as well as imitation and praxis skills (Srinivasan et al., 2013). Researchers speculate that children with ASD are more engaged with a humanoid robot because they find the robots less intimidating than humans due to their social simplicity. The robots were controlled by adults, and children with ASD were instructed to greet the robot and imitate the robot’s movement. The robot danced to music while greeting the participants, yet researchers did not indicate any effect of music or the type of music used (Kaur et al., 2013). Srinivasan et al. (2013) used music with a robot in a similar way and specified that music helped recruit the attention of children with ASD; however, music type was not specified. In summary, a variety of physical activity approaches have provided multiple opportunities for children with ASD to address motor differences, including martial arts programs.

**Martial Arts Programs**

Martial arts programs have benefited numerous typical and clinical populations. Researchers have examined the effects of martial arts training on health, motor and non-motor skills of healthy adults. Results demonstrated significant improvements in reaction
time, perception of physical health, mood, and posture with eyes closed (Marie-Ludivine, Papouin, Saint-Val, & Lopez, 2010). Additionally, older adults with Parkinson’s Disease (PD) participated in a weekly qigong group (Schmitz-Hubsch et al., 2006). When examining the motor symptoms of PD, results revealed improvements that were significant at three months, close to significant at six months, and not significant at 12 months of weekly classes. Martial arts training is beneficial for adults with and without a neurologic disorder.

Other researchers have examined martial arts programs to target challenges in balance, communication, and social skills in children with ASD. Children with ASD participating in such programs demonstrated significant improvements in communication (Bahrami et al., 2016) and social (Movahedi et al., 2013) skills, which lasted for 30 days beyond treatment. Furthermore, children with ASD demonstrated significantly improved balance following eight weeks of a martial arts group program (Kim et al., 2016). These findings demonstrate that martial arts programs are beneficial in addressing multiple differences in children with ASD.

To explore a gap in physical activity programs addressing stereotypy behaviors, Bahrami et al. (2012) examined the effect of kata training on stereotypy behaviors of children with ASD. In kata training, the children learned a modified form of a Heian Shodan kata. A kata is a karate form of martial arts comprised of a set sequence of blocking, punching, sticking, and kicking techniques performed as a specific number of movements in several different spatial directions. In performing a kata, the individual executes defensive and offensive techniques of blocks and strikes to surrounding imaginary opponents.
To learn a kata, students first learned the basics of stances, kicking, hand and foot motions, and body movements. Prior to each training session, participants watched a video of an expert model performing the specific technique and kata to be learned that session. Each session consisted of a warm-up of stretching and jogging, kata training, and a cool-down. During the warm-up and cool-down, recorded Persian music played from a stereo system. The researchers did not discuss if music was used during the kata training or if music was used to facilitate training in individual sessions (Bahrami et al., 2012).

Results indicated the kata group demonstrated a significant reduction in stereotypy behavior from pre-test to post intervention while the control group demonstrated a slight reduction in stereotypy, though not significantly. In addition, even after not practicing kata for 30 days, stereotypy behavior remained significantly decreased for children with ASD. Repetition of the kata techniques training, including blocks, hand strikes, and stances, may be similar to the proprioceptive and vestibular input of a stereotypy behavior. Thus, participants’ need to self-stimulate may have been sufficiently obtained through physical exercise. Furthermore, 14 weeks of kata techniques training appears to be an effective way to decrease stereotypy behaviors in children with ASD. However, although music was played, the authors did not state if music influenced the participants in any way (Bahrami et al., 2012).

In summary, children with ASD improved motor, social, and communication skills through physical activity and martial arts programs. These unique programs benefited children on the spectrum by addressing their developmental needs, and some programs included the use of music. However, some of the researchers did not explain the specific pieces of music used, the type of music, or the effect of the music on the
children. The gaps in the current literature warrant exploration of music to support physical activity training. This study focuses on rhythm given its impact on motor movements through increased muscle endurance, prolonged muscle activity, and furthered accurate movements (Thaut, Schleiffs, & Davis, 1991). Further, reasons to believe that rhythm can enhance the observed motor effect are based on the similar neural structures that regulate both rhythm and movement. With improved knowledge of how rhythm functions to elicit motor behavior, effective interventions can be designed to produce desired changes in sensorimotor behavior.

**Central Nervous System Structures and Rhythm Perception**

Listening to music, especially rhythm, activates specific brain areas. The following studies all involved TD adults because such findings are not yet available for children with ASD. However, because the same neural structures are developed or are developing in children, these findings are still relevant to children with ASD (Haartsen, Jones, & Johnson, 2016; Giedd & Rapoport, 2010). Children with ASD demonstrate varying neural activity during motor behaviors, and this study is interested in providing a rhythm stimulus to activate the same neural structures to impact movement. Neuroimaging studies regarding perception of beat-based and nonbeat-based rhythms show activation in the supplementary motor area (SMA), premotor cortex (PMC), basal ganglia, and cerebellum (Chen, Penhune, & Zatorre, 2008b; Grahn & Brett, 2007; Grahn & Rowe, 2009; Grahn & Watson, 2013). The basal ganglia are active when perceiving a consistent rhythmic beat, while the cerebellum is active when a beat is not detected (Grahn & Brett, 2007; Grahn & Rowe, 2009; Grahn & Watson, 2013; Grube, Cooper, Chinnery, & Griffiths, 2010; Teki, Grube, Kumar, & Griffiths, 2011).
Coupling is an integration of the auditory and motor systems when listening to musical stimuli and using the information to move in time with the beat (Grahn & Rowe, 2009). The basal ganglia communicate with the SMA and PMC during beat perception as part of coupling (Grahn & Brett, 2007). Researchers have speculated that the putamen in the basal ganglia facilitates the ability to tap along to a beat. The enhanced connectivity between the basal ganglia and the SMA, PMC, and auditory cortex facilitates individual coordinated movement with rhythm (Grahn & Rowe, 2009).

To consider coordinated movement resulting from neural activity, Bengtsson et al. (2009) examined brain activity during beat perception. Attentively listening to rhythm utilized the dorsal premotor area (PMD), SMA, pre-supplementary motor area (pre-SMA), and the cerebellum. The lateral cerebellum played a role in timing function and processing highly complex intervals, and also supported the SMA and pre-SMA in the prediction of basic timing of stimuli. Pre-SMA and PMD activation in rhythm perception prepare the brain mechanisms to perform motor behaviors. Listening to rhythms increased the activation of the motor and premotor cortices, which encourages an individual to execute a movement, such as spontaneously dancing or tapping one’s feet in synchrony with auditory rhythmic stimuli.

While participants attentively listened to rhythms in the previous study, Chen, Penhune, and Zatorre (2008a), sought to determine which brain regions were activated during active and passive listening to rhythm. Active listeners were told they would have to tap rhythms following listening, while passive listeners were not told that they would tap the rhythms until later in the study. Researchers found the SMA, mid-PMC and cerebellum were recruited during both active and passive listening conditions. Ultimately,
researchers concluded that the brain is primed for action when listening to rhythms, whether one is consciously planning to move or not, thus preparing an individual for movement. To summarize, the basal ganglia, cerebellum, pre-motor cortex, SMA and pre-SMA are active when perceiving rhythm. Next, determining brain areas that regulate motor skills will establish a link between the similar neural structures involved in both rhythm perception and motor skills, which will provide support for the proposed influence of rhythm on motor behavior.

**Central Nervous System Structures in the Learning and Execution of Motor Skills**

Researchers have conducted neuroimaging studies to explore specific brain areas involved in learning motor skills (Grafton, Hazeltine, & Ivry, 1995; Imamizu et al., 2000; Karni et al., 1998). The process of motor learning has been described as having three stages: fast (or early) learning, slow (or later) learning, and retention (Doyon & Benali, 2005; Doyon et al., 2009; Kamibayashi, 2014). In the early learning stage, repetition of movement in a single training session leads to improved motor behaviors (Grafton, Hazeltine, & Ivry, 1995). Although movement patterns are not yet established, sensory input from the somatosensory cortex informs the movements and leads to motor learning. Learning a new motor behavior recruits the motor-related cortical regions of primary motor cortex (M1), PMC, pre-SMA, SMA, and some of the cingulate motor regions of the basal ganglia and cerebellum (Doyon et al., 2009). While M1 sends motor commands, the PMC prepares and plans movements, and with the pre-SMA, also executes movement. The cerebellum provides feedback processing to correct errors in movement while the striatum of the basal ganglia encodes the motor program (Kamibayashi, 2014).
Following the early learning stage, practice of learned motor behavior occurs over several practice sessions in the later learning stage (Kamibayashi, 2014). Sensory inputs lead to learning the motor behavior, at which point the speed and accuracy of the movement improve and the movement becomes automatic (Doyon et al., 2009; Kamibayashi, 2014). During this stage, neural activity observed in the early learning stage changes in response to training. For example, the SMA is more active, especially in the execution of sequential movement (Jenkins et al., 1994), while the PMC is less active.

In the retention stage, even when movements are not practiced for a long time, the learned movement patterns are still retained (Doyon et al., 2009; Kamibayashi, 2014). The cerebellum creates an internal model of the movement through continuous regulation of its spatial and temporal aspects. The cortical-motor areas execute the movements based on internal information stored in the cerebellum (Kamibayashi, 2014).

These cortical regions work together to execute voluntary movement. M1 generates commands and stores new motor memories (Kamibayashi, 2014), while the PMC uses maps of learned sequences to execute movements (Penhune & Steele, 2012), and the SMA plans and executes sequences of complex movements (Kamibayashi, 2014; Watson et al., 2010). Subcortically, the cerebellum coordinates both basic and complex movements (i.e., balance and running) (Kamibayashi, 2014; Penhune & Steele, 2012; Watson et al., 2010). In addition, the striatum, part of the basal ganglia, determines how individual movements relate to one another in a sequence and combines smaller groups of movements within the sequence, to execute longer and more complex sequences (Watson et al., 2010). In sum, motor skills are regulated by specific cortical and subcortical structures that are also associated with rhythm perception.
Scientific Overlap

Both rhythm perception as well as the learning and execution of motor skills utilize a neural network that includes the premotor cortex, supplementary motor area, pre-supplementary motor area, basal ganglia, and cerebellum. The overlap in neural processing provides a hypothetical rationale to support an intervention involving rhythm and motor behavior. Thus, using rhythmic cueing in movement will engage the brain structures needed for learning of coordinated movement by impacting the timing of motor execution. However, further research is needed to examine the effect of a rhythmic cue on motor skills, particularly in children with ASD.

Rhythmic Entrainment of Children with ASD

Rhythmic entrainment occurs when the motor and auditory systems couple to facilitate movement patterns, due to motor responses following rhythm dynamics over time (Thaut, 2005; Thaut & Rice, 2014). The effect of rhythm on movement in children with ASD may be impacted by their ability to entrain movements with rhythm. Moran, Foley, Parker, and Weiss (2013) explored if adolescents with expressive language impaired-autism spectrum disorder could match their motor output to an auditory cue. Results indicated that adolescents were able to hop at a self-selected pace. Although the children were successful at hopping at different paces, they were unsuccessful at hopping to match different beats, with the exception of one participant who successfully coordinated hopping to two different tempi three out of four times. The researchers found that individuals with this disorder had difficulty matching a whole body movement to an auditory cue, which may indicate sensory and auditory processing deficits.
Later, Tryfon et al. (2017) examined auditory-motor rhythm synchronization in ASD and TD males from 6 to 15 years old. Participants tapped their fingers in synchrony to a metronome beat, and later tapped while listening to rhythmic patterns. Results showed that children with ASD performed the task at a similar level to TD children, and task performance improved with age in both groups. Thus, auditory-motor integration may be intact to support basic synchronization for children with ASD (Tryfon et al., 2017). In conclusion, some researchers found that children with ASD can entrain with rhythm while other researchers found they had difficulty entraining. These discrepancies may reflect inconsistent research methodologies, differences in the type of motor tasks, or may be due to the spectrum of ASD.

The Effect of Music in Movement Programs on Motor Skills

Rhythm is one element of music, a complex stimulus that may also involve pitch, timbre, harmony, and form (Thaut, McIntosh, & Hoemberg, 2015). These components of music allow for more varied movements and accommodations (Derri, Tsapakidou, Zachopoulou, & Kioumourtzoglou, 2006). Examining the results of music and movement programs for TD children may provide insight into potential benefits for children with ASD. Venetsanou, Donti, and Koutsouba (2014) investigated preschool children’s motor rhythmic ability after participating in a music/movement program. The experimental group’s sessions included game-like activities based on Orff and Dalcroze approaches, such as participating in traditional singing games and producing rhythmic movements accompanied by music.

Results indicated that the experimental group scored significantly higher after the program than the control group on all motor tasks, including jumping to a personal
rhythm and jumping with an auditory rhythmic stimulus. Similarly, preschool children in another Orff-based music and movement program significantly improved jumping skills and dynamic balance (Zachopoulou, Tsapakidou, & Derri, 2004). Through these music and movement programs, preschool-aged children improved their ability to execute gross motor skills.

To explore further, Betancourt and Hernandez (2012) examined the impact of music and movement activities with school-aged children. Results indicated that children in a special education program and peers from a multi-age classroom significantly improved coordination of upper and lower extremities when musical elements were integrated with locomotor skills. In summary, overall physical activity programs using rhythmic music resulted in varied and positive outcomes for TD children and children with special needs.

The Use of Music in Martial Arts

Research regarding the influence of music in martial arts on motor skills of children with ASD has yet to be published; however, researchers have examined the impact of listening to music prior to performing a martial arts sequence (Ferguson, Carbonneau, & Chambliss, 1994). The immediate listening effects of positive music, negative music, or no music on performing a kata sequence were compared with TD adolescents and adults with training in Skotokan karate. Although this study was conducted more than 20 years ago, it is still relevant as it informs how music may impact martial arts movements. The researchers defined positive music as happy, inspired, or content, and consisting of fast-tempo and loud songs, and negative music as sad, unmotivated, or discontent, and involving slow-tempo and soft songs.
Results showed significantly higher mean scores for the katas performed after positive or negative music compared to white noise. However, comparing the positive and negative music conditions, no significant differences emerged in mean performance ratings. Most of the participants self-reported that the music helped them feel more comfortable and more relaxed. This study examined how music listening improves the performance of martial arts movements (Ferguson et al., 1994).

A common use of music in martial arts presentations involves performing martial arts movements with music in an asynchronous way. McGuire (2015) observed Chinese martial artists of the Hong Luck Kung Fu Club for more than five years in the use of music in both the practice and demonstration of Chinese martial arts. During practice sessions, the martial artists learned the movements without music. Music was introduced when preparing for a performance, so the performer learned what the music sounded and felt like while performing martial arts. The performers were instructed to remain asynchronous to the music to show control of their movements; however, they tended to match their strikes with the rhythm.

As part of McGuire’s observation, during the martial arts performance, a rhythm ensemble of drum, gong, and cymbals produced rhythmic music for the performers. While some strikes (i.e., punches or kicks), aligned with the rhythmic beats to accentuate the striking movements, the martial artists purposefully executed most movements to not synchronize with the music. In fact, the martial artist’s strikes appeared to be in conflict with the rhythm. Thus, the rhythm appeared as an invisible opponent. Overall, instead of coordinating strikes with the rhythm, the music provided energy, motivation, and support for TD martial artists during the presentation (McGuire, 2015).
By contrast, by using rhythm as a sensory cue to facilitate movements, this current study will fill the gap left by Ferguson et al. (1994) since music did not occur during the martial arts performance in that study. In contrast, McGuire (2015) described how music is commonly used in many martial arts presentations to accentuate strikes, but movements are not consistently synchronized with the rhythm. This current study will explore the use of rhythm to facilitate and synchronize martial arts movements to determine its impact on performance as well as motor skills.

The Effect of Patterned Sensory Enhancement (PSE) on Motor Skills

Research on the effects of rhythmic cueing on motor skills has been demonstrated in clinical populations using Patterned Sensory Enhancement (PSE). PSE is a neurologic music therapy technique that uses musical elements to structure and guide the execution of movements patterns (Thaut, 2005; Thaut, 2014). For example, prerecorded tracks of descending and ascending scales facilitated sit-to-stand movements for children with spastic diplegia (Wang et al., 2013). Results indicated the children made significant gains in gross motor capacity and the effects lasted at least three months beyond the program. In addition, the children were more motivated to exercise with the music, and thus performed more repetitions in a shorter period. Children with ASD typically do not have spastic muscle tone; however, these results suggest that exercise with PSE music is motivating and the repetitive practice it provides may improve motor skills.

In another study, adult stroke patients significantly increased their functional arm performance following bilateral arm training with rhythmic cues, and improvements were sustained eight weeks after training (Whitall, Waller, Silver, & Macko, 2000). Although
this study included adults and the current study involves children, the positive results of
the program support using a rhythmic cue in a training program to improve motor skills.

Regarding motor skills of children with ASD, very few studies have examined
PSE with individuals on the spectrum. Researchers provided descriptions of the
therapeutic PSE protocol to address motor difference of ASD and demonstrated how to
apply it with one child. A music therapist designed and played live rhythmic cues on
guitar, piano, autoharp, and other percussive instruments to improve the motor skills of a
7-year-old male diagnosed with ASD, targeting his difficulty in motor organization and
coordination. The rhythmic cues helped the child initiate and end each movement pattern,
and were adapted in the moment to facilitate the child’s movements and redirect
behavior. Rhythm provided timing cues for each movement, and musical elements of
melody, dynamics and pitch were added to denote movement range, force of movement
execution, and movement sequencing. Researchers noted that the child responded more
quickly to musical cues without words compared to hearing lyrics, music, and verbal
prompts (LaGasse & Hardy, 2013).

Although outcomes were not statistically analyzed, the authors noted that the
child improved basic motor movements, such as crossing midline, crossing one foot over
the other, hopping, frog jumping, and skipping. He also learned how to imitate and
sequence movement patterns, such as passing an item behind the head from one hand to
the other hand, which he performed with minimal physical touch cues following
intervention. Moreover, the child made gains in bilateral coordination and learned how to
start and stop movement patterns, such as starting to run and then slowing down to stop.
The client’s family remarked and observed that he made faster motor gains in music
therapy as compared to occupational therapy. In addition, his strength increased so that he no longer needed full support and could independently maintain his body weight on a therapy ball (LaGasse & Hardy, 2013). To summarize, by focusing on rhythmic considerations in musical cues, the music therapist effectively improved motor and movement skills of a child with ASD in individual sessions.

In another approach, Srinivasan et al. (2015) compared the effects of a rhythm group, a robot group, and a comparison group on the imitation/praxis, bilateral coordination, balance, and synchrony with an adult in children with ASD. Children in the rhythm group engaged in simple and complex movement-based games with music from finger-play to whole body movements, and playing of musical instruments (however, the type of music, tempo, or the intended effect of music, if any, on the participants was not specified). Robot group participants imitated the movements of a robot, which included a variety of dual limb and multi-limb imitation through body stretches, as well as walking in letters and shapes patterns by following a robot, all facilitated without music. The comparison group engaged in academic and fine motor tabletop activities by reading books, playing with toys, and doing arts and crafts activities.

Compared to the control group, results revealed that children in both the rhythm and robot groups made significant improvements in body coordination, and interpersonal synchrony (Srinivasan et al., 2015). Interpersonal synchrony occurs when one coordinates actions with social partners, which requires social attention, imitation, and turn-taking skills. Furthermore, all three groups demonstrated a significant reduction in imitation errors. Examining the children’s behavior further, the rhythm group significantly decreased self-injury behaviors and episodes of non-compliance, compared
with the other two groups. Therefore, movement activities with music or with a robot can address motor differences in children with ASD. Although this current study will not consider robot interactions, the impact of rhythm on body coordination and motor skills in children on the spectrum provides support for a rhythm and movement-based intervention.

**Summary**

In conclusion, by age 7 most children develop greater control of fundamental gross motor skills and fully coordinate these skills by age 12. However, children between 6 and 12 with ASD exhibit difficulty with certain gross motor skills, such as balance, bilateral coordination, standing and hopping, and jumping side to side while maintaining balance. These motor challenges are likely due to atypical activity in neural structures implicated in motor movement, including the supplementary motor area, the cerebellum, and the motor cortex. To address these differences, children with ASD have participated in physical activity programs, such as swimming, jogging, and bicycling. These programs have benefited children with ASD by promoting improvements in fitness, strength, and bilateral coordination. A specific physical activity, such as martial arts, has been shown to benefit adults and children with and without neurologic disorders. In response to martial arts, children with ASD improved communication, social, and balance skills and decreased stereotypy behaviors. These motor improvements may be enhanced by using rhythm.

Rhythm perception, as well as the learning and execution of motor skills, activate the same neural areas. The overlap of neural networks includes the premotor cortex, the supplementary motor area, the pre-supplementary motor area, the cerebellum, and the
basal ganglia. These shared activation patterns suggest that processing rhythm can prime motor behaviors by engaging the neural structures needed for learning and executing movements. Therefore, adding a rhythmic stimulus in martial arts programs would most likely activate neural areas needed for movement execution and ultimately enhance performance in children with ASD.

Evidence is inconsistent as to whether or not children with ASD can entrain with rhythm. However, both TD children and children with special needs improved motor and locomotor skills following music and movement programs. Further, listening to music prior to or performing with rhythm in martial arts presentations resulted in improved kata performance for TD adolescents and adults.

In rhythm-based movement interventions, including Patterned Sensory Enhancement, children and adults with neurologic disorders have improved their motor skills. More specifically, children with ASD have shown enhanced motor skills, body coordination, interpersonal synchrony, and decreased non-compliance behaviors (e.g., yelling, running away). Several studies that included the use of music with a motor intervention did not explain how the music was used or prepared. Further, the specific influence of music on motor outcomes was not articulated. More research on movement and rhythm-based interventions is needed to promote motor skills in children on the spectrum. Furthermore, no published study has looked at the effect of rhythmic cueing in martial arts on the motor skills of children with ASD. Thus, this study will fill the gap in the literature and examine a rhythm and martial arts intervention on the motor skills of children with ASD ages 7 to 12.
Research Questions

Based on the presented evidence, this study addressed the following research questions:

1. What is the effect of rhythmic cueing in martial arts on the gross motor skills of children with ASD? More specifically, on:
   • bilateral coordination of upper and lower extremities;
   • static and dynamic balance;
   • running speed and hopping agility; and
   • sustained strength.

2. How well do children with ASD learn martial arts movements?
Chapter 3

Methodology

This chapter provides detailed information about participants, including recruitment and inclusion criteria, the measures, and the steps of the procedures. In addition, this chapter outlines the design and variables, martial arts and rhythmic cueing intervention, and how the data were analyzed.

Participants

This study involved male children diagnosed with ASD between the ages of 7 and 12 years old. This study included only male children because ASD is four times more common among males than females (Centers for Disease Control and Prevention, 2018). Parents confirmed the diagnosis of autism and children at all levels of functioning were included. This age range of 7 to 12 years is similar to that found in the literature in which the effects of physical activity programs on motor skills were explored in children with ASD (Srinivasan et al., 2014). In addition, the student investigator has clinical experience teaching martial arts to children with ASD in this age range.

Recruitment involved calling and emailing various clinics and schools in the Miami, Florida area, including the Center for Autism and Related Disabilities, Rosemont Academy, Gordon School, Cushman School, Vanguard, and High Point Academy. Staff members at each organization were informed of this study and were provided flyers (see Appendix A) and letters of invitations (see Appendix B) to distribute to families of children with ASD. The fliers and letters informed parents about the rhythm and martial arts study and how to contact to participate. Other recruitment mechanisms included in-
person meetings at a local summer camp for children with ASD, where the student investigator met with families who were interested in the study.

To be eligible for the study, each child needed to meet the following inclusion criteria:

- must be able to understand English and concepts of up, down, faster, and slower;
- must be able to follow directions from an unfamiliar adult;
- must be able to perform simple physical activity (i.e., raise and lower arms, alternate standing on one leg, etc.);
- does not have a hearing or physical impairment (i.e., injured leg or uses an assistive device); and
- has no martial arts experience.

These criteria were assessed through a phone call between the student investigator and the child’s parent (see Appendix C). If an answer to any one of the questions was “no,” then the student investigator thanked the parent for their interest and time. If the child met all criteria, then the child was eligible to participate in the study. The student investigator and parent scheduled a one-hour meeting to conduct the initial assessments.

Measures

**Social Responsiveness Scale – Second Edition (SRS-2).** The SRS-2 (Constantino & Gruber, 2012; Bruni, 2014) is a 65-item rating scale that rates the severity of social impairment associated with ASD for individuals ages 2.5 to adult. The assessment consists of five subscales: social awareness, social cognition, social communication, social motivation, and restricted interest and repetitive behaviors. The
SRS-2 includes a version for preschool-aged individuals (2.5 to 4.5 years), school-age individuals (4 to 18 years), adults (19 years and older), and an adult self-report form (19 years and older). For this study, the school-aged form was used and completed by a child’s caregiver. A child’s caregiver can complete the scale in 15 to 20 minutes.

Individuals completing the form rate each behavior item on a 4-point Likert scale: 1 = not true, 2 = sometimes true, 3 = often true, and 4 = almost always true. These ratings are summed as raw scores and then converted to T-scores to generate scores for the five subscales. The scores are converted to control for individual’s difference in gender and raters completing the questionnaire. The T-score indicates the severity of ASD, such that scores of 59 and below indicates the child is within typical limits and may be high functioning or not on the spectrum, while scores between 60 to 65 indicate mild to moderate deficits in social interactions. Scores between 66 to 75 indicate a moderate level of social impairment, with clinically significant social deficits that interfere with everyday interactions. Scores of 76 or higher indicate severe impairment with significant deficits in social functioning that are associated with a diagnosis of ASD. The SRS-2 scale demonstrates strong test/re-test reliability (r = .90) (Constantino et al., 2009) and inter-rater reliability between parent reports (r = .91) (Bölte, Poustka, Constantino, 2008; Constantino et al., 2009). Scores in all ranges of the SRS-2 were accepted for this study.

**Bruininks-Oseretsky Test of Motor Proficiency – Second Edition (BOT-2).**

The BOT-2 (Bruininks & Bruininks, 2005; Deitz, Karin, & Kopp, 2007) assesses children’s motor proficiency, and is appropriate for typically-developing children and children with motor skill differences, ages four to 21 years. The BOT-2 measures gross and fine motor skills through eight subtests. The current study assessed the motor
proficiency of participants using the gross motor component only, which includes 26 items and can be completed in 25 to 30 minutes. The test measures gross motor skills in four subtests: bilateral coordination, balance, running speed and agility, and strength. From the subtests, bilateral coordination and balance scores are also combined for a composite score of Body Coordination. Further, combining running speed and agility scores and strength scores produces the Strength and Agility composite score. The sum of the scores of the four subtests results in a Gross Motor Composite score.

To administer the BOT-2, the examiner demonstrates each task to the participant and manually scores frequency or duration of the child’s attempt at completing each movement. Each of the four subtest scores is converted to a scale score. Standard scores are also generated for each of the composite scores. Both scale and standard scores can be used to determine how well the child performed compared to other children of the same age. Standard and scale scores that are two standard deviations or lower than the age group mean fall into the Well-Below Average category, and one to two standard deviations below the mean signify Below Average. The Average category indicates the score is one standard deviation below or above the age group mean, while scores one to two standard deviations above the mean are considered Above Average. Two standard deviations or more than the age group mean indicate performance is Well-Above Average (Bruininks & Bruininks, 2005). A researcher and associate professor in physical therapy recommended the BOT-2 to assess motor skills of children with ASD (J. Moore, personal communication, February 20, 2018).

The BOT-2 was used in a study with children with high functioning autism matched by age with typically-developing (TD) children (Bruininks & Bruininks, 2005).
The ASD group received significantly lower scores than the TD children on the Complete Form, which includes all eight subtests. The results demonstrated that BOT-2 scores distinguish between groups of children in regard to motor skills. Further, the Bruininks-Oseretsky Test of Motor Proficiency, the first version of BOT-2, has been used by researchers to evaluate motor differences of children with ASD (Dewey et al., 2007; Fragala-Pinkham et al., 2005; Kaur et al. 2013). Researchers found children with ASD had poor motor coordination skills and mostly scored in the Well-Below and Below Average categories for gross motor skills.

Though BOT-2 reliability scores for children with ASD are not reported, reliability scores for TD individuals have been examined. The mean internal reliability scores of the gross motor subtests ranged from .77 to .86, while the mean internal reliability scores of the three gross motor composites ranged from .86 to .94 (Bruininks & Bruininks, 2005a; 2011). The inter-rater reliability scores for the gross motor subtests and composites were all above 0.90 (Bruininks & Bruininks, 2005a). The test-retest reliability scores for the gross motor subtests were in the upper .70s, and the mean reliability scores of the gross motor composites were in the low .80s. A small practice effect was noted for the Body Coordination composite, meaning that taking the test more than once may improve the score. In light of these data, the BOT-2 appears to be a reliable measure of motor skills in typically-developing children.

Below are descriptions of the gross motor subtests for the BOT-2.

**Bilateral coordination.** This section includes seven items that assess body control in sequential and simultaneous coordination of upper and lower limbs. Scoring is based
on precision and accuracy of movements and the number of consecutive controlled movements.

**Balance.** This section includes nine items that measure trunk stability, movement, and proprioception or use of visual cues. Scoring is based on maximum time needed to complete and the total number of correct items performed.

**Running speed and agility.** This section includes five items that assess running speed and agility using shuttle run, hopping tasks, and lateral movement. Scoring is based on form and speed as well as the time to complete and the total number of correct items performed.

**Strength.** This section includes five motor tasks that measure core, upper body, and lower body strength through standing long jump, push-ups, sit-ups, wall sit, and v-up, which is raising the head, chest, and extended arms and legs up while laying on the floor. Scoring is based on strength, good form, time, and total number of correct items performed.

**Mastery of Martial Arts Test.** The Mastery of Martial Arts Test (MMAT) is a videotaped test designed by the student investigator to determine whether or not children with ASD could perform the martial arts movements. In this 15-minute test, the student investigator demonstrates each martial arts movement and then verbally prompts the child with ASD to imitate the movement. The child is given 20 seconds to imitate the movement. This sequence of demonstration and imitation is completed for all the movements from the intervention, including front position, horse stance, half-moon stance, front two-knuckle punch, front ball kick, eight-point blocking system (forward and backward), and kick-cross-uncross sequence. Additional movements are half-moon
forward and backward with the eight-point blocking system (which is separated into forward sequence and backward sequence), Pinan #1, side blade kick, kick-punch-punch sequence, and step-sidekick-cross-uncross sequence. The student investigator facilitated the test as a “copycat game” to the children.

The student investigator trained two data coders to rate each child’s performance from videotape. Raters had previous martial arts training and experience, which allowed them to accurately assess the children’s performance. The raters were blind to the purpose of the study, the children’s diagnoses, and whether the children had completed an intervention. Raters watched the videos, and rated how well the child performed each movement on a 5-point Likert scale (see Appendix D). The coders obtained a minimum of 80% interrater agreement with the student investigator in the training sessions before the coding process. The interrater agreement between the two data coders was 93% for 20% of all observations. The coding process for the motor performance consisted of the following:

1 = Not at All. Participant did not imitate the movement at all (i.e., did not move or respond to the prompt).

2 = Few. Participant correctly imitated very few parts of the movement (i.e., imitated very few parts of a one-part movement or few parts of a sequence; imitation of the arms, trunk, or legs resembled very few parts of the movement).

3 = Some. Participant correctly imitated some parts of the movement (i.e., imitated some parts of a one-part movement or some parts of a sequence; imitation of the arms, trunk, or legs resembled some parts of the movement).
4 = **Most.** Participant correctly imitated most of the movement (i.e., imitated most parts of a one-part movement or most parts of a sequence; imitation of the arms, trunk, or legs resembled most parts of the movement).

5 = **All.** Participant correctly imitated all parts of the movement (i.e., imitated all parts of a one-part movement or all parts of a sequence; imitation of the arms, trunk, or legs resembled all parts of the movement).

**Code N/A** = When the child’s body was blocked for half of the movement (i.e., by the student investigator’s body) or when the child was outside of the video frame for half of the movement.

**Design and Variables**

This study incorporated a one group pre-test/post-test design, in which a small sample received an intervention. This exploratory pilot study was designed to assess the feasibility of the intervention; therefore, no control group was included for comparison. The independent variable was martial arts with rhythmic cueing. The dependent variables were the gross motor skills of bilateral coordination of upper and lower extremities, static and dynamic balance, running speed and hopping agility, and sustained strength. An additional dependent variable was the ability to learn martial arts movements.

**Procedure**

The research protocol was approved by the University of Miami’s Institutional Review Board. Testing and intervention sessions took place in the cafeteria at a summer camp for children with ASD in Miami, FL as well as in a conference room in the Flipse Building and in a large classroom in the Plumer Building, at the University of Miami, Coral Gables campus.
At the first meeting, the parent signed the informed consent form (see Appendix E) and video consent form (see Appendix F), while the child signed the assent form (see Appendix G). After providing consent, the parent then completed the SRS-2 (Constantino & Gruber, 2012) to determine the child’s level of functioning. The student investigator was available to answer questions and had books and manipulatives available for the child with ASD while the parent did the paperwork.

On the same day, the BOT-2 (Bruininks & Bruininks, 2005) was administered as a pre-test by Doctor of Physical Therapy students, a Physical Therapy faculty member from the University of Miami, or the student investigator. A Physical Therapy or Music Therapy faculty member was present during all administrations of the BOT-2. The physical therapy students were blind to the purpose of the study and to the children’s diagnoses. The BOT-2 occurred within one week prior to the intervention. Lastly, the student investigator worked with the parent to determine meeting times for the intervention.

Prior to the first martial arts session, the student investigator conducted the MMAT (Copycat Game) as a pre-test with the child to assess his ability to perform the prescribed martial arts movements. The student investigator showed the child a sheet (see Appendix H) with a list of the 15 movements prior to beginning the copycat game. The purpose of the list was to provide structure and help the child visually map their progress when imitating the movements. For the intervention, each child participated in two, individual 30-minute rhythm and martial arts sessions per week over a 4-week period, for a total of eight sessions. After the last martial arts session, the student investigator conducted the MMAT as a post-test. Finally, the student investigator worked with the
Figure 1. Timeline of participants' commitments and activities from the first meeting to the final meeting for a commitment of 10 days in a minimum of 4 weeks and a maximum of 6 weeks.
parent to schedule a meeting time for the BOT-2 as a post-test within one week of the last martial arts session, utilizing the same procedure as the BOT-2 pre-test. Figure 1 provides an outline of participant activities.

**Rhythm and Martial Arts Intervention**

*Rhythmic cueing stimulus.* Rhythmic cues were utilized to guide martial arts movement patterns based on the Neurologic Music Therapy technique of Patterned Sensory Enhancement (PSE) (Thaut, 2005; Thaut, 2014). Verbal cues were also paired with the rhythmic cues to indicate the martial arts move or an action word for each part of the movement. The rhythmic cue for each martial arts movement pattern was conceptualized by considering how it would guide and facilitate the movement. Using drum kit and percussion MIDI files, the student investigator created and arranged rhythmic cues to coordinate and guide each movement pattern. Recordings were made in GarageBand on a MacBook Pro laptop computer (early 2015 version) and instrument sounds included claves, conga, snare drum, bongo, kick drum, cymbal, and chimes. The rhythmic cues provided information on the temporal, spatial, and force parameters of each movement (Thaut, 2005; Thaut, 2014).

*Temporal cues.* Temporal cues directed the timing or speed of each movement pattern, providing a consistent structure to anticipate the interval of time between movements and when to execute movements (Thaut, 2005; Thaut, 2014). No steady, ongoing beat was used during the protocol. Cues were created in rhythmic patterns specifically designated to accentuate each part of multi-point movements, such as an upward arm block where the forearm blocks the space above the head. For example, the rhythmic pattern for an upward arm block consisted of various drum cues to direct the
four different parts of the movement (see Table 2). Tempo was recorded at 60 bpm for each movement pattern and according to the student investigator, was similar to the tempo used when a new movement was introduced for children with ASD in standard martial arts instruction. The student investigator asked each participant if the rhythmic cue was at a comfortable pace for him to execute movement. Depending on the child’s answer, the tempo of the cue was adjusted. The student investigator also observed the child’s ability to follow the cue. If he was moving faster or slower than the cue, the cue was adjusted.

Table 2

*Sample Description of How a Particular Movement (Upward Arm Block) was Cued*

<table>
<thead>
<tr>
<th>Movements</th>
<th>Instruments</th>
<th>Rhythmic Cues</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arm bent at belly level</td>
<td>Snare drum tuned down by 9 semitones</td>
<td>Temporal and spatial cue</td>
</tr>
<tr>
<td>Arm move up toward head</td>
<td>Crescendo djembe drum rub</td>
<td>Temporal, spatial, and force cue</td>
</tr>
<tr>
<td>Arm stop above head</td>
<td>Snare drum tuned up 9 semitones</td>
<td>Temporal and spatial cue</td>
</tr>
<tr>
<td>Arm move to side of body</td>
<td>Original bongo sound</td>
<td>Temporal and spatial cue</td>
</tr>
</tbody>
</table>

*Spatial cues.* Spatial cues directed range of motion in the horizontal and vertical planes, indicating the starting, stopping, and turning points for the movement direction of strikes, stances, and sequences (Thaut, 2005; Thaut, 2014). Pitch level cued the direction of movement, with high frequency pitches prompting ascending arm and leg movements, while lower pitches designated descending arm and leg movements. In addition, pitch level distinguished arm and leg movements, with higher pitches guiding arm movements, while lower pitches directing leg movements. For example, the snare drum pitch was
tuned to nine semitones lower and higher, which was used to indicate the start and end points of an upward arm block. Dynamics were also incorporated, such as a decrescendo of a hand rubbing across the drum (drum rub) that prompted downward head and body movements, while a crescendo indicated upward motion. In addition, the long sound duration of the chimes conveyed fluid movements of bringing feet and hands together into position.

**Force cues.** Force cueing simulated the amount of muscle effort needed to execute the movement (Thaut, 2005; Thaut, 2014). A tempo of 60 bpm indicated a slow, controlled movement, while faster tempi prompted more force in the movements. A faster tempo, such as 72 bpm, was used when cueing punches and kicks after first learning the movements at the slow tempo. Changes in dynamics cued the change in strength of muscle needed for a movement. Increased volume prompted more effort for a punch, kick or block, while softer sounds cued less effort with smaller movements, such as shifting body weight. A decrescendo rubbing of the drum head directed a decrease in muscle force to slide and rest the foot, while a crescendo sound created the feeling of increased muscle force to slide the foot outward.

**Martial arts movements.** At the first session, the student investigator explained martial arts to the participants. The student investigator informed participants that they would learn how to be stronger and control their body, how to train their body and move in a different way, how to be a “ninja,” and have fun. The student investigator also explained the rules of conduct for performing martial arts movements in space, and not on other people, listening to the student investigator’s directions, and performing the movements as best they could.
The student investigator has clinical experience teaching individual and group martial arts classes for TD children, adults with ASD and developmental delays, children with ASD, and integrated classes of TD children and children with ASD. The student investigator designed the 4-week program incorporating some of the material required at the white and yellow belt level in the United Studios of Self Defense (USSD) Shaolin Kempo style (United Studios of Self Defense [USSD], 2008). Shaolin Kempo style focuses on striking, kicking, joint manipulation, and grappling skills as fighting techniques. Table 3 outlines the white and yellow belt movements that were taught to participants in this study.

Table 3

Martial Arts Materials

<table>
<thead>
<tr>
<th>White Belt Material</th>
<th>Yellow Belt Material</th>
</tr>
</thead>
<tbody>
<tr>
<td>Front position</td>
<td>Side blade kick</td>
</tr>
<tr>
<td>Horse stance</td>
<td>Kick-punch-punch sequence (adapted from Kempo #1)</td>
</tr>
<tr>
<td>Half-moon stance</td>
<td>Step-side blade kick-cross-uncross sequence (Defence Maneuver #7)</td>
</tr>
<tr>
<td>Front-two knuckle punch</td>
<td>Pinan #1</td>
</tr>
<tr>
<td>Front ball kick</td>
<td></td>
</tr>
<tr>
<td>Eight-point blocking system forward</td>
<td></td>
</tr>
<tr>
<td>Eight-point blocking system backward</td>
<td></td>
</tr>
<tr>
<td>Kick-cross-uncross sequence (Defence Maneuver #6)</td>
<td></td>
</tr>
<tr>
<td>Half-moon forward with the eight-point blocking system</td>
<td></td>
</tr>
<tr>
<td>Half-moon backward with the eight-point blocking system</td>
<td></td>
</tr>
<tr>
<td>Half-moon forward and backward with the eight-point</td>
<td></td>
</tr>
<tr>
<td>blocking system</td>
<td></td>
</tr>
</tbody>
</table>

*Note. Adapted from United Studios of Self Defense Student Manual (2008).*

The plan used in the study (see Table 4) was similar to plans the student investigator has developed for other children with ASD and adults with developmental delays. Both groups were successful at learning the basic strikes, kicks, blocks, stances,
<table>
<thead>
<tr>
<th>Week</th>
<th>First Session</th>
<th>Second Session</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Front position</td>
<td>Eight-point blocking system: right outward, left outward, right inward, left inward, right upward, left upward, right downward, left downward</td>
</tr>
<tr>
<td></td>
<td>Horse stance</td>
<td>Half-moon forward with the eight-point blocking system</td>
</tr>
<tr>
<td></td>
<td>Half-moon stance</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Front two knuckle punch</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Front ball kick</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Kick-punch-punch sequence</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Kick-cross-uncross sequence</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Eight-point blocking system in reverse</td>
<td>Half-moon forward and backward with the eight-point blocking system</td>
</tr>
<tr>
<td></td>
<td>Half-moon and 8 blocks moving backward</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Pinan #1: Bow - dragon breathes fire - cat stance - left half-moon stance - left downward block - half-moon forward - right punch - cat stance - right half-moon stance - right downward block - half-moon forward - left punch - cat stance - left half-moon stance - left downward block with “kiai” - half-moon forward - right punch - half-moon forward - left punch - half-moon forward - right punch</td>
<td>Pinan #1 continued: cat stance – left half-moon stance – left downward block – half-moon forward – right punch – cat stance – right half-moon stance – right downward block – half-moon forward – left punch – cat stance – left half-moon stance – left downward block with “kiai” – half-moon forward – right punch – half-moon forward – left punch – half-moon forward – right punch</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Side blade kick</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Step-side blade kick-cross-uncross sequence</td>
</tr>
</tbody>
</table>

*Note.* Adapted from United Studios of Self Defense Student Manual, 2008.
and three movement sequences. Some children with ASD and adults with developmental delays had difficulty executing the sequence of half-moon stances and blocks; however, other children and adults successfully learned and performed half-moon and blocks going forward and backward within eight sessions. One child with ASD successfully learned and performed all movements of Pinan #1, a movement sequence of delivering blocks and punches to imaginary targets in multiple directions.

In the current study, each session began with a bow, a 30-second meditation period, and four minutes of stretching with no music. This sequence is typical of martial arts classes and is similar to warm-ups outlined in martial arts studies (Bahrami et al., 2012; Bahrami et al., 2016; Kim et al., 2016; Marie-Ludivine et al., 2010; Movahedi et al., 2013). During meditation, participants were instructed to sit with their legs folded under them or in a crisscross manner, close their eyes, and focus on breathing for 30 seconds. Stretching activities included 20 different muscle group stretches for 10 seconds each, such as ankle rotations and seated hamstring stretch.

The next 25 minutes of the session involved learning martial arts movements and reviewing previously acquired skills. Table 4 outlines the movements and combinations taught in each session. Not all children completed all steps or learned all movements. The student investigator used verbal encouragement, positive reinforcement, and provided verbal feedback to participants. The student investigator also used motivational techniques of setting goals and providing incentives. For example, if a child set and achieved a goal of completing moves without cues, he could choose the next movement to review, or practice strikes on hand target bags. Verbal instructions were minimized to emphasize demonstrated movements as an instructional strategy. The sessions ended with
a 30-second meditation period with no music and a bow, which was similar to what was done in the beginning of the session. This format is also typical of martial arts classes and was included in previous martial arts studies (Bahrami et al., 2012; Bahrami et al., 2016; Kim et al., 2016; Marie-Ludivine et al., 2010; Movahedi et al., 2013).

The procedure for the rhythmic cueing with martial arts component within each session followed these steps:

1. The student investigator demonstrated the movement with a verbal cue (“Watch me!”) while the participant observed.

2. The student investigator demonstrated the movement with a verbal cue while the participant simultaneously imitated. The student investigator used tactile and verbal cues to correct participant’s movements as needed for appropriate pacing and movement execution.

3. The student investigator demonstrated the movement with a verbal cue and a rhythmic cue while the participant simultaneously imitated.

4. The student investigator demonstrated the movement with only the rhythmic cue while the participant simultaneously imitated.

5. The participant independently performed the movement with the rhythmic cue. The student investigator did not demonstrate the movement for the participant.

6. The participant independently performed the movement without any cues.

The participant repeated any step of the intervention as many times as needed within the session. After a participant demonstrated a movement independently (i.e., without any cues) with his legs, arms, and trunk performing most of the movement, a new movement was taught in the same manner.
Additionally, throughout the program, the student investigator talked to parents and informed them of what she observed in the sessions and how the child was learning martial arts. The student investigator informally asked parents throughout the program what they were noticing at home regarding their child’s motor skills and behavioral activity. Finally, when each child finished the study, the student investigator informally asked what he thought of the sessions and presented him with a certificate of achievement for completing the martial arts sessions.

**Statistical Analysis**

A series of paired $t$-tests were conducted on each dependent variable to determine whether post-test scores were different from pre-test scores. More specifically, $t$-tests were conducted comparing pre-and post-test scores of the BOT-2 for balance, bilateral coordination, strength, running speed and agility, and gross motor skills, as well as scores from the Mastery of Martial Arts Test. In addition, Cohen’s $d$ was conducted to measure effect size and magnitude of differences of pre-test and post-test scores of the BOT-2 and the Mastery of Martial Arts Test. Descriptive analyses were run on the demographic variables of age and level of functioning.
Chapter 4

Results

This chapter describes the results obtained from data collection, and the statistical analyses conducted on the data. Descriptive and inferential analyses are provided for the two research questions. The analyses were performed utilizing the Statistical Package for the Social Sciences (SPSS) version 24. Prior to showing the analyses results, participants demographics are presented.

Participants

Twenty-one male children diagnosed with ASD between the ages of 7 and 12 years old were recruited for participation, with a mean age of 8.0 years ($SD = 0.65$). An autism diagnosis was confirmed by children’s parents. Eleven children were not included in data analysis for several reasons. Some of the children were too young ($n = 3$), already had martial arts experience ($n = 3$), lived too far from the testing site ($n = 1$), or did not respond to student investigator’s phone call ($n = 1$). Other children did not attend the initial meeting ($n = 1$), did not start the invention ($n = 1$), or did not complete the rhythm and martial arts protocol ($n = 1$). Twelve children gave assent, and 10 participants completed the entire study protocol. Three of these 10 participants also had a diagnosis of Attention Deficit Hyperactivity Disorder, according to parents.

The data analysis pertains to the 10 children who met the inclusion criteria, provided assent, and completed the protocol. The Social Responsiveness Scale (2nd ed.) (SRS-2; Constantino & Gruber, 2012) was used to determine each child’s level of social impairment associated with ASD. Of the 10 participants included in the data analysis, two participants’ SRS-2 scores were identified within typical limits, meaning the children
may be high functioning or not on the spectrum. One participant’s score fell in the mild range, which indicates mild to moderate deficits in social interactions. SRS-2 scores for four participants were categorized as moderate, with clinically significant social deficits that interfere with everyday interactions. Three participants' SRS-2 scores indicated severe impairment with significant deficits in social functioning that are associated with a diagnosis of ASD. See participant demographics in Table 5.

Table 5

Demographics of Participants

<table>
<thead>
<tr>
<th>Demographic Variables</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>10</td>
</tr>
<tr>
<td>Age (in years)</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>6</td>
</tr>
<tr>
<td>8</td>
<td>4</td>
</tr>
<tr>
<td>9</td>
<td>0</td>
</tr>
<tr>
<td>10</td>
<td>0</td>
</tr>
<tr>
<td>11</td>
<td>0</td>
</tr>
<tr>
<td>12</td>
<td>0</td>
</tr>
<tr>
<td>Level of Functioning</td>
<td></td>
</tr>
<tr>
<td>Within Typical Limits</td>
<td>2</td>
</tr>
<tr>
<td>Mild</td>
<td>1</td>
</tr>
<tr>
<td>Moderate</td>
<td>4</td>
</tr>
<tr>
<td>Severe</td>
<td>3</td>
</tr>
</tbody>
</table>

Statistical Analysis

Basic assumptions were examined and requirements were met for the BOT-2 and MMAT scores prior to computing the paired t-tests (Gravetter & Wallnau, 2017b). Effect sizes were examined using Cohen’s $d$, and were interpreted using the following criteria: $.20 = \text{small effect}, .50 = \text{medium effect}, \text{and} .80 = \text{large effect}$ (Gravetter & Wallnau, 2010a).
Research Question One: What is the effect of rhythmic cueing in martial arts on the gross motor skills of children with ASD?

Descriptive analysis. The following are the mean and standard deviation (SD) scores for pre- and post-tests of the gross motor subtests of the BOT-2. The possible range of scale scores for each subtest is 1 to 35, and 20 to 80 for the composite standard scores, with lower numbers signifying below average skill level, and higher numbers for above average skill level. The average score for bilateral coordination of upper and lower extremities for all participants at the pre-test was 10.5 ($SD = 4.50$), and the post-test mean bilateral coordination score was 13.7 ($SD = 4.32$). The mean score for balance for all participants at the pre-test was 8.7 ($SD = 2.83$), while the post-test mean balance score was 9.7 ($SD = 3.65$). The mean score for body coordination composite (combination of bilateral coordination and balance scores) for all participants at the pre-test was 38.1 ($SD = 6.08$), and 42.5 ($SD = 7.35$) at post-test.

The average score for running speed and hopping agility for all participants at the pre-test was 9.5 ($SD = 4.6$), while the post-test mean score was 9.3 ($SD = 4.74$). The mean score for sustained strength for all participants at the pre-test was 8.8 ($SD = 3.05$), and the post-test mean strength score was 9.3 ($SD = 3.16$). The mean score for strength and agility composite (combination of running speed and hopping agility with strength scores) for all participants at the pre-test was 37.6 ($SD = 6.72$), and the post-test mean strength and agility composite score was 37.9 ($SD = 7.11$). The mean score for gross motor composite (combination of body coordination and strength and agility composite scores) for all participants at the pre-test was 36.4 ($SD = 7.55$), while the post-test mean gross motor composite score was 38.9 ($SD = 8.02$). See descriptive BOT-2 gross motor
scores in Table 6. See pre- and post-test gross motor scores of the BOT-2 in Figures 2 and 3.

Table 6

*Descriptive Analyses for Gross Motor Skills as Assessed by the Bruininks-Oseretsky Test of Motor Proficiency (2nd ed.)*

<table>
<thead>
<tr>
<th>Gross Motor Skills</th>
<th>Pre-Test Mean</th>
<th>Pre-Test SD</th>
<th>Post-Test Mean</th>
<th>Post-Test SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bilateral Coordination</td>
<td>10.5</td>
<td>4.50</td>
<td>13.7</td>
<td>4.32</td>
</tr>
<tr>
<td>Balance</td>
<td>8.7</td>
<td>2.83</td>
<td>9.7</td>
<td>3.65</td>
</tr>
<tr>
<td>Body Coordination Composite (of bilateral coordination and balance)</td>
<td>38.1</td>
<td>6.08</td>
<td>42.5</td>
<td>7.35</td>
</tr>
<tr>
<td>Running Speed and Agility</td>
<td>9.5</td>
<td>4.6</td>
<td>9.3</td>
<td>4.74</td>
</tr>
<tr>
<td>Strength</td>
<td>8.8</td>
<td>3.05</td>
<td>9.3</td>
<td>3.16</td>
</tr>
<tr>
<td>Strength and Agility Composite (of running speed and agility, and strength)</td>
<td>37.6</td>
<td>6.72</td>
<td>37.9</td>
<td>7.11</td>
</tr>
<tr>
<td>Gross Motor Composite (of body coordination and strength and agility composites)</td>
<td>36.4</td>
<td>7.55</td>
<td>38.9</td>
<td>8.02</td>
</tr>
</tbody>
</table>
Figure 2. Average pre- and post-test scale scores of gross motor skills as assessed by the Bruininks-Oseretsky Test of Motor Proficiency (2nd ed.). ** $p < .01$

Figure 3. Average pre- and post-test standard scores of gross motor skills as assessed by the Bruininks-Oseretsky Test of Motor Proficiency (2nd ed.). * $p < .05$
Inferential analysis. The following are the results of the paired $t$-tests, p values, and Cohen’s $d$ for the pre- and post-tests of the BOT-2. The mean difference in bilateral coordination from pre- to post-test was 3.2 with $SD = 2.9$, which indicated a statistically significantly difference, $t(9) = 3.49, p = 0.007$. The Cohen’s $d$ value ($d = 1.1$) specified that the differences in pre- to post-test bilateral coordination scores demonstrated a large effect. Differences for balance from pre- to post-test were $M = 1$ with $SD = 2.36$, which was not significantly different, $t(9) = 1.34, p = 0.213$. Cohen’s $d$ value ($d = 0.42$) showed a medium effect size for changes in balance scores. The mean change for body coordination composite from pre- to post-test was 4.4 with $SD = 4.33$, which was a statistically significantly difference, $t(9) = 3.22, p = 0.011$. Cohen’s $d$ value ($d = 1.02$) indicated a large effect size for changes in body coordination scores.

The mean change for running speed and agility from pre- to post-test was -0.2 with $SD = 2.15$, which was not significantly different, $t(9) = -0.29, p = 0.775$. Cohen’s $d$ value ($d = -0.09$) demonstrated a small effect for changes in running speed and agility scores. Differences in strength from pre- to post-test were $M = 0.5$ with $SD = 2.07$, and were not significantly different, $t(9) = 0.76, p = 0.464$. Cohen’s $d$ value ($d = 0.24$) signified that the pre- to post strength comparisons exhibited a small effect. The mean change for strength and agility composite from pre- to post-test was 0.3 with $SD = 3.37$, which was not significantly different, $t(9) = 0.28, p = 0.785$. Cohen’s $d$ value ($d = 0.09$) showed that the pre- to post-test strength and agility composite scores showed a small effect. The mean change for gross motor composite from pre- to post-test was 2.5 with $SD = 3.72$, and was not significantly different, $t(9) = 2.13, p = 0.062$. Cohen’s $d$ value ($d$
designated that the pre- to post-test strength and agility composite scores demonstrated a moderate effect. See inferential analysis of the BOT-2 scores in Table 7.

Table 7

Paired t-Test Results for Gross Motor Skills as Measured by the Bruininks-Oseretsky Test of Motor Proficiency (2nd ed.)

<table>
<thead>
<tr>
<th>Gross Motor Skill</th>
<th>Mean Difference</th>
<th>SD Difference</th>
<th>t statistic</th>
<th>p</th>
<th>d</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bilateral Coordination</td>
<td>3.2</td>
<td>2.9</td>
<td>3.49</td>
<td>0.007 **</td>
<td>1.1</td>
</tr>
<tr>
<td>Balance</td>
<td>1</td>
<td>2.36</td>
<td>1.34</td>
<td>0.213</td>
<td>0.42</td>
</tr>
<tr>
<td>Body Coordination Composite</td>
<td>4.4</td>
<td>4.33</td>
<td>3.22</td>
<td>0.011 *</td>
<td>1.02</td>
</tr>
<tr>
<td>Running Speed and Agility</td>
<td>-0.2</td>
<td>2.15</td>
<td>-0.29</td>
<td>0.775</td>
<td>0.09</td>
</tr>
<tr>
<td>Strength</td>
<td>0.5</td>
<td>2.07</td>
<td>0.76</td>
<td>0.464</td>
<td>0.24</td>
</tr>
<tr>
<td>Strength and Agility Composite</td>
<td>0.3</td>
<td>3.37</td>
<td>0.28</td>
<td>0.785</td>
<td>0.09</td>
</tr>
<tr>
<td>Gross Motor Composite</td>
<td>2.5</td>
<td>3.72</td>
<td>2.13</td>
<td>0.062</td>
<td>0.67</td>
</tr>
</tbody>
</table>

Note. * p < .05, ** p < .01

Changes in Participants’ Motor Skills Compared to Normative Data

The BOT-2 (Bruininks & Bruininks, 2005) provides age-equivalent data for each point score of the gross motor skills that were measured. These data provide a point of reference for the gross motor skill level of ASD participants at pre- and post-test compared with typically-developing (TD) children. The average age of all participants in the current study at pre-test was 8:0 years. By the post-test, the mean age of all study participants was 8:1 years. The following age-equivalent scores from the BOT-2 (Bruininks & Bruininks, 2005) are of TD male children in comparison to study participants.
According to the age-equivalent scores, the average bilateral coordination score for 8:0 to 8:2-year-old TD males is 20 (Bruininks & Bruininks, 2005). In the present study, participants’ mean bilateral coordination pre-test score was 13.6. This score corresponds to the average age-equivalent score earned by TD children ages 5:8 through 5:9 years. The participants’ average bilateral coordination post-test score was 17.6, which matches the mean age-equivalent score of children ages 6:9 to 6:11 years. One study participant scored above 20 for bilateral coordination at pre-test, and 5 participants scored 20 or more at post-test. Additionally, two other participants scored between 17 and 19 for bilateral coordination at post-test.

As stated in the BOT-2 (Bruininks & Bruininks, 2005), TD males ages 8:0 through 8:2 years score an age-equivalent average of 32 on the balance test. In comparison, the mean pre-test balance score of ASD participants was 22.9. This score corresponds to an average age-equivalent score earned by TD children ages 4:6 to 4:7 years. The mean balance post-test score of all ASD participants was 24.8, and matches the average age-equivalent score obtained by TD children between 4:10 to 4:11 years. None of the participants scored 32 for balance at pre-test, and two participants scored 32 or more at post-test. Five participants had high pre-test scores of 27 to 30 for balance, and four other participants scored between 26 to 31 at the post-test.

For the running speed and agility test of the BOT-2 (Bruininks & Bruininks), the average age-equivalent score of TD males ages 8:0 to 8:2 years is 31. The mean running speed and agility pre-test scores for ASD participants was 21, which is similar to a mean age-equivalent score earned by TD children ages 5:4 to 5:5 years. The mean running speed and agility post-test score of study participants was 20.7, and corresponds to the
average age-equivalent score achieved by TD children ages 5:2 to 5:3 years. In the current study, one participant scored above 31 for running speed and agility, both at pre- and post-test. One other participant scored between 28 to 30 for running speed and agility, both at pre- and post-test.

In the BOT-2 (Bruininks & Bruininks, 2005), the average age-equivalent strength score of 20 (with knee push-ups) or 19 (with full push-ups) is earned by TD males ages 8:0 to 8:2 years. The study participants had a mean pre-test strength score of 11, which corresponds to an average age-equivalent score achieved by TD children ages 5:2 to 5:3 years (with knee push-ups) or TD children ages 5:4 to 5:5 years (with full-push-ups). At post-test, study participants’ mean score for strength was 12.6, which is similar to an average age-equivalent score of TD children ages 5:4 through 5:5 years (with knee push-ups) or TD children ages 5:8 to 5:9 (with full push-ups). None of the participants earned a strength score of 19 or 20 at pre-test, and one participant scored 19 at post-test. Five participants scored between 15 to 16 at pre-test and four participants scored between 15 to 17 at post-test. See age comparisons of gross motor skills in Table 8, and number of participants with scores similar to average TD males scores in Figure 4. See individual pre- and post-test scale and standard gross motor scores in Table 11 (see Appendix I).
Table 8

Changes in Average Participants’ Gross Motor Skills as Compared to Age Equivalent Data According to the Bruininks-Oseretsky Test of Motor Proficiency (2nd ed.)

<table>
<thead>
<tr>
<th>Gross Motor Skills</th>
<th>Pre-Test mean age = 8:0 years</th>
<th>Post-Test mean age = 8:1 years</th>
<th>TD Score for 8:0 to 8:2 years</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean Raw Score</td>
<td>Age-equivalent</td>
<td>Mean Raw Score</td>
</tr>
<tr>
<td>Bilateral Coordination</td>
<td>13.6</td>
<td>5:8 to 5:9</td>
<td>17.6</td>
</tr>
<tr>
<td>Balance</td>
<td>22.9</td>
<td>4:6 to 4:7</td>
<td>24.8</td>
</tr>
<tr>
<td>Running Speed and Agility</td>
<td>21</td>
<td>5:4 to 5:5</td>
<td>20.7</td>
</tr>
<tr>
<td>Strength (knee push-ups)</td>
<td>11</td>
<td>5:2 to 5:3</td>
<td>12.6</td>
</tr>
<tr>
<td>Strength (full push-ups)</td>
<td>11</td>
<td>5:4 to 5:5</td>
<td>12.6</td>
</tr>
</tbody>
</table>

Figure 4. Number of participants who achieved gross motor scores similar to age-equivalent TD children as per the Bruininks-Oseretsky Test of Motor Proficiency (2nd ed.).
Research Question Two: How well do children with ASD learn martial arts movements?

Mastery of Martial Arts Test (MMAT). The MMAT was a videotaped assessment to determine whether children with ASD could learn martial arts, where the student investigator demonstrated each of the 15-martial arts movements and then verbally prompted each participant to imitate the movement. Data coders then scored movements from video, using a 5-point Likert scale, from 1 = participant did not imitate the movement at all to 5 = participant correctly imitated all parts of the movement.

Each child was pre- and post-tested on all movements in the MMAT. However, the number of movements taught in the protocol varied across children. To explain, a child needed to independently, without any verbal or rhythmic cues, demonstrate most parts of a learned movement before progressing to a new movement in a treatment session. Some children needed more repetition of movements, than others, before progressing to a new movement.

All participants learned moves 1 through 8. However, some children did not demonstrate the ability to independently perform enough of movements 9 through 12 to progress further. Therefore, not all children learned all 15 movements (see Figure 5). One child learned moves 1 thru 9 and another child learned moves 1 thru 10. A different child learned moves 1 thru 11 and another child learned moves 1 thru 12. Five children had the opportunity to learn all 15 movements (see Table 12 in Appendix I). Components of many of the complex movement sequences were comprised of movements learned previously, thus, even children who did not learn all movements could still perform some components of later sequences (i.e., movements 9 through 15) during post-testing.
Descriptive analysis. The following are the mean and standard deviation (SD) scores for pre- and post-tests of the 15 martial arts movements. In the first week of the protocol, participants had the opportunity to learn nine movements or movement sequences. The mean pre-test score for the first movement, front position, was 3.4 ($SD = 0.84$), and the post-test mean score was 4.4 ($SD = 1.08$). The average pre-test score for horse stance position was 2.3 ($SD = 0.68$), while the post-test mean score was 4.3 ($SD = 1.25$). The mean pre-test score for half-moon stance was 2.4 ($SD = 1.17$), with a post-test mean score of 4.2 ($SD = 0.92$). The average pre-test score for front-two knuckle punch was 3.4 ($SD = 1.35$), and 4.2 ($SD = 1.48$) at post-test.

The mean pre-test score for front ball kick was 3.5 ($SD = 0.85$), while the post-test mean score was 4.6 ($SD = 0.52$). The average pre-test score for the kick-punch-punch sequence was 2.8 ($SD = 0.92$) and 4.7 ($SD = 0.48$) at post-test. The mean pre-test score
for the kick-cross-uncross sequence was 2.4 ($SD = 0.84$), and the post-test mean score was 4.2 ($SD = 0.92$). The average pre-test score for the eight-point blocking system was 1.1 ($SD = 0.32$), with a post-test mean score of 3.9 ($SD = 0.57$). The mean pre-test score for half-moon forward with the eight-point blocking system was 1.2 ($SD = 0.42$), and 3.3 ($SD = 1.25$) at post-test.

In the second week of the protocol, participants had the opportunity to learn three additional movement sequences. The average pre-test score for eight-point blocking system in reverse for all participants was 1.2 ($SD = 0.42$), and 3.6 ($SD = 0.97$) at post-test. The average pre-test score for half-moon backward with eight-point blocking system for all participants was 1 ($SD = 0$), while the post-test mean score was 3.6 ($SD = 1.17$). The mean pre-test score for half-moon forward and backward with eight-point blocking system for all participants was 1.1 ($SD = 0.32$), and 3.8 ($SD = 1.03$) at post-test.

During the third and fourth week of sessions, a total of three movement sequence opportunities were presented to participants. The mean pre-test score for Pinan #1 for all participants was 1.2 ($SD = 0.42$), while the post-test mean score was 2 ($SD = 0.94$). The average pre-test score for side blade kick for all participants was 2.5 ($SD = 0.97$), and the post-test mean score was 4.2 ($SD = 1.03$). The average pre-test score for step-side blade kick-cross-uncross for all participants was 2.2 ($SD = 0.63$), and 3.9 ($SD = 0.99$) at post-test. See descriptive MMAT scores in Table 9. See pre- and post-test MMAT movement scores in Figure 6. See individual pre- and post-test MMAT scores in Table 12 (see Appendix I).
Table 9

Means and Standard Deviations for Martial Arts Movements Assessed by the Mastery of Martial Arts Test

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>Pre-test Mean</th>
<th>Pre-test SD</th>
<th>Post-test Mean</th>
<th>Post-test SD</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Week 1</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Front position</td>
<td>3.4</td>
<td>0.84</td>
<td>4.4</td>
<td>1.08</td>
</tr>
<tr>
<td>2. Horse stance</td>
<td>2.3</td>
<td>0.68</td>
<td>4.3</td>
<td>1.25</td>
</tr>
<tr>
<td>3. Half-moon stance</td>
<td>2.4</td>
<td>1.17</td>
<td>4.2</td>
<td>0.92</td>
</tr>
<tr>
<td>4. Front two knuckle punch</td>
<td>3.4</td>
<td>1.35</td>
<td>4.2</td>
<td>1.48</td>
</tr>
<tr>
<td>5. Front ball kick</td>
<td>3.5</td>
<td>0.85</td>
<td>4.6</td>
<td>0.52</td>
</tr>
<tr>
<td>6. Kick-punch-punch sequence</td>
<td>2.8</td>
<td>0.92</td>
<td>4.7</td>
<td>0.48</td>
</tr>
<tr>
<td>7. Kick-cross-uncross sequence</td>
<td>2.4</td>
<td>0.84</td>
<td>4.2</td>
<td>0.92</td>
</tr>
<tr>
<td>8. Eight-point blocking system</td>
<td>1.1</td>
<td>0.32</td>
<td>3.9</td>
<td>0.57</td>
</tr>
<tr>
<td>9. Half-moon forward with eight-point blocking system</td>
<td>1.2</td>
<td>0.42</td>
<td>3.3</td>
<td>1.25</td>
</tr>
<tr>
<td><strong>Week 2</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10. Eight-point blocking system in reverse</td>
<td>1.2</td>
<td>0.42</td>
<td>3.6</td>
<td>0.97</td>
</tr>
<tr>
<td>11. Half-moon backward with eight-point blocking system</td>
<td>1</td>
<td>0</td>
<td>3.6</td>
<td>1.17</td>
</tr>
<tr>
<td>12. Half-moon forward and backward with the eight-point blocking system</td>
<td>1.1</td>
<td>0.32</td>
<td>3.8</td>
<td>1.03</td>
</tr>
<tr>
<td><strong>Weeks 3 and 4</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13. Pinan #1</td>
<td>1.2</td>
<td>0.42</td>
<td>2</td>
<td>0.94</td>
</tr>
<tr>
<td>14. Side blade kick</td>
<td>2.5</td>
<td>0.97</td>
<td>4.2</td>
<td>1.03</td>
</tr>
<tr>
<td>15. Step-side blade kick-cross-uncross sequence</td>
<td>2.2</td>
<td>0.63</td>
<td>3.9</td>
<td>0.99</td>
</tr>
</tbody>
</table>
Figure 6. Average pre- and post-test mastery scores of the 15 martial arts movements as assessed by the Mastery of Martial Arts Test. * $p < .05$, ** $p < .01$, *** $p < .001$
Inferential analysis. The following are the results of paired $t$-tests, $p$ values, and Cohen’s $d$ for the pre- and post-tests of the MMAT. The mean difference in front position from pre- to post-test was 1 with $SD = 0.67$, which indicated a statistically significant difference, $t (9) = 4.74$, $p = 0.001$. Cohen’s $d$ value ($d = 1.5$) showed a large effect for changes in front position scores. Results for horse stance position from pre- to post-test was $M = 2$ with $SD = 1.41$, which demonstrated a statistically significant difference, $t (9) = 4.47$, $p = 0.002$. Cohen’s $d$ value ($d = 1.41$) denoted a large effect for changes in horse stance position scores. The mean change difference in half-moon stance from pre- to post-test was 1.8 with $SD = 1.4$, which showed a statistically significant difference, $t (9) = 4.07$, $p = 0.003$. Cohen’s $d$ value ($d = 1.29$) revealed a large effect for changes in half-moon position scores.

Results for front two knuckle punch from pre- to post-test was 0.8 with $SD = 0.92$, which was statistically significant, $t (9) = 2.75$, $p = 0.022$. Cohen’s $d$ value ($d = 0.87$) showed a large effect for changes in front two knuckle punch scores. The mean change mean difference in front ball kick from pre- to post-test was 1.1 with $SD = 0.88$, which was a statistically significant difference, $t (9) = 3.97$, $p = 0.003$. Cohen’s $d$ value ($d = 1.26$) demonstrated a large effect for changes in front ball kick scores. The mean difference in kick-punch-punch sequence from pre- to post-test was 1.9 with $SD = 0.99$, which was statistically significant, $t (9) = 6.04$, $p = 0.000$. Cohen’s $d$ value ($d = 1.91$) signified a large effect for changes in kick-punch-punch scores.

Results for mean difference in kick-cross-uncross sequence from pre- to post-test was 1.8 with $SD = 0.92$, which was a statistically significantly difference, $t (9) = 6.19$, $p = 0.000$. Cohen’s $d$ value ($d = 1.96$) indicated a large effect for changes in kick-cross-
uncross scores. The mean difference in eight-point blocking system from pre- to post-test was 2.8 with $SD = 0.79$, which was statistically significant, $t (9) = 11.23, p = 0.000$. Cohen’s $d$ value ($d = 3.55$) denoted a large effect for changes in eight-point blocking system scores. The mean difference in half-moon forward with eight-point blocking system from pre- to post-test was 2.1 with $SD = 1.1$, which was statistically significant, $t (9) = 6.03, p = 0.000$. Cohen’s $d$ value ($d = 1.91$) demonstrated a large effect for changes in half-moon forward with eight-point blocking system scores.

The mean difference in eight-point blocking system in reverse from pre- to post-test was 2.4 with $SD = 0.97$, which was statistically significant, $t (9) = 7.86, p = 0.000$. Cohen’s $d$ value ($d = 2.48$) revealed a large effect for changes in eight-point blocking system in reverse scores. The mean difference in half-moon backward with eight-point blocking system from pre- to post-test was 2.6 with $SD = 1.17$, which was a statistically significant difference, $t (9) = 7.01, p = 0.000$. Cohen’s $d$ value ($d = 2.21$) signified a large effect for changes in half-moon backward with eight-point blocking system scores. The mean difference in half-moon forward and backward with eight-point blocking system from pre- to post-test was 2.7 with $SD = 1.06$, which was statistically significant, $t (9) = 8.06, p = 0.000$. Cohen’s $d$ value ($d = 2.55$) showed a large effect for changes in half-moon forward and backward with eight-point blocking system scores.

The mean difference in Pinan #1 from pre- to post-test was 0.8 with $SD = 0.79$, which was statistically significant, $t (9) = 3.21, p = 0.011$. Cohen’s $d$ value ($d = 1.01$) denoted a large effect for changes in Pinan #1 scores. The mean difference in side blade kick from pre- to post-test was 1.7 with $SD = 1.06$, which was statistically significant, $t (9) = 5.08, p = 0.001$. Cohen’s $d$ value ($d = 1.61$) indicated a large effect for changes in
side blade kick scores. The mean difference in step-side blade kick-cross-uncross from pre- to post-test was 1.7 with \( SD = 0.68 \), which was a statistically significant difference, \( t(9) = 7.97, p = 0.000 \). Cohen’s \( d \) value (\( d = 2.52 \)) demonstrated a large effect for changes in step-side blade kick-cross-uncross scores. See martial arts movements scores as assessed by the MMAT in Table 10.

Table 10

**Paired t-Test Results for Martial Arts Movements as Measured by the Mastery of Martial Arts Test**

<table>
<thead>
<tr>
<th>Martial Arts Movement</th>
<th>Mean Difference</th>
<th>SD Difference</th>
<th>( t ) statistic</th>
<th>( p )</th>
<th>( d )</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Week 1</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Front position</td>
<td>1</td>
<td>0.67</td>
<td>4.74</td>
<td>0.001***</td>
<td>1.5</td>
</tr>
<tr>
<td>2. Horse stance</td>
<td>2</td>
<td>1.41</td>
<td>4.47</td>
<td>0.002**</td>
<td>1.41</td>
</tr>
<tr>
<td>3. Half-moon stance</td>
<td>1.8</td>
<td>1.4</td>
<td>4.07</td>
<td>0.003**</td>
<td>1.29</td>
</tr>
<tr>
<td>4. Front two knuckle punch</td>
<td>0.8</td>
<td>0.92</td>
<td>2.75</td>
<td>0.022*</td>
<td>0.87</td>
</tr>
<tr>
<td>5. Front ball kick</td>
<td>1.1</td>
<td>0.88</td>
<td>3.97</td>
<td>0.003**</td>
<td>1.26</td>
</tr>
<tr>
<td>6. Kick-punch-punch sequence</td>
<td>1.9</td>
<td>0.99</td>
<td>6.04</td>
<td>0.000***</td>
<td>1.91</td>
</tr>
<tr>
<td>7. Kick-cross-uncross sequence</td>
<td>1.8</td>
<td>0.92</td>
<td>6.19</td>
<td>0.000***</td>
<td>1.96</td>
</tr>
<tr>
<td>8. Eight-point blocking system</td>
<td>2.8</td>
<td>0.79</td>
<td>11.23</td>
<td>0.000***</td>
<td>3.55</td>
</tr>
<tr>
<td>9. Half-moon forward with eight-point blocking system</td>
<td>2.1</td>
<td>1.1</td>
<td>6.03</td>
<td>0.000***</td>
<td>1.91</td>
</tr>
<tr>
<td><strong>Week 2</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10. Eight-point blocking system in reverse</td>
<td>2.4</td>
<td>0.97</td>
<td>7.86</td>
<td>0.000***</td>
<td>2.48</td>
</tr>
<tr>
<td>11. Half-moon backward with eight-point blocking system</td>
<td>2.6</td>
<td>1.17</td>
<td>7.01</td>
<td>0.000***</td>
<td>2.21</td>
</tr>
<tr>
<td>12. Half-moon forward and backward with the eight-point blocking system</td>
<td>2.7</td>
<td>1.06</td>
<td>8.06</td>
<td>0.000***</td>
<td>2.55</td>
</tr>
<tr>
<td><strong>Weeks 3 and 4</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13. Pinan #1</td>
<td>0.8</td>
<td>0.79</td>
<td>3.21</td>
<td>0.011*</td>
<td>1.01</td>
</tr>
<tr>
<td>14. Side blade kick</td>
<td>1.7</td>
<td>1.06</td>
<td>5.08</td>
<td>0.001***</td>
<td>1.61</td>
</tr>
<tr>
<td>15. Step-side blade kick-cross-uncross sequence</td>
<td>1.7</td>
<td>0.68</td>
<td>7.97</td>
<td>0.000***</td>
<td>2.52</td>
</tr>
</tbody>
</table>

*Note: \( * p < .05, ** p < .01, *** p < .001 \)*
Levels of Martial Arts Mastery. Using MMAT scores, different mastery levels for the movements were created to further conceptualize participants’ scores. These levels provided a way to systematically compare pre- and post-test scores of each participant to determine how well children with ASD could learn martial arts movements. The highest total possible score of the MMAT was first calculated (15 movements x 5 points = 75 points). This number was then subtracted by the lowest possible total score of 15 (75 – 15 = 60). Based on the five anchors of the Likert scale, the number 5 was then divided from 60 (60/5 = 12). The calculation resulted in a 12-point spread, which led to the identification of five separate levels of mastery. Scores between 15 to 27 points = “Beginning” skill level; 28 to 39 points = “Emerging” skill level; 40 to 51 points = “Developing” skill level. Scores from 52 to 63 points = “Proficient” skill level; 64 to 75 points = “Mastery” skill level.

At pre-test, two participants identified in the “Beginning” skill level, seven in the “Emerging” skill level, one in the “Developing” skill level; no participants identified in the “Proficient” or “Mastery” skill level. At post-test, three participants identified in the “Developing” skill level, three in the “Proficient” skill level, four in the “Mastery” skill level. Further, no participants were in the “Beginning” or “Emerging” skill level at post-test. See pre- and post-test levels of martial arts mastery in Figure 7. See individual pre- and post-test mastery levels in Table 12 (see Appendix I).
**Figure 7.** Participants’ levels of martial arts mastery from pre- to post-test as measured by the Mastery of Martial Arts Test.
Chapter 5

Discussion

The purpose of the current study was to examine the effect of a rhythm and martial arts program on motor skills in children with autism. Specifically, the study investigated whether participation in a rhythm and martial arts program would influence bilateral coordination of the upper and lower extremities, static and dynamic balance, running speed and agility, and sustained strength. The motor skill scores or participants were also compared to the scores of typical male children of similar age. Additionally, the study sought to determine whether children with autism can learn martial arts movements. Furthermore, limitations of the current study are discussed, recommendations are provided for future research and clinical implications are offered.

The Effect of Rhythmic Cueing in Martial Arts on the Motor Skills of Children with ASD

This research found that the rhythm and martial arts program, appeared to be more effective for some gross motor skills than others in children with ASD. In particular, the findings showed that the protocol had a greater impact on bilateral coordination and balance skills, and a less of an impact on strength and running speed and agility. Furthermore, overall gross motor skills of children with ASD improved following the intervention.

Bilateral coordination and body coordination. Results of the current study indicated that children with ASD who participated in the rhythm and martial arts protocol showed a statistically significant improvement in bilateral coordination of the upper and lower extremities, as well as body coordination (e.g., composite of bilateral coordination
and balance). This statistical significance demonstrates that the changes in these skills were unlikely to occur due to chance, and the observed changes in children with ASD can be attributed to the protocol. Changes in both bilateral and body coordination scores over time also generated large effect sizes, thus indicating practical significance. This practical significance shows that the 4-week rhythm and martial arts protocol produces functional changes in bilateral and body coordination skills of children with ASD.

In week one of the protocol, eight of the nine martial arts movements taught to participants involved bilateral coordination skills, and all nine movements taught involved body coordination skills. Body coordination skills is a combination of bilateral coordination and balance skills. In week two, all three martial arts movement sequences that were taught involved bilateral coordination and body coordination. In weeks three and four, two of the three movements and movement-sequences taught involved bilateral coordination, and all movements and movement-sequences involved body coordination.

As one example, the kick-punch-punch is a movement sequence taught in the first week using bilateral coordination and balance for body coordination. In this sequence, the participants had to alternate between one kick and two punches. To execute a kick, participants stood with legs apart, balanced their weight on their left leg, and kicked to the front with their right leg. After the kick, they returned to the original position and executed a right and left punch to the front. Overall, the protocol provided participants with multiple opportunities to learn, practice, and master bilateral coordination and balance skills through the martial arts movements in all eight sessions. This frequent repetition contributed to the significant findings of improved bilateral coordination and body coordination skills in children with ASD.
These findings support results of existing research on rhythm and movement-based interventions for children with ASD. In previous studies (Kaur et al., 2013; LaGasse & Hardy, 2013; Srinivasan et al., 2015), rhythm was used to facilitate movement patterns for children with ASD to learn gross motor skills, particularly bilateral coordination. Rhythmic music and movement activities significantly improved bilateral coordination of TD children and children with special needs, such as ADHD (Betancourt & Hernandez, 2012). Interactions with robots and imitating movements of robots with rhythm improved bilateral coordination skills of a child with ASD (Kaur et al., 2013). Moreover, children with ASD significantly improved their body coordination when engaged in simple and complex whole body movements while listening to rhythm as well as imitating an adult or a robot (Srinivasan et al., 2015). The rhythmic cues were used in combination with a model (adult or robot), which is similar to this current study where participants imitated the movements of the student investigator.

In addition, these studies (Kaur et al., 2013; Srinivasan et al., 2015) involved protocols of two and four sessions per week held over 4 and 8 weeks to provide participants with opportunities to learn and practice simple and complex whole body movements with rhythm. The 4-week timeline of this study as well as the progression from short, simple movements to more complex movements is similar to a previous study (Kaur et al., 2013). Furthermore, Patterned Sensory Enhancement using rhythm improved the bilateral and body coordination of a child with ASD (LaGasse & Hardy, 2013). Through providing live rhythmic cues on guitar, piano, and autoharp, a music therapist helped the child to start and stop movement patterns that involved bilateral coordination within 8 weeks (LaGasse & Hardy, 2013). Thus, the results of the present study concur
with previous research findings, which showed that rhythm interventions and physical activity support changes in bilateral and body coordination of children with ASD.

Moreover, in previous studies (Betancourt & Hernandez, 2012; Kaur et al., 2013; LaGasse & Hardy, 2013; Srinivasan et al., 2015), the participants learned simple and complex dance, karate, or body movements, whereas this current study focused on learning martial arts movements. The precision of executing martial arts movements and the complexity of the movement sequences differ from other studies that focused on repetitive dance movement patterns, such as marching and clapping on the beat. The additional complexity in martial arts makes a particularly effective impact on bilateral coordination skills because the martial arts movement-sequences began with simple movements and continued to build into longer combinations. To execute more complex movements involve more bilateral and body coordination. Thus, the participants continually practiced multiple movements in each sequence that increased in difficulty, which may have contributed to their significant improvements in bilateral and body coordination skills. Therefore, using rhythmic cues in martial arts is a possible intervention to address bilateral and body coordination skills of children with autism.

Many participants in this study demonstrated less competency in bilateral coordination skills at pre-test than 8-year-old TD peers, according to BOT-2 age-equivalent data (Bruininks & Bruininks, 2005). Although their average chronological age was 8:0 years at pre-test, the children performed at an average age equivalent of 5:9 years in bilateral coordination skills. By post-test, the participants reached an average age equivalency of 6:1 years. The participants on average improved their bilateral
coordination skills by 1 year and 2 months within a 4-week protocol, which demonstrates the practical significance of the protocol.

Most participants improved their bilateral coordination skills, and furthermore, four of these children improved their function to a level similar to TD peers, which shows that the protocol impacted bilateral coordination skill in children with ASD within eight sessions. This improvement may likely due to the frequent opportunities to practice movements that incorporated bilateral coordination of right/left sides as well as upper/lower body.

**Balance.** The findings of the current study indicated that children with ASD who participated in the rhythm and martial arts protocol showed an improvement from pre- to post-test for balance, though not statistically significant. In addition, changes in balance scores generated medium effect sizes, which indicates some practical significance. This practical significance demonstrates that the 4-week rhythm and martial arts protocol impacts balance skills.

Performing all 15 martial arts movements involved balance, as participants were standing throughout each session to perform movements. For example, participants executed a sideblade kick by standing with legs apart, balancing their weight on their left leg, and kicking to the right side with their right leg. After the kick, they returned the right leg to the original position. Based on the student investigator’s observation, a few participants struggled to maintain balance when executing a kick, likely due to difficulty transitioning and shifting weight from one leg to another. This protocol provided numerous and continuous opportunities for participants to practice balance through learning and performing each movement in all eight sessions.
The results of this current study agree with the results of past research on rhythm and physical activity interventions with children. Previous researchers found that rhythm and movement programs improved balance of TD preschool children (Zachopoulou et al., 2004). The children played rhythmic games and learned and improvised creative simple and complex movements with rhythm. Movement-based games set to rhythm, as well as imitating robot movements, significantly improved balance skills of children with ASD (Srinivasan et al., 2015). Similarly, the participants in this study imitated the student investigator while learning the martial arts movements in each session.

Additionally, a martial arts program without rhythm, held for two sessions per week for 8 weeks, improved the balance of children with ASD (Kim et al., 2016). The intervention program included a warm-up (stretching, jogging, and strengthening exercises), blocking, punching, and kicking exercises, Poomse (offensive and defensive movement sequences), and a cool down (stretching, group game) (Kim et al., 2016). This current study followed a similar session structure; however, because of the time constraint in a 30-minute session, this protocol did not include jogging or a cool down. Focusing on martial arts movements provided multiple opportunities to consistently practice basic movements, such as kicks, that involved balance. Using rhythmic cues in martial arts with a visual model and in a structured session is a feasible option to address balance skills of children with ASD. Thus, the results of the current study agree with previous research that rhythm and movement intervention can positively impact balance skills of children with ASD.

The participants demonstrated less competency in balance skills at pre-test compared with 8-year-old TD peers, per age-equivalent data of the BOT-2 (Bruininks &
Bruininks, 2005). The children were delayed at pre-test as evidenced by performing at an average age equivalent of 4:7 years even though their average chronological age was 8:0 years. By post-test, they reached an average age equivalency of 4:11 years. Thus, the participants on average improved their balance skills by 4 months within a 4-week protocol, which demonstrates the practical significance of the protocol. Some children took longer to transition body weight to balance and stand on one foot, and some lost their balance when attempting to stand on one leg. Many participants improved their balance from pre- to post-test, two of whom achieved age equivalent scores by post-test, thus demonstrating that the protocol positively impacted balance skills.

**Running speed and agility.** Results of the current study found that running speed and agility scores showed a slight decrease over time, although not statistically significant, for children who participated in the rhythm and martial arts protocol. Changes in running speed and agility scores generated a small effect size, which demonstrates that the protocol most likely had little impact on these skills. It is important to note, however, that the rhythm and martial arts protocol did not include a running component.

These findings differ from results of existing research on physical activity programs. Past researchers found that children with ASD increased their speed of walking and the distance walked following walking, jogging, and snowshoe programs that did not include rhythm (Kern et al., 1982; Pitetti, et al., 2007; Todd & Reid, 2006). Children with ASD also improved walking efficiency in an aerobics program of activities with music, such as marching, doing karate kicks, and dancing with ribbons (Fragala-Pinkham et al., 2005). Thus, the results of this study differ with previous research on the running speed of children with ASD because the protocol did not provide opportunity to
practice or improve running skills. To impact running speed of children with ASD, the program should include a running component. A martial arts research study included jogging as a warm-up (Kim et al., 2016) and running is commonly included in martial arts sessions as a warm-up outside of research studies.

The participants demonstrated less competency in running speed and agility skills at pre-test compared with 8-year-old TD peers, per age-equivalent data of the BOT-2 (Bruininks & Bruininks, 2005). At pre-test, the children were performing on average an age equivalency of 5:5 years. By post-test, the children on average at an age equivalency of 5:3 years. Although the program had limited impact on running speed and agility, it was necessary to assess this skill to calculate a gross motor composite score for each child per the BOT-2 scoring procedures.

**Strength.** Findings of the current study revealed that strength increased over time, but changes were not statistically significant. Changes in strength scores generated a small effect size, which indicates the rhythm and martial arts protocol impacted strength skills to a small degree.

All 15 martial arts movements taught involved strength as participants needed arm, torso, and leg strength to execute each movement and movement sequence. Six of nine movements in week one, all movements in week two, and one movement in weeks three and four, addressed arm strength. Seven movements in week one, two of three movements in week two, and all three movements in weeks three and four emphasized leg strength. Five movements in week one, all movements in week two, and one movement in weeks three and four emphasized combined or alternating arm and leg strength. All 15 movements involved torso strength as participants needed to support
their body and maintain an erect posture with a straight back. Thus, this protocol provided repetitive and continuous opportunities for participants to practice arm, torso and leg strength in each of the eight sessions.

For example, to perform a horse stance, participants were taught to stand with feet double-shoulder width apart with knees flexed and back straight, similar to a leg squat position. While standing or moving with knees flexed, some participants were bent over with their torsos leaning forward. They appeared to lack adequate core strength to keep their torsos upright. Notably, a few participants lay down on the floor and needed a break during the sessions because of their limited experience with exercise.

These findings agree with results of past research involving physical activity. Children with ASD improved abdominal strength in an aerobic exercise program without music (Magnusson et al., 2012). Additionally, stationary bicycling programs, without rhythm, improved muscular strength of children with ASD (Lochbaum & Crews, 2003). Previous researchers found that children with ASD improved their muscle strength in a program of aerobic activities completed with music (Fragala-Pinkham et al., 2005). Furthermore, a music therapist used PSE to provide live rhythmic cues which improved the strength of a child with ASD, where he supported himself in a “plank position” on a therapy ball (LaGasse & Hardy, 2013).

Similar to previous studies (Fragala-Pinkham et al., 2005; Magnusson et al., 2012), this current study also incorporated two individual intervention sessions a week and improved strength of children with ASD. Thus, the results of the current study support previous research that rhythm and movement programs can enhance the strength of children with ASD. The increase in strength scores demonstrate that the combination
of rhythm and martial arts for two individual sessions a week likely impact strength skills of children with ASD.

The participants demonstrated less competency in strength compared to 8-year-old TD peers at pre-test, according to BOT-2 age-equivalent data (Bruininks & Bruininks, 2005). At pre-test, the children were delayed in this skill, as evidenced by performing at an average age equivalent of 5:3 years (knee push-ups) or 5:5 years (full push-ups) even though their average chronological age was 8:0 years. By post-test, the participants reached an average age equivalency of 5:5 years (knee push-ups) or 5:9 years (full push-ups). Thus, the participants on average improved their strength skills by 2 or 4 months within a 4-week protocol, which demonstrates practical significance.

Some of the children seemed tired of standing in the session and requested multiple breaks to sit or lie down on the floor. A few of the children appeared to perform arm movements with little strength and control. However, at post-test, these children seemed to more easily perform movements. The same children who needed multiple breaks in the earlier sessions requested fewer breaks and could perform longer sequences later in the protocol sessions. Furthermore, some children improved their strength skills, including one child whom improved his strength function similar to TD peers aged 8 years within eight sessions. This improvement is likely due to the continuous and repetitive opportunities to practice movements that required leg, arm, and torso strength.

**Strength and agility composite.** The outcome of the current study found that strength and agility composite scores (e.g., a combination of strength and running speed and agility) showed a slight increase, although not statistically significant, for children who participated in the rhythm and martial arts protocol. Changes in strength and agility
scores generated a small effect size, which demonstrates that the protocol most likely had little impact on these skills.

**Gross motor composite.** Results of the current study showed that the gross motor composite scores (e.g., combination of body coordination, and strength and agility scores) of children with ASD increased from pre- to post-test, though not significantly. In addition, changes in gross motor composite scores achieved a medium to large effect size, which indicates practical significance. This practical significance demonstrates that the 4-week rhythm and martial arts protocol impacts gross motor skills. Therefore, the improvements in bilateral coordination, balance, and strength show the possibility to improve these skills in children with ASD in eight sessions. These results further support the functional impact of this program to help children with ASD close the gap in their gross motor skills.

**Rhythmic cues.** Improved gross motor skills may have resulted in part from rhythmic cues used to direct each movement pattern. The rhythmic cues were designed using a specific instrument sound to cue a specific movement, such as a clapper instrument for a front ball kick. Participants systematically learned to associate the sound of the clapper with the specific movement because the same auditory cue was used to facilitate the front ball kick in all other sequences. Rhythmic cues provided information on the temporal, spatial, and force parameters for each point of a martial arts movement.

**Temporal cues.** Temporal cues directed the timing of movements and provided information to sequence each part of multi-point movements. This protocol did not include a metronome or a steady, ongoing beat. The participants learned how to coordinate each movement sequence by following and anticipating the timing of the cues.
as well as the space of time between movements. No grouping of beats was used to indicate meter. The tempo of the cues was recorded at a quarter note equals 60 bpm, which is similar to the tempo used when the student investigator previously taught new movements to children with ASD. The student investigator observed that participants had difficulty following the pacing of rhythmic cues for Pinan #1. Therefore, the tempo of Pinan #1 was adjusted to be slower at 54 bpm for participants to use the rhythmic cues to facilitate the sequence. For a few participants, the tempo for half-moon and eight block sequences was adjusted to 56 bpm when first learning the sequence.

**Spatial cues.** Spatial cues provided information on the range of motion as well as the starting and stopping points of the martial arts movements. For instance, pitch level was used to distinguish upper and lower extremity movements that involved bilateral coordination of the upper and lower body. Higher pitches on a snare drum indicated arm movements, while lower pitches on a djembe denoted leg movements. In addition, pitch level cued movement direction with higher pitches prompting ascending movements and lower pitches indicating descending movements. Participants had the opportunity to practice six different sequences in the whole protocol using these spatial cues to indicate the bilateral use of arms and legs. Pitch was also used to indicate the range of motion for eight right and left arm blocks. For example, a snare drum pitch tuned semitones higher indicated the start point, and an original snare drum pitch directed the end of a downward arm block. Dynamics were also used to provide spatial information. For example, a bell with a decrescendo directed bringing arms and legs medially toward the body.

**Force cues.** Force cues indicated the muscle effort or strength needed to perform the martial arts movements. For example, softer dynamics on claves cued participants to
shift their body weight to balance entirely on one leg to prepare for a kick. The volume on the clapper and conga sounds was increased for kicks and punches, respectively, to prompt participants to increase the amount of force needed to execute these strikes. In addition, a decrescendo and crescendo on the djembe directed participants to control their leg strength to complete leg adduction and abduction movements. Slower tempo was used to indicate controlled movements with less force.

**Review of rhythmic cues.** Rhythmic cues appeared to be helpful in guiding the martial arts movements; however, some cues did not provide enough direct information for children to execute sequential movements. For instance, the cues did not inform participants to alternate movements from one side of the body to the other. Thus, some children performed two right arm movements in a row instead of alternating from right to left. Therefore, in future research, a distinction in rhythmic cues could be added, such as unique pitches to indicate the difference between left and right side movements.

The rhythmic cues also consisted of long and short sounds to indicate the duration a 90 or 270 degree turn. However, the cues did not direct children to turn clockwise or counterclockwise, which is important for accurate learning and execution of martial arts movement. Thus, future rhythmic cues may consider incorporating ascending or descending pitches so children with ASD can distinguish between turning clockwise or counterclockwise.

**Children’s responses to rhythmic cues.** When independently performing the movements, three children, who identified with severe social impairment, verbalized that they were thinking about the corresponding rhythmic cues when performing the movements without any cues. Three other participants, with an additional diagnosis of
ADHD, verbalized that they wanted to finish the moves quickly, and often stopped and said that they forgot what they were doing in the middle of performing a sequence. When directed to listen to the rhythmic cues, the children with ADHD often appeared to slow down to match the auditory timing of the rhythmic cues and stopped less frequently in the middle of the sequence. Thus, it appears the rhythmic cues helped the children with ADHD focus and remember movement sequences.

One child with ASD who completed the protocol was nonverbal; he communicated with gestures and was working on producing one-syllable sounds. He appeared to understand the directions in the sessions and uttered one-syllable sounds that resembled the verbal cues while he learned and practiced each movement pattern. In the sessions, he seemed to appear to execute the movements the best with the rhythmic cues and the student investigator. Based on the student investigator’s observations, the rhythmic cues provided a timing structure, the verbal cues indicated the moves, and the visual model aided him to imitate and perform the moves. Overall, rhythmic cues in martial arts appeared to be accessible to children with varying levels of autism.

Some participants verbalized to the student investigator that the rhythmic cues helped them “remember the moves” and “do the moves” because the cues “sounded like” the movements. Many children with ASD seemed to appear to prefer performing martial arts with the rhythmic cues and requested to practice sequences with the rhythmic cues before they performed the sequences independently without cues. They listened intently to the cues and asked to repeat the exercise with the rhythmic cues multiple times. When the participants needed assistance remembering the movements, they chose to repeat the verbal cues and/or imitate the student investigator as a visual model in combination with
the rhythmic cues. A few children verbalized that the rhythmic cues were motivating and appeared to be a sound effect to their movements. The children further stated that they enjoyed doing martial arts with the rhythmic cues.

**Summary of rhythmic cues.** The repetition of performing martial arts movements with rhythmic cues in each session seemed to contribute to improved gross motor skills. During the stages of motor learning, participants’ brains may have processed the rhythm, which may have contributed to better motor output. Exposure to the rhythmic cues may have activated neural networks within the premotor cortex, supplementary area, pre-supplementary area, basal ganglia, and cerebellum, all of which process rhythm and regulate motor skills. This neural activation likely primed the children to execute the corresponding martial arts movements. Experiencing this rhythm-based activation during motor execution likely enhanced motor output as participants received information about the temporal, spatial, and force parameters of the movements and were thus ready to perform the moves. Considering the significant findings of improved bilateral and body coordination skills as well as improved balance, strength, and gross motor skills, the rhythmic cues used in the protocol likely may have engaged the brain structures that execute movement and enhanced movement performance.

**Children with ASD’s Ability to Learn Martial Arts Movements**

This research found that a rhythm and martial arts protocol appeared to be effective for children with ASD to learn 15 simple and complex martial arts movements. In particular, the findings showed that children with ASD can learn simple one move stances, punches, and kicks as well as movement-sequences involving 3 to 24 moves.
Overall, children with ASD showed statistically significant improvements in performing the prescribed 15 martial arts movements from pre- to post-test.

These findings present new information about children with ASD’s ability to learn and independently perform martial arts movements. Previous researchers have used martial arts programs to address and improve various skills of children with ASD, such as communication (Bahrami et al., 2016) and social skills (Movahedi et al., 2013). In these studies, each session consisted of a warm-up of stretching and jogging, learning martial arts movements, and a cool-down. However, researchers did not indicate how well the children performed the martial arts movements. This current study adds additional knowledge of using rhythmic cueing to teach martial arts while following a similar session structure of a warm-up with stretching and teaching movements to combine into longer sequences in later sessions.

In addition, this study is similar to other martial arts studies (Bahrami et al., 2012; Bahrami et al, 2016; Kim et al, 2016; Movahedi et al, 2013) with teaching stances, strikes, and movement-sequences, reviewing learned materials in each session and introducing new materials through visual demonstration. Three of the previous studies had recorded Persian music playing in the room during warm-up and cool down; however, the researchers did not include if music was used to facilitate martial arts training (Bahrami et al., 2012; Bahrami et al, 2016; Movahedi et al, 2013). Furthermore, the results of this study inform how using rhythmic cues in martial arts effectively improves gross motor skills of children with ASD. This study contributes to the few investigations (LaGasse & Hardy, 2013) that have used rhythmic cueing with children with ASD. Previous studies focused on exercise and dance movements, and this study
demonstrates the possibility of extending using rhythmic cues to facilitate martial arts movements to improve gross motor skills of children with ASD.

**Levels of martial arts mastery.** Results of an original assessment of the martial arts movements for this current study indicated that children with ASD who participated in the rhythm and martial arts protocol can learn martial arts movements. Levels were created to further interpret and conceptualize progress of the child’s ability to perform individual movement components and the number of moves over time.

- “Emerging”: executed very few components of moves or very few moves.
- “Beginning”: executed a few parts of movements or a few moves.
- “Developing”: executed some parts of movements or some of the moves.
- “Proficient”: executed most parts of movements or most of the moves.
- “Mastery”: executed all parts of the movements or all the moves.

Participants progressed through the following levels of mastery from pre- to post-test. Four participants advanced three levels (“Emerging” to “Mastery”), four participants advanced two levels (“Emerging” to “Proficient,” and “Beginning” to “Developing”), and two participants advanced one level (“Emerging” to “Developing,” and “Developing” to “Proficient”). Furthermore, five 7-year-old participants were at the Developing or Proficient level while four 8-year-old participants were at the Mastery or Proficient level by post-test. The delayed motor development and the child’s age impacted children’s ability to proceed in learning all movements, such that the 8-year-old children learned and performed all 15 martial arts movements better than 7-year-old children.

All participants demonstrated the ability to learn martial arts movements and advanced one, two, or three levels of martial arts mastery, most likely due to the
opportunity to learn, practice, and master the martial arts movements within 8 sessions. Moves taught in week one were simple movements that were combined into short or complex sequences in later sessions. Thus, the participants built a repertoire of martial arts movements and had multiple chances to practice each movement in both simple and longer sequences. No literature has looked at children’s ability to perform martial arts, so these findings presents new information about the ability of children with ASD to learn and master martial arts movements.

Limitations and Recommendations for Future Research

Certain limitations existed within this study pertaining to the timing, participants, and assessments. Many of the participants attended a summer camp and participated in the rhythm and martial arts sessions at the end of a 5-hour day. Some of the participants were tired at this point; thus, the timing of when sessions were received was not ideal. Two participants were picked up early from camp, and thus received two shorter sessions that were 10 to 20 minutes long, instead of the full 30 minutes. One participant was 10 minutes late to three sessions because of transitioning from his previous camp activity.

Not enough time and exposure to the protocol may have impacted participants’ experience with the protocol. Some of the children were tired and did not fully participate in the sessions, which may have hindered results from achieving statistical and practical significance for balance and gross motor skills. When children are attentive, rested, and have opportunity to engage in a full 30-minute session, they may receive the most benefit to improve gross motor skills. Thus, future research should consider an optimal time of day for sessions when children with ASD are alert to learn and practice movement
exercises. In addition, future researchers should also explore consistent session lengths for children with ASD.

Interruptions to the timing of the protocol for 4 consecutive weeks was another limitation. Three participants had scheduling conflicts that prevented them from consistently attending two sessions a week, resulting in the protocol being extended from 4 weeks to 5 or 6 weeks. These participants had only one treatment session for 2 or 4 weeks of the protocol. One participant had a 2-week break between the third and fourth week of the protocol due to a family vacation. These changes disrupted the participants’ opportunity to practice, learn, and engage in sessions, so the children had to slightly start over with a reminder of the rhythmic cues and movements each time. Therefore, their motor scores may have been impacted by a less consistent protocol, possibly hindering their balance or gross motor skills from achieving statistical and practical significance.

In addition, because gross motor skill was close to achieving statistical significance and had a medium-high practical significance, the protocol of eight sessions over 4 weeks may not have been enough time to produce significant change. Thus, future research could design a protocol with more consistent sessions, perhaps two times a week over 8 weeks or two times a week over 14 weeks. This time frame is similar to other physical activity programs (Pan, 2011; Srinivasan et al., 2015) that achieved significant and beneficial changes in gross motor skills of children with ASD.

Other limitations in the study were associated with assessment. Six children with ASD were assessed in an unfamiliar testing site with unfamiliar adults for the BOT-2 for pre- and post-tests. The student investigator, professor of physical therapy, and doctor of physical therapy students observed that some children were overwhelmed with the open
space of the room, equipment in the room, and number of people in the room. For example, one participant refused to follow the directions of the assessment by sitting with his arms crossed and shaking his head. He finished the assessment another day at the site where he received rhythm and martial arts sessions. Another participant required assistance from his father to take the assessment, as the participant was verbalizing scripts of videos while exhibiting repetitive stereotypical behavior of flapping his hands. A few other participants seemed to appear unsure of what they were doing, where to look during the assessment, and appeared unfocused as they needed multiple prompts to complete the assessment. For those participants who had difficulty during testing, the assessments and treatment sessions occurred in two different settings.

Four other participants completed assessments at the same site as the treatment protocol and appeared to be more focused when being assessed. The changes in the testing and treatment sites may have impacted children’s ability to perform their best as they were not familiar with the site, so the pre-and post-test results may not accurately show changes in gross motor skills. If children with ASD are overwhelmed and feel overstimulated, they may be distracted at the time of the assessment, which may cause an inaccurate reflection of current skill level. All these distractions, disruptions, and changes, which may be affected the participants’ performance on the BOT-2, may also have impacted gross motor skills from achieving statistical and practical significance. Therefore, future researchers should consider logistics and coordination of testing and treatment sites. Children with autism may have difficulty with changes in their routines and transitions (APA, 2013); thus, future research should ideally perform all testing and protocol in one location and not change the routine.
**Clinical Implications**

The present study suggests that a 4-week rhythm and martial arts protocol can be a viable intervention to improve gross motor skills of children with ASD. Findings indicate that the children improved bilateral coordination, balance, and overall gross motor skills as well as learned 15 martial arts movements in eight sessions. The progression of teaching martial arts from short, simple movements to more complex sequences was effective for children with ASD. Based on the student investigator’s observations, participants were smiling, willing, and ready to leave their classroom to attend each session when the student investigator met participants at camp. In addition, they were enthusiastic to attend sessions as evidenced by requesting martial arts moves they wanted to review and asking what they were going to learn that day.

Additionally, participants were willing to practice the same moves with rhythmic cues multiple times as directed by the student investigator or when given a choice to do a move again, with or without the rhythmic cues. Many participants also requested to practice the martial arts movement again with the rhythmic cues because they appeared to want to perform the movements precisely in time with the rhythm. Rhythmic cues should be used to support students with autism who are in martial arts lessons to better facilitate the movements.

Most of the children with ASD appeared to attend to the rhythmic cueing protocol as evidenced by performing physical activity while listening to rhythmic cues within the 30-minute session. Through the student investigator’s observation, the participants had varying levels of experience with physical activity as evidenced by the ability to complete the session with or without breaks. Several participants needed one or two short
breaks in some of the eight sessions as evidenced by sitting down and/or asking for a drink of water. One child with limited physical activity experience had five breaks in the first session, and, by the last session, he only requested one break. In addition to their physical abilities, most of the children appeared to attend to the student investigator and perform martial arts movements for 30 minutes. Observations of the student investigator suggest that when the rhythmic cues were played, the children with ASD listened and performed the corresponding movements. Often, when the student investigator verbalized that the plan was to do one more movement, the child agreed.

The findings of this study may inform music therapists who work with children with ASD. Music therapists can incorporate their knowledge of different physical activity exercises, such as martial arts, to address the gross motor skills of children with ASD. In particular, music therapists may use audio files to design rhythmic cues to facilitate movement patterns that inform the timing, range of motion, and amount of muscle effort needed for each movement. When designing these cues, a specific sound should be associated with a particular movement so that children with ASD may link that information together. Based on the tempo adjustments in this study, music therapists could provide live rhythmic cues to determine the ideal tempo to facilitate the child’s movements. Tempo can also be adjusted on certain devices.

This study found that the combination of rhythm and martial arts impacted bilateral coordination and balance more than strength, running speed and agility. Thus, music therapists may choose to focus on movements that incorporate bilateral coordination and balance skills. The rhythmic cues should direct each point of a multi-move sequence to provide clarity to the movements. Besides designing rhythmic cues,
music therapists should also communicate with the children’s parents about the progress of the sessions as well as observations of the child’s motor behaviors.

Throughout the protocol, the student investigator informally asked parents if they noticed changes in their child’s motor skills. Several parents reported changes in their child’s balance as well as bilateral and body coordination, such as smoothly walking up stairs, tripping less, falling less, clapping and moving body on the beat of music, and learning to ride a bicycle. Several parents also shared that they noticed their child’s body movements were more coordinated and stronger when walking or doing a movement, such as using one arm to directly give a high five with more force and strength than previously. One parent said that their child was vocalizing more sounds and that speech production increased during the protocol. During the protocol sessions, this child uttered one-word syllables that reflected the verbal cues of the movements while performing the movements. Furthermore, several parents stated that their child was calmer and more focused after the lessons. Most parents expressed that their child was willing and excited to go to sessions each week and that the children overall did not want the sessions to end.

At the end of the protocol, parents articulated that they were interested in enrolling children in a martial arts program in the community or with the student investigator. Many parents used the study as an opportunity to explore how well their child could learn martial arts. Several parents verbalized that having sessions was a highlight of their child’s day. Many parents shared that they did not have to coerce their child to attend sessions as their child was ready to get in the car when it was time to drive 15 minutes to 1 hour to attend the session. Overall, parents verbalized that they were pleased with the individual rhythm and martial arts sessions, the progress of their child
learning martial arts, and the child’s improved gross motor skills. Based on parents’
comments, researchers and music therapists should have regular contact and
communicate with parents, in order to be informed about the child’s motor skills outside
of sessions.

**Conclusions and Future Directions**

Autism is a neurological disorder that is characterized by social, communication,
and motor differences. These motor differences may impact social interactions because
responding to and initiating social cues could be impacted by a lack of motor
coordination. Previous research shows that children with ASD have enrolled in physical
activity programs, such as bicycling, rhythm and robot interventions, and martial arts to
improve their motor differences.

Rhythm provides an auditory timing cue that can enhance movements of children
with and without ASD. Furthermore, rhythm and motor skills are processed in similar
areas of the brain, including the premotor cortex, supplementary motor area, pre-
-supplementary motor area, basal ganglia, and cerebellum. Hearing the rhythmic cues
primes the brain to execute the movements by providing information about the timing,
spatial, and muscle effort needed for each movement. For children with ASD, these
rhythmic cues can be used to enhance and improve their gross motor skills.

The purpose of this current study was to examine the effect of a rhythmic cueing
in martial arts protocol on the motor skills of children with ASD and to determine if they
could learn martial arts movements. Ten children diagnosed with autism received 8
treatment sessions of rhythm and martial arts over a 4-week period. Each 30-minute
treatment session consisted of a bow, meditation period, stretching, and reviewing and
learning martial arts movements with pre-programmed rhythmic cues. Pre- and post-test assessments included the gross motor subtests of the Bruininks-Oseretsky Test of Motor Proficiency (2nd ed.) (Bruininks & Bruininks, 2005) and a Mastery of Martial Arts Test to determine the child’s ability to perform martial arts movements.

The results showed that the children improved some gross motor skills more than others. In particular, they made significant improvements in bilateral and body coordination and non-significant improvements in balance and strength skills. In addition, findings indicated that children with ASD demonstrated significant improvements in learning and performing martial arts movements.

The present study provides theoretical insight to how auditory rhythm may influence movement. The rhythmic cues may have provided a temporal structure needed for precise motor output and may have resulted in more effective and efficient motor planning. Such planning may have resulted from the activation of neural areas involved in producing rhythmic, motoric behaviors. The findings from this current study suggest that within a 4-week rhythm and martial arts protocol, children with ASD can improve their gross motor skills and learn martial arts movements.

When performing movements with rhythmic cues, children with ASD seemed to appear focused on listening to the cues to execute the martial arts movements. Thus, to objectively evaluate the effectiveness of rhythmic cues to teach martial arts, future researchers should use a pre-test/post-test design with an experimental and control group of children with ASD who learn martial arts with and without rhythmic cues, respectively. Researchers should also design a randomized control trial in which participants are assigned to either the intervention or the control group. This design
would provide more evidence that the combination of rhythm and martial arts does impact gross motor skills of children with ASD.

The small sample size was adequate for this pilot study to determine the impact of the protocol and how children with ASD respond to the intervention. Most of the children in the sample were primarily 7 and 8-years-old. Given the young age and small sample size, findings of statistical and clinical significance are noteworthy. However, due to the spectrum of ASD, each child is unique; therefore, the small sample size impacts the ability to generalize the findings. Thus, future research should recruit a larger sample size, such as 30 children with ASD per group, to achieve greater statistical power. Researchers should also recruit older children to determine the responses from children who are slightly older.

Future research may analyze how the different cues - temporal, spatial, and force - affect gross motor skills and martial arts performance, particularly, by examining how the different musical elements in each of the three cues affect outcomes. As each individual with ASD is unique, each child may respond to varying pitches, tempi, and dynamics in different ways. Some children may need to hear more contrast with a larger range of high and low pitches to indicate the range of motion to execute a movement. Other children may perform better in response to smaller differences in pitches to indicate a movement.

The findings of this current study show that engaging the protocol results in better motor learning, which leads to enhanced motor outcomes. The encouraging results show that rhythm puts children on a trajectory to improve motor skills, which may have an impact on social skills. Differences in social skills may be underlined by poor motor planning and lack of coordination. Improving children’s body control enhances their
ability to make gestures, catch a ball, and respond to social cues. Future research may conduct individual sessions or a group format of two or three children per group to assess the impact of using the protocol. Based on the student investigator’s clinical experience, groups of two or three children will provide the least distracting format for children with ASD. Researchers should assess the children’s social skills before and after the protocol to determine how the improved motor coordination translates to social skills.

In conclusion, participants who received the rhythm and martial arts intervention improved some gross motor skills more than others, and improved their ability to learn martial arts movements. However, given the small sample size and lack of a comparison group, future research is needed to test the impact of this type of program and to explore how different components of rhythmic cues may enhance motor skills.
References


Appendix A
Recruitment Flyer

Rhythm & Martial Arts Research Study
Looking for Boys Ages 7-12 with Autism Spectrum Disorder
4 Weeks of Private Lessons
100% Free for Study Participants

Led by a board certified music therapist and black belt in Shaolin Kempo

Requirements and eligibility
Boys with ASD (ages 7 to 12)
Understands English
Has no martial arts experience

Program Details
4 weeks, 2 lessons a week, 45 minutes each.
Child will need to participate in two tests before and after the study.

If interested, contact Hilary Yip, MT-BC 415-609-XXXX
Graduate student, Frost School of Music, University of Miami
Appendix B
Letter of Invitation

Rhythm and Martial Arts for Children with Autism!

Your child is invited to participate in a research study for children with autism spectrum disorder (ASD) that is being done through the University of Miami in Coral Gables, Florida.

If you have a male child between the ages of 7 and 12 with a diagnosis of ASD, your child may be eligible to participate in this study. Your child needs to understand simple directions in English and have no martial arts experience. If you have more than one child who meets these criteria, all of your children may be eligible to participate.

This study will examine how rhythm can help children learn martial arts and possibly impact motor skills. The rhythm and martial arts program is 4 weeks long. Two sessions will occur each week. Each session will be 30 minutes long. Your child will complete a total of 8 martial arts sessions.

Parents will fill out a questionnaire about the social skills of your child. Your child will be asked to complete two motor skills test and two copycat games of martial arts movements. The copycat games will be videotaped.

If you would like to be a part of this study, you will need to schedule a one-hour appointment that will take place at the University of Miami, Coral Gables campus. You will need to bring your child to the appointment.

Research Title: The Effect of Rhythmic Cueing in Martial Arts on the Motor Skills of Children with Autism.

If you would like to be a part of this study, please call or email:
Hilary Yip, MT-BC
415-609-XXXX or hxy251@miami.edu
Master’s Thesis Research
Appendix C
Phone Script

The Effect of Rhythmic Cueing in Martial Arts on the Motor Skills of Children with Autism

Hello (insert parent’s name),

My name is Hilary Yip. I am a music therapist in the masters of music therapy program in the Frost School of Music at the University of Miami.

Thank you for calling me in regards to the flyer that was sent home with your child that introduced a research study I am doing as part of my education. I am inviting children who are 7 to 12 years old and on the autism spectrum to participate in this research.

I would like to tell you a little bit about the study. The purpose of this study is to help me learn how using rhythm in martial arts may help children learn martial arts and improve their motor skills. I hope to have twenty boys in the study. Your participation is completely voluntary.

If you agree, your child will participate in a rhythm and martial arts program that may last from 4-6 weeks. Two sessions will take place each week. Each session is 30 minutes long, for a total of 8 sessions. Your child will play a 15-minute martial arts copycat game that will be videotaped at the first and last session of the program. Your child will also complete a 30-minute motor skills test at the beginning and end of the program.

My purpose in talking with you today is to see if you are interested in learning more about the study and to answer any questions you may have. If you do want to learn more, the next step will be for us to schedule a meeting. We will need about 60 minutes for this meeting. At the beginning of the meeting, I will review an informed consent form with you. You will have the chance to ask any questions. I will also review an assent form with your child. If you and your child give consent/assent, you will next fill out a questionnaire about the social skills of your child. Then your child will complete his motor skills test.

Your time and willingness to participate is greatly appreciated. You may want to bring a source of entertainment to the session for your child, such as an iPAD or book, so that they will have something to do while we discuss and fill out paperwork. Do you have any questions?

(Answer questions.)

Before we schedule a meeting, would you mind if I ask you a few quick questions to determine whether your child may be eligible to participate?
If a parent indicates yes, the following questions will be asked:

Does your child understand English?
Does your child understand concepts of up, down, faster, or slower?
Does your child follow simple one-step directions from an unfamiliar adult?
Does your child perform simple physical activity?
Does your child have a hearing or physical impairment, such as an injury or does he use any assistive devices?
Has your child participated in a martial arts class before?

*If the parent asks for clarification regarding simple physical activity:* Simple physical activity can include raising and lowering arms, standing on alternate legs, and walking.

*If a parent says that they would prefer not to answer any questions:* Thank you (parent name) for your time today and consideration. Have a wonderful day.

(Answer questions. Schedule session, if appropriate.)

*If the child meets pre-screening eligibility requirements and a meeting is scheduled:* Thank you (parent name) for your time today. I look forward to meeting you on (insert date) at (insert location). If you have any questions between now and then, please do not hesitate to contact me at 415-609-6992.

*If the child does not meet the pre-screening eligibility requirements:* Thank you (parent name) for your time today and your consideration. Have a wonderful day.
### Appendix D

**Mastery of Martial Arts Test Scoring Sheet**

Mastery of Martial Arts Test Data Collection Form

<table>
<thead>
<tr>
<th>Movement</th>
<th>1 = Not at all</th>
<th>2 = Very few</th>
<th>3 = Some</th>
<th>4 = Most</th>
<th>5 = All</th>
<th>N/A</th>
</tr>
</thead>
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<td>1. Front position</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>N/A</td>
</tr>
<tr>
<td>2. Horse stance</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>N/A</td>
</tr>
<tr>
<td>3. Half-moon stance</td>
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<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>N/A</td>
</tr>
<tr>
<td>4. Front two knuckle punch</td>
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<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>N/A</td>
</tr>
<tr>
<td>5. Front ball kick</td>
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<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
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</tr>
<tr>
<td>6. Kick-punch-punch sequence</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
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</tr>
<tr>
<td>7. Kick-cross-uncross sequence</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>N/A</td>
</tr>
<tr>
<td>8. Eight-point blocking system</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
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</tr>
<tr>
<td>9. Half-moon forward with eight-point blocking system</td>
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<td>2</td>
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<tr>
<td>10. Eight-point blocking system in reverse</td>
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<td>2</td>
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<td>4</td>
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</tr>
<tr>
<td>11. Half-moon backward and eight-point blocking system</td>
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<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>N/A</td>
</tr>
<tr>
<td>12. Half-moon forward and backward with eight-point blocking system</td>
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<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>N/A</td>
</tr>
<tr>
<td>13. Pinan #1</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
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</tr>
<tr>
<td>14. Side blade kick</td>
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<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
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</tr>
<tr>
<td>15. Step-side blade kick-uncross sequence</td>
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<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
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</tbody>
</table>

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<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th><strong>Total score</strong></th>
</tr>
</thead>
</table>
Appendix E
Informed Consent

University of Miami
CONSENT TO PARTICIPATE IN A RESEARCH STUDY

The Effect of Rhythmic Cueing in Martial Arts on the Motor Skills of Children with Autism

Hilary Yip, Masters Degree Graduate Student
Music Therapy, University of Miami

Shannon de l'Etoile, Ph.D.
Associate Dean of Graduate Studies and Professor, Music Therapy
Frost School of Music, University of Miami

The following information describes the research study in which you and your child are being asked to participate. Please read the information carefully. At the end, you will be asked to sign if you agree to participate and to allow your child to participate.

REQUEST TO PARTICIPATE:
You and your child are being asked to participate in a research study because your child is 7 to 12 years old and diagnosed with autism spectrum disorder.

PURPOSE OF STUDY:
The purpose of this study is to determine if using rhythm in martial arts will influence your child’s motor skills.

PROCEDURES:
During our first meeting, you will be asked to read an informed consent document and decide if you want to allow your child to participate. If you decide to allow your child to participate, I will read an assent form to your child which explains the research study in developmentally-appropriate terms. Your child will sign the assent form or provide verbal assent if he agrees to participate in the study.

After you and your child give consent, the following activities will take place:

- You will be asked to fill out a questionnaire about the social skills of your child. This should take 15-20 minutes.
- Your child will be asked to complete a motor skills test for 30 minutes. The test will be given by graduate students of physical therapy.

On your next visit, these activities will take place:

- Your child will play a martial arts copycat game with me for 15 minutes. The copycat game will be videotaped.
- Your child will participate in his first martial arts session which will last for 30 minutes. He will be given an explanation of martial arts, the rules of performing martial arts, and taught how to perform each movement with a rhythmic cue. The movements include basic stances, strikes, and blocks in various sequences and directions.
Over the next 4 weeks, your child will participate in 7 more martial arts sessions. Each session will last 30 minutes. Two sessions will take place each week. Your child will complete a total of 8 martial arts sessions.

- At the last martial arts session, your child will repeat the martial arts copycat game which will last 15 minutes. This game will also be videotaped.

On your last visit, these activities will take place:
- Your child will be asked to complete a motor skills test for 30 minutes. The test will be given by graduate students of physical therapy.

Overall, your child is expected to participate in the study for 10 days over a period of 4 to 6 weeks.

**RISKS AND/OR DISCOMFORTS:**
No foreseeable risks or discomforts are anticipated for your child by participating in this study.

**BENEFITS:**
It is possible that your child will benefit from this study by learning martial arts movements and demonstrating improved motor skills. Your child’s involvement in the study may also help other children on the autism spectrum who have difficulty with motor skills. The study will help us learn how rhythm can be used as a way to help children develop better motor skills.

**ALTERNATIVES:**
You have a right to not allow your child to participate in the research study.

**CONFIDENTIALITY:**
The student investigator will consider your and your child’s records confidential to the extent permitted by law. Individuals from the University of Miami Institutional Review Board (a committee that reviews and approves research studies), the U.S. Department of Health and Human Services (DHHS), and regulatory auditors may look at records related to this study to make sure we are doing proper, safe research, and protecting human participants. The results of this research may be published or presented to others. You will not be named in any reports of the results.

The collected data will not contain any information that could be used to identify your child. All data will be identified by an assigned code and not by your child’s name. All paper and electronic records will be stored in a locked filing cabinet and a password-protected computer, respectively, to which the student investigator, Hilary Yip, will have the only access. All records will be kept in this locked location for a period of seven years. After that time, all data will be destroyed.

**COSTS:**
There are no costs associated with you or your child's participation in this study.

**COMPENSATION:**
There will be no compensation for participation in this research study.

**RIGHT TO DECLINE OR WITHDRAW:**
Your child’s participation in this study is voluntary; he has the right to withdraw from the study at any time. Your child’s withdrawal or lack of participation will not affect the treatment he is
The investigator reserves the right to remove your child without your child’s consent at such time that they feel it is in the best interest for your child.

**CONTACT INFORMATION:**
The principal investigator, Dr. Shannon de l’Etoile, at 305-284-6913 or the student investigator, Hilary Yip at 415-609-XXXX or at hxy251@miami.edu will gladly answer any questions you may have concerning the purpose, procedures, and outcome of this project. If you have questions about your child’s rights as a research participant in this study, you may contact the University of Miami’s Human Subjects Research Office at 305-243-3195.

**PARTICIPANT AGREEMENT:**
I have read the information in this consent form and agree to participate, and to allow my child to participate. I have had the chance to ask any questions I have about this study, and they have been answered for me. I am entitled to a copy of this form after it has been read and signed.

___________________________________
Child’s name

___________________________________
Parent’s Name

___________________________________
Parent’s Signature

___________________________________
Date

___________________________________
Signature of Person Obtaining Consent

___________________________________
Date
# Video Consent

I hereby authorize the University of Miami, Department of [ ], to take still photographs, videotapes, and/or sound recordings of me/ (my child).

I authorize the University to use in any manner said photographs, film, video or tape recordings, in whole or in part as follows (Please read and check box next to appropriate permission statement):

- For the purpose of teaching, research, scientific meetings and scientific publications, including professional journals or medical books;
- For research purposes only.

I agree that the University of Miami, its Trustees, officers, employees, faculty and agents will not be responsible for any claims arising in any way out of the taking and use as described above of such photographs and/or recordings. I understand that I will not have an opportunity to inspect and approve such photographs or recordings prior to their use.

<table>
<thead>
<tr>
<th>Signature of Participant:</th>
<th>Printed Name of Participant:</th>
<th>Date:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Signature of Witness:</th>
<th>Printed Name of Witness:</th>
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</tr>
</thead>
<tbody>
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<table>
<thead>
<tr>
<th>Signature of Parent (if applicable):</th>
<th>Printed Name of Parent (if applicable):</th>
<th>Date:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Appendix G
Child Assent Form

We are doing research about rhythm, martial arts, and how our bodies move. Research is something people do when they want to learn more about people and how they do things. If you decide you want to be a part of this research, you will use music to learn martial arts, or ninja moves.

I would like your help to play a copycat game with me. I am going to show you a ninja move and you are going to copy me. I am going to show you different types of ninja moves and your job is to copy what I do. This will take about 15 minutes.

You will then have ninja lessons with me. In the lessons, I will show you how to do the ninja move and your job is to copy me. Then we will use music to help us learn the ninja move. You will also do the ninja move by yourself with the music and without music. Each lesson is 30 minutes long. You will have two lessons a week for one month, so you will have a total of 8 ninja lessons.

Your parent will be outside the room the whole time, but can come in with you if you want them to. If your parent is in the room with you, they will not be able to help you.

This study will not cost you or your parents any money. You can ask me questions any time. When we are done, I am going to write a report about what I found out. I won’t use your name or any personal information in the report. One day, the report may be in a special magazine for people to read.

If you don’t feel like being in the study, you don’t have to. You can stop at any time and that will be okay. If you say okay now and want to stop later, that’s okay, too. No one will be upset or mad at you if you say no or if you change your mind. You can stop any time you want. All you have to do is tell me.

I, _____________________________________, want to be in this research study.

(Printed Name of Child)

Signature of Child __________________________ Date ____________

Signature of Person Obtaining Assent __________________________ Date ____________

Printed Name of Person Obtaining Assent __________________________

Circle one: This assent was 1) verbally explained to the child
2) read by the child

Circle one: 1) Child appeared to understand the information and gave verbal or written assent.

2) Child did not appear to understand the information and thus assent was waived.
Ninja Copycat Game

1. front position
2. horse stance
3. half-moon stance
4. front two knuckle punch
5. front ball kick
6. kick-punch-punch
7. kick-cross-uncross
8. eight blocks forward
9. half-moon forward with 8 blocks
10. eight blocks backward
11. half-moon backward with 8 blocks
12. half-moon forward and backward with 8 blocks
   forward and backward
13. pinan #1
14. side blade kick
15. step-side blade kick-cross-uncross
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<th>Age</th>
<th>Level of Functioning</th>
<th>Bilateral Coordination Scale Score Pre-Test</th>
<th>Bilateral Coordination Scale Score Post-Test</th>
<th>Balance Scale Pre-Test</th>
<th>Balance Scale Post-Test</th>
<th>Body Coordination Composite Standard Score Pre-Test</th>
<th>Body Coordination Composite Standard Score Post-Test</th>
<th>Running Speed and Agility Composite Standard Score Pre-Test</th>
<th>Running Speed and Agility Composite Standard Score Post-Test</th>
<th>Strength Scale Score Pre-Test</th>
<th>Strength Scale Score Post-Test</th>
<th>Strength and Agility Composite Standard Score Pre-Test</th>
<th>Strength and Agility Composite Standard Score Post-Test</th>
<th>Gross Motor Composite Standard Score Pre-Test</th>
<th>Gross Motor Composite Standard Score Post-Test</th>
</tr>
</thead>
<tbody>
<tr>
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<td>Within Typical Limits</td>
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<td>11</td>
<td>7</td>
<td>5</td>
<td>36</td>
<td>35</td>
<td>5</td>
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<td>32</td>
<td>31</td>
<td>31</td>
</tr>
<tr>
<td>7:5 - 7:6</td>
<td>Within Typical Limits</td>
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<td>13</td>
<td>12</td>
<td>15</td>
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<td>9</td>
<td>8</td>
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<tr>
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