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# The Effects of Music & Robotic Interventions on the Affective States, Interpersonal Synchrony, and Praxis Skills of Children with Autism Spectrum Disorders

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The Effects of Music & Robotic Interventions on the Affective States, Interpersonal Synchrony,  
and Praxis Skills of Children with Autism Spectrum Disorders

Isabel Park

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The Effects of Music & Robotic Interventions on the Affective States, Interpersonal Synchrony,  
and Praxis Skills of Children with Autism Spectrum Disorders

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## Abstract

**Background:** Children with Autism Spectrum Disorders (ASDs) present with multiple comorbidities in addition to their primary impairments. These comorbidities include difficulties with affective states as well as motor problems such as poor interpersonal synchrony and poor praxis on imitation. In the present study, I examined the effects of two types of rhythmic interventions, music and robot, on the affective states and motor skills of children with ASDs as compared to the traditional standard of care intervention. **Methods:** Thirty-six children with ASDs between 5 and 12 years were randomly assigned to one of three groups: music, robot, or academic. All children received 16 training sessions across 8 weeks in music-, robot-, or academic-based contexts. Children were assessed pre- and post-training on a standardized test of praxis performance as well as during training for task-specific synchronous actions and affective states. **Results:** Children in the music group showed the most positive affect, followed by the academic group, and then the robot group. Both music and robot groups showed similar levels of disinterest or negative affect and the academic group showed the highest levels of interested affect. In terms of motor behavior, the music group increased their in-synchrony with training. In the standardized praxis test, all three groups showed a trend for decrease in the total number of praxis errors post-training. The music group showed a significant decrease in the amount of time to best effort post-training. **Conclusions:** Music-based interventions increased positive affect as well as motor skills and could be a promising intervention tool for children with ASDs.

*Keywords:* Affect, motor, praxis on imitation, music therapy, socially assistive robotics, autism

## **Chapter 1: Introduction**

### **Autism Spectrum Disorders (ASDs)**

Autism spectrum disorders (ASDs) are characterized by primary impairments in social communication skills as well as restricted, repetitive interests and behaviors (American Psychiatric Association, 2013). Children with ASDs demonstrate poor social communication skills such as reduced or lack of eye contact and lack of spontaneous interest sharing with others (Mundy & Stella, 2000). Repetitive interests and behaviors include persistent fixation with certain objects, adherence to fixed routines, and motor stereotypies such as flapping of hands, finger flicking, and body rocking (Kanner, 1943; Leekam et al., 2011). In addition to their primary impairments, there is a multitude of comorbidities associated with this population. A variety of affective impairments are commonly associated with children with ASDs. Based on the literature, I have categorized them into three subsets: emotion regulation and negative behaviors, emotional expressivity and nonverbal communication, and lastly, emotion recognition and intentional understanding (Mazefsky et al., 2012; Maskey et al., 2013; Uljarevic & Hamilton, 2013; Vivanti et al., 2011; Decety & Moriguchi, 2007). There is also strong evidence for the presence of motor impairments in children with ASDs (Leary & Hill, 1996; McCleery et al., 2013; Fournier et al., 2010; Mari et al., 2003; Bhat et al., 2011; Green et al., 2009; Mostofsky et al., 2007). Specifically, motor difficulties include fine and gross motor incoordination (Jansiewicz et al., 2006; Provost et al., 2007; Lloyd et al., 2013; Lopata et al., 2007), poor balance (Fournier et al., 2010; Jansiewicz et al., 2006; Miyahara et al., 1997; Ghaziuddin et al., 1994), abnormal gait (Fournier et al., 2014; Minshew et al., 2004; Molloy et al., 2003; Rinehart et al., 2006), poor imitation and interpersonal synchrony (Rogers et al., 2003; Mostofsky et al., 2006; Stone et al., 1990; Stone et al., 1997; Smith & Bryson, 1998; Dowell et al., 2009; Vivanti

et al. 2008; Vivanti et al., 2014), and dyspraxia or poor motor planning (Dowd et al., 2012; Linkenauger et al., 2012; Rinehart et al., 2001; Rinehart et al., 2007; Fabbri-Destro et al., 2009; Van Swieten et al., 2010). Motor delays are reported in the literature from an early age (Ozonoff et al., 2008; Gernsbacher et al., 2008; Bhat et al., 2012; Charman et al., 1997; Landa & Garrett-Mayer, 2006) and continue into late childhood and adolescence or adulthood as balance and coordination problems (Ghaziuddin et al., 1994; Green et al., 2009; Mostofsky et al., 2006; Isenhower et al., 2012, Minshew et al., 2004).

## **Affective Impairments in Children with ASDs**

### *Emotion Regulation and Negative Behaviors*

In general, children with ASDs have a difficult time regulating their emotions (Mazefsky et al., 2012; Maskey et al., 2013; Cohen et al., 2013; Pouw et al., 2013; Rieffe et al., 2011; Konstantareas & Stewart, 2006; Jahromi et al., 2012). Emotion regulation is defined as the ability to effectively modify or control one's emotional state to accomplish a goal-directed or adaptive behavior (Thompson, 1994) in a socially acceptable way (Rieffe et al., 2011). Examples of poor emotion regulation include anxiety (Rieffe et al., 2006), neutral or flat affective states (Kanner, 1943), aggression towards others or self-injurious behaviors (Pouw et al., 2013), crying, and tantrums (Mazefsky et al., 2012). A recent review by Mazefsky et al. (2013) suggested that while little is known behind the mechanisms of these impairments, there is a general consensus in the literature for the presence of poor emotion regulation skills in ASDs. In a study conducted on the comorbidities in ASDs, temper tantrums were reported to be the third most common behavioral problem in a sample size of 863 children with ASDs (Maskey et al., 2013). Children with ASDs are unable to use effective emotion regulation strategies to redirect their attention away from a desired object, as compared to typically developing children

(Konstantareas & Stewart, 2006). Children with ASDs exhibited higher intensity and durations of negative behaviors such as frustration when presented with the challenge of opening a locked box. Specifically, children with ASDs had more difficulty in regulating their frustration during the locked box task, whereas the typically developing children turned to effective strategies such as verbalizing to cope with their frustration levels (Jahromi et al., 2012). Typically developing children are taught at an early age how to appropriately react in social settings (Rieffe et al., 2011), however, emotion regulation impairments in children with ASDs affects their ability to learn and develop socially appropriate behaviors and relationships. Although the exact mechanism for impaired emotion regulation is unknown (Mazefsky et al., 2013), effective emotion regulation strategies require a balance between understanding and responding using facial expressions and non-verbal communication cues of others. Children with ASDs lack in both these aspects, i.e. understanding and responding.

### *Emotional Expression and Nonverbal Communication*

Typically developing children use various non-verbal communication skills such as gestures (Mostofsky et al., 2006; Rogers et al., 1996; Stone et al., 1997; Smith & Bryson, 1998), postures (Nickel & Thatcher et al., 2013), eye gaze, facial expressions (Kanner, 1943), as well as joint attention (Mundy et al., 1990, Gernsbacher et al., 2008) to express their affective states and emotions. These skills are crucial not only to express but also to communicate emotions and affective states to others and hence, connecting with others in everyday social settings (Tomasello, 1995). Many of these non-verbal communication skills such as gestures, body postures, and facial expressions are motor-based skills and could be impaired in children with ASDs. Although motor difficulties are not considered a primary impairment of ASDs, the current literature suggests they are a key impairment in this population (Fournier et al., 2010).

Specifically, due to generalized praxis impairments (Dziuk et al., 2007), children with ASDs show poor imitation of gestures, especially non-symbolic hand gestures (Smith & Bryson, 1994; Rogers et al., 1996) as well as poor imitation of toy play with caregivers (Toth et al., 2006). Additionally, children have greater difficulty imitating body actions compared to imitating actions on objects (Stone et al., 1997). In a longitudinal study on infants, high-risk infants for autism showed delayed development of sitting and standing postures more slowly as compared to the low-risk infants (Nickel & Thatcher, 2013). Imitation skills and good posture help to create opportunities in interacting with caregivers and peers. These movements allow us to use our joint attention skills to synchronize with social partners. Joint attention is defined as the ability to coordinate or share attention on an object or event with a social partner (Mundy & Burnette, 2005). Children with ASDs have such deficits in gestural (such as pointing) joint attention skills (Mundy et al., 1990). Similarly, looking is necessary to successfully share the focus of your attention with a partner (Mundy & Burnette, 2005). A recent meta-analysis by Uljarevic and Hamilton (2013) found several studies that concluded children with ASDs did show reduced attention to the eyes (Dalton et al., 2005; Boraston et al., 2007; Pelphrey et al., 2002) and increased attention to the mouth (Klin et al., 2002) as compared to matched typically developing controls. This reduced or lack of eye contact, as well as impaired joint attention skills, would lead to missed opportunities for children with ASDs to look at others and communicate feelings or judge their emotions. This, in turn, would have an effect on their social interactions and any potential long-term relations.

Children with ASDs often display odd and flat facial expressions, which would have an effect on their social interactions with others (Uljarevic & Hamilton, 2013). For example, in a play environment, children with ASDs did not respond with appropriate facial expressions to

typically developing peers and had difficulty adjusting their expressions to match their interactions with their partners (Reddy et al., 2002; Dawson et al., 1990). In a first impression task, typically developing children gave lower scores on all aspects of a friendship measurement scale when asked to rate the expressivity of children with ASDs (Stagg et al., 2013). Given these motor and affect impairments, children with ASDs do have a difficult time communicating and developing social relationships with caregivers and fellow peers.

### *Emotion Recognition and Intentional Understanding*

Emotion recognition is defined as the ability to recognize and understand the emotional states of others (Decety & Moriguchi, 2007). This impairment of emotion recognition in children with ASDs could be due to the lack of sustained eye contact with others resulting in inability to recognize facial expressions, as well as the inability to perceive or understand non-verbal acts of communication such as eye gaze and posture. While the literature shows mixed results regarding emotion recognition, there is sufficient evidence suggesting that children with ASDs do have these difficulties (Vivanti et al., 2011; Wong et al., 2012; Bons et al., 2012; Sivaratnam et al., 2012; Jolley et al., 2013; Golan et al., 2009; Uljarevic & Hamilton, 2013).

Uljarevic and Hamilton (2013) suggested that children with ASDs have difficulties recognizing only a few of the six basic emotions - happiness, anger, fear, sadness, disgust, and surprise (Ekman and Friesen, 1976). In an emotion recognition task, high-functioning children with ASDs, typically developing children, and children with social phobia all identified happy emotion more quickly and accurately than others, such as disgust (Wong et al., 2012). Additionally, children with ASDs were able to identify and understand basic emotions through novel measures such as drawing (Jolley et al., 2013) and comic strip tasks (Sivaratnam et al., 2012). As children with ASDs are able to recognize some emotions, several studies have shown



that an emotion recognition training program can help to improve such emotion recognition skills (Ryan & Charragain, 2010; Golan et al., 2009). However, these skills are not always generalized over time (Williams et al., 2012), i.e., improvements are not sustained over time. Children with ASDs are however, not tuned into the goal-directed actions of others and have a hard time detecting subtle changes in intentions and affective states of their social partners (Vivanti et al., 2011). In a multiple behavioral study, testers performed pattern tasks with the children that required the use of appropriate eye contact and emotion recognition skills to complete the tasks. Children with ASDs were unable to pick up on subtle cues such as a head turn by the tester, which indicated a shift in the pattern, as compared to typically developing children (Vivanti et al., 2011). Overall, affective impairments are prevalent in children with ASDs and there is an urgent need for effective interventions addressing these impairments along with the primary impairments of autism.

## **Motor Impairments in Children with ASDs**

### *Interpersonal Synchrony Impairments*

Interpersonal synchrony is the ability to coordinate movements, temporally and spatially with a social partner. Interpersonal synchrony encompasses both the motor skills such as intra- and inter-limb coordination, imitation, as well as social skills such as social monitoring, joint attention, and turn taking (Kleinspehn-Ammerlahn et al., 2011; Colombi et al., 2009; Isenhower et al., 2012; Vivanti et al., 2008; Marsh et al., 2009; Stone et al., 1990; Fitzpatrick et al., 2013; McDuffie et al., 2007). Children with autism are clearly different from typically developing children in terms of their motor and social attention skills, which can affect their ability to coordinate movements with others (Isenhower et al., 2012). In a rocking chair task examining

spontaneous interpersonal synchrony between parent-child pairs, children with autism showed significantly less in-phase rocking coordination than typically developing children (Marsh et al., 2013). Deficits in interpersonal coordination due to poor social monitoring, i.e. not looking towards the parent chairs, may have contributed to less in-phase coordination for children with autism (Marsh et al., 2013). Children with autism also show more inconsistency during inter-limb coordination skills such as drumming and marching compared to typically developing children (Isenhower et al., 2012). In a drumming task, children with autism were unable to sustain advanced drumming patterns, suggesting that motor difficulties may have contributed to their poor intrapersonal synchrony (Isenhower et al., 2012). As discussed above, imitation and social monitoring skills are significant correlates of cooperative behavior, suggesting that impairments in these can affect the development of such skills and prevent children with autism from fully participating in social interactions (Berger & Ingersoll, 2013; Stone et al., 1990; McDuffie et al., 2007; Vivanti et al., 2008; Vivanti et al., 2014).

### *Praxis Impairments*

There is strong evidence in the literature suggesting impaired praxis abilities in children with autism, i.e. the ability to series of complex motor sequences (Mostofsky et al., 2006; MacNeil & Mostofsky, 2012). Praxis is a broader concept, which includes the ability to perform skilled motor gestures to imitation (requiring visual skills), to command (requiring verbal skills), and with tool use (requiring past understanding of how to use tools) (Mostofsky et al., 2006). In a series of imitation tasks, children with autism produced significantly more incorrect responses during gestures to imitation, gestures to command (Dewey et al., 2007), as well as in gestures with tool use compared to typically developing children (Mostofsky et al., 2006). Additionally, children with autism have more difficulty imitating non-meaningful gestures such as an abstract

hand motion as compared to meaningful gestures such as waving goodbye (Vanvuchelen et al., 2007; Smith & Bryson, 1998). However, when compared to typically developing and language impaired children, children with autism still had less accuracy in both meaningful and non-meaningful gestures (Smith & Bryson, 2007). This suggests there is a generalized imitation impairment in this population, and this impairment is not restricted to difficulty maintaining eye contact. Eye trackers have been used to examine visual attention patterns of children with autism and typically developing children (Vivanti et al., 2008), as well as Global Developmental Delay (GDD, Vivanti et al., 2014) groups while observing actions on objects and gestures. Children with autism focused more on the demonstrator's actions than his face during the imitation tasks. They also imitated less frequently compared to the typically developing and GDD groups (2014), and showed reduced imitation precision as compared to typically developing children (2008). Imitation is vital for young children to learn new skills and behaviors, and may be the foundation that affects later social communication skills (McDuffie et al., 2007; Bhat et al., 2011). For this reason, it is important to implement successful interventions to specifically target those skills.

## **Chapter 2: Traditional Treatments**

While affective and motor impairments are common in children with ASDs, few traditional interventions focus on the development of these skills. Most of the “standard of care” interventions continue targeting the primary social communication impairments of ASDs through Applied Behavior Analysis (ABA, Lovaas, 1987), the Picture Exchange Communication System (PECS, Bondy & Frost, 1998; 2001), and the Treatment and Education of Autistic and related Communication-handicapped Children (TEACCH, Mesibov et al., 2005). These programs use specific strategies for social interaction and environmental structure to promote positive behaviors in children with ASDs (Landa, 2007). ABA facilitates spontaneous verbal and non-verbal communication development with opportunities to increase frequency and duration of positive behavioral responses and academic skills in a tightly controlled environment by the adult (Lovaas, 1987; Landa, 2007). PECS is a structured intervention program that teaches both verbal and nonverbal communication skills while promoting the ABA principles using picture-based methods. The PECS phases range from learning how to communicate, learning to approach to communicate, making visual discrimination between pictures, creating picture sentences using multiple pictures, communicating without prompts, and lastly, communicating with more than one picture sentence (Bondy & Frost, 2001). Lastly, TEACCH encompasses both ABA and PECS by using an approach called “Structured Teaching” to promote independent goal-directed activities and task completion. This is facilitated through physical organization of the teaching environment, visual information as guides or schedules of activities to increase organization and predictability, and individual workstations to promote independence (Mesibov & Shea, 2010; Landa, 2007; Hume et al., 2012).

Although positive social behaviors improve through the use of these standard of care interventions, they do not necessarily promote high levels of positive affect in the children. Children learn how to behave appropriately in social and academic settings but this does not mean the activities are a particularly enjoyable context. The few studies in the literature that have targeted affective skills in children with ASDs were inconclusive and showed mixed results. These studies implemented the same emotion recognition-training program, which involved role-playing, drawing, and matching tasks using emotional and facial expressions. While some reported significant improvements in emotion recognition of facial expressions in children with ASDs (Ryan & Charragain, 2010; Golan et al., 2009), others reported only an improvement in anger recognition and no generalization over time (Williams et al., 2012). Similarly, the standard of care interventions also fail to target the motor impairments found in this population. These interventions primarily offer ways to communicate and interact with children with ASDs to better their social or language skills. While motor and affective impairments are not considered a primary impairment in ASDs, there is a need for more holistic interventions that target these secondary impairments as well as the social-communication or language impairments. Therefore, I turned to two novel ideas, music and robotics, as potential interventions to examine their multi-system effects on children with ASDs.

## **Chapter 3: Novel Treatments**

### **Music Therapies**

Children with ASDs have a predilection for music, with enhanced abilities in pitch perception, specifically in categorizing high and low pitched tones; pitch discrimination, identifying individual notes as well as notes within musical chords; and disembedding skills, recognizing different notes played within the same chord (Bonnel et al., 2003; Heaton, 2003; Altgassen et al., 2005). There are reasons why they find musical activities particularly enjoyable (Srinivasan & Bhat, 2013). Music based interventions also have many potentials for children with autism, as music therapies can be motivating yet interesting for children (Lim, 2010) and can help address the various primary and secondary impairments in this population. They promote active participation, including both verbal and non-verbal responses (Lim, 2010), along with interactive communication and play (Wigram & Gold, 2006). Another important aspect of music therapy is a stable and structured environment. The stability allows the children to feel comfortable while demonstrating their spontaneity and creativity through engaging musical activities and exploration of instruments in social environments with a therapist or trainer (Wigram & Gold, 2006; Srinivasan & Bhat, 2013).

Various types of music therapies have shown success in this population, as well as other developmental disorders. These include Auditory-Motor Mapping Training (AMMT, Wan et al., 2011), improvisational music therapy (Kim et al., 2009), and rhythm therapy (Overy, 2000). AMMT focuses on promoting speech development and production through a training method of singing and drum tapping associations, leading to a facilitation of sound-motor mapping that allows the child to make the connection between the tones and the target words. Activities progress from listening, to unison singing, to partially supported production, to immediate word

repetition, and lastly, to word production on their own (Wan et al., 2011; Wan & Schlaug, 2010). After 40 treatment sessions, six non-verbal children with autism significantly improved their vocalizations and speech production (2011), suggesting AMMT has the potential to facilitate language development.

Improvisational music therapy uses live music to focus on establishing a shared and meaningful relationship between the therapist and child (Alvin & Warwick, 1991; Kim et al., 2009; 2008), through musical elements such as vocal and instrumental, as well as eye contact, gestures, and facial expressions (Wigram, 2002). Improvisational music therapy has been used to facilitate joint attention skills (Kim et al., 2008), positive facial expressions and compliance (Kim et al., 2009), speech production (Lim, 2010), musical communication behaviors in tempo, rhythm, structure, and pitch (Edgerton, 1994), as well as social interactions and reduction of negative behaviors (Boso et al., 2007).

Rhythm therapy has been implemented in children with dyslexia, which focuses on rhythm and basic timing skills, major areas of difficulties in this population (Overy, 2003). As children with dyslexia also show higher pitch skills than typically developing peers (Overy et al., 2003), music-based therapies seem fitting for these impairments. Rhythm training therapy includes clapping, drumming games and singing through simple and engaging ways, with gradual progress into more complex rhythmic skill levels (Overy, 2000).

Long-term music therapies have also been used in young adults to improve their behavioral performance. Musical sessions consisted of drumming, piano playing, and singing, to facilitate social improvement and reduce negative behaviors. Results showed significant improvements in behaviors such as agitation, abnormal behavior, and lack of interaction with the

therapists (Boso et al., 2007). Overall, there were improvements in various behavioral and social communication as well as joint attention skills in these studies. Therefore, despite the studies consisting of case studies with small sample sizes (Wan et al., 2011; Overy et al., 2003; Boso et al., 2007) or non-standardized testing measures (Kim et al., 2009;), music therapy could also be beneficial for the comorbidities associated with this population.

### **Socially Assistive Robotics**

While typically used for rehabilitation and various physical therapies (not in a social role), the use of socially assistive robotics has become a new focus in assisting and interacting with children with autism (Scassellati et al., 2012; Feil-Seifer & Mataric, 2005). Robots also have much potential for children with autism, as they are predictable and easy for children to comprehend (Nadel, 2004). Robots can also be designed to fit the interests and specific needs for children with autism, as well as to encourage social development through simple appearances and exchanges in contrast to potential feelings of overwhelming pressure to socially interact with people (Duquette et al., 2008; Robins et al., 2004; Kozima et al., 2009; Wainer et al., 2013).

These interventions have facilitated both social communication skills including social collaborations, eye contact, joint attention, turn taking, and verbalization skills (Wainer et al., 2013; Kozima et al., 2007; Kozima et al., 2009; Srinivasan & Bhat, 2013), as well as some motor performance skills such as imitation with and without objects and bilateral coordination skills (Robins et al., 2005; Robins et al., 2009; Kaur et al., 2013; Srinivasan et al., 2013; Duquette et al., 2008).

In a pilot study, Kaspar was compared to a human partner in collaborative video game sessions with children with ASDs, as well as to examine the influence of robotic interactions on subsequent human interactions with the children. Children were interested and entertained by



the robot and had better collaborative behaviors with the human partner after playing with Kaspar. This suggested the robot had positive social impacts on the children that could potentially carry over to a human partner (Wainer et al., 2013). Keepon, another robot, was used to study the effects of robotic interactions on attention and emotions of children with ASDs. Over time, children increased their spontaneous engagement and interactions with the robot. In addition, the robot also promoted triadic episodes of engagement where children used the robot as a focus of interactions with other children and caregivers (Kozima et al., 2007). Similarly, Robota, a humanoid robotic doll, has been successful as a mediator in improving social interaction skills through imitation and turn taking games, encouraging more complex opportunities for interactions to increase touch, imitation, and proximity skills in children (Robins et al., 2005). Mobile robots such as Tito have also showed success in facilitating shared attention and play imitation patterns, as compared to a human mediator. Children who were exposed to Tito exhibited more visual contact and physical proximity with the robot, as well as increased imitation of smiling, imitations of familiar actions with and without objects, and body movements (Duquette et al., 2008).

Previous studies involving Isobot (Tomy, Inc.) a 7-inch tall humanoid robot, completed by our lab have shown improved solo and social bilateral coordination, imitation, and praxis skills in typically developing children and a small sample of children with ASDs through imitation-based games involving the practice of karate and dance themed movements (Kaur et al., 2013; Srinivasan et al., 2013).

Perhaps robots have been successful in these therapies because they are more predictable, provide a simple and safe environment, and can act as a social mediator for children unable to express their emotions themselves (Mead & Mataric, 2009; Fong et al., 2003). Overall, there is

evidence that suggests robots can be used as facilitators to promote positive affective states and motor skills in children with ASDs (Dauntehahn & Werry, 2004). However, there are limitations in the literature, including the aforementioned studies. They are mostly anecdotal evidence as single case studies very small sample sizes (Duquette et al., 2008; Robins et al., 2004; Kozima et al., 2009; Wainer et al., 2013; Kaur et al., 2013; Srinivasan et al., 2013). Therefore, I am extending this work further by assessing the efficacy of robotic interactions on the affective and behavioral impairments, as well as on the interpersonal synchrony and praxis on imitation skills of children with ASDs.

## **Chapter 4: Proposed Study Aims**

### **Statement of Purpose**

The purpose of the study was to address the need for a randomized controlled trial study by examining the affective and motor effects of musical and robot interventions in children with ASDs. Specifically, I aimed to compare the effects of music and robotic interventions to the standard of care treatment on the affective states as well as the interpersonal synchrony and praxis skills of children with ASDs. The idea of music therapy is highly theorized as a good intervention program; therefore, I devised a music-based protocol that uses rhythmic movements to address the impairments of ASDs. Based on my lab's preliminary findings through the use of robots as a potential tool for improving imitation, coordination, and social interaction skills (Srinivasan et al., 2013; Kaur et al., 2013; Srinivasan and Bhat, 2013b), I extended this training to explore the effects on affective and motor impairments. The standard of care or academic group engaged in stationary, tabletop activities that were familiar to children with ASDs.

### **Aims and Hypotheses**

**Aim 1:** To compare the training-related changes in affective states during a music- and robot-based intervention protocol and the standard of care, academic intervention in children with ASDs.

**Hypothesis 1.1:** Children with ASDs in the music and robot groups will show greater percent duration and rates of positive affect compared to the children in the academic group.

**Hypothesis 1.2:** Children in the music and robot groups will show an increase in the percent duration or the rates of positive episodes such as smiling in the late training sessions compared to the mid or early sessions.

**Aim 2:** To compare the training-related and generalized effects of the music- or robot-based intervention and the academic intervention on the motor coordination deficits of children with autism.

**Hypothesis 2.1:** Children in the music and robot groups will show training-specific improvements in interpersonal synchrony for rhythmic actions in the late training session compared to mid or early sessions.

**Hypothesis 2.2:** Children in the music and robot groups will show greater improvements in generalized praxis on imitation skills post-training whereas similar improvements will not occur in the academic group.

## Chapter 5: Methods

### Participants

Thirty-six children (32 males, 4 females) diagnosed with ASDs between the ages of 5 to 12 years ( $M (SD) = 7.95 (2.54)$ ) participated in this study. Children were recruited through phone calls and/or fliers distributed to autism schools and early intervention centers, as well as online postings. Children were screened for social impairments using the Social Communication Questionnaire (SCQ, Rutter et al., 2003). The ASD diagnosis was confirmed through medical records and using the gold standard assessment for autism diagnosis, the Autism Diagnostic Observation Schedule (ADOS, Lord, Rutter, DiLavore, & Risi, 1999). In addition, each child's intelligence quotient (IQ) was determined using the Stanford-Binet Intelligence Test (SBIT, Becker, 2003). Exclusion criteria included hearing, visual, orthopedic, cardiovascular, or other neurological diagnoses that prevented participation.

Children were matched on level of functioning and age bands (4-6, 7-9, 10-12 years). Their level of functioning was assessed through a subjective rating of children's social communication and motor skills on a scale of 1 to 4 indicating low to high levels of functioning based on the child's pretest performance. Once all children were matched, they were randomly assigned the children to the three training groups – music, robot, and academic. The groups did not differ significantly from each other in terms of age (music = 7.88 (2.56); robot = 7.52 (2.22); academic = 7.36 (2.02),  $p > 0.05$ ), gender (music: 10M, 2F; robot: 11M, 1F; academic: 11M, 1F,  $\chi^2 p > 0.05$ ), or level of functioning (composite rating score from subjective ratings of children's motor and social communication skills: music = 2.49 (0.78), robot = 2.57(0.81), academic = 2.90 (0.43),  $p > 0.05$ ). Children were enrolled in the study following informed parental consent as approved by the Institutional Review Board at the University of Connecticut.

## Procedural Overview

The testing and training sessions were delivered over 10 weeks. The pretest and posttest sessions were conducted in the first and the last week of study participation, respectively, and included the Bilateral Motor Coordination (BMC) subtest of the Sensory Integration and Praxis Test (SIPT). I used the Vineland Adaptive Behavior Scale-Second Edition (VABS-II) (Sparrow & Cicchetti, 2005) and the Movement Assessment Battery for Children-Second Edition (Henderson et al., 2007) to assess the behavioral regulation and motor skills baseline of children with ASDs. In addition, I evaluated the affective states of the children with ASDs as well as the motor coordination skills, which included interpersonal synchrony and praxis on imitation skills. In between the testing weeks, 16 expert training sessions were delivered to each training group over eight weeks with two sessions per week (see Table 1 for study timeline). Parents were also asked to deliver home sessions to further reinforce the skills learning during training sessions. All the testing and the training sessions were videotaped.

Table 1: *Study Timeline*

Frequency	2 days/week (Expert sessions) 2 days/week (Parent sessions)
Duration	8 weeks
Time	45 minutes/session
Type	Music, Robot, or Academic Intervention
Baseline Measures	1. Vineland Adaptive Behavior Scale – 2 <sup>nd</sup> Edition (questionnaire filled out pre-training) 2. Movement Assessment Battery for Children – 2 <sup>nd</sup> Edition

	(questionnaire filled out pre-training)
Testing Measures	<ol style="list-style-type: none"> <li>1. Bilateral Motor Coordination of SIPT (pre, post sessions)</li> <li>2. Affective States (early, mid, late sessions)</li> <li>3. Synchrony (early, mid, late sessions)</li> </ol>

## Baseline Measures

### 1. Vineland Adaptive Behavior Scale-Second Edition (VABS-II)

VABS-II is a parent questionnaire, which assesses the child's level of functioning in various domains including daily, social-communication, and motor skills as well as maladaptive and negative behaviors. For the current study, I analyzed the Maladaptive Behavior domain (Internalizing, Externalizing, and other behaviors) to assess the behavioral regulation skills of children with ASDs. Internalizing behaviors included anxiety, depression, and withdrawal while externalizing behaviors included attentional deficits, non-compliance, and aggressive behaviors (Bornstein et al., 2010). Each question was scored on a scale ranging from 0 (Never) to 2 (Often), with high scores indicating high frequency of maladaptive behaviors. Raw scores were summed and converted to a *v*-scale score, which provided a comparison of the child's maladaptive behavior with the normative sample. The *v*-scale scores ranged from levels of average (suggested the child displayed about the same number of maladaptive behaviors as the normative sample), elevated (indicated the child showed more than 84% of maladaptive behaviors than those in the normative sample), and clinically significant scores (indicated the child showed more than 98% of maladaptive behaviors than those in the normative sample and further evaluation should be completed; Sparrow & Cicchetti, 2005).

## 2. Movement Assessment Battery for Children-Second Edition (MABC-2)

The MABC-2 is a parent checklist that assesses the motor competence of children between 5 to 12 years of age on a variety of tasks involving movements in static and dynamic environments. The static task examples included stork balancing, standing still on one leg, while dynamic task examples included jumping jacks and heel-to-toe walking. Each activity was scored on a scale ranging from 0 (child does the activity “very well”), 1 (child does the activity “just okay”), 2 (child “almost” does the activity), to 3 (child is “not close” to completing the activity). Raw scores were summed and categorized into three, color zones with higher scores indicated more motor impairments. The “green” zone included children above the 15<sup>th</sup> percentile compared to the normative sample, “amber” zone included children between sixth and 15<sup>th</sup> percentile compared to the normative sample, and “red” zone included children below the fifth percentile compared to the normative sample (Henderson et al., 2007).

### **Testing Measures**

#### 1. Sensory Integration and Praxis Tests (SIPT)

The Sensory Integration and Praxis Tests (SIPT) are a standardized battery of tests to assess motor coordination, sensory integration, and praxis function in children between 4.0 and 8.11 years of age (Ayres, 1996). Specifically, I used the Bilateral Motor Coordination (BMC) subtest. The BMC subtest evaluates the ability to coordinate both sides of the body during simple and complex rhythmic hand, leg, and foot movement sequences during 18 actions. The actions included 10 hand, four leg, and four foot tapping movement sequences. SIPT-BMC was used to examine general improvements in praxis on imitation before and after training. Pre- and posttests were coded for the total number of errors across the various actions, as well as the



average time taken to complete the various actions (see Appendix 2 for the scoring sheet). The following temporal and spatial errors were coded for each action of the SIPT-BMC:

- i. Segmentation errors were obvious pauses within a continuous movement sequence.
- ii. Rhythmicity errors were errors in which the child had difficulty distinguishing speed changes within a demonstrated rhythmic sequence.
- iii. Sequencing errors were errors in the order of the movement sequence and included an addition, omission, or merging of movements.
- iv. Mirroring errors were errors in which the child used the opposite arm or foot to perform the movement sequence.
- v. Movement overflow errors were extra movements by the child beyond what the tester performed.
- vi. Body part errors were errors in which the child used the incorrect body part to perform the movement sequence.
- vii. Time to best effort was the time between the start of the child's movement to the end of the child's movement.

Note – Children who were low functioning and unable to do complex patterns were excluded. Four children from the music group, three children from the robot group, and three children from the academic group were excluded from the final SIPT analysis.

## 2. Training-specific actions

### 2a. Affect

The affective state of each child was coded moment-to-moment using the OpenSHAPA coding software ([openshapa.org](http://openshapa.org)), an open source video coding software that can be used to code

for durations or frequencies of different behaviors. Durations of each affective state and rate of positive affect were coded as follows.

*Rate of positive affect* was defined as the number of smiles per minute.

*Duration of positive affect* was defined as time spent smiling with or without vocalizations.

*Duration of negative/disinterested affect* was defined as time spent off-task with behaviors such as looking away and pouting, frowning, or clear distress, with or without vocalizations.

*Duration of interested affect* was defined as time spent on-task and in compliance with the trainer though not smiling nor demonstrating other negative behaviors described above. All duration codes were calculated for an early, mid, and late training session. Percent durations were then calculated for each variable based on the total duration time of each condition.

## 2b. Interpersonal Synchrony

I also examined the training-specific changes in interpersonal synchrony in the early, mid, and late training sessions using standardized test actions involving whole body movements as well as musical instruments in the music and robot groups. In the music group, these were conducted during the training conditions of Beat Keeping, Music Making, and Moving Game. The Beat Keeping test actions involved front-and-back and side-to-side bilateral arm movements using maracas. The Music Making test moves were one-handed and two-handed, symmetrical and asymmetrical drumming motions. Lastly, the Moving Game test actions were a series of jumping, marching, clapping, and skipping. In the robot group, the test actions were conducted during the training conditions of Action Game, Drumming Game, and Walking Game. The Action Game test actions were a combination of side-to-side, bilateral arm movements. The

Drumming Game test actions were a galloping pattern involving unilateral and bilateral drumming motions. Lastly, the Walking Game involved walking in-synchrony with the adult to trace shapes or letters on the floor.

The interpersonal synchrony of each child was coded moment-to-moment at a microsecond level using the OpenSHAPA coding software ([openshapa.org](http://openshapa.org)). Interpersonal synchrony was a measure of how the child moved in relation to the adult and was considered to be in-synchrony, out-of-synchrony, or in-synchrony with assistance. The durations of interpersonal synchrony were reported as follows:

*Duration of in-synchrony* was defined as the amount of time the child's motions were synchronized in timing (in the same or opposite direction) to the adult.

*Duration of out-of-synchrony* was defined as the amount of time the child's motions were not synchronized in time compared to the adult.

*Duration of in-synchrony with assistance* (assisted synchrony) was defined as the amount of time the child's motions were moving in the same direction with hand-on-hand assistance from the adult.

Note that intra- and inter-rater reliability of 84% was established for all the testing measures after coding for 20% of the entire dataset.

## **Training Protocol**

Training was provided over 8 weeks, in between the pre- and post-testing weeks. Expert training sessions (conducted by physical therapists or Kinesiology graduate students with significant pediatric training) were conducted twice a week, for a total of 16 expert sessions.

Caregivers were asked to complete two more sessions each week at home. Each session was about 30 to 45 minutes. Each child interacted with a human or robot trainer and an adult confederate model within a triadic context (see Figures 1a-c).



Figure 1a: Training set-up for the music group.



Figure 1b: Training set-up for the robot group.



Figure 1c: Training set-up for the academic group.

Social skills such as greetings, farewells, sharing, and commenting in between the movement periods were emphasized to structure the social interactions. Conversations were used to promote social interactions in the robot and academic groups whereas singing was used to promote social interactions in the music group. Each child in the music and robot groups engaged in joint action and rhythmic synchronization during coordinated upper body and whole body movements.

In the music group (see details in Table 2 for full details on specific conditions) training conditions included a hello song, an action song, beat keeping, music making using musical instruments (see Figure 2 for instruments), whole body moving games, a calming song and a farewell song. Rhythmic actions were practiced in the Beat Keeping, Music Making, and Moving Game conditions; hence they have been used to assess the changes in interpersonal synchrony following training.

Table 2: Conditions in the music group.

Condition	Description	Exemplar Activities	Props Used	Themes
Hello Song	Singing introductory songs	<ul style="list-style-type: none"> <li>• Patting knees</li> <li>• Clapping</li> </ul>	<ul style="list-style-type: none"> <li>• Puppets</li> </ul>	<ul style="list-style-type: none"> <li>• Start &amp; Stop</li> <li>• Steady Beat</li> <li>• Turn Taking</li> <li>• Slow &amp; Fast</li> <li>• Move on a Count</li> <li>• Soft &amp; Loud</li> </ul>
Action Song	Songs with gestures to illustrate the words & phrases in song	<ul style="list-style-type: none"> <li>• “Here is a Bunny”</li> <li>• “Do Your Ears Hang Low?”</li> </ul>	<ul style="list-style-type: none"> <li>• None</li> </ul>	
Beat Keeping	Moving to a rhythm/beat with body	<ul style="list-style-type: none"> <li>• Shaking/waving hands</li> <li>• Stepping/reaching feet</li> </ul>	<ul style="list-style-type: none"> <li>• Scarves</li> <li>• Maracas</li> <li>• Shakers</li> </ul>	
Music Making	Making music with various instruments	<ul style="list-style-type: none"> <li>• Symmetric patterns</li> <li>• Alternating patterns</li> </ul>	<ul style="list-style-type: none"> <li>• Drums</li> <li>• Xylophones</li> <li>• Maracas</li> <li>• Wood blocks</li> <li>• Tambourines</li> </ul>	
Moving Game	Whole body movements	<ul style="list-style-type: none"> <li>• Marching</li> <li>• Skipping</li> <li>• Jumping</li> </ul>	<ul style="list-style-type: none"> <li>• None</li> </ul>	
Calming Song	Relaxation period	<ul style="list-style-type: none"> <li>• Lying down</li> </ul>	<ul style="list-style-type: none"> <li>• Flashlights</li> </ul>	
Farewell Song	Singing goodbye songs	<ul style="list-style-type: none"> <li>• Patting knees</li> <li>• Clapping</li> </ul>	<ul style="list-style-type: none"> <li>• Puppets</li> </ul>	



Figure 2: Materials for the music group.

In the robot group, the human trainer controlled a 23” humanoid robot, Nao (Aldebran Robotics), and a mobile robot, Rovio™ (WowWee®), through a laptop system with custom software to deliver the training (see Table 3 for full details on specific conditions, see Figure 3 for robots). Training included the following contexts: a hello period with Nao, warm up games that involved a variety of movement sequences, an action game that involved action songs and

rhythmic actions such as marching and tapping, simple and complex drumming, walking games in which children were to follow Rovio™ to trace letters and shapes on the floor, and lastly, a farewell period with Nao. In terms of data analysis, I focused specifically on the Action Game, Drumming Game, and Walking Game conditions to assess the changes in interpersonal synchrony following training. In both the music and robot groups, the biweekly sessions were based on various themes such as start and stop, slow and fast, moving on a count, moving on a steady beat, and turn taking.

Table 3: Conditions in the robot group.

Condition	Description	Exemplar Activities	Props Used	Themes
Hello	Introduction to Nao & activities	• Waving	• None	<ul style="list-style-type: none"> <li>• Start &amp; Stop</li> <li>• Steady Beat</li> <li>• Turn Taking</li> <li>• Slow &amp; Fast</li> <li>• Move on a Count</li> </ul>
Warm Up	Imitating Nao in simple rhythmic movements	<ul style="list-style-type: none"> <li>• Head rotations</li> <li>• Moving elbows in &amp; out</li> </ul>	• None	
Action Game	Moving to rhythm with arms & legs	• Moving arms in & out	• None	
Drumming Game	Various drumming patterns	<ul style="list-style-type: none"> <li>• Symmetric patterns</li> <li>• Alternating patterns</li> </ul>	• Drums	
Walking Game	Following Rovio to trace various shapes & letters on ground	<ul style="list-style-type: none"> <li>• Triangle</li> <li>• Letter “Z”</li> </ul>	• None	
Farewell	Saying good-bye	• Waving	• None	

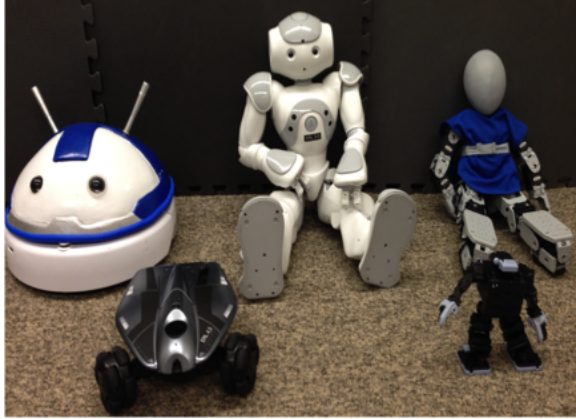


Figure 3: Materials for the robot group.

In comparison to the music and robot groups, the academic group engaged in stationary and academic activities to promote reading and fine motor skills. Training included the following contexts: a reading condition, in which children read a fictional or non-fictional book appropriate to their developmental level; a building condition, in which children made creations using either Play-Doh® (Hasbro), Duplo® or LEGO® (The LEGO Group), or Zoobs (InfiniToy); and lastly, an arts and crafts condition, in which children colored, cut, and glued to make creations based on the themes (see Table 4 for full details on specific conditions, see Figure 4 for supplies). In the academic group, sessions were based on academic themes including basic shapes, the solar system, places, people and the human body, healthy foods, living things, weather and seasons, and water bodies.

Table 4: Conditions for the academic group.



Condition	Description	Exemplar Activities	Props Used	Themes
Hello	Introduction to session & activities	• Waving	• None	<ul style="list-style-type: none"> <li>• Basic shapes</li> <li>• Solar system</li> <li>• Places</li> <li>• People &amp; the human body</li> <li>• Healthy foods</li> <li>• Living things</li> <li>• Weather &amp; seasons</li> <li>• Water bodies</li> </ul>
Reading	Reading book appropriate to developmental level		• Books	
Building	Making creations using various building materials	<ul style="list-style-type: none"> <li>• Zoob Cube</li> <li>• Lego Apple</li> <li>• Play-doh Alien</li> </ul>	<ul style="list-style-type: none"> <li>• Play-doh®</li> <li>• Zoobs</li> <li>• LEGO®</li> <li>• Duplo®</li> <li>• Puzzles</li> <li>• Building blocks</li> </ul>	
Arts & Crafts	Making creations by coloring, cutting, gluing	<ul style="list-style-type: none"> <li>• Fruit Basket</li> <li>• Paper Chicken</li> <li>• Barn Animals</li> </ul>	<ul style="list-style-type: none"> <li>• Crayons</li> <li>• Scissors</li> <li>• Glue</li> <li>• Glitter</li> </ul>	
Clean Up	Placing all materials back in bags/containers		• None	
Farewell	Saying good-bye	• Waving	• None	



Figure 4: Materials for the academic group.

In addition to the expert sessions, parents and caregivers were strongly encouraged to provide at least two additional home sessions per week to practice and reinforce the skills learned during expert training sessions. In-person training, parent manuals, session-specific instructions, and the various musical instruments, robots, or art supplies required to conduct these sessions were provided each week. Parents/caregivers were encouraged to observe the

expert conducted sessions as well. Siblings were also encouraged to participate in the home training activities to act as a buddy and model for the child. All expert sessions and two home sessions (early and late) were videotaped for later coding of a variety of relevant behaviors. All expert trainers and testers involved in the study received significant training from the PI, Anjana Bhat, and expert collaborators before beginning training sessions. Lastly, all adult models received a 6-hour in-person, written, and video-based training before beginning the training sessions. At the end of each session, children were given small toys. All children received \$50 as participation reimbursement at the end of the study.

## **Statistical Analysis**

### *Affect Data*

A multifactorial ANOVA was conducted using groups as the between-subject factor (Music, Robot, Academic), and session (Early, Mid, Late), variable (rate of positive affect, duration of positive affect, duration of interested affect, and duration of negative affect) and condition (refer to Tables 1a-c) as the within-subjects factor using SPSS software (SPSS, Inc.). I have reported  $p$ - and  $F$ -values after performing the Pillai's Trace. Post-hoc comparisons were conducted using paired or unpaired  $t$ -tests. Statistical significance was set following Bonferroni corrections and  $p$ -values between the corrected value and up to 0.1 were considered a statistical trend due to the preliminary nature of our data. In some cases, range of data values were reported.

### *Synchrony Data*

Two multifactorial ANOVAs were conducted for interpersonal synchrony assessment using session (Early, Mid, Late), variables (in-synchrony, out-of-synchrony, assisted synchrony)

and conditions (refer to section above for specific condition names) as the within-subjects factor using SPSS software (SPSS, Inc.) for the music and robot groups' data. I have reported  $p$ - and  $F$ -values after performing the Pillai's Trace. Post-hoc comparisons were conducted using paired or unpaired  $t$ -tests. Statistical significance was set following Bonferroni corrections and  $p$ -values between the corrected value and up to 0.1 were considered a statistical trend due to the preliminary nature of our data. Range of data values were reported.

#### *SIPT Data*

Wilcoxon's nonparametric tests were done for within-group comparisons of the SIPT-BMC data. Statistical significance was set at  $p < 0.05$  and  $p$ -values between 0.05 and up to 0.1 were considered a statistical trend due to the preliminary nature of our data.

## **Chapter 6: Results and Discussion on Affective States**

### **Baseline Results**

#### *VABS-II*

Thirty-four out of 36 questionnaires were filled and returned by the parents. There were no significant differences between groups ( $p > 0.05$ ). Results suggested the following: 10 out of 10 children in the music group, 10 out of 12 children in the robot group, and nine out of 12 children in the academic group showed an elevated and/or clinically significant internalizing score; four children in the music group, seven children in the robot group, and five children in the academic group showed an elevated and/or clinically significant externalizing score; and lastly, nine children in the music group, 11 children in the robot group, and eight children in the academic group showed an elevated and/or clinically significant other behaviors score. These results highlight that children in this population and more specifically, in this sample size, have problems with behavior regulation.

### **Affect Results**

A full model ANOVA for rates of positive affect and durations of positive, negative, and interested affects revealed a main effect of Variable ( $F(3, 31) = 718268.90$ ,  $p < 0.01$ ),  $\eta^2 = 1.000$ ), a main effect of Condition ( $F(4, 30) = 11.181$ ,  $p < 0.01$ ),  $\eta^2 = 0.599$ ), and a Variable x Condition x Group interaction ( $F(24, 46) = 2.255$ ,  $p < 0.01$ ),  $\eta^2 = 0.541$ ). There were no session effects. I examined the three-way interaction effect using post-hoc analyses to determine between-group and within-group differences.

#### *Between-Group Differences*

Between-group differences were observed for rates of positive affect, durations of positive affect, durations of interested affect, and durations of negative affect. For rates of positive frequency, the music group ( $M = 0.36$ ,  $SD = 0.35$ , range = 0 – 1.31, see Figure 5a) showed greater rates as compared to the robot ( $M = 0.14$ ,  $SD = 0.16$ , range = 0 – 0.68,  $p < 0.01$ ) and academic groups ( $M = 0.18$ ,  $SD = 0.19$ , range = 0 – 0.79,  $p < 0.01$ ). In terms of individual differences, 9 - 11 out of 12 children within each group followed the group trends.

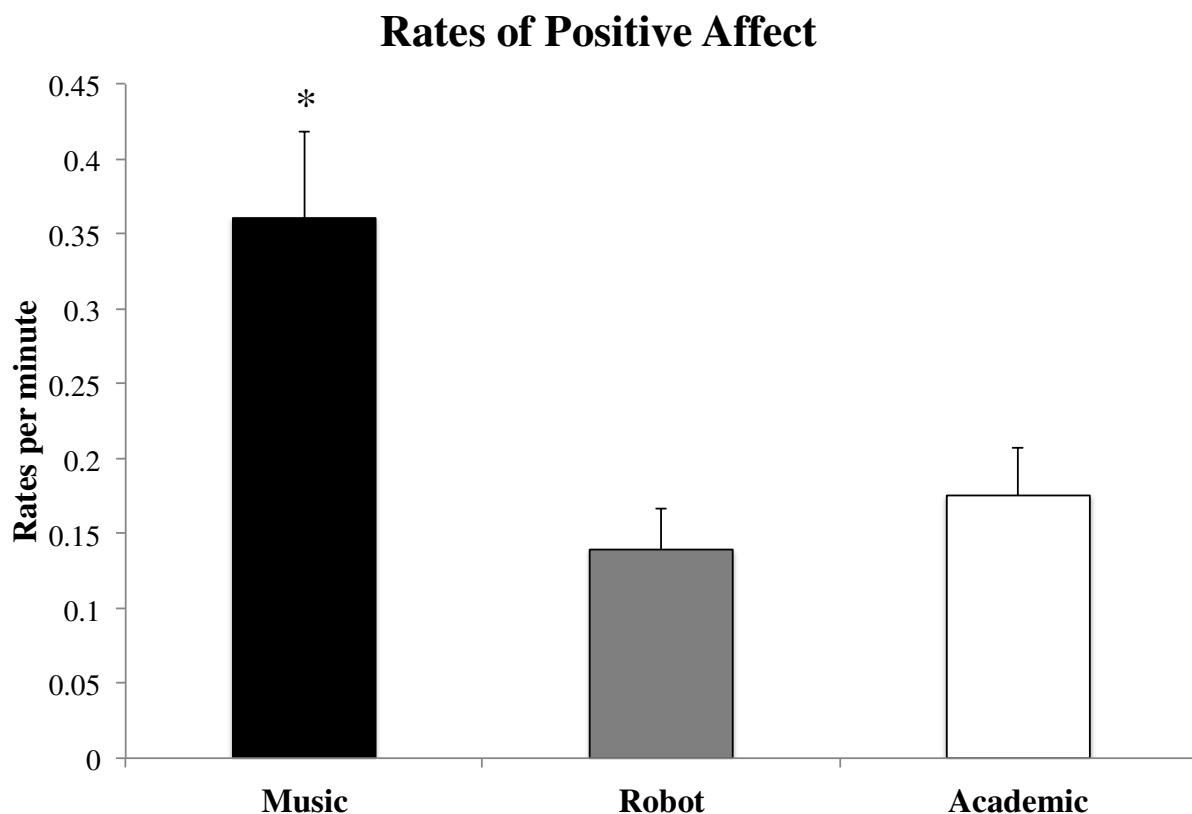


Figure 5a: Rates of positive affect between the music, robot and academic groups.

Similarly for durations of positive affect, the music group ( $M = 5.92$ ,  $SD = 8.19$ , range = 0 – 43.49, see Figure 5b) showed greater positive affect compared to the robot ( $M = 2.00$ ,  $SD = 2.67$ , range = 0 – 12.32,  $p < 0.01$ ) and academic groups ( $M = 2.11$ ,  $SD = 2.62$ , range = 0 – 10.62,  $p < 0.01$ ).

0.01). In terms of individual differences, 8 out of 12 children within each group followed the group trends. For durations of interested affect, the academic group ( $M = 89.36$ ,  $SD = 13.14$ , range = 52.47 – 99.65) showed greater interested affect compared to the music ( $M = 72.92$ ,  $SD = 17.65$ , range = 35.78 – 97.93,  $p < 0.01$ ) and robot groups ( $M = 75.87$ ,  $SD = 16.75$ , range = 40.08 – 100,  $p < 0.01$ ). In terms of individual differences, 10 out of 12 children within each group followed the group trends. Lastly, for durations of negative affect, the music ( $M = 20.28$ ,  $SD = 15.68$ , range = 0.73 – 55.86,  $p < 0.01$ ) and robot groups ( $M = 22.13$ ,  $SD = 17.04$ , range = 0 – 56.13,  $p < 0.01$ ) showed greater negative affect compared to the academic group ( $M = 8.53$ ,  $SD = 13.17$ , range = 0 – 46.34). In terms of individual differences, 8 - 10 out of 12 children within each group followed the group trends.

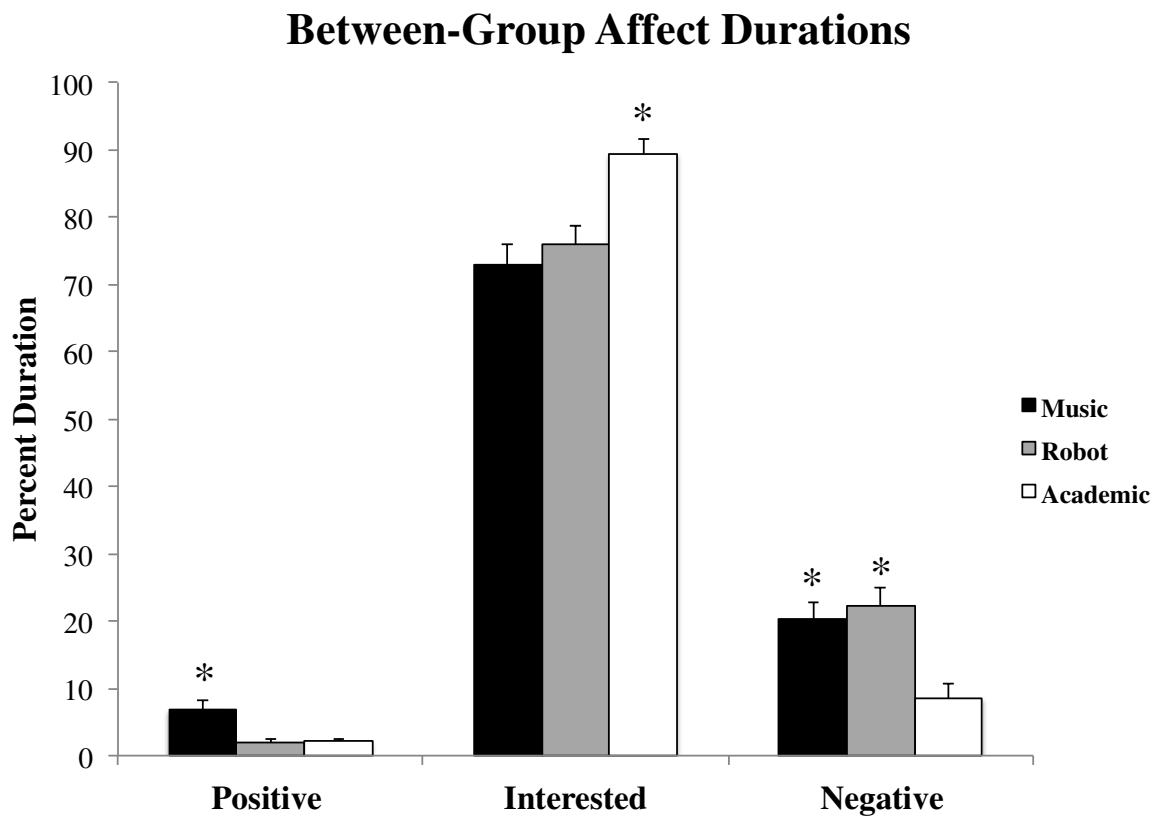


Figure 5b: Percent durations for affect in music, robot, and academic groups.

### *Within-Group Differences*

The music group showed the highest rates of positive affect in Hello Song and Farewell Song ( $M = 0.62$ ,  $SD = 0.60$ ,  $p < 0.05$ , see Figure 5c), followed by Moving Game ( $M = 0.57$ ,  $SD = 0.77$ ,  $p < 0.01$ ) as compared to the other conditions. In terms of individual differences, 6 - 8 out of 12 children followed the group trends.

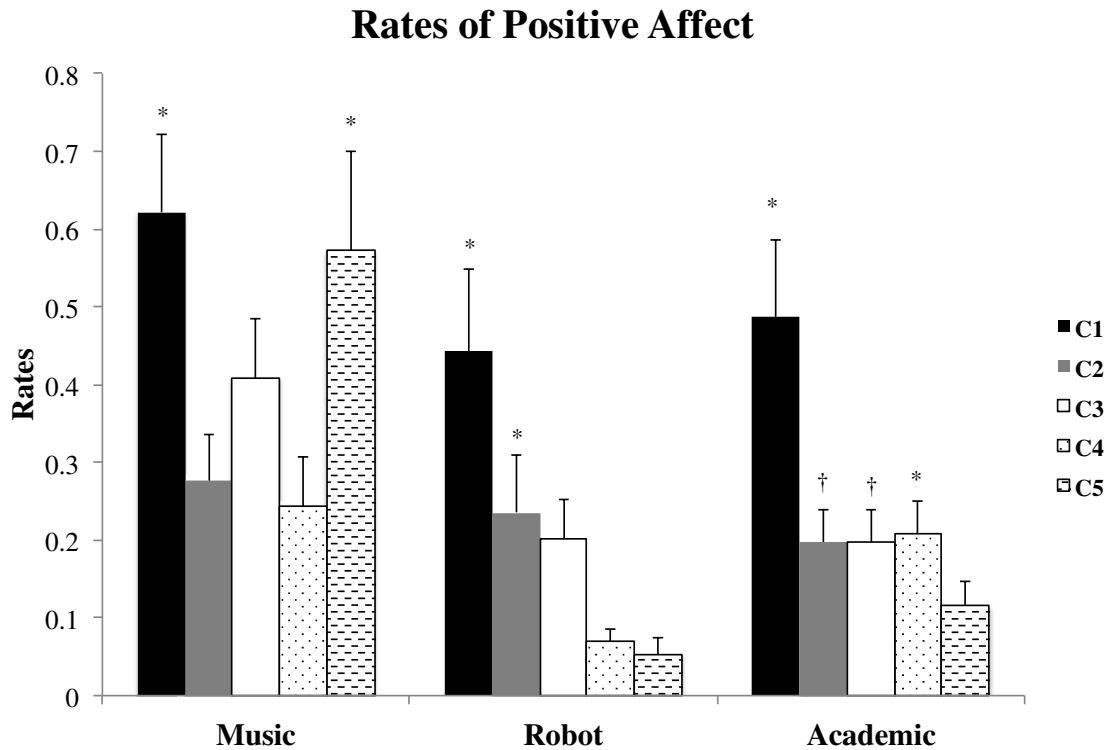


Figure 5c: Rates of positive affect across conditions for music, robot, and academic groups. Note - Music: C1 = Hello & Farewell Songs, C2 = Action Song, C3 = Beat Keeping, C4 = Music Making, C5 = Moving Game. Robot: C1 = Hello & Farewell, C2 = Warm Up Game, C3 = Action Game, C4 = Drumming Game, C5 = Walking Game. Academic: C1 = Hello & Farewell, C2 & C3 = Reading, C4 = Building, C5 = Arts & Crafts.

Similarly for durations of positive affect, children in the music showed greater positive affect in Moving Game ( $M = 11.45$ ,  $SD = 18.66$ ,  $p < 0.01$ , see Figure 6) and Hello Song and Farewell Song ( $M = 10.78$ ,  $SD = 14.35$ ,  $p < 0.01$ ) as compared to the other conditions. In terms of individual differences, 6 – 8 of out 12 children followed the group trends. The highest durations of interested affect were also in Hello Song and Farewell Song ( $M = 76.89$ ,  $SD = 18.90$ ,  $p < 0.10$ ) as compared to the other conditions. In terms of individual differences, 8 out of 12 children followed the group trend. Lastly, the highest durations of negative affect were in Beat Keeping ( $M = 21.98$ ,  $SD = 20.65$ ,  $p < 0.01$ ), Music Making ( $M = 21.39$ ,  $SD = 17.77$ ,  $p < 0.01$ ), and Action Game ( $M = 21.19$ ,  $SD = 19.78$ ,  $p < 0.01$ ) as compared to the other conditions. In terms of individual differences, 7 - 8 out of 12 children followed the group trends.

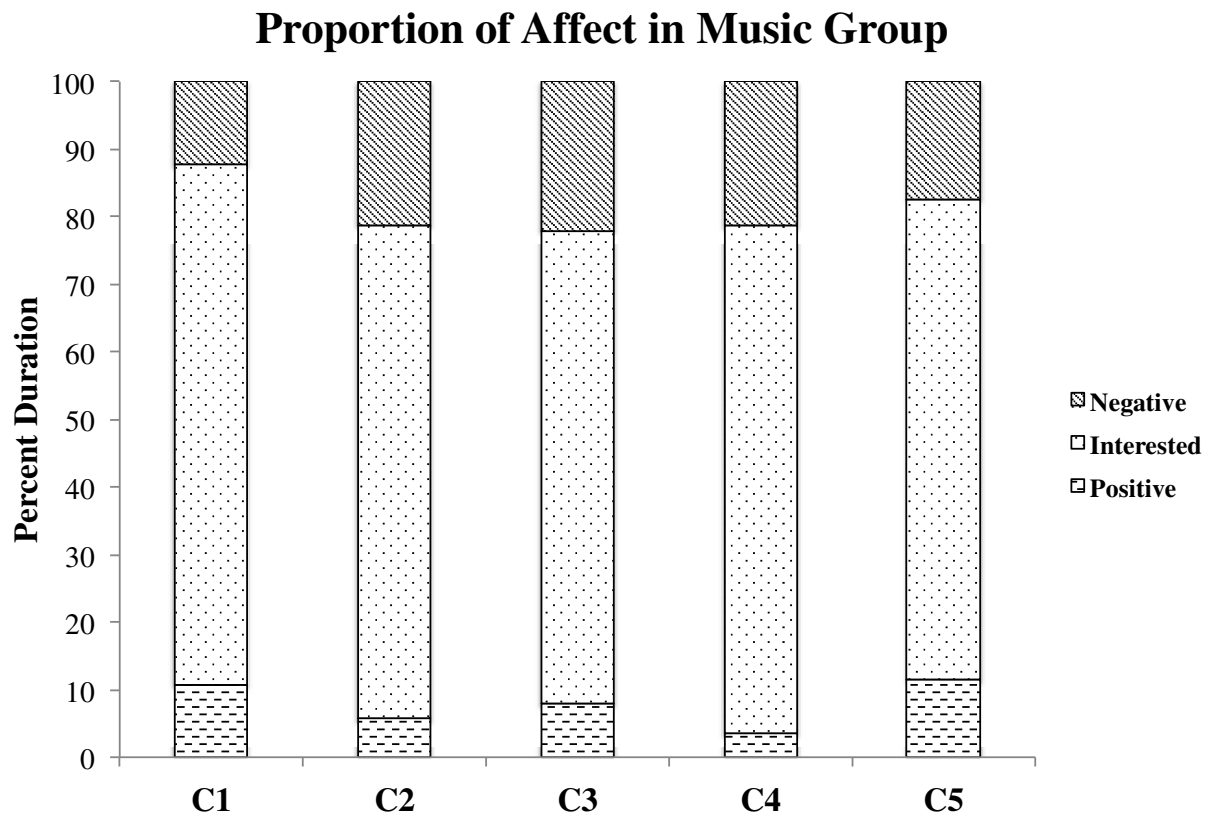




Figure 6: Durations of affect across conditions in the music group. Note: C1 = Hello & Farewell Songs, C2 = Action Song, C3 = Beat Keeping, C4 = Music Making, C5 = Moving Game.

Overall, Hello Song and Farewell Song as well as Moving Game generated high levels positive levels and engagement in the music group. This also confirms that the other conditions were not enjoyable, with higher levels of negative affect in Beat Keeping, Music Making, and Action Game.

The robot group showed the highest rates of positive affect in Hello and Farewell ( $M = 0.44$ ,  $SD = 0.63$ ,  $p < 0.05$ , see figure 5c), followed by Warm up Game ( $M = 0.24$ ,  $SD = 0.45$ ,  $p < 0.05$ ) and Action Game ( $M = 0.20$ ,  $SD = 0.30$ ,  $p < .05$ ) as compared to the other conditions. In terms of individual differences, 7 - 11 out of 12 children followed the group trends. Similarly for durations of positive affect, children in the robot group showed greater positive affect in Hello and Farewell ( $M = 6.82$ ,  $SD = 11.80$ ,  $p < 0.05$ , see Figure 7), Warm Up Game ( $M = 4.91$ ,  $SD = 11.93$ ,  $p < 0.05$ ), and Action Game ( $M = 2.38$ ,  $SD = 4.27$ ,  $p < 0.05$ ) as compared to the other conditions. In terms of individual differences, 6 - 10 out of 12 children followed the group trends. The highest durations of interested affect were in Walking Game ( $M = 87.73$ ,  $SD = 14.21$ ,  $p$  values ranged from 0.000 to 0.06) as compared to the other conditions. In terms of individual differences, 11 out of 12 children followed the group trends. Lastly, the highest durations of negative affect were in Drumming Game ( $M = 26.56$ ,  $SD = 22.10$ ,  $p$  values ranged from 0.001 to 0.10), followed by Action Game ( $M = 24.66$ ,  $SD = 23.10$ ,  $p < 0.05$ ), then Hello and Farewell ( $M = 19.90$ ,  $SD = 23.78$ ,  $p < 0.05$ ) as compared to the other conditions. In terms of individual differences, 7 – 9 out of 12 children followed the group trends.

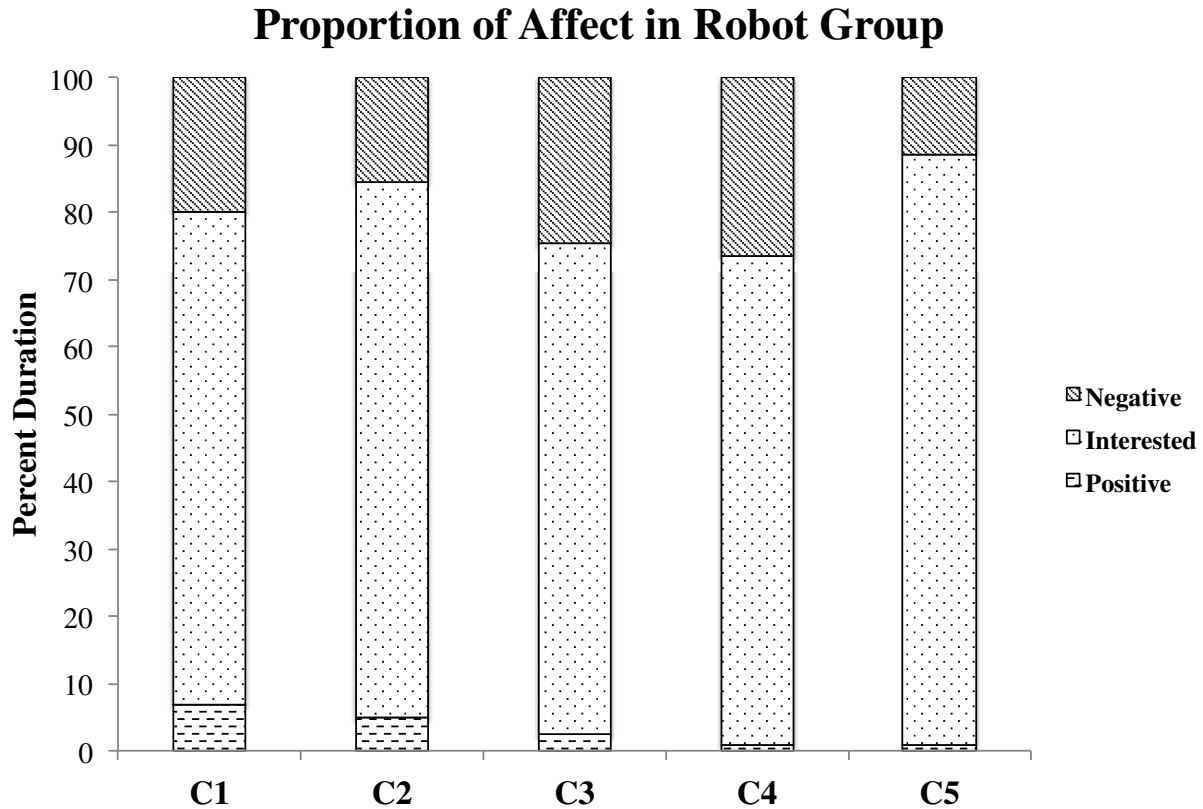


Figure 7: Durations of affect across conditions in the robot group. Note: C1 = Hello & Farewell, C2 = Warm Up Game, C3 = Action Game, C4 = Drumming Game, C5 = Walking Game.

Overall, Hello and Farewell as well as Warm Up Game, Action Game, and Walking Game generated higher levels positive levels and engagement in the robot group. There were higher levels of negative affect in Drumming Game, as well as in Action Game and Hello and Farewell.

The academic group showed the highest rates of positive affect in Hello and Farewell ( $M = 0.49$ ,  $SD = 0.60$ ,  $p < 0.01$ , see Figure 5c) followed by Building ( $M = 0.21$ ,  $SD = 0.26$ ,  $p < 0.01$ ) and Reading ( $M = 0.20$ ,  $SD = 0.26$ ,  $p < 0.10$ ), and as compared to the other conditions. In terms of individual differences, 7 - 11 out of 12 children followed the group trends. Similarly for durations of positive affect, children in the academic group showed greater positive affect in

Hello and Farewell ( $M = 10.79$ ,  $SD = 19.82$ ,  $p < 0.05$ , see Figure 8), followed by Building ( $M = 2.57$ ,  $SD = 3.60$ ,  $p < 0.01$ ) as compared to the other conditions. In terms of individual differences, 7 - 10 out of 12 children followed the group trends. The academic group showed the highest durations of interested affect in Reading ( $M = 91.38$ ,  $SD = 14.86$ ,  $p < 0.05$ ) and Arts and Crafts ( $M = 91.12$ ,  $SD = 13.80$ ,  $p$  values ranged from 0.02 to 0.09) as compared to the other conditions. In terms of individual differences, 10 - 11 out of 12 children followed the group trends. There were no condition related differences for negative affect in the academic group.

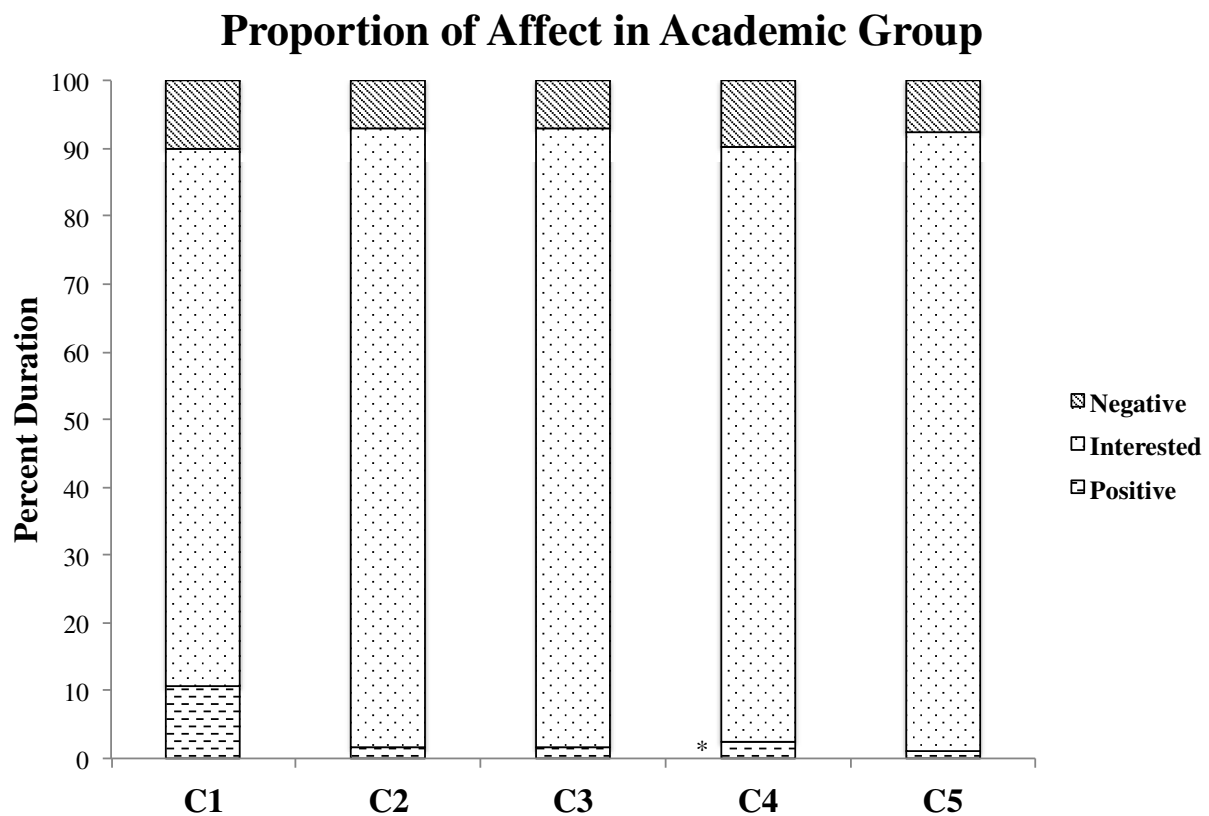


Figure 8: Durations of affect across conditions in the academic group. Note: C1 = Hello & Farewell, C2 & C3 = Reading. C4 = Building, C5 = Arts & Crafts.

Overall all the conditions generated higher levels positive levels and engagement in the academic group. There were no condition related differences for negative affect in the academic group.

### **Summary of Affect Results**

In terms of between-group differences, the music group displayed the most positive affect followed by the academic group and lastly, the robot group. The academic group showed the highest levels of interested affect compared to the other two groups. Lastly, both music and robot groups showed similar levels of negative affect compared to the academic group.

In terms of within-group differences, the music group enjoyed Hello Song, Farewell Song, and Moving Game by showing higher positive affect compared to other conditions. Children showed the most compliance and interested during Hello Song and Farewell Song. For the remaining conditions, Action Song, Beat Keeping, and Music Making, the music group showed greater negative affect. The robot group enjoyed Warm-up Game and showed the most compliance and interest during Walking Game. Hello, Farewell, Action Game, and Drumming Game were not as enjoyable given the greater negative affect observed. The academic group enjoyed Hello, Farewell, and Building compared to other conditions. They showed the most compliance and interest in Reading and Arts & Crafts compared to the other conditions. There were no condition-related differences for negative affect.

### **Discussion of Results**

#### *Greater Positive Affect and Condition-Related Negative Affect in the Music Group*

The music group displayed the most positive affect as compared to the robot or academic groups. These findings are similar to those of Kim et al. (2009), which reported greater positive affect and compliance in children with ASDs participating in improvisational music sessions

compared to toy play sessions. Specifically, the children were more joyous and initiated joint engagement bids during the music sessions. This could have been due to their inherent musical attunement. Several factors could be responsible for the positive affect results observed in the music group. Children with ASDs have a predilection for music, indicated by better pitch discrimination, perception, and disembedding skills as compared to typically developing peers (Heaton, 2003; Altgassen et al., 2005; Bonnel et al., 2003). Children with ASDs showed better performance levels in pitch discrimination, i.e. the ability to identify individual notes as well as notes within musical chords (Heaton, 2003). Additionally, children with ASDs showed differential perception for music tones and successfully categorized high and low pitched tones (Bonnel et al., 2003). Lastly, children with ASDs have also shown superior disembedding skills, i.e. the ability to recognize different notes played within the same chord (Altgassen et al., 2005). In this study, different music tones, instruments, and songs were used to give opportunities to perceive high and low pitched music while enjoying the music. This enjoyment was seen in the greater number of smiles in the music group, as they displayed more positive affect compared to the robot and academic groups.

Children with ASDs in the music group enjoyed Hello Song, Farewell Song, and Moving Game compared to other training conditions. Hello and Farewell songs were used to note the start and end of each session, by singing “hello” and “good-bye” to the child, trainer, and model. During these songs, the use of greetings, eye contact, singing, and hand gestures such as waving and patting were emphasized. The children learned and enjoyed the songs while developing preferences for particular songs towards the end of the training. These activities may have been more familiar to the children due to continuous practice in school settings and hence, enjoyable. In addition, Moving Game emphasized whole body coordination during complex rhythmic

actions such as marching, jumping, and skipping, as well as social monitoring, interpersonal synchrony, and singing. It is possible that the children may have enjoyed the freedom to stand and move their whole bodies to music while synchronizing their actions with others. Such group-based whole body experiences may promote turn taking, joint attention, and social connections with other individuals (Kim et al., 2009). Children with ASDs improved joint attention behaviors such as turn taking and eye contact following improvisational music sessions compared to play sessions (Kim et al., 2008). Overall, the content developed within each of the aforementioned conditions could have been more enjoyable to the children resulting in the increased positive affect found in this group.

Children in the music group did not find certain training conditions enjoyable; these were Action Song, Beat Keeping, and Music Making. This could be attributed to the nature and complexity of the motor activities involved in these training conditions. As discussed earlier, Action Song, Beat Keeping, and Music Making included a range of fine and gross motor activities, which could have challenged the motor repertoire of children with ASDs. Children with ASDs present with fine motor and gross motor deficits, poor imitation and praxis on movement sequences, as well as poor interpersonal synchrony during continuous rhythmic actions (Dewey et al., 2007; Lopata et al., 2007; Miyahara et al., 1997; Stone et al., 1997; Vanvuchelen et al., 2007; Provost et al., 2007; Mostofsky et al., 2006). Specifically, deficits in fine motor skills such as manual dexterity (Miyahara et al., 1997; Stone et al., 1997; Vanvuchelen et al., 2007; Provost et al., 2007) and gestures (Mostofsky et al., 2006), as well as poor visuo-motor coordination (Dewey et al., 2007; Lopata et al., 2007), would lead to increased difficulty imitating Action Song sequences or xylophone patterns during Music Making and thus resulted in the disinterested and negative affect found during these conditions.

Children with ASDs show poor interpersonal synchrony, i.e., difficulty synchronizing their actions with others (Marsh et al., 2013; Colombi et al., 2009). In a rocking chair paradigm in which children had to synchronize with a parent, children with ASDs showed significantly less in-phase coordination as compared to typically developing children (Marsh et al., 2013). Similarly, poor performance in children with ASDs was observed during socially cooperative tasks and was attributed to poor skills in imitation and social monitoring skills (Colombi et al., 2009). Therefore, children's difficulties in social monitoring may have complicated Beat Keeping and Music Making, which involved group synchronization. On the other hand, increased variability during bimanual drumming have been observed in children with ASDs, with the suggestion that their inability to perform consistent drumming actions may affect their ability to synchronize actions with others (Isenhower et al., 2012). All these deficits in interpersonal synchrony, along with the complex motor tasks, may have lead to the disinterest and negative affect captured in these conditions in this study.

#### *Reduction in Positive Affect and a Greater Negative Affect with Training in the Robot Group*

The robot group showed reduced positive affect with training along with higher durations of disinterest or negative affect. These negative and disinterest behaviors included pouting, frowning, and clear facial distress as well as looking away from the trainers. The lab's past work (Srinivasan & Bhat, 2013) with two children with ASDs also showed similar results. The children showed a steady decline of attention towards the robot and an increase in attention towards elsewhere over training, i.e. anywhere other than the robot or trainer. Similarly in the current study, the novelty of the robot may have reduced over time, leading to boredom and reduced positive affect towards the later training sessions.

The current findings do not fit the existing literature on socially assistive robotics in children with ASDs, specifically studies with the NAO robot, which were able to maintain the child's interest in the training along with improvements in joint attention (Zheng et al., 2013; Bekele et al., 2013; Warren et al., 2013) and spontaneous communication skills (Huskens et al., 2013). However, these contrasting findings could be attributed to the differences in the training duration among the studies. A majority of the NAO robot studies included just one (Bekele et al., 2013), four (Zheng et al., 2013; Warren et al., 2013), or 10 (Huskens et al., 2013) training sessions as compared to my relatively long timeline of 16 sessions conducted over eight weeks with two sessions per week. Our findings suggest that these existing studies capitalized and reported on the initial excitement and interest observed in children during interactions with NAO, but somehow neglected the effects of long-term use of robots in this population. This study showed that the NAO robot was unable to sustain engagement with children with ASDs across several weeks of training.

The present study found that NAO robot's limited repertoire in speech, fine and gross movements, as well as balance limited its range of activities and ability to engage the children with a variety of interactive games. In addition, the robots could not contingently respond to the child's needs as the majority of the interactions were preprogrammed and as a result, stunted in nature. When children were first introduced to the robot, they were excited about this new social entity but were unaware of the motor repertoire of the robot. Over time they possibly realized that the robot was unable to adapt to their behaviors and expectations, which may have contributed to their growing disinterest. Specifically, the children in the robot group did not enjoy the majority of the training conditions including Action Game and Drumming Game. The repetitive and simple arm/hand movements in the latter two conditions added to the child's



disinterest or negative affect during the training sessions. Additionally, technical issues including robot failures requiring rebooting also contributed to disinterest of the child in the training sessions. Taken together, these limitations may have led to the overall disinterest or negative affect during training.

On the other hand, there are long-term robot training studies reporting positive effects on imitation, turn taking, and social interaction skills of children with ASDs while maintaining the child's interest throughout the training (Robins et al., 2005; Kozima et al., 2009; Robins et al., 2004; Robins et al., 2009). Specifically in these studies, an autonomous robot was used as a mediator and an object of shared attention between the child and adult, not as the main investigator. Keepon, designed for nonverbal social interactions with typically developing children as well as children with ASDs, led to an increase in interpersonal communication between the robot and the child (Kozima et al., 2009). KASPAR, a minimally expressive humanoid robot, was a successful social mediator in facilitating social interactions between the children and the caregiver through increased imitation, eye contact, and turn taking skills (Robins et al., 2009). Robota, another humanoid robotic doll, was also a successful social mediator in joint attention skills between the robot, child, and the adult caregiver, and led to an increase in shared joint attention as well as in gestural skills such as looking and pointing towards the robot (Robins et al., 2004). Additionally, Robins et al. (2009), suggested the repeated exposures to the robot did not lead to a decrease in interest, but instead, allowed the children to explore various robot-human interactions and over time, increased their social skill such as imitation and turn taking. Timelines for these studies varied from 15 sessions over five months to 39 sessions over 17 months (Keepon), 15 sessions over 12 weeks, with an average of nine trials (Robota), and a one-time session to several months (KASPAR). However, in these

studies, an autonomous robot was used as a mediator and an object of shared attention between the child and adult. In this study, the robot's served the role of an expert trainer, with the human adult simply controlling the laptop and giving additional feedback to the child if needed. Careful considerations should be taken when interpreting studies involving robots; results could differ from study to study based on timelines, as well as the type of robots used in the study. Based on our results, I would suggest that robots should be used as an adjunct to the therapist or clinician and should be used cautiously to avoid negative results.

#### *Greater Interested Affect in the Academic Group*

The academic group consistently showed positive or interested affect, indicating greater enjoyment and compliance, compared to the other two groups. For the majority of the sessions, the children did not show any negative affect and enjoyed all the training conditions, especially Building. Children with ASDs are familiar with the standard of care interventions often incorporated in the academic activities such as reading, writing, and arithmetic, as well as other activities involving basic cognitive and problem-solving skills (Lovaas, 1987; Landa, 2007; Dunlap et al., 2001; Rosenwasser & Axelrod, 2001; Koegel et al., 2001; Virues-Ortega et al., 2013). These interventions focus on modifying the behavior and the environment of the child (Dunlap et al., 2001) to improve the social, communication, and behavioral skills through structured teaching (Bondy & Frost, 1994; Schopler et al., 1995; Mesibov et al., 2005; Ozonoff & Cathcart, 1998). They employ various methods, including modifying the task size or duration, adding students' interests into traditional curriculum activities (Kern et al., 2000) providing the opportunities for choice making (Dunlap et al., 1994), as well as presenting a variety of tasks (Dunlap, 1984).

Similar standard of care interventions were incorporated within our academic group. Multiple repetitions of activities, positive gestural and verbal reinforcement, spontaneous exploration time, graded prompting (verbal and visual model, followed by hand-on-hand assistance if needed), PECS boards, as well as consistency among people and materials involved in the sessions were also included. ABA interventions have decreased destructive (McComas et al., 2000) or disruptive behaviors and have shown improved interest and performance in academic tasks (Koegel et al., 2010) such as math and writing activities. The activities in this study were academic-based, giving the children a familiar set of activities to practice in the training session. Additionally, all the activities were performed while seated at a table and guarded by the trainer and the model on both sides, which gave fewer opportunities to the child to demonstrate off task behaviors including running away from the table.

Among the different training conditions, the academic group children enjoyed Building and were compliant during Reading and Arts & Crafts. Building included the use of LEGO®, Play-Doh®, and Zoob supplies to make various creations. The activities were structured and predictable as we used a sequence of visual instructions along with prompting to guide the children to make the creations. In a comparison of different forms of play in groups of children with autism, behavior disorders, and IQ-matched typically developing children, construction play showed the second highest amount of positive social interactions between the different groups of children, possibly due to the compelling structure of the toys and the children's preference for objects (Dewey et al., 1988). Specific studies on LEGO® therapy have shown improved social skills in children with ASDs (Owens et al., 2008; Legoff & Sherman, 2006). LEGO® therapy involves group collaboration projects in building, with each person designated as the engineer (reads the directions), the supplier (finds the pieces needed to build), or the builder (follows the

directions of the engineer and puts the pieces together). Roles are switched once a task is completed. LEGO® therapy uses these methods to promote collaborative play, requiring both verbal and non-verbal communication, joint problem solving, and attention to the task, such as eye contact and turn taking (Owens et al., 2008). Children who received LEGO® therapy reduced their maladaptive behaviors following training compared to a non-LEGO® group. The present study included similar skills, i.e. turn taking and eye contact, to promote play and assisting each other to construct specific projects, resulting in the academic group displaying the most interested and compliant behavior as the aforementioned studies.

Children with ASDs are familiar with structured environments; therefore, a structured toy is something they could easily adjust towards, particularly with the visual instruction guides provided to the children in our study. Studies have also shown children with ASDs and infants who later developed autism have unusual preferences for objects and attend to objects for longer durations (i.e. non-social attention) when compared to social attention towards caregivers or experimenters (Chawarska, 2012; Shic & Charwarska, 2011; Swettenham, 1998). In general, this unusual object preference that is often associated with this population was not promoted. This study focused on prompting social interaction throughout all the conditions. The child was given multiple opportunities to show off their creations, to make choices in various colors or in building pieces, and in sharing and commenting on their creations. However, it is possible that this preference towards objects among children with ASDs could partially be responsible for more positive affect demonstrated during Building. In all, children were familiar with all the activities included in the academic group. They have seen and played with these toys at school or home settings and are toys that children would enjoy playing with (structure of toys and reward of accomplishing building an item). Thus, the ensured structure and familiarity in

materials may have lead to the overall compliance in the academic group, as well as the enjoyment in Building.

## **Chapter 7: Results and Discussion on Motor Performance**

### **Baseline Results**

#### *MABC-2*

Thirty-four of the 36 children participated in the MABC-2. There were no significant differences between groups ( $p > 0.05$ ). Results suggested the following: three out of 10 children in the music group, two out of 12 children in the robot group, and four out of 12 children in the academic group scored in the “green” zone; one child in the music group, two children in the robot group, and no children in the academic group scored in the “amber” zone; and lastly, six children in the music group, eight children in the robot group, and eight children in the academic group scored in the “red” zone. These results highlight that children in this population and more specifically, in this sample size, have problems with motor performance.

### **Synchrony Results: Condition- and Training-Related Changes in Interpersonal Synchrony in the Music Group**

A full model ANOVA revealed a main effect of Variable ( $F(2,10) = 340.772$ ,  $p = 0.000$ ),  $\eta^2 = 0.986$ ), a Variable x Condition interaction ( $F(4,8) = 6.737$ ,  $p = 0.01$ ),  $\eta^2 = 0.771$ ), and a Variable x Session interaction ( $F(4,8) = 8.712$ ,  $p = 0.005$ ),  $\eta^2 = 0.813$ ). I examined these interactions using post-hoc analyses to determine within-group, condition-related and training-related differences in synchrony for the music group.

#### *Condition-Related Differences*

The music group had maximum in-synchrony during Music Making ( $M = 57.76$ ,  $SD = 31.09$ , range = 0 – 95.48, see Figure 9a), followed by Moving Game ( $M = 49.13$ ,  $SD = 23.46$ , range = 4.47 – 92.49) compared to Beat Keeping ( $M = 39.48$ ,  $SD = 31.61$ , range = 1.03 – 92.85,

$p < 0.05$ ). In terms of individual differences 8 out of 12 children followed the group trends. Children in the music group had maximum out-of-synchrony during Beat Keeping ( $M = 51.53$ ,  $SD = 26.52$ , range = 7.15 – 93.61) and Moving Game ( $M = 49.71$ ,  $SD = 21.66$ , range = 7.51 – 87.64) compared to the Music Making ( $M = 34.57$ ,  $SD = 24.12$ , range = 4.32 – 79.21,  $p < 0.01$ ). In terms of individual differences 8 – 9 out of 12 children followed the group trends. Lastly, the music group required the most assistance during Beat Keeping ( $M = 8.99$ ,  $SD = 11.70$ , range = 0 – 52.52) and Music Making ( $M = 7.67$ ,  $SD = 9.99$ , range = 0 – 34.88) compared to Moving Game ( $M = 1.16$ ,  $SD = 4.03$ , range = 0 – 17.73,  $p < 0.01$ ). In terms of individual differences 8 out of 12 children followed the group trends. Overall it appears children in the music group synchronized well with others in Music Making, followed by Moving Game, and lastly, Beat Keeping.

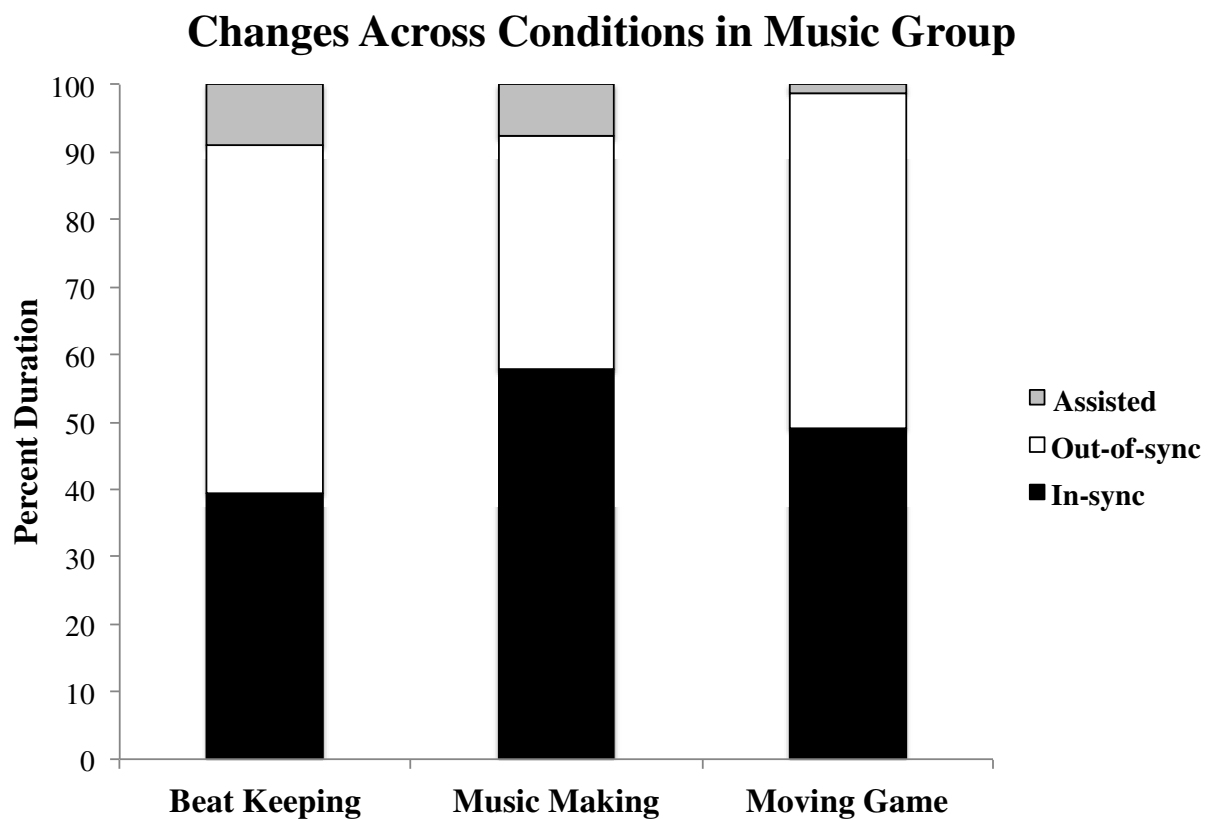


Figure 9a: Durations of synchrony across conditions in the music group.

### *Training-Related Differences*

The music group had greater in-synchrony during the late session ( $M = 52.91$ ,  $SD = 30.57$ , range = 4.19 – 92.85,  $p < 0.05$ , see Figure 9b) compared to the early session ( $M = 45.59$ ,  $SD = 29.45$ , range = 1.03 – 95.48). In terms of individual differences 7 out of 12 children followed this group trend. There was a decrease in assisted synchrony in the late session ( $M = 4.02$ ,  $SD = 7.43$ , range = 0 – 29.86) compared to the mid ( $M = 7.09$ ,  $SD = 12.26$ , range = 0 – 52.52) and early sessions ( $M = 6.71$ ,  $SD = 8.82$ , range = 0 – 31.43,  $p < 0.1$ ). In terms of individual differences 7 – 8 out of 12 children followed the group trends. Overall with training, children in the music group increased their in-synchrony behaviors while reducing assisted synchrony.



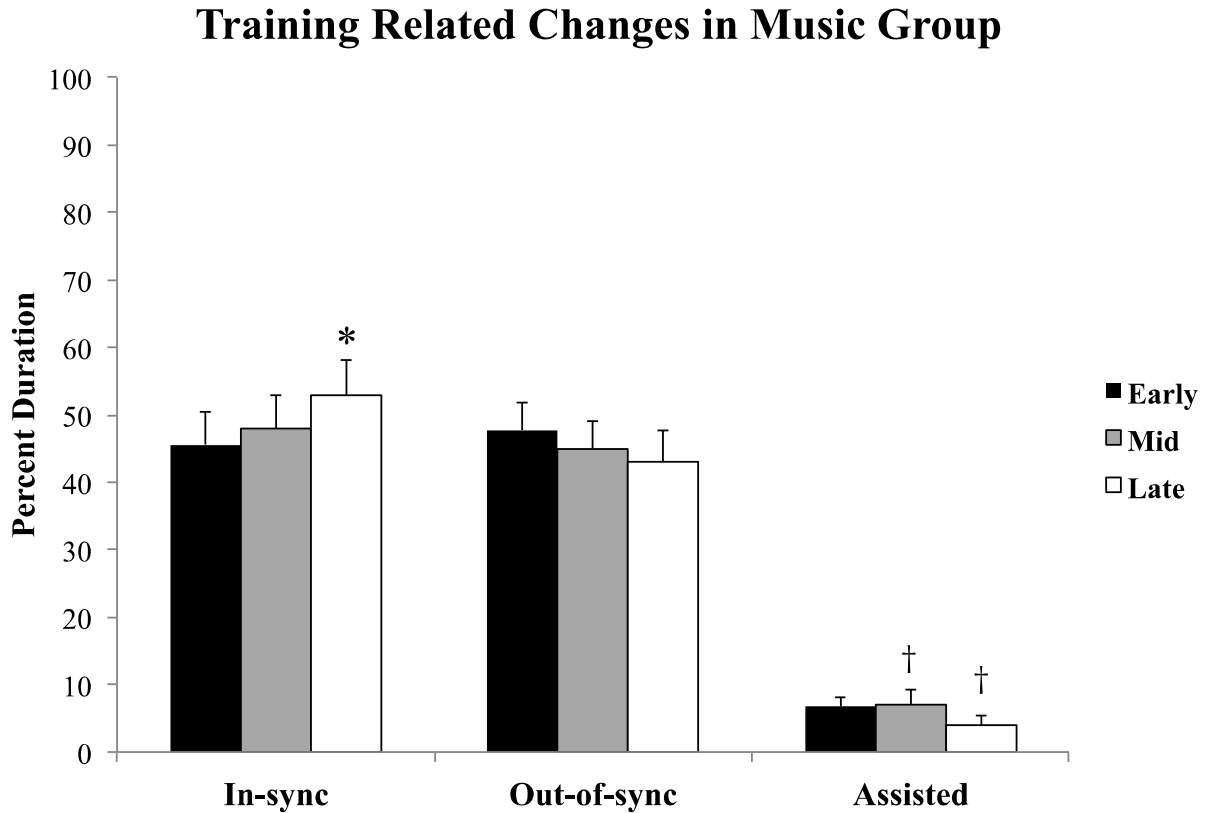


Figure 9b: Durations of synchrony across training in the music group.

### Synchrony Results: Condition-Related Changes in Interpersonal Synchrony in the Robot Group

A full model ANOVA revealed a main effect of Variable ( $F(2,10) = 6.933$ ,  $p = 0.01$ ),  $\eta^2 = 0.581$ ) and a Variable  $\times$  Condition interaction ( $F(4,8) = 5.263$ ,  $p < 0.05$ ),  $\eta^2 = 0.725$ ). I examined this interactions using post-hoc analyses to determine within-group, condition-related differences in synchrony for the robot group.

In terms of condition-related differences, the robot group had maximum in-synchrony during Walking Game ( $M = 58.86$ ,  $SD = 21.85$ , range = 16.92 - 100,  $p < 0.01$ , see Figure 10), then Action Game ( $M = 39.61$ ,  $SD = 32.90$ , range = 0 - 96.21,  $p < 0.05$ ), as compared to

Drumming Game ( $M = 30.08$ ,  $SD = 27.26$ , range = 0 – 91.25). In terms of individual differences 6 - 12 out of 12 children followed the group trends. Children in the robot group had maximum out-of-synchrony during Drumming Game ( $M = 45.40$ ,  $SD = 21.23$ , range = 5.01 – 97.00,  $p < 0.05$ ), as compared to Action Game ( $M = 33.47$ ,  $SD = 20.54$ , range = 3.79 – 86.10) and Walking Game ( $M = 41.14$ ,  $SD = 21.85$ , range = 0 – 83.08). In terms of individual differences 10 out of 12 children followed the group trend. Lastly, the robot group required the most assistance during Action Game ( $M = 26.92$ ,  $SD = 30.58$ , range = 0 – 86.22) and Drumming Game ( $M = 24.52$ ,  $SD = 24.27$ , range = 0 – 86.11), as compared to Walking Game ( $M = 0$ ,  $SD = 0$ , range = 0 – 0,  $p < 0.01$ ). In terms of individual differences 8 - 11 out of 12 children followed the group trends, respectively. Overall it appears children in the robot group synchronized well with others in Walking Game, followed by Action Game, and lastly, Drumming Game.

There were no training-related differences in the robot group.

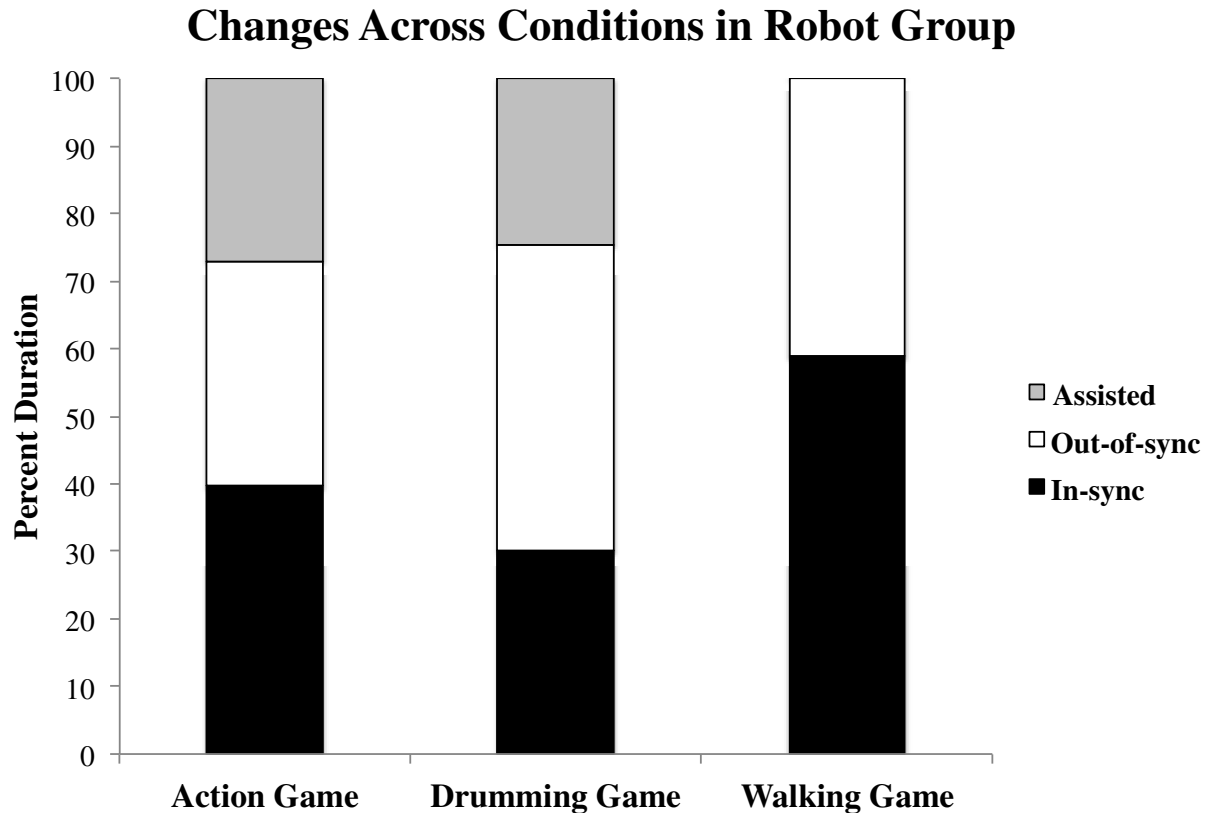


Figure 10: Durations of synchrony across conditions in the robot group.

### Summary of Synchrony Results

In the music group there were both condition- and training-related differences for interpersonal synchrony. Children in the music group showed maximum in-synchrony during Music Making and maximum out-of-synchrony during Beat Keeping and Moving Game. They required the most assistance during Music Making and Beat Keeping. Children also showed greater in-synchrony during the late session as compared to the early session, as well as a decrease in assisted synchrony in the late session compared to the early and mid sessions, indicating an improvement in interpersonal synchrony after training.

Children in the robot group had maximum in-synchrony during Walking Game and Action Game and maximum out-of-synchrony in Drumming Game. They required the most assistance

during Action Game and Drumming Game. There were no training-related differences in the robot group.

## **Discussion of Synchrony Results**

### *Greater Interpersonal Synchrony with Training in the Music Group*

Interpersonal synchrony encompasses both motor skills such as limb coordination and imitation, as well as social skills such as social monitoring and sustained eye contact. Children with ASDs have difficulties with both the motor coordination and social components of synchrony. The children in the music group showed greater interpersonal synchrony skills in the late session than early session, indicating an improvement with training. I feel these improvements could be due to improved social monitoring skills with the music training. There is evidence in the literature suggesting social monitoring skills such as social attention and looking can improve after music-based therapy in children with autism (Kim et al., 2008; Wimporary et al., 1995; Stephens, 2008). Improvisational Music Therapy (IMT) has been effective in increasing such social attention skills in children with autism. When compared to a toy play session, the IMT sessions resulted in significant improvements in eye contact, as well as longer turn-taking skills in children with autism (Kim et al., 2008). Musical Interaction Therapy (MIT), which synchronizes live music to adult-child interactions, focuses on interpersonal contact and joint attention skills in children with autism. After two years of a MIT training intervention, a child with autism improved in social acknowledgement, eye contact, and initiations of social interactions. These skills were maintained even after a two-year follow-up (Wimpory et al., 1995). Similarly, music has been used through dance and instrument imitation play to promote spontaneous social relating skills. After a child-led social routine in which the adult imitated the child, children with autism learned and demonstrated shared social attention on

imitation behaviors with the researcher within the musical routine (Stephens, 2008). Overall, children with autism could benefit from music-based interventions that focus on improving social monitoring skills, which can lead to improved interpersonal synchrony skills.

Improvement in synchrony skills may have also been a result of improved motor coordination skills over training. These whole-body coordination skills require both gross motor skills as well as visuo-motor skills. Music- and movement-based interventions have shown improvements in such motor skills such as jumping and balancing for typically developing children. With a focus on three types of movement - percussion movements (clapping, patting knees, tapping floor with feet), readiness and reaction movements, and improvisation and creative movements, children improved their performance on post-test measures as compared to the control group, which received similar training without a rhythmic component. These results indicated that with developmentally appropriate music and movement programs, children could improve performance of gross motor skills (Zachopoulou et al., 2004). Following a music- and movement-based program that involved improvisation and creativity skills and movements using instruments, children also showed greater improvements in galloping, leaping, horizontal jumping, and skipping skills as compared to a control group (Ulrich & Ulrich, 1985). A similar training program, which included repeated rhythmic exercises to train for precision of movements as well as singing games, showed improvements in the perceptual-motor performance of children post-training (Brown et al., 1981), providing further evidence for the use of music integration into physical and movement-based interventions.

#### *Condition-Related Changes in Interpersonal Synchrony in the Music Group*

The condition-related changes observed in the music group demonstrate that the children's performance is really a function of the nature of the activities (Provost et al., 2007;

Green et al., 2009; Fournier et al., 2010; Mostofsky et al., 2007; Marsh et al., 2013; Isenhower et al., 2012). Children showed maximum in-synchrony during Music Making and maximum out-of-synchrony during Beat Keeping and Moving Game. Music Making was generally easier, including symmetrical drumming to simple and alternating drumming patterns. Most of the children easily imitated the pattern and were able to repeat it after a few practice trials. While children with ASDs are unable to sustain complex drumming patterns, they are able to keep up with simple, in-phase patterns and resort back to this when asked to complete a more difficult pattern (Isenhower et al., 2012). Both Beat Keeping and Moving Game involved complex motor actions. Beat Keeping included bilateral arm and hand coordination during a musical beat, while Moving Game involved whole body coordination during difficult rhythmic actions such as marching, jumping, and skipping. Both conditions required constant social monitoring and interpersonal synchrony skills. This would be difficult for children with autism, as this population often displays fine motor and gross motor impairments, poor imitation and praxis skills, and difficulties with interpersonal synchrony during rhythmic actions (Provost et al., 2007; Green et al., 2009; Fournier et al., 2010; Mostofsky et al., 2007; Marsh et al., 2013). More specifically, they always show poor visuo-motor coordination (Dewey et al., 2007; Lopata et al., 2007) and manual dexterity (Miyahara et al., 1997; Stone et al., 1997; Vanvuchelen et al., 2007), both required for imitating and coordinating within a social setting.

#### *Lack of Training-Related Changes in Interpersonal Synchrony in the Robot Group*

There were no training-related changes observed for interpersonal synchrony in the robot group. This could be due to various factors, including the limited repertoire of the robot's actions. NAO's limitations in speech, fine and gross movements, as well as balance restricted its range of activities and ability to adapt to the children's behaviors. The movements of the robot

were stereotypical and mundane, which could have led to boredom or disinterest over time in the children. This could have made them lose the motivation to continue to move in synchrony with the robot. NAO also had some technical issues, including failures requiring rebooting and lack of response to the children's spontaneous movements or bids, as well as a mismatch of the verbal cues from NAO and the actions being performed. There were also times when the actions were not very clear to the children, as NAO's range of motion was so small. This could have led to less time in-synchrony between the child and NAO.

The lack of training-related changes in the robot group could have also been a function of the activities performed. The movements of the robot were fairly simple, leaving no room for improvement as the children were already performing at their ceiling level. For some of the more difficult movements, such as drumming, the pattern proved to be too difficult for the children. The quarter and eighth note patterns, combined with NAO's limited actions, were too hard for the children to synchronize with. Overall, the robot-based intervention was not engaging or necessarily appropriate to promote long-term interpersonal synchrony skill improvement in children with ASDs.

#### *Condition-Related Changes in Interpersonal Synchrony in the Robot Group*

The condition-related changes observed in the robot group could have been due to the nature of the activities. Children showed maximum in-synchrony during Walking Game and Action Game and maximum out-of-synchrony during Drumming Game. Walking Game and Action Game were simple tasks that involved following Rovio to trace out letters and shapes on the floor or following Nao during repetitive arm and hand movements, respectively. During Walking Game, this was the only condition in which a different robot was used with the children.

Rovio was engaging and motivating for the children, as they had to guess which letter or shape they were tracing. During Action Game NAO conducted movements at a relatively slow pace, one that a child would be able to keep up and synchronize with. The pattern during Drumming Game was faster and more complex. Children may have had difficulty keeping up with the robot's pace. Unlike the music human trainer, the pre-programmed robot did not have the ability to adapt to the child's speed and level of drumming. Based on the results of the children's performances across conditions, a robot-based intervention may not be the ideal intervention for this population. While the robot novelty may appeal to the children at first, there are many limitations that come with using the robot for increasing interpersonal synchrony skills over training with our protocol.

### **Results: Changes in Praxis on Imitation**

Wilcoxon's nonparametric tests revealed a statistical trend for decrease in the total number of errors for all three groups in the posttest compared to the pretest (music: pretest = 33.38, posttest = 25.13,  $p < 0.10$ ,  $z = -1.893$ , robot: pretest = 26.63, posttest = 21.38,  $p < 0.10$ ,  $z = -1.577$ , academic: pretest = 21.11, posttest = 14.89,  $p < 0.10$ ,  $z = -1.680$ , see Figure 11a). In terms of time to best effort, only the music group (pretest = 3.49, posttest = 3.02,  $p < 0.01$ , see Figure 11b) showed a significant decrease in the amount of time to best effort in the posttest compared to the pretest. The academic and robot groups did not show any differences in their post-training time to best effort.



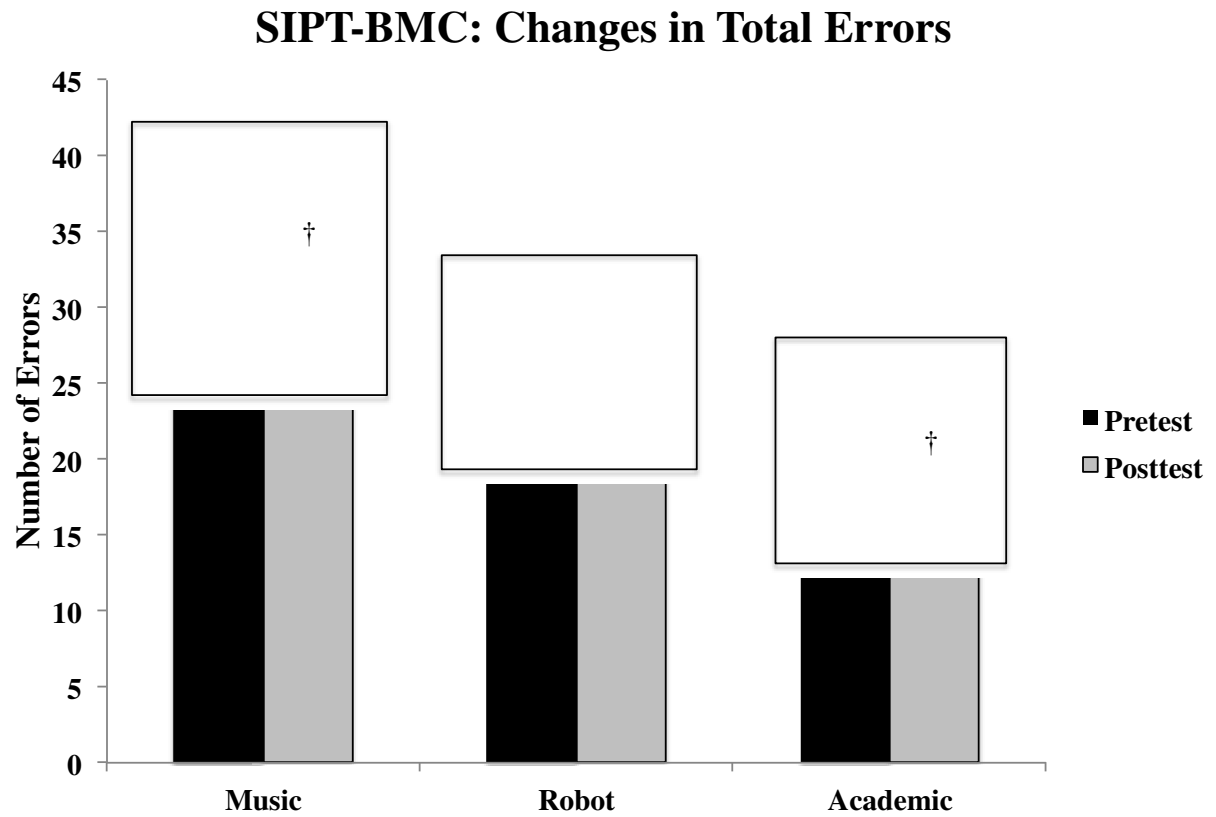


Figure 11a: Changes in total number of errors in SIPT.

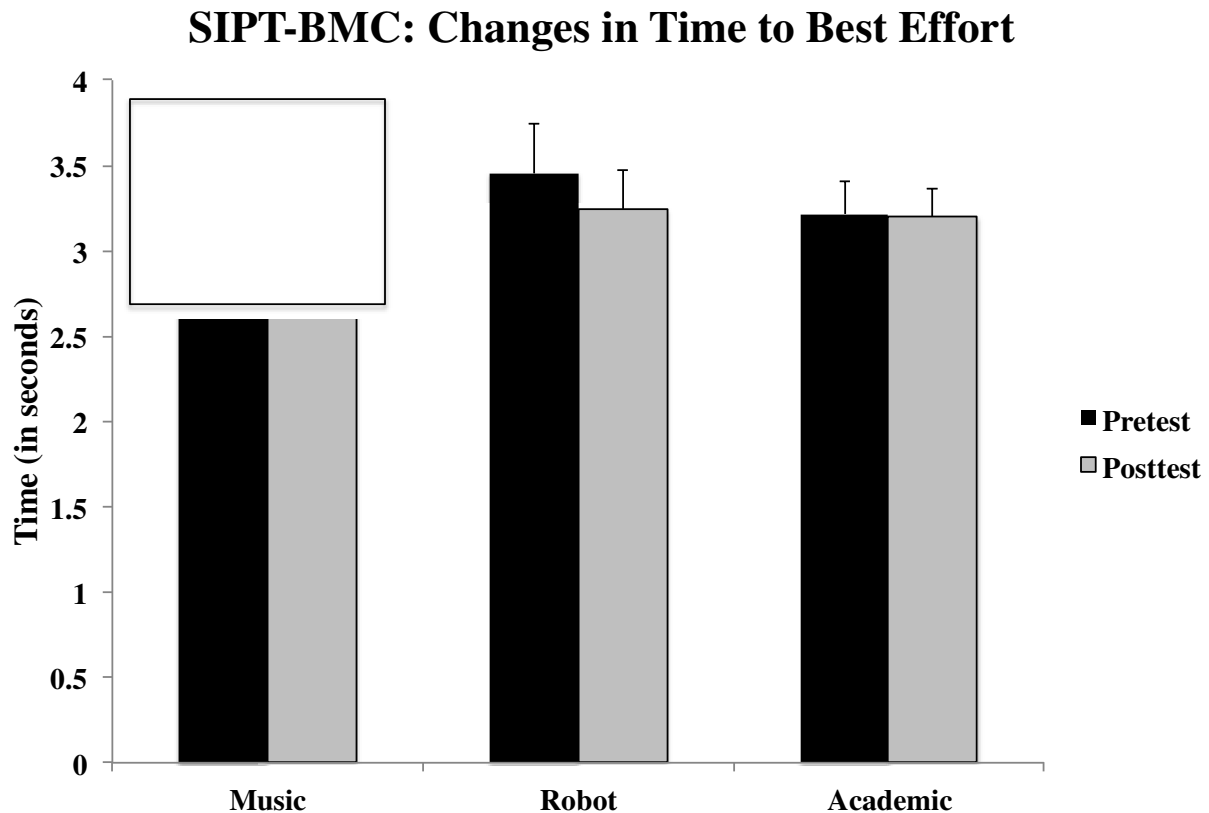


Figure 11b: Changes in time to best effort in SIPT.

## Discussion of Praxis on Imitation Results

### *Changes in Praxis on Imitation Skills with Training for All Three Groups*

All three groups, music, robot, and academic showed a trend for decrease in praxis errors. Specifically, these changes were seen in the total number of errors post-training. This indicates that these trends for improvements could be due to effects of repeated testing, that is the children simply showed an improvement in the posttest from remembering or practicing the movements in the pretest. Additionally, the SIPT standardized testing measure may not have been sensitive enough to capture the possible small changes in the children, post training. The trend for

decrease in total number of errors cannot be attributed to the training, as all three groups showed the same trend.

#### *Changes in Time to Best Effort with Training for Music Group*

The music group was the only group that showed a significant reduction in time taken to complete the actions post-training. This decrease in time to best effort could be due to some carry over from the activities practiced within the music conditions. Typically developing children have shown better performance in a fine motor learning task, which involved performing a timed, 4-finger sequence pattern, after receiving at least three years of instrumental music training in piano, violin, or cello (Forgeard et al., 2008). Similarly in the present study, children in the music group were given multiple opportunities to practice with a variety of instruments, which could have contributed to their increase in motor skills and speed.

## **Chapter 8: Overall Summary and Future Directions**

### **Clinical Implications**

I feel that music therapy interventions could be beneficial for children with ASDs, given the greater amounts in positive affect as well as motor improvements in interpersonal synchrony and praxis skills. Musical activities are valuable therapeutic contexts because they are engaging to children with ASDs and promote positive affective states in a population that typically has a flat or neutral affective state (Katagiri, 2009; Heaton et al., 1999; Allen et al., 2009), as well as promoting social monitoring skills and potential motor skills (Srinivasan & Bhat, 2013; Kim et al., 2008; Wimpory et al., 1995; (Zachopoulou et al., 2004).

Robotics is a novel intervention tool; it appears to be an exciting social entity for children with ASDs but should be used with caution, as I observed boredom in children in the robot group. It does not seem to have the same effect in terms of synchrony and praxis improvements in this population of children. While robots could be a favorable adjunct to the trainer, they cannot be a standalone intervention. Perhaps with modifications to the limitations of the robot, they could be potentially used to address affective or motor impairments of ASDs.

Sedentary interventions like the academic-based intervention do have some value in improving fine motor and praxis skills. Therefore, they can be helpful in addition to the suggested music-based intervention. The academic group interventions are typically preferred because it is easier for clinicians to control the child and environment but there is a need for more movement-based interventions, which have the potential to impact the primary social-communication impairments as well as the secondary perceptuo-motor impairments of this population.

## **Study Limitations**

While this preliminary study showed promising results, there were limitations in the design of the study. There was a clear lack of blinding; the coder was able to see the grouping of each child across all three groups. There was no follow-up study conducted after the posttests; therefore, I cannot assume the observed changes generalized over time to new or real life situations after the intervention had ended. In terms of training activities, multiple repetitions of each activity may have lead to boredom and disinterest, seen by the increase in negative affect in some of the children during the training sessions in the music and robot groups. Particularly for the robot group, the trainer was limited in terms of working with the child because they had to control the robot. The robot movements were predictable and repetitive, which lead to boredom and disinterest over time. The robot was also unable to respond appropriately to the child's actions and behaviors, unlike the human trainer in the music group, who was able to adapt to the child. There were delays in the robot's response to the child's bids/conversations due to software issues when a non pre-programmed response had to be used. This was only a pilot randomized controlled trial. There is need to study the efficacy of these interventions on larger samples of children, with better control over study design and implementation.

## **Conclusions**

This study compared two novel interventions, music and robot, to the traditional academic intervention typically received by children with ASDs. I specifically examined the effect of these interventions on the affective states, along with the interpersonal synchrony and praxis skills of children with ASDs. I found that the music group showed the highest amount of positive affect, while the robot group showed more disinterest or negative states of affect. The

academic group showed the most interested or compliant affect compared to the other two groups.

In terms of synchrony, I found that the music group showed both condition and training-related changes, with an increase in interpersonal synchrony skills over training. The robot group showed only condition-related changes. In terms of praxis skills, all three groups showed a trend for differences in total number of errors, post-training. Only the music group showed a significant decrease in time to best effort, post-training.

Although a pilot project, these results suggest that music-based interventions are engaging and exciting for children with ASDs and can address the affective states of this population. I also feel there is enough evidence to support music-based interventions for synchrony and praxis improvements in children with ASDs. It is the first, to my knowledge, music-based intervention that focused on the interpersonal synchrony and praxis impairments in children with ASDs. The findings of this study highlight the importance of the need for an intervention that focuses on motor impairments in children with ASDs. Further research in this field should be conducted through replications of this study to see if similar results can be found with larger samples.

## Appendix

### a. Scoring sheet for BMC subtest of SIPT

ID #: \_\_\_\_\_

Circle one: Pretest/Posttest

Coder's initials \_\_\_\_\_

	Segmentation Error	Rhythmicity Error	Sequencing Error: Omit/Merge/Add	Mirroring Error	Movement Overflow Error	Body Part Error	Time to Best Effort (sec)
1.	Y / N	Y / N	O / M / A	Y / N	Y / N	Y / N	
2.	Y / N	Y / N	O / M / A	Y / N	Y / N	Y / N	
3.	Y / N	Y / N	O / M / A	Y / N	Y / N	Y / N	
4.	Y / N	Y / N	O / M / A	Y / N	Y / N	Y / N	
5.	Y / N	Y / N	O / M / A	Y / N	Y / N	Y / N	
6.	Y / N	Y / N	O / M / A	Y / N	Y / N	Y / N	
7.	Y / N	Y / N	O / M / A	Y / N	Y / N	Y / N	
8.	Y / N	Y / N	O / M / A	Y / N	Y / N	Y / N	
9.	Y / N	Y / N	O / M / A	Y / N	Y / N	Y / N	
10.	Y / N	Y / N	O / M / A	Y / N	Y / N	Y / N	
11.	Y / N	Y / N	O / M / A	Y / N	Y / N	Y / N	
12.	Y / N	Y / N	O / M / A	Y / N	Y / N	Y / N	
13.	Y / N	Y / N	O / M / A	Y / N	Y / N	Y / N	
14.	Y / N	Y / N	O / M / A	Y / N	Y / N	Y / N	
15.	Y / N	Y / N	O / M / A	Y / N	Y / N	Y / N	
16.	Y / N	Y / N	O / M / A	Y / N	Y / N	Y / N	
17.	Y / N	Y / N	O / M / A	Y / N	Y / N	Y / N	

18.	Y / N	Y / N	O / M / A	Y / N	Y / N	Y / N	
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Note: Y stands for Yes (or presence of errors)

N stands for No (or absence of errors)



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