MASSEY, SARA MILLER, PhD. The Effects of Auditory-Motor Mapping Training on Speech Output of Nonverbal Elementary Age Students with Autism Spectrum Disorder. (2016)
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The purpose of this study was to investigate the effect of auditory-motor mapping training (AMMT) on the speech output of nonverbal elementary age students with autism spectrum disorder (ASD). Auditory-motor mapping training facilitates the development of association between sounds and articulatory actions using intonation and bimanual drumming activities. This intervention purportedly stimulates neural networks that may be dysfunctional in persons with ASD.

Seven nonverbal children with a primary diagnosis of ASD participated in twelve 20-minute weekly sessions consisting of engagement with 15 predetermined target words through imitation, singing, and motor activity (all components of AMMT). Assessments were made at baseline, mid-point, and post AMMT intervention sessions. These probes were used to determine the effects of AMMT on expressive language abilities of speech output. A null hypothesis was tested to determine the significance of the independent variables of singing, showing visual cues, and drumming on the speech output of nonverbal children with ASD, age five through eight years ($p \leq .05$). Additionally, effects of AMMT on children's development of social communication skills also were examined at the end of each intervention session.

Results of the study revealed no significant effect of the AMMT intervention on the speech output of elementary age children with ASD from the best baseline to probe one and probe two ($p = .424$), therefore the null hypothesis that there was no significant

effect of auditory-motor mapping training (AMMT) on speech output of nonverbal elementary children with ASD was retained. Additionally, a comparison of the growth of the independent 'High Five' gesture from session one to session twelve yielded no statistical significant results ($p > .05$). The McNemar chi-square was used to compare this secondary AMMT effect from sessions two to eleven, and revealed a positive growth trend that approached a significant outcome associated with the children's social communication responses ($p = .063$).

Although significant changes in the nonverbal children's speech output were not substantiated in this study, there were areas of growth for all children in this study that were highlighted through qualitative analysis and descriptive narratives. Confounding variables that possibly affected children's speech output and social communication development were addressed. Additionally, recommendations were made for future research involving music as a vehicle for speech development for nonverbal elementary age children with ASD.

THE EFFECTS OF AUDITORY-MOTOR MAPPING TRAINING ON SPEECH OUTPUT OF NONVERBAL ELEMENTARY AGE STUDENTS WITH AUTISM SPECTRUM DISORDER

by

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Approved by

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To my precious daughter Kristen, whose strength of character is unmatched in spite of her schizoaffective disorder. Rising above her circumstance through music prompted this research pursuit and continues to inspire me.

APPROVAL PAGE

This dissertation written by Sara Miller Massey has been approved by the following committee of the Faculty of The Graduate School at The University of North Carolina at Greensboro.

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CHAPTER I

INTRODUCTION

The Center for Disease Control's Autism and Developmental Disabilities Monitoring Network estimates that about 1 in 68 children have been identified with autism spectrum disorder (ASD). Globally, the prevalence of ASD has increased twentyfold to thirtyfold since the earliest epidemiologic studies were conducted in the late 1960s and early 1970s. One in 42 boys likely have a diagnosis of some form of autism. Autism spectrum disorder is reported to occur in all racial, ethnic and socioeconomic groups (Center for Disease Control [CDC], 2014; corresponding author – Baio, J.).

Facilitating the development of communication skills for nonverbal elementary children with ASD is the focus of this study**.** Children with ASD have overall lower rates of intentional communication and limited nonverbal behaviors when compared to their age-matched peers. Intentional communication occurs when meaning is expressed to a listener in such a way that he or she can receive the message and act on it (Chiang, Soong, Lin, & Rogers, 2008). Language proficiency is one of the most important factors in predicting outcomes for people with autism, with the other critical factor being IQ (National Institutes of Health [NIH], 2012). Interventions for language acquisition are a priority among outcome goals for children with ASD to aid in overcoming the disabling effects of language deficiency (Rogers, 2006).

Presentation of the Research Problem

Autism spectrum disorder (ASD) is a range of complex neurodevelopmental disorders that are characterized by "persistent deficits in social communication and social interaction across multiple contexts," and "restricted, repetitive patterns of behavior, interests, or activities" (American Psychiatric Association [APA], 2013, p. 50). The Diagnostic and Statistical Manual of Mental Disorders (DSM-5) outlines the symptoms of ASD using a dimensional approach which is a shift from traditional categorical approach of previous versions of this manual (APA, 2013). A strong link exists between the communication deficits and social deficits that characterize ASD. Due to this strong link, the merger of the communication deficit dimension and the social deficit dimension into a single domain in the latest edition published in May 2013 was justified. The present definition of ASD includes two domains: social communication and interaction domain, and the restricted, repetitive behavior domain. The persistent communication deficits of persons with ASD prompts this research question: want are the effects of a music intervention called auditory-motor mapping training on the speech output of nonverbal elementary children with autism spectrum disorder.

Summary of Auditory-Motor Mapping Training

The music intervention of auditory-motor mapping training (AMMT) uses three modalities to address some of the persistent deficits that are evidenced in persons with ASD, including motoric movement, intonation of words, and visual picture cues. The motoric movement component of AMMT uses tuned drums to focus the repetitive movement condition of children with ASD to aid in speech development. Another component of AMMT uses the intonation of words (singing), which makes use of the natural prosody of speech. A final component of AMMT uses visual cue cards to prompt the association of the word being taught with its visual representation.

The repetitive motor movement that is common in ASD can be focused into the drumming component of the AMMT intervention. Descriptions of AMMT in this paper will show how the motoric movement component of this intervention uses the pre-existing condition of patterned repetitive movement to benefit speech development in elementary children with ASD. Sounds produced by the tuned drums may facilitate the auditory-motor mapping that is essential for meaningful vocal communication (Koelsch, Gunter, Wittforth, & Sammler, 2005).

Prosody is the rhythm, stress, and intonation of speech. The patterns of rhythm, stress, intonation, phrasing, and contour most likely drive much of the early processing in both music and language (McMullen, 2004). Using the natural prosody of speech is an important component of the auditory motor mapping training (AMMT) that aids in the facilitation of speech for nonverbal children with autism. This intervention requires the intoning of high probability words or social phrases using the melodic contour of these words. Natural prosody has the stressed syllable having the higher of the two pitches and the unstressed syllable having the lower of the two pitches in speech (Wan, 2011).

Aided augmentative communication (ACC) is an interactive system using pictures used by music therapists (Gadberry, 2011). Picture schedules are the form of aided augmentative communication ACC that is used most often, but the use of AAC to promote literacy and expressive communication has been reported by 43.8% of Board

Certified Music Therapists. The use of AAC to develop expressive language output is an important component of AMMT. The present study uses Pics for Pecs (Bondy and Frost, 2011) to provide visual cue cards as words are introduced by singing and simultaneous drumming. This form of ACC was selected because the classroom teachers of students with ASD in the school where the present study was conducted routinely use Pics for Pecs with their nonverbal students.

Communication Development for Persons with ASD

Communication is a central area of focus for intervention and therapy for children with ASD. Children with ASD experience deficits or delays in both receptive and expressive communication (Noen & van Berckelaer-Onnes, 2004). Receptive language skills describe the comprehension of language. Comprehension requires attention, listening, and processing the message to gain information. Communication involves understanding messages that are received. Receptive language skills include attention, receptive vocabulary, following directions, and understanding questions. Expressive language skills are those that describe how a person communicates their wants and needs. This broad form of communication involves nonverbal skills such as facial expressions and gestures, as well as verbal communication involving the use of language via vocabulary, semantics, morphology, and syntax (Baltazar, & Piantanida, 2006).

Music therapists and speech pathologists identify communication as one of the primary treatment goals for children with ASD (Kaplan and Steele, 2005). Researchers estimate that between 30% and 50% of children with ASD will not develop adequate speech to meet their communication needs (Prizant & Wetherby, 1993).

The linguistic ability of individuals with ASD varies greatly. As many as 25% of individuals with ASD lack the ability to communicate with others using speech sounds. Some have adequate linguistic knowledge, but display impairments in the understanding of language in context (Tager-Flusberg & Caronna, 2003). Presently, there appears to be no evidence-based intervention that consistently produces notable improvements in expressive language in individuals with ASD (Francis, 2005). Deficits in communication frequently present an ongoing challenge for individuals with ASD and their families.

Foundations for the Use of Music for Speech Development for Nonverbal Persons with ASD

Wan, Demaine, Zipse, Norton, and Schlaug (2010) maintain that many individuals with ASD have keen interests in music. When music is combined with interventions, such as visual supports and reference to routines, there may be positive outcomes. Social interactions or skills of persons with ASD may improve when music materials are combined with other interventions (Carnihan, Rao & Bailey, 2009).

Singing, more than speaking, engages a bilateral reciprocal network between frontal and temporal regions, which contain some components of the putative mirror neuron system (MNS) (Brown, Martinez, Hodges, Fox, & Parsons, 2004). A main function of the MNS is action understanding and vocal production. Strategies that engage the brain regions involved in action observation that may be a part of the MNS have potential in developing expressive language for individuals with ASD with communication deficits. Therefore, ASD is hypothetically linked with MNS dysfunction. Singing engages the MNS network that is believed to be deficient in individuals with

ASD. The combination of the musical elements of rhythm, pitch, timbre, harmony and texture make music a functional tool to facilitate social-communicative behaviors for children with ASD. As they gain social-communicative skills through music and begin to apply them independently, music can be faded with the goal of executing the skill without music facilitation (Chou, 2008; Edgerton 1994).

Koelsch, Gunter, Friederici and Schröger (2000) findings support a strong neural overlap in the processing of music and language syntax. Koelsch, Gunter, Yves v. Cramon, Zysset, and Lohmann (2002) subsequently investigated the neural correlates of music processing and found that brain structures (Broca and Wernicke's area, the superior temporal sulcus, Heschl's gyrus, both planum polare and planum temporale, anterior superior insular cortices) that were once thought to be domain-specific for language processing are also involved in music processing. Both of these studies use event related potential (ERP) to examine neural anatomy. An event-related potential **(**ERP**)** is a noninvasive means of measuring brain functioning that is the direct result of a specific sensory, cognitive or motor event.

Patel (2003) believes that linguistic and musical syntax share certain syntactical processes. One such neuroimaging study supporting Patel's hypothesis uses fMRI technique to examine shared and distinct neural correlates of singing and speaking in experimental conditions (Ozdemir, Norton and Schlaug, 2006). Results suggest a bi-hemispheric network for vocal production regardless of whether the words/phrases were intoned or spoken. Singing more than humming showed additional right-lateralized activation of superior temporal gyrus, inferior central operculum, and frontal gyrus. The findings of Ozdemir et al. (2006) may offer an explanation for the clinical observation that individuals with non-fluent aphasia due to left hemispheric lesions are able to sing the song texts while they are unable to speak the same words.

According to Kaplan and Steele (2005), music therapists rank developing language/communication skills as a main goal of therapy with many of their clients. Supporting the benefits of this goal, Gold, Wigram and Elefant (2006) report the potential utility of music interventions to improve communication skills for individuals with ASD. Gold et al. (2006) emphasize that structure is an essential element of music that is important for the potential effectiveness of music interventions for persons with ASD. When the rhythmic, melodic, and dynamic structures of music are applied systematically in therapeutic experiences, there is potential for effective engagement for children with ASD.

The use of music, visual supports, and words from daily routines are all components of AMMT and utilize the musical strengths of individuals with ASD (Heaton, 2008). Schlaug and Wan (2010) maintain that AMMT may be used to engage and strengthen the connections between frontal and temporal regions that are abnormal in children with ASD, and potentially affect the development of language skills of individuals with autism. Auditory-motor mapping training is an intervention that features dyadic sessions between individuals with ASD and therapist that engage sensory and motor modalities.

Accurate perception of metrical structure may be critical for phonological development, and consequently for the development of literacy. Metrical structure, defined as the succession of stressed syllables, has been shown to have developmental links to phonemic awareness, which is essential for language acquisition. The discernment of the strong and weak beats that create regular rhythmic patterns are at the core of understanding metrical structure (Goswami, 2012). The auditory cortex of the human brain responds to rhythms by aligning to the syllabic structure of incoming speech (Luo & Poeppel, 2007). The approximate regularity of stressed syllables may be important in linguistic processing (Goswami, 2012).

Based on a study by Corriveau and Goswami (2009), children with speech and language difficulties demonstrate significant impairment in the metronome tapping conditions, with weaker performances compared to both age-matched and younger language-matched control children. These findings suggest that at least part of the comorbidity between language and motor impairment found in children with specific language impairment results from a rhythmic processing deficit.

When comparing individuals with ASD with typically developing peers, those with ASD tend to focus more on the perceptual (e.g., prosodic) information rather than the linguistic information of speech. This tendency to focus on perceptual information may contribute to their language and communication deficits for individuals with ASD (Mottron, Peretz & Menard, 2000). Difficulties in accurately processing auditory rhythmic cues to prosody could impair the acquisition of language (Corriveau & Goswami, 2000). These difficulties, which are present from infancy, disrupt the suprasegmental processing required to extract words and syllables from the speech stream. As caretakers communicate with infants in infant-directed speech, an early insensitivity to auditory cues of rhythm and stress could have profound and lasting consequences on the development of the language system. The rhythm and stress difficulties in metrical processing are associated with basic processing difficulties.

Rhythm and beat perception are central to appreciating music. Rhythm organizes music into patterns, forms, and rhythm. Edgerton's (1994) investigation of the relationship between the perception of musical metrical structure and basic auditory perception shows that metrical structure functions to organize the phonology of language via speech prosody. Her study supports the notion that the rhythmic repetitive behaviors of persons with ASD tend to give stability at the frequency at which these behaviors occur. In Edgerton's study, tempo consists of beating/vocalizing in a steady tempo, matching the experimenter's tempo and beating/vocalizing and matching tempo variations. This study also supports the notion that music contributes substantially to the ability of persons with ASD to follow directions and elaborate social play.

The use of hand tapping that is aligned with the melodic-rhythmic patterns of spoken phrases offer a communicative modality in which persons with ASD may experience immediate success. The sequence for melodic intonation therapy, a precursor of AMMT, includes the therapist, followed by the client, tapping the left hand one time per syllable. This tapping of the left hand possibly engages the right-hemisphere sensorimotor network that controls both hand and mouth movements. Interventions that engage the right hemisphere may also facilitate sound-motor mapping that is a critical component of meaningful vocal communication. The tapping may act like a metronome in pacing the speaker and provide continuous cueing for vocal production (Norton, Zipse, Marchina & Schlaug, 2009).

These studies have stimulated interest in the possibility of shared neural basis of music and language (e.g., Corriveau & Goswami, 2008; Edgerton, 1994; Patel, 2006; Peretz & Coltheart, 2003). Corriveau and Goswami's findings support Koelsch's research in the belief that exploring the use of rhythmic training interventions with speech- and language-impaired children is worthwhile (2000, 2002). Simple activities such as singing to music or playing a drum in time with the stressed syllables in nursery rhymes may have previously unsuspected benefits for the development of language, phonology and literacy.

Auditory-Motor Mapping Training (AMMT) is an intervention designed to help children with ASD associate target words with actions. The ultimate goal of AMMT is to increase expressive speech output for nonverbal children with ASD. AMMT combines intoning (singing) target words on 'sol mi' or 'mi sol' and using drums with high-low pitch capacity to facilitate auditory-motor mapping training. Researchers in a 2011 'proof of concept' study with six non-verbal children with ASD aged five to nine years have demonstrated positive effects of AMMT on expressive language development (Wan et al, 2011).

Two main components of AMMT appear to play a role in why it may serve as a viable intervention to assist individuals with autism develop expressive language. First, intonation or singing of words/phrases is known to engage a bilateral region between the frontal and temporal regions of the brain. These regions overlap with language regions such as the arcuate fasciculus and uncinate fasciculus (Wan, 2010). Wan proposes that the mirror neuron system (MNS) could be abnormal in persons with ASD, and that AMMT may engage brain regions that overlap with the MNS. According to Rizzolatti and Craighero (2004), the mirror neuron system is a neurophysiological mechanism within the motor cortex that appears to play a fundamental role in both action understanding and imitation. Another component of AMMT that may underlie effective gains with the intervention is the motor activity of bimanual drumming that captures the participants' interest, but also engages the sensorimotor network that controls the orofacial and articulatory movements in speech. The auditory-motor mapping that is necessary for meaningful vocal communication may be facilitated by sounds produced by the tuned drums (Koelsch, Gunter, Wittforth, & Sammler, 2005). Auditory-motor mapping trains the association between sounds and articulatory actions with the goal of facilitating speech output. Auditory-motor mapping involves intensive repetition of singing and drumming in a highly structured environment with the goal of increasing speech output in nonverbal children with ASD.

Statement of Purpose

The purpose of this study was to investigate the effect of auditory-motor mapping training (AMMT) on the expressive language abilities of elementary age students with the primary diagnosis of Autism Spectrum Disorder (ASD). The following null hypothesis was tested at a significance level of less than or equal to .05. There will be no effect of auditory-motor mapping training (AMMT) on speech output of nonverbal elementary children with ASD.

A secondary purpose of this study was to examine the development of pre-linguistic gestural communication demonstrated by the independent 'High-Five' gesture of participants in the concluding song of each session. Representational gestures, such as 'High Five' or 'Shhh', develop between the ages of 18-24 months in typical children, but are minimal or completely absent in children with autism (Crais, Watson, & Baranek, 2009). The current researcher examined growth trends to determine if these representational gestures develop, and if so, the duration of time required to facilitate the repetitive occurrence of this pre-linguistic gestural communication

Finally, the researcher systematically reviewed the data to create conceptual categories that formed a framework for descriptive analysis about each participant in this study. The purpose for this aspect of this study was to examine specific areas of growth in speech development for participants, while highlighting the diverse backgrounds and factors that may contribute to individual growth. Understanding the distinctive features of individual growth also supported the recognition of the diverse nature of persons with ASD. Individual narratives provided particular attention to confounding variables that may have influenced growth, if any, as a result of auditory-motor mapping training sessions.

CHAPTER II

REVIEW OF LITERATURE

This review of literature supports the present research study undertaken for this dissertation. Discreet topics are presented deductively to support the primary research question about the effect of auditory-motor mapping training in speech development of nonverbal elementary children with ASD. Autism spectrum disorder (ASD) is broadly discussed in the first section with a particular emphasis on the communicative deficits of persons with this neurodevelopmental disorder. Topics move from general to specific, synthesizing ASD with topics of music learning, music therapy, neural anatomy, language, and music development. The neuroanatomical structures associated with ASD, and the neural areas associated with music and language development for typical children contrasted with those with ASD are presented. Finally, the purported efficacy of the music intervention called auditory-motor mapping training (AMMT) for speech development for nonverbal children with ASD is discussed.

Autism Spectrum Disorder

Autism spectrum disorder has been described as a neurodevelopmental disorder that was first discovered in the early 1940s by psychiatrists Leo Kanner in the United States and Hans Asperger in Austria. Autism spectrum disorder remained mostly unnoticed outside of psychiatry through the 1980s, but has now been defined in the *Diagnostic and Statistical Manual of Mental Disorders*, *Fifth edition* (DSM–5; APA,

2013) as a disorder that has included a range of clinical representations characterized by functional impairments in communication, social reciprocity, and restricted, repetitive behaviors. Children with ASD usually have exhibited impairment in two domains in the early years: the social-communicative domain, and in the domain characterized by restrictive, repetitive behaviors with fixated interests.

Identification of symptoms prior to age three was required according to *Diagnostic and Statistical Manual of Mental Disorders*, *Fourth edition* (DSM-IV) and editions prior to 2013. However, a major change in the time of diagnosis has been made with the most recent edition of the DSM. The DSM-5 has allowed for diagnosis of ASD in later years or young adulthood when symptoms may be more fully manifest and/or when the social requirements have exceeded the capabilities of those with ASD. (APA, 2013). There has been great variability in specific symptoms and the degree of severity for individuals with ASD (Tager-Flusberg & Caronna, 2007).

Auditory-motor mapping training (AMMT) is a music intervention for speech development for nonverbal elementary children with ASD developed by a research team at Harvard Medical School as a result of their work with melodic intonation therapy (Wan, Demaine, Zipse, Norton & Schlaug et al., 2010). This intervention utilizes the musical activities of drumming and intoning of words and phrases simultaneous with the presentation of visual cue cards representing these words and phrases. Melodic intonation therapy (MIT), the precursor to AMMT, was an effective rehabilitative technique for restoring language function in aphasic individuals (Wan et al., 2010). Lead by Gottfried Schlaug, this research team found that auditory-motor mapping training had the potential to enlist the neural regions associated with the motoric activity of hand tapping and intoned vocal output with the purported result of generating speech just as MIT had done with aphasic individuals (Albert, Sparks & Helm, 1973). An examination of the following discrete topics is required to understand the underpinnings for the potential efficacy of AMMT that will be covered in this review of literature: autism spectrum disorder; music learning; music therapy and ASD; neurology of persons with ASD; neural areas associated with music and language; and music, language and ASD.

Social-Communicative Domain

Deviance from socially normative behavior was the most distinctive feature of ASD confirmed by original descriptions of Kanner in 1943. He observed that problem behaviors were a concern among young children with ASD due to their limited communication skills and poor social development. Effective education and social development were significantly affected by problem behaviors such as physical aggression, self-injury, property destruction, pica, stereotypy, defiance, tantrums, and disruptions (Horner, Carr, Strain, Todd & Reed, 2002). These behaviors noted by Kanner and Horner et al. (2002) continue to be observed in persons with ASD today.

Social-communication was one of two primary domains of ASD identified by Volkmar, Paul and Schopler (2005), but it is difficult to assess the social developmental aspect relative to overall cognitive ability in individuals with this disorder. Social communication difficulties may be non-verbal communication deficits including areas such as eye contact, body language, facial expression, gesture, and integration of language and nonverbal behaviors (Lord & Jones, 2012). Volkmar et al. (2005)

identified eight specific social processes from the social communication domain where deficits were observed in individuals with ASD. He used the terms gaze, social speech, joint attention, imitation, play, attachment, peer relations, and affective development to describe these eight social processes where deficits may occur.

Social Processes Deficits in Individuals with ASD

Gaze. Typical children demonstrated selective attention to social stimuli and human faces from infancy called 'gaze.' However, in children with ASD, patterns of mutual gaze failed to establish and the human face holds little interest to them. Lack of appropriate gaze behaviors in children with autism interfered with inter-subjectivity, which broadly refers to the psychological relationship between people. Trevarthen (2011) applied this term to the development of human infants, and how they biologically were wired to coordinate their actions with others. However, in infants with ASD, Trevarthen (2011) found that the ability to coordinate and sync their actions with others was severely diminished. In a typically developing child, this ability for inter-subjectivity facilitated cognitive and emotional learning through social interaction, but this learning was hampered for children with ASD because of their inappropriate gaze behaviors. Trevarthen's findings supported the premise of Volkmar et al. (2005) that the development of shared emotional meaning between infant and parent or caregiver requires inter-subjectivity, so gaze development is integral for appropriate psychological development.

Social Speech. The lack of interest in social speech involving social reciprocity including the sharing of interests, verbal dialogue, turn taking, sharing of affection, and initiation in social encounters was also noted by Volkmar et al (2005). Deficits in relationships encompass adjusting behavior to suit various social contexts, sharing within imaginative play, and difficulties forming and/or maintaining relationships appropriate to age and developmental level (Lord & Jones, 2012).

Kanner & Eisenberg (1956) found that social speech required language acquisition that was crucial to the diagnosis and prognosis for children with ASD. Functional speech by five years of age was and still is one of the most important distinguishing characteristics between children with ASD who make appropriate adjustment to social and educational environments. Language development by ages ranging from 30 months to six years is a strong predictor of later development (Bagley & McGeein, 1989).

Children with ASD may be nonverbal, or may have language characterized by echolalia, scripted speech, unusual prosody, or developing language. Mental retardation is diagnosed in at least half of those with ASD. Those who do not have cognitive delays are considered to be high functioning although they may have significant impairments in adaptive functioning and language communication (Tager-Flusberg & Caronna, 2007).

Pickett, Pullara O'Grady, and Gordon (2009) reviewed 64 papers that dealt with speech acquisition for non-verbal individuals with ASD; this review of literature provides a significant synthesis of research on this topic. The purpose of this review was to: (a) identify individuals with ASD who had been reported to develop speech for the first time at age five or older, and, if possible, the size of the populations from which these individuals were drawn; (b) determine how much speech and language had been accomplished; and (c) determine what characteristics of these individuals, or of the training methods that may have been responsible for these accomplishments. Most participants developed speech between the ages of 5 and 7, but some initiated speech up to 13 years of age. The variability of the initiation of speech was substantial, despite continuing efforts to get them to do so. Yet, once speech began, subsequent improvements were often quite rapid. These researchers speculate that achieving initial competence with sound production and words lays the foundation for which much more efficient learning of speech elements and abilities.

The generally accepted notion is that time and effort is critical for learning speech and language. This was not always the case in the studies reviewed by Pickett et al. (2009) who report a likely field-wide bias among researchers and educators toward younger participants in the development of speech. This may be due to the fact that older participants do not respond as well to speech interventions compared to younger participants, and/or because older participants are not as frequently included for speech interventions. Nevertheless, there are few examples reported in scholarly literature about older nonverbal individuals with ASD acquiring speech.

The development of social speech begins with the sound of the mother's voice. Typical infants prefer their mother's voice on the basis of pre-natal learning. Infants acquire linguistic and musical input specific information in their prenatal environments. 'Motherese,' or infant-directed speech is maximally attractive to infants. Contrasted with adult-directed speech, motherese is characterized cross-linguistically by a slower rate of speech, higher fundamental frequency, greater range of pitch variation, longer pauses, and characteristic repetitive intonation contours. Infant-directed speech may also enhance learning because vowels are produced in a more extreme manner, resulting in a heightened distinctiveness between vowel categories.

McMullen & Saffran (2004) found that prosodic cues may also played a role in delineating the structural information that infants must learn to process language and music. This pair of researchers observed that the verbal communication between infants and caregivers played a vital role in social interaction before speech was acquired. However, beginning at a very young age, children with ASD appeared to lack a preference for speech sounds over other kinds of sounds. Children with ASD demonstrated less preverbal vocalizations, and those that were exhibited were atypical. They lacked interest in speech and typical language patterns that were formative in interpersonal patterns and all later communication (Volkmar et al., 2005).

Three nonverbal behaviors that should emerge in typical early development of communication were identified by Franco, Davis, and Davis (2013). These behaviors included vocalizations, eye gaze, and gestures and are still considered the basic components of pre-linguistic communication that are formative for the future development of symbolic language. Pre-linguistic gestural communication emerges in typically developing children between the ages of 18-24 months and should continue after the onset of spoken or linguistic communication. Crais et al. (2009), however, observed that this precursor to spoken language was typically absent or impoverished in children with ASD, and their observations are still common seen in children with ASD today.

Franco et al. (2013) observed an increase the number of communicative interactions among young children with ASD who function at a nonverbal level when pre-linguistic communication was developed within the context of social play routines. He observed participants initially demonstrating few consistent interactions with others, but all of the children increased in the number of communicative interactions, in the overall rate of initiated intentional communication, and in their ability to sustain these interactions.

The findings of Franco et al. (2013) are important as they apply to the present research study which utilizes a music intervention for speech development for nonverbal children with ASD. This study utilizes an intervention called auditory-motor mapping training (AMMT) that employs a sequence requiring social interactions between participants and therapist using singing, drumming, and viewing pictures that represent target words for daily routines. Similar to the participants in the study by Franco et al., the participants in the present research study were young children with ASD who functioned at a nonverbal level. The enjoyable interactive nature of AMMT served as a social play routine for participants which most often sustained their engagement in the social interaction required for this intervention.

Joint Attention. Joint attention was another social process identified by Volkmar et al. (2005) where characteristic deficits exist for individuals with ASD. Volkmar et al. defined joint attention as a preverbal social communication skill that involves sharing with another person the experience of a third object or event. This social process typically emerges prior to one year of age, but is consistently impoverished in children with ASD. Protoimperative gesturing and protodeclarative gesturing are specific patterns of joint attention that are often dysfunctional in individuals with ASD. Protoimperative involves the use of eye gaze/gestures to gain the assistance of another person for the purpose of obtaining an object or outcome. Protodeclarative gesturing involves eye gaze and gesturing with the sole aim of calling another's attention to an object or person without a specific purpose for doing so. Protoimperative gesturing is sometimes used by persons with ASD while protodeclarative gesturing is usually absent. (Volkmar, 2005).

Imitation. Volkmar et al. (2005) identified imitation as a social behavior that is important for symbolic development, but is deficient among children with ASD. Different aspects of executive function are involved in the two conditions for imitation. One condition for imitation is spontaneous imitation, which is done at will, and the other condition is induced imitation, which implies the capacity to plan an action without a personal motive. Children with ASD demonstrate less spontaneous imitation of the actions of others. This condition for imitation supposes that the child is able to select specific actions for reproduction, and inhibit the reproduction of others. For example, when compared with their typical peers, children with ASD show less imitation of the oral-facial demonstration and reciprocal social play in their interactions with their parents (Charman & Stone, 2006).

The value of spontaneous imitation for learning and communication is important. This type of imitation is of frequent use in infancy and continues for normal communication to development. The learning that can occur with spontaneous imitation requires socially embedded conditions so that there is the detection and understanding of what is being imitated. Performance in spontaneous imitation requires use of motor synchrony. When combined with recognition of what is being imitated, it leads to turn taking and synchrony of action and reenactment (Charman & Stone, 2006).

These components of spontaneous imitation that involve motor synchrony are important features of AMMT. The motor synchrony required for the drumming feature of auditory-motor mapping training has underpinnings in the value of spontaneous imitation for learning and communication (Charman & Stone, 2006). The drumming component of the AMMT intervention may be challenging due to the challenges with spontaneous imitation for individuals with ASD, however, the dyadic nature of the AMMT intervention will provide one-on-one support for the development of motor synchrony. Just as Charman and Stone (2006) suggest, when individuals with ASD in this study recognize what is being imitated, it may lead to the turn taking and synchrony of action required for success with the drumming component of AMMT, which may aid in speech development for these individuals with ASD.

Executive impairment in individuals with ASD may make induced imitation without personal motives difficult to perform. Comparative studies between typically developing children and children with ASD indicated that scores for imitation of hand positions were significantly lower in children with ASD younger than 42 months than those of typical children. However, impairment of praxis is not universal across the autistic spectrum (Charman & Stone, 2006)

Play. Play was another social process identified by Volkmar et al. (2005) where deficits are still commonly observed in individuals with ASD. In the typical development of children, play skills move from simple manipulation to symbolic thought. By contrast, play skills of children with ASD are characterized by lack of social engagements as well as stereotyped object manipulation and nonfunctional use of objects. Symbolic play is limited in children with ASD, most likely due to the general challenges with symbolic thought and language.

Attachment. Volkmar et al. (2005) also identified attachment deficits in children with ASD. Attachment is a social process that emerges during the first year of life for typically developing infants. Infants respond to caregivers with a keen sense of attachment upon which survival is based. Individuals with ASD face a risk of attachment insecurity because they often do not respond to the nurture of caregivers as typically developing infants do. Sometimes idiosyncratic attachments to objects such as cereal boxes or hard toys may be seen.

Peer Relations. The development of peer relations was another social process identified by Volkmar et al. (2005) where individuals with ASD showed deficits compared to their peers. Typical development of social skills was demonstrated in increased differentiation of peer relations, pro-social skills, and increased capacity for self-regulation. Children with ASD exhibited limited interest in social interaction and contact with peers. Past research supported the premise that problem behaviors may result in increased the risks of isolation and exclusion in educational, social, home and community environments (Horner, Carr, Strain, Todd, & Reed, 2002). Based on past research, children with ASD made fewer appropriate initiations with others than their typical peers and were sometimes content to be left alone, possibly resulting in feelings of inadequacy and isolation.

Affective Development. Affective development was a final social process identified by Volkmar et al. (2005) where deficits are common for individuals with ASD. In typical development, children begin to label emotional states at age two or three; however, individuals with ASD are challenged to recognize emotional states. This may be due to perceptual difficulty with recognizing facial affect, or due to a more cognitive-affective inability. They also demonstrate difficulty with spontaneous expression and purposeful reproduction of affective response. Empathy is also deficient likely due to their differences in emotional expression, imitation and recognition (Volkmar et al., 2005).

Restricted, Repetitive Behavior Domain

Restricted, repetitive behaviors (RRB) and interests are included in one of the two domains used to define ASD. Lord & Jones (2012) found that the number and intensity of RRBs at the age of two was a unique contributor to the prediction of a stable autism diagnosis by the age of nine. This predictive characteristic of RRBs is still commonly accepted today. This domain includes stereotyped and repetitive behaviors that are both verbal and nonverbal, insistence on sameness and rituals, fixated interests, and unusual reactions to sensory input. Restricted, repetitive behaviors (RRB) are often context-dependent, and are more heterogeneous than the manifestations of autism in the social communicative domain.

Theoretical Models

Volkmar et al. (2005) suggested four theoretical models to account for the social dysfunction for individuals with ASD. They included the Theory of Mind (ToM) hypothesis, the central coherence theory, executive functioning skills (EF) approach, and the enactive mind theory. These models continue to be widely accepted theories to aid in understanding the social dysfunction for individuals with ASD.

The Theory of mind (ToM) hypothesis supports the notion that the characteristic deficits in social interaction are due to a basic problem of inter-subjectivity. Inter-subjectivity can be understood as the psychological relationship between people. According to ToM, individuals with ASD are unable to understand the beliefs, intentions, feelings, and desires of others causing an inability to negotiate the social world successfully. Typically developing children develop the ability for inter-subjectivity because their gaze behaviors develop in a routine way as infants, which in turn supports normal cognitive and emotional development. In contrast, children with ASD lack appropriate gaze behaviors that normally appear during infancy, so there is a deficiency in the cognitive and emotional development that is necessary to understand beliefs, intentions, feelings and desires of others. Typically developing children learn through social interaction, but children with ASD are hampered in this type of social learning because of their inappropriate gaze behaviors. Theory of mind skills are strongly related to language, so ToM explains why higher functioning individuals with autism or Asberger's can be successful with the functional use of language and still be socially disabled (Volkmar et al., 2005).

Executive functioning (EF) involves the use of higher-order processes closely associated with the prefrontal cortex to solve a broad goal. According to this theory, the social dysfunction in autism can best be accounted for by the difficulty in forward planning and set shifting. Executive functioning processes are necessary for regulating and controlling behavior (Volkmar et al., 2005).

Developmental and functional outcomes of individuals with ASD are highly variable, so the executive functioning theoretical model provides an explanation for some of this variability. These outcomes include differences in social awareness, real-life adaptive behavior, and readiness to learn in school (Pellicano, 2012). Not all individuals with ASD show executive functioning difficulties, which has lead researchers to move away from a framework that emphasizes a single underlying cause of ASD (Happé, Ronald, & Plomin, 2006). Researchers now generally agree that executive functioning problems unlikely play a primary causal role in ASD, but the degree of difficulties in executive functioning could play a substantial role in the developmental outcomes for children with ASD. These developmental outcomes include social competence, adaptive behavior, and success in school.

Central coherence theory, also known as the weak central coherence theory, describes a perceptual cognitive approach that accounts for how humans integrate information into meaningful wholes. This theory describes the central disturbance that underlies the limited ability of individuals with ASD to understand context or to 'see the big picture.' Weak central coherence theory attempts to explain how some people diagnosed with ASD can show remarkable ability in subjects like mathematics and engineering, yet struggle with language skills. Formative in this theory is the appreciation of context and overall meaning, so persons with ASD and tend to live in an isolated social world because they are lacking in their ability to understand information in a broad conceptual framework (Volkmar et al., 2005).

Enactive mind theory (EM) views the development of social cognition from a social-interactive context. In this view, the capacity for understanding the salient features of social stimuli in a normative way is overridden in individuals with ASD producing a general orientation toward a world of things rather than specifically toward people. According to Klin, Jones, Schultz, Volkmar, and Cohen, (2002), cognitive-symbolic thought is disrupted for individuals with ASD. Although, individuals with autism are capable of acquiring language, concepts, and even vast amounts of information about people, but this knowledge is largely gained outside the realm of active social engagement. The mind of the individual with ASD may hold the constructs and definitions about language and how to interact with people, but their foundational experiences are lacking. Without these foundational experiences, individuals with ASD are largely unable to produce moment-by-moment social adaptive reactions in naturalistic social situations, so their social behavior tends to be slow and inefficient compared to their typical peers.

Technological innovations that promote improved assessment of social behavior for individuals with ASD have greatly benefitted methodological advances in this field. However, a comprehensive theoretical perspective that accounts for the myriad of divergent patterns of social functioning among is still needed (Volkmar et al., 2005).

Assessment Tools for Diagnosing ASD

The utility of particular assessment strategies and instruments for diagnosis, treatment planning and monitoring, and evaluation of outcomes for individuals with ASD was evaluated by Ozonoff, Goodlin-Jones, and Solomon (2005). Their research described what is known about the symptoms, etiologies, developmental course, and outcomes of ASD included domains of core ASD symptomatology, intelligence, language, adaptive behavior, neuropsychological functions, comorbid psychiatric illnesses, and contextual factors (e.g., parent well-being, family functioning, and quality of life). The conclusion included a discussion of how well the extant literature meets criteria for evidence-based assessments. Practitioners should be cognizant of symptoms, etiologies, and other developmental concerns as they select assessment tools for ASD.

The *Childhood Autism Rating Scale* (CARS) (Schopler, Bougondien, Wellman & Love, n.d.) is frequently used as part of the diagnostic process for the assessment of ASD. Although there is no gold standard among rating scales in detecting autism, CARS is widely accepted because this scale incorporates the criteria of founders Leo Kanner (1943) and Creak (1964). This scale includes characteristic symptoms of ASD and has a criterion-related validity of r = .80. This validity was determined by comparing CARS diagnoses to diagnoses made independently by child psychologists and psychiatrists, which indicated that the CARS diagnosis was in agreement with clinical judgments. Schopler, Reichler, and Renner (1986) refined and revised The *Childhood Autism Rating Scale* in 1986 with a strong interest in differentiating autism from other diagnoses such as developmental delays and mental retardation.

The Autism Diagnostic Observation Schedule *(ADOS)* (Lord & Rutter, 2000) is another respected instrument for diagnosing ASD. This assessment tool provides four modules for observing the social and communicative behaviors of individuals with ASD. Internal consistency for all domains and modules ranges from .47 to .94. Inter-rater reliability within each module is considered excellent, ranging from .65–.78. The test-retest reliability over an average period of nine months' ranges from .59-.82. The strong reliability and validity of this diagnostic instrument provides clear differentiation between children with ASD and verbally matched children with non-spectrum disorders.

Auditory-Motor Mapping Training

A music intervention called auditory-motor mapping training (AMMT) uses drumming, intoning (singing) of words or phrases, and the presentation of visual cues for the purpose of developing speech output for nonverbal children with ASD (Wan et al., 2010). This intervention takes advantage of the overlap between the language and music systems of the brain. Brain regions recruited during these interventions include the sensori-motor feedback regions and the auditory-motor mapping network thus giving auditory-motor mapping training its name (Norton, Zipse, Marchina & Schlaug, 2009). A thorough discussion of the research that supports the purported efficacy of this music intervention is necessary to understand the purposes for the present study.

Discrete topics discussed in this section include how music learning occurs, and music therapy for children with speech and language dysfunction. The neural anatomy supporting language and music in typical children and those with ASD, and the neuroanatomical structures associated with ASD, and specifically the neural areas associated with music and language development for typical children contrasted with those with ASD are presented. Finally, a thorough discussion of auditory-motor mapping training will highlight features of this intervention that underscore why AMMT is a viable approach for speech development for nonverbal children with ASD.

Music Learning

Gordon's extensive research on the process of music learning revealed that language and music develop in similar ways in children. In utero, the typically developing fetus begins building a listening vocabulary by perceiving and reacting to sounds. After birth, the infant expands the listening vocabulary as they hear speech, so the breadth and depth of the infant's listening vocabulary depends on the breadth and depth of language in the environment. Language that is heard allows the infant's listening vocabulary to expand and become the foundation for all other language vocabularies (Gordon, 2007a).

Infants begin vocalization in response to sounds of language spoken in context and syntax. Initially these vocalizations sound like random noises, but over time these are interpreted as intentional language babble, approximations, imitations, and improvisations through conversation. As the infant grows to become a school-aged child, he uses language interactions with others to develop a thinking vocabulary, while he/she is continuing to cultivate a listening and speaking vocabulary, and to develop language reading and writing vocabularies (Gordon, 2007a, 2007b).

Gordon (2007a, 2007b) hypothesized that music learning develops in a fashion similar to language. Gordon used the term audiation in his music learning theory to describe inner hearing, or hearing music in the mind when it is not physically present.

Building on Gordon's music learning theory, Campbell and Kassner (2006) compared thinking in language to audiating in music. They supported the notion that development of a listening vocabulary of music and the development of language begins before birth. The more expansive and repetitive the music experiences are, the deeper and richer the music listening vocabulary will become, and this lays a foundation for all other music vocabularies (Gordon, 2007a, 2007b).

Gordon focused on a systematic sequencing of musical skill building that begins with aural perception and discrimination learning, and progresses through the development of music reading and writing, improvisation, and a theoretical understanding of music (Gordon, 1997). Similar to Gordon's music theory, language learning involves interactions between children with peers and adults that is initially informal yet sequential. Similarly, children are dependent on peers and adults for guidance in the initial stages of music learning through music interactions. A core premise of Gordon's music learning theory is that children learn music in much the same way that they learn language.

Benedict discussed how audiation develops in music teaching curriculum in a whole/part/whole process. Repertoire is considered the 'whole.' while tonal and rhythm patterns are the 'parts.' Benedict discussed how these patterns relate to the language learning process in that the way humans learn to speak (as cited in Abeles & Custodero, 2010). Over time, we hear total sentences rather than single word utterances. Humans make meaning of these utterances by hearing them in context. Rhythm and meter are reinforced through movement. As the sequence progresses, solfege and rhythm syllables are added to the tonal and rhythm patterns (Gordon, 1999).

The use of music to stimulate linguistic memory in learning disabled children is considered vital by Gfeller (1986). His observation of children's ability to sing TV commercials before they are of the age to understand their meaning highlights the notion that musical awareness and performance precede linguistic awareness. Music assists learners not only with acquisition of vocabulary, but also mastery of language-relevant information.

Gfeller's ideas are supported by Gordon's theory (1971) that maintains the interest and prominence of musical features over text for children. Grandin's review of selected literature also reinforces this idea; she states that children preferred to listen to sung lyrics rather than spoken lyrics of the same song (1988). Applebaum, Egel, Koegel, and Imhoff (1979) noted clinical observations of individuals with ASD who have a special responsiveness or unusual interest in musical stimuli. He also observed that they have the ability to imitate pitches as well as or better that children without autism.

Music and language development are important components of the present research study with auditory-motor mapping training (AMMT). Gfeller (1986) supports the use of music to stimulate linguistic awareness and the acquisition of vocabulary. Auditory-motor mapping utilizes music by intoning target words that are common in the daily routine of children. Drumming words as they are simultaneously intoned is also a component of AMMT. Children with speech and language impairments including those with ASD have been shown to be significantly less sensitive than controls to auditory cues for rhythm timing. Tapping in synchrony with a beat has been described as the simplest rhythmic act that humans perform (Corriveau & Goswami, 2008). Bimanual drumming is a part of the intervention sequence for auditory-motor mapping training, so understanding the essential nature of rhythm for music and language development is fundamental for this research study.

Music Therapy and Autism Spectrum Disorder

Music therapy can be defined as "a systematic process of intervention wherein the therapist helps the client to promote health, using musical experiences and relationships that develop through them as dynamic forces of change" (Bruscia, 1998, p. 20). Music consists of the elements of rhythm, pitch, melody, timbre, harmony and texture. When these musical elements are combined together, music therapy can serve as a functional tool to facilitate social-communication behaviors (Berger, 2001). Creating a reciprocal sonorous dialogue with voice and instruments between the therapist and child is the aim of music therapy for the development of expressive speech (Raglio, Traficante & Oasi, 2011).

Music researchers have noted that children with ASD show a sensitivity and attentiveness to music (Applebaum et al., 1979; Gfeller, 1986; Grandin, 1988; Gordon, 2007a, 2007b; Heaton & Wallace, 2004). Armstrong and Darrow (1999) observed that individuals with autism often demonstrate a high level of musical ability. The purported benefits of music therapy to facilitate communication, promote social engagement and aid children in succeeding academically have been reported by many (Armstrong & Darrow, 1999; Applebaum et al., 1979; Chou, 2008; Gold et al., 2006; Kaplan & Steele, 2005; Lim 2010; Simpson & Keen, 2011). use of music to facilitate communication is fundamental to AMMT. Results from music research has highlighted the parallels between speech/singing, rhythm/motor behavior, memory for song/memory for academic material, and overall ability of music to enhance mood, attention, and behavior for the purpose of learning (Applebaum et al., 1979). The aforementioned studies support the use of music to facilitate communication which is a fundamental component of AMMT.

Individuals with ASD not only enjoy music, but often also have strong musical ability (Armstrong & Darrow, 1999; Heaton, Hermelin, & Pring, 1999). Heaton et al. (1999) examined fourteen children and their age and intelligence matched controls and concluded that children with ASD showed no deficits in processing musical stimuli compared to their matched controls. This finding contrasts the deficits that are generally found in the performance of children with ASD in the social and interpersonal domains.

Music educators and therapists can build on this ability to help students with ASD succeed academically while behaving in a setting with their age-matched peers. Children with ASD have a need for structure and organization that is inherently characteristic of music. Responsiveness to music is often characteristic of children with ASD, so educational and therapeutic settings that take advantage of this feature can reinforce these abilities and minimize the deficiencies that can be associated with ASD (Armstrong & Darrow, 1999).

Chou's (2008) research with music therapy focused on the development of social-communicative skills in children with ASD in therapy sessions using eye contact, vocalization/verbalization and gestural imitation as dependent variables. Chou found that social-communication sessions with or without music may be effective for increasing gestural imitation for children with ASD. Additionally, social interactions between children with ASD and their typically developing peers may produce the best outcomes for social-communicative exchanges. Chou notes that an important goal of music therapy for children with ASD is to develop expressive communication that can be applied independently and generalized for use in daily living. When these transfers from music therapy are generalized to non-therapy environments, the music may be gradually faded. Then the children with ASD may be able to demonstrate the newly learned skills without the use of music. Auditory-motor mapping training uses the musical components of singing and drumming to stimulate speech development for nonverbal children with ASD. Just as Chou noted in his study, the goal of AMMT is to develop expressive communication using music. The musical features can be gradually faded once transfers of speech output are generalized to non-therapy environments.

Similar to the twelve-day duration of Chou's study, Gold, Wigram and Elefant (2006) examined the short-term effect of daily music therapy interventions over one week for children with ASD. Music therapy sessions were found to be superior to the 'placebo' therapy with respect to verbal and gestural communication skills. Placebo conditions were designed to control for the therapist's attention; these included activities such as reading a social story rather than singing it, or play activities without songs or musical instruments. The findings by Gold et al. (2006) may indicate that music therapy may help children with ASD improve communication skills by stimulating emotional sharing, regulating anxiety, and increasing motivation with more understandable communication.

Carnihan, Musti-Rao, and Bailey (2009) and Lim (2010) have also conducted important research pertaining to the use of music for speech and language development. Lim (2010) compared speech and music training on verbal production of children with autism spectrum disorder (ASD). Participants (*N*=50) significantly increased their verbal production with training compared to no training; however, low functioning participants showed a greater improvement after the music training than speech training. He concluded that children with ASD perceive important linguistic information embedded in music stimuli organized by principles of pattern perception, and produced in functional speech.

Carnihan et al. (2009) found that children with ASD show increased engagement with the teacher and other students when interactive materials were combined with music during small group language activities. When the same interactive materials were used without music, some students demonstrated lower rates on engagement. Carnihan et al. (2009) also noted that when music was present, socially inappropriate behaviors that are often characteristic of ASD were absent. These behaviors include self-stimulatory behaviors, closed eyes, or turning away from the learning material.

Aided augmentative communication (AAC) is an interactive system using pictures used by music therapists. Gadberry (2011) surveyed 159 Board Certified Music

Therapists (MT-BCs) to determine the frequency of ACC use by music therapists. She found that only 14.6% reported the use AAC in the sessions with all of their clients, but 33.8% of MT-BCs reported using ACC with most of their clients. Aided augmentative communication in the form of picture schedules was used most often, but the use of AAC to promote literacy and expressive communication was reported by 43.8% of Board Certified Music Therapists MT-BCs. Music therapists indicated that they most often focus on the emotion and communication of the music by soliciting instrumental or vocal responses rather than using an AAC system.

The use of pictures to represent target words from daily routines was a component of auditory-motor mapping training (AMMT) used in the present study. Pics for Pecs (Bondy and Frost, 2011) is a picture communication system that was used in the present study. Classroom teachers for students with ASD at the school where the present study was conducted routinely use Pics for Pecs in their classrooms, so this ACC system was the logical choice since these children with ASD were familiar with this form of picture cues.

The use of pictures by 43.8% of MT-BCs reported by Gadberry (2011) to promote literacy and expressive communication has strong implications for the present research study. She also noted that the instrumental or vocal responses served as a means of indicating the emotional and communicative aspects of the music. Auditory-motor mapping training is supported by Gadberry's (2011) research in that AMMT also requires instrumental responses in the form of drumming to indicate the syllables as they simultaneously being intoned. She also noted that the vocal responses may serve as a means of indicating the communicative aspects of the music. Auditory-motor mapping training uses vocal responses in the form of intoned words by the children for the purpose of developing expressive communication (Wan et al., 2011).

Music can serve as a means of communication for non-verbal children with ASD. Grandin (1988) observed that some children with ASD are able sing a response when they are unable to speak the same response. Non-verbal children with ASD demonstrate a preference for music over other auditory stimuli, perhaps because some of these children are threatened by the world of words (Benenzon, 1976; Simpson & Keen, 2011; Thaut, 1987).

Language/communication was the primary goal most often identified by music therapists for clients that were diagnosed with ASD in a study by Kaplan and Steele (2005) that spanned two years. Researchers in this study analyzed the effectiveness of a music therapy programs based on the type of intervention most frequently used, what goals were most frequently addressed, and whether the skills attained were generalized to other settings. One hundred percent of the 40 participants reached their initial objective within one year or less regardless of session year or less regardless of session type. The intervention type most often used to achieve primary goals was interactive instrument playing which promoted social interaction between therapist, client and peers. A survey of the parents/caregivers at the end of each year indicated that 100% of the subjects generalized the responses acquired in music therapy to nonmusical therapy environments. These reports of generalization are positive, but their limitation should be acknowledged since these data sources were not neutral parties. The responses may have been influenced by their desire for the individuals to succeed.

Neurology of Persons with ASD

An examination of the neurology of individuals with autism compared with typical controls is important in order to understand how auditory-motor mapping training may activate intact neural connections to develop expressive language for children with ASD. Research focusing on the neural areas associated with language and music for individuals with autism has included behavioral and electrophysiological studies using event-related potentials (ERP), event-related fields (ERF), positron emission tomography (PET), and functional Magnetic Resonance Imaging (fMRI). Various aspects of language and music have been studied, including the acoustic features of auditory and speech processing in individuals with ASD (Haesen, Boets, & Wagemans, 2011), brain lateralization (Boddaert et al., 2008), speech processing (Zatorre & Gandour, 2008), pitch perception (Kraus, Skoe, Parbery-Clark, & Ashley, 2009; Russo et al., 2008), brainstem function for speech and music (Russo, Nicol, Zecker, Hayes & Kraus, 2005), and speech prosody (McMullen, 2004).

Haesen et al. (2011) reviewed behavioral and electrophysiological literature pertaining to acoustic features of auditory and speech processing in individuals with ASD. Pitch processing was of particular interest in their study, as well as pure tones, complex tones, and speech sounds. The participants in the 43 reviewed studies differed in age and in gender, with a prevalence of males due to the prevalence of males compared to females with ASD. Participants also differed in intelligence, including low-functioning as well as high-functioning individuals. In all studies, controls were matched for age, gender, and (nonverbal) IQ, unless otherwise specified.

Active responses were required for the behavioral studies, while the electrophysiological studies involving event-related potentials (ERP) and event-related fields (ERF) had responses that were viewed electronically. Responses were analyzed and arranged according to the applied methodology and stimulus complexity.

Results showed evidence of enhanced local and auditory processing in individuals with ASD, regardless of stimulus complexity. This was most apparent for pitch processing, which was more enhanced in pure tones and speech sounds. Absence of auditory global interference was also evidenced in several studies, suggesting a bias towards more local processing in ASD. Individuals with ASD are more focused upon local, perceptual features, even speech sounds, whereas controls spontaneously focus on more socially relevant cues such as speech. A consistent finding of all studies was the enhanced local pitch processing ability in participants with ASD giving rise to the notion that this superiority may be due to atypical brain lateralization of auditory processing and speech perception in individuals with ASD.

Haesen et al. (2011) review focused on auditory and speech processing in ASD. In order to understand the context of the conclusions of his research, it is important to note that auditory and speech processing are usually embedded in the broader context of social communication. Haesen et al. (2011) findings underscore his conviction that children with ASD have difficulty with communication and social function. More specifically, this review concluded that speech orientation plays an important role in learning to comprehend and process speech, as well as develop oral language and communication. Haesen et al. (2011) findings of the complex interrelations between social orientation, auditory processing and speech perception is pertinent to the focus of this research study on developing speech output for students with ASD.

Consistent with Haesen et al. (2011), Boddaert et al. (2003) found atypical brain lateralization in individuals with ASD, but her evidence comes from positron emission tomography (PET) studies. Positron emission tomography (PET) scans have found evidence of right hemisphere dominance of auditory processing in individuals with ASD, with typical controls showing left hemisphere dominance for auditory processing.
A new model to explain speech processing for individuals with ASD was proposed by Zatorre and Gandour (2008). This model reconciles two models that have long been the accepted norms for speech processing. Formerly, pitch and vowel processing was hypothesized to occur mainly in the right hemisphere, while the left hemisphere was believed to be responsible for the processing of consonants, spoken words and sentences. Using fMRI, Zatorre and Gandour found evidence of right auditory cortex involvement in pitch processing, but higher order, linguistic features of the stimuli are thought to influence the patterns of hemispheric specialization. For example, pitch processing that typically is lateralized to the right hemisphere will shift to the left when linguistically relevant tones are presented.

Taken together, the research by Boddaert et al. (2003), Haesen et al. (2011), and Zatorre and Gandour (2008) show evidence of altered lateralization of auditory and linguistic processing in persons with ASD. Haesen et al. (2011) proposed that the auditory enhancements as well as deficits may possibly be explained by atypical right hemisphere dominance in individuals with ASD.

Individuals with ASD may have issues with pitch perception in the context of language (Kraus et al., 2009; Russo et al., 2008). For example, these individuals often cannot discern the prosodic aspects of language that may distinguish a question with rising pitch from a statement with a level or falling pitch.

Russo et al. (2008) examined the neuro-anatomic basis for this prosodic deficit. The normal development of the brainstem involves experience-dependent postnatal pruning in multiple subcortical components of the auditory system. Irregularities in this process may underlie disordered connectivity within the brainstem and between the cortex and brainstem. In addition to neuro-anatomic deficits in brainstem-cortical connections, there may be deficiencies in the sensory encoding of speech within the cortex that may account for the auditory processing impairment in individuals with ASD (Boddaert et al., 2004). Brainstem function for speech and music has been shown to be malleable with short-term training and sharpened by lifelong auditory experience with language, and music (Russo et al., 2005).

Because speech prosody involves the musical features of rhythm, stress, and intonation in language, music therapy may facilitate pitch learning in language. The patterns of rhythm, stress, intonation, phrasing, and contour most likely drive much of the early processing in both music and language (McMullen, 2004). With continued exposure to music, auditory encoding of speech containing prosodic pitch contours appears to improve in individuals with ASD (Russo et al., 2008).

Neural Areas Associated with Music and Language

Neuroimaging research shows overlapping responses to music and language stimuli supporting the value of incorporating principles of music making in the treatment of language disorders (Corriveau & Goswami, 2009; Koelsch, Gunter, Friederici & Schroger 2000, Koelsch, Gunter, Wittforth & Sammler, 2005; Kraus et al., 2009; Ozdemir, Norton, & Schlaug, 2006; Patel, 2003; Schlaug, Marchina, & Norton, 2008). Research experiments have involved the use of event-related potential studies (ERP), positron emission tomography (PET), and functional Magnetic Resonance Imaging (fMRI) to study neural areas associated with music and language.

Ozdemir et al. (2006) used fMRI to examine shared and distinct neural correlates of singing and speaking. Areas of activation that were common to all tasks included the inferior pre- and post-central gyrus, and superior temporal sulcus bilaterally, indicating a large shared network for motor preparation and execution. The results suggest a bi-hemispheric network for vocal production regardless of whether the words/phrases were intoned or spoken. Singing more than humming or intoned speaking showed additional right-lateralized activation of the superior temporal gyrus, inferior central operculum, and the frontal gyrus. This may offer and explanation for the clinical observation that students with non-fluent aphasia due to left hemispheric lesions are able to sing the text of a song while they are unable to speak the same words.

Corriveau and Goswami (2009) suggest that there are possible shared neural bases for music and language. In their study that explored the expressive motor abilities of children with speech and language impairment on motor tasks requiring rhythmic processing and on motor tasks lacking a rhythmic component, they proposed the potential benefit for the development of language, phonology and literacy from singing or playing a drum to stressed syllables in speech. Children with speech language impairment (SLI) were found to be impaired in a range of measures of paced rhythmic tapping compared to their age-matched and younger language-matched control children with the severity of impairment linked to language and literacy outcomes. These findings suggest the possible comorbidity of language and motor impairment in some children with speech and language impairments that may stem from a rhythmic processing deficit. Based on this study, it is plausible that both music and language could be affected by impairment in the perception and expression of rhythmic timing.

Schlaug et al. (2008) reported the unique engagement of the right hemisphere during the singing and tapping condition of their study using a music intervention for speech development for individuals with Broca's aphasia. The intervention, called Melodic Intonation Therapy (MIT), was developed based on the observation that individuals with non-fluent aphasia are better at singing lyrics rather than speaking the same words. Results of their study showed that melodic intonation and tapping that are unique elements of MIT may be responsible for the significant therapeutic effect of this intervention compared to the controlled intervention called Speech Repetition Therapy (SRT). Predominant right hemisphere activation patterns were observed using fMRI during Post40 and Post75 assessments for the MIT prototypical patient. Auditory-Motor Mapping Training (AMMT) is an intervention for nonverbal individuals with ASD that is based on the research with MIT. Schlaug et al. (2008) developed AMMT for speech development because of its potential to engage language-capable regions in the right hemisphere in children with ASD.

Similar to Schlaug et al. (2008), Koelsch et al. (2000) also used fMRI in investigating the neural correlates of music processing. He found that music processing relies on a cortical network that comprises the inferior fronto-lateral and anterior as well as the posterior temporal lobes in both hemispheres. This network is very similar to the network known to support auditory processing suggesting considerable overlap. The foundational role of the musical elements of speech in the acquisition of language is a strong implication of Koelsch et al. (2000) research, as well as the notion of syntactic and semantic dimensions of music (like language). This study involved non-musicians, giving rise to therapeutic implications given the sensitive musical responses of brains of this population of participants.

A more recent study by Koelsch et al. (2005) employed the use of event-related potential (ERP) technology to investigate the simultaneous processing of language and music. Results from this study demonstrated that processing of musical syntax reflected in the early right anterior negativity (ERAN) interacts with the processing of linguistic syntax as reflected in the left anterior negativity (LAN). This interaction is not due to a general effect of deviance-related negativities. These general effects typically precede LAN indicating a strong overlap of neural resources involved in the processing of syntax in language and music.

Kraus et al. (2009) also used ERP in his research focusing on the many shared acoustic features of language and music. The perception of pitch, timbre and timing have some shared properties, but acoustic cues associated with these categories have distinct subcortical representations that can be selectively enhanced or degraded in certain populations, including persons with ASD. The research of Kraus et al. (2009) demonstrates that pitch, timbre and timing can be enhanced with short-term linguistic training and lifelong musical experience. This finding suggests that some children with ASD may benefit from an auditory training intervention that integrates musical and linguistic training as a means of improving brain stem pitch tracking. The effects of musical experience on subcortical auditory processing are pervasive and extend beyond music to domains of language and emotion.

Peretz and Colheart (2003) used neuroimaging to support a modular framework for music and language that follows the formulation by Fodor (1983, 2001). This framework is useful when exploring the idea that music and language are potentially affected by impairment in rhythmic timing. Their model stands in contrast to the view that music and language share neural networks (Corriveau & Goswami, 2009). The modularity model holds that there are distinct architectural brain regions that subserve language and music. Furthermore, these regions are encapsulated so that there is no sharing of information between them. According to this model, pitch organization does not appear to be impaired in children with language and literacy problems. However, rhythm and meter analysis that require temporal organization, do appear to be impaired in children with language and literacy problems.

Patel (2003) compared the ERPs elicited by syntactic incongruities in language and music. He proposed that there is a point of a convergence between the syntactical processing of language and music. Syntax involves the way in which discrete structural elements are combined into sequences. These principles apply to the formation of words, phrases and sentences in language, and for the formation of chords, chord progressions and keys in music. Patel's hypothesis reconciles the contradictions between neuropsychology that suggests dissociation, and neuroimaging, which suggests overlap research. Patel's shared syntactic integration resource hypothesis (SSIRH) supports the notion that music and language share certain syntactic processes. These processes are instantiated in overlapping frontal brain areas and domain-specific representations in posterior brain regions (Patel, 2003).

McMullen and Saffran (2004) explored the possible links between music and language from a developmental perspective. Their focus was to examine to what extent the mechanisms of learning and memory subserve the acquisition of knowledge in these two domains. They examined the putative modularity of mechanisms used for learning in young learners aged six months to 11 years, in contrast to the mature adult learners. Their research focus was organized around three ideas: what we learn, meaning in language and music, and how we learn it. McMullen and Saffran (2004) draw some parallels between the faculties of language and music during development, but they acknowledge that there is substantial neurological evidence for cortical separation of these functions in adults, and some neuroimaging evidence that supports this dissociation as well.

McMullen and Saffran (2004) concurred with Patel's (2003) proposal that a distinction should be made between the processing resources used by the cognitive faculty and the content that the processing creates. This perspective states that general auditory processing mechanisms responsible for pattern analysis are involved in the perception of both speech and music. However, large stores of knowledge that relate to these separate domains may be stored in separate places in the brain.

The most important finding by McMullen and Saffran (2004) is the distinction between cortical regions subserving some aspects of musical and linguistic processing in young children versus mature learners. Although the authors reference a great preponderance of research that support separate cortical regions in musical and linguistic processing, they find it quite plausible that functional localization is not fixed in young children as it is in adults. There are relatively few imaging studies with young children due to the risks associated with positron emission tomography (PET), but with the advent of less invasive techniques like functional magnetic resonance imaging (fMRI), it has become possible to see whether modularity in adults is also evidenced in children. The brains of young children are quite plastic; McMullen and Saffran (2004) propose that experience has a profound effect of cortical organization.

Brown, Martinez, Hodges, Fox, and Parsons (2004) examined the auditory and vocal components of the human song system as well as those neural areas involved in imitation, repetition, and the pitch tracking processes underlying harmonization using O-water positron emission tomograghy (PET). All three vocal tasks showed strong activations in the primary auditory cortex and the mouth region of the primary motor cortex. Results of their study indicate that singing (more than speaking) is known to engage a bilateral reciprocal network between frontal and temporal regions, which contain some components of the putative mirror neuron system.

One important function of the mirror neuron system (MNS) is action understanding and vocal production. Autism spectrum disorder (ASD) is hypothetically linked with MNS dysfunction (Rizzolatti, & Craighero, 2004). Strategies that engage the brain regions involved in action observation that may be a part of the MNS may have potential in developing expressive language for individuals with ASD who have communication deficits. Singing engages the MNS network that is believed to be deficient in individuals with ASD (Wan et al, 2010).

The intervention of auditory-motor mapping training (AMMT) that is the focus of the present research relies on the intentional involvement with the individual while engaging the multiple sensory and motor modalities. An important aspect of AMMT is motor action from bimanual drumming coupled with sound that is designed to engage the mirror neuron system (Wan & Schlaug, 2010).

Music has been shown to elicit pleasurable responses shown by activity in the brain regions implicated in reward and emotion. Blood and Zatorre (2001) used positron emission tomography (PET) to measure regional cerebral blood flow (rCBF) changes while participants listened to self-selected music to predictably elicit the euphoric experiences of chills. Participants were asked to rate the emotional intensity of their responses to music selections during PET scan while heart rate (HR), electromyogram (EMG), respiration depth (RESP), electrodermal response, and skin temperature were measured using polygraph instrumentation system. After each PET scan, participants rated their emotional reactions to each stimulus by using analog rating scales. Participants reported experiencing chills during 77% of scans when their own selected music was played, with the rating of 7.4 out of 10 for emotional intensity being the highest compared to “chills” or “pleasantness.” The results of this study have interesting implications for the ability of music to induce pleasure. The intervention of AMMT requires the intentional involvement of the individuals involved in the treatment sessions. The pleasure elicited by the musical components of this intervention may be important to stimulate the sustained interest of the participants.

In summary, there is empirical evidence that supports a bi-hemispheric role in the production of singing and speaking (Brown et al, 2004; Ozdemir et al, 2006). Speaking has a tendency for greater left lateralization under normal physiological conditions. Non-invasive neuroimaging technology has shown a dysfunctional mirror neuron system in individuals with ASD. The use of singing in the musical intervention AMMT engages the mirror neuron system, and therefore may have potential in developing expressive language for individuals with ASD who have communication deficits (Wan et al, 2010). Using motor rhythms may aid in the development of auditory rhythmic sensitivity in children with little or no language ability. Whether the neural networks for music and language are shared (Corriveau & Goswami, 2008; Koelsch et al., 2002, 2005; Kraus, et al., 2009; Patel, 2003, 2006), or distinct (Peretz & Colheart, 2003), interventions such as AMMT with a singing and rhythmic components seem worthwhile to explore as a vehicle for developing expressive language for nonverbal children with ASD.

Music, Language, and ASD

Exceptional musical skills were described by Kanner (1943) in his first report of autism. Enhanced music perception skills continue to be a common observation in many individuals with ASD. Research by Heaton, Hudry, Ludlow, & Hill (2008) has shown that individuals with ASD have superior pitch memory relative to controls and anecdotal reports indicate unusually strong absolute pitch abilities. Children with autism often exhibit superior musical abilities and demonstrate positive responses to music (Wan et al, 2011).

Interventions for speech development have significant therapeutic potential when they take into account the musical interests of individuals with ASD (Heaton, et al., 2008; Wan et al, 2011; Wigram, 2002). Music interventions may help these children interact in activities with others that could facilitate the acquisition of communication skills.

The potential of music for treating language disorders such as those prevalent among individuals with ASD is reinforced by neuroimaging research showing overlap in neural regions associated with music and language (Koelsch et al., 2002, 2005; Patel, 1998). Studies with fMRI show activation of Broca's area during music perception tasks (Koelsch et al., 2002) and active music activities such as singing (Ozdemir et al., 2006).

Some studies focusing on language development are based on behavioral, developmental, and relationship-oriented intervention that do not take into account the neural regions associated with language in individuals with ASD. Rogers et al. (2006) representative study compared two models of intervention: Denver Model, which combines behavioral, developmental, and relationship-oriented interventions, with

PROMPT, a neurodevelopmental approach for speech production disorders. There were no differences on acquired language skills by intervention group. However, the best responders were those with mild to moderate symptoms of ASD who showed improvement in motor imitation skills and also demonstrated emerging joint attention skills. Music was not a component of this study.

Relatively few studies have focused on speech development for non-verbal children with autism. As a consequence, interventions for increasing speech output in non-verbal children are very limited. The paucity of interventions is disquieting given that social-communication impairment is one of the key diagnostic features of ASD (*The Diagnostic and Statistical Manual of Mental Disorders* 5th ed.; DSM–5; American Psychiatric Association, 2013). The specific symptoms and degree of severity of individuals with ASD varies greatly, but up to 25% of those with ASD lack the ability to communicate with others using speech sounds (Tager-Flusberg & Caronna, 2007). The ability to communicate verbally is considered one of the most important positive outcome indicators for children with ASD (Lord et al., 2006). There are some reported cases of speech development in older children with ASD, but there is lack of clarity about methods used for this language acquisition (Pickett et al., 2009).

Auditory-Motor Mapping Training: Speech Development for Children with ASD

Music therapists cite the effectiveness of musical activities to attain language and communication goals for language-delayed children (Edgerton, 1994; Kaplan & Steele, 2005). Many children with autism who are non-verbal or have reduced speech ability are able to sing a response when they are unable to speak the same response (Grandin, 1988).

Wan et al., (2010) propose an intervention called auditory-motor mapping training (AMMT) for speech develop for children with ASD that involves musical activities of drumming and intoning of words and phrases. This intervention takes advantage of the overlap between the language and music systems of the brain and may provide an alternate means for engaging this system.

Auditory-motor mapping training (AMMT) is related to melodic intonation therapy (MIT), a rehabilitative technique that has been successful in restoring language function in patients with aphasia. Both AMMT and MIT accentuate the prosody of speech through slow, pitched vocalizations and enlist the specific neural regions through the association of hand tapping and intoned vocal output (Albert et al., 1973). Brain regions recruited during these interventions include the sensori-motor feedback regions and the auditory-motor mapping network thus giving auditory-motor mapping training its name (Norton, Zipse, Marchina & Schlaug, 2009). Intensive therapy using MIT with patients with non-fluent aphasia has had favorable results in generating speech (Albert et al., 1973; Schlaug et al., 2008).

Melodic intonation therapy has been modified from the original treatment for aphasia to treat children with ASD. The modified treatment involves repeated trials of sound-motor mapping, thus reinforcing the name of auditory-motor mapping training for this intervention (Wan et al., 2009). After a comfortable environment for the child with ASD is established, training sessions involve vocalization procedure where the child is guided to vary the length and intensity of speech sounds. High frequency words, actions, or social phrases are then presented along with picture stimuli using a singing procedure from MIT (Norton et al, 2009). As words are being intoned, the therapist is simultaneously intoning (singing) the words and tapping on the drums on the same two pitches to facilitate sound-motor mapping. The sequence of the intervention begins with the child passively listening, to singing in unison, to partially supported singing, to immediate repetition, and then producing the target word or phrase on their own. Intensive repetition is essential for nonverbal child to learn to vocalize and potentially associate sound with meaning (Wan et al., 2009).

The potential for AMMT to facilitate language development via overlap between brain regions with the putative mirror neuron system (MNS) is based on evidence from prior research (Koelsch et al., 2002; Patel, Gibson, Ratner, Beeson & Holcomb, 1998; Ozdemir et al., 2006). Auditory-motor mapping training makes connections between the perception of sounds with oral articulatory and motor actions. This link between perception and action is essential for meaningful vocal communication. This intervention can engage and potentially strengthen anatomical pathways that include the arcuate faciculus and the uncinate faciculus. Three components of AMMT may be particularly important in understanding why this intervention may help facilitate the acquisition of language skills: singing, imitation, and motor activity (Wan et al., 2010).

Singing compared to speaking has been shown to engage a bilateral fronto-temporal network more prominently; some components of the MNS are contained in this network (Brown et al., 2004; Ozdemir et al., 2006). Intonation, or singing, has been shown to engage the network between the frontal and temporal regions that overlaps with language-related pathways such as the arcuate faciculus and the uncinate faciculus (Wan et al., 2010). Singing is an important feature of MIT (Norton et al., 2009) that has been shown to facilitate expressive language in aphasic individuals with right hemisphere lesions by recruiting the fronto-temporal network in the brain's right hemisphere (Ozdemir et al., 2006). Auditory-motor mapping training is an adapted form of MIT that also uses singing as a prominent feature of the intervention. Based on these commonalities, AMMT shows promise in its potential for developing speech output for nonverbal individuals with ASD.

Imitation is another component of AMMT that is of particular importance in understanding why this intervention may help facilitate the acquisition of language skills. The link between the mirror neuron system and imitation is beneficial in the development of expressive speech production in MIT and AMMT. Treatment sessions involve interactions where the participant attends to the therapist's oro-facial actions, and then imitates the words or phrases that have been sung by the therapist (Albert et al., 1973). Prior research with MIT that incorporates imitation has proven effective in facilitating language development with other groups of individuals, including stroke victims with non-fluent Broca's aphasia (Schlaug et al., 2008). Melodic intonation therapy uses the association of hand tapping and intoned words or phrases to engage brain regions associated with auditory-motor mapping and sensorimotor feedback (Wan et al., 2010). Research with MIT supports the notion that AMMT that includes imitation should have positive outcomes for expressive speech development for children with ASD.

A final component of AMMT that may be particularly important in understanding why this intervention may help facilitate the acquisition of language skills is motor activity (Wan et al., 2010). Auditory-motor mapping training engages the sensorimotor network through hand-tapping on drums. This bimanual tapping captures the child's interest and engages the multiple sensorimotor systems (Norton et al., 2009). This action has the potential to strengthen neural connections between auditory and motor regions. The motor activity primes the sensorimotor network that controls oro-facial and articulatory movements in speech (Koelsch et al., 2002). Bimanual drumming sounds may also aid in auditory-motor mapping that is essential for meaningful vocal communication (Koelsch et al., 2005).

The use of hand tapping has some other interesting implications. The concurrent use of hand gestures with speech is common in daily life activities, so the use of tapping may serve the same function as a metronome in rehabilitation of other motor activities. The tapping may facilitate speech production because of the natural tendency for entrainment in daily activity (Norton et al., 2009).

Thaut (2005) offers another perspective for why an intervention that involves a rhythmic component may be effective for children with ASD. He suggests that rhythm may be absorbed on a physiological level while bypassing the cognitive deficits of children with ASD. Rhythmic repetitive behaviors are characteristic of children with ASD. The rhythmic repetitive behaviors of persons with ASD are considered to give stability in the frequency at which the repetitive behaviors occur. Due to these fundamentally rhythmic behaviors, children with ASD will likely experience success with interventions using this communicative modality. Rhythm organizes musical events into patterns and forms, and rhythm. These structures also play an organizational function in the phonology of language, via speech prosody (Edgerton, 1994).

Musical experiences offer a means for persons with ASD to communicate that bypasses the speech and language barriers frequently experienced by those with this condition (Edgerton, 1994). The very act of music making has the potential to facilitate speech development, socialization, and interaction in children with ASD because it takes into account their strong musical interest that has long been noted in children with ASD (Blood & Zatorre, 2001; Kanner, 1943). This positive response to music allows for interaction with activities that can potentially improve social, language and motor skills (Wigram, 2002).

Restatement of Purpose

Based on the research reviewed in this study, additional study is needed to understand the value of incorporating the principles and practices of music making in the treatment of language disorders for children with ASD. Neuroimaging research has shown overlapping responses to music and language stimuli (Koelsch et al., 2002, 2005; Patel, 2003). Activation of neural region strongly linked with language has been observed in fMRI studies with music perception tasks (Koelsch et al., 2002), active music tasks such as singing (Ozdemir et al., 2006), and imagining playing an instrument (Bauman et al., 2007). Language proficiency has been identified as one of the most important factors in predicting outcomes for individuals with ASD, highlighting the need for interventions that may potentially develop speech output for nonverbal elementary children with ASD.

The primary purpose of this study was to investigate the effect of auditory-motor mapping training (AMMT) on the expressive language abilities of nonverbal elementary age students who have the primary diagnosis of Autism Spectrum Disorder (ASD). Auditory-motor mapping training is an adapted form of Melodic Intonation Therapy (MIT). Researchers have found a positive effect of MIT for treating non-fluent aphasiac patients (Norton et al., 2009).

"Nonverbal" was defined operationally as ranging from the complete absence of intelligible words through a percentile rank score of 0 on the Expressive One-Word Vocabulary Test that was administered prior to intervention sessions. Participants had a primary diagnosis of ASD, and no other major medical conditions that confounded the therapeutic effect of AMMT. Other inclusion criteria required the ability of participants to sit in a chair for more than 15 minutes, follow one-step commands without prompting, imitate simple gross motor and oral movements such as clapping, stomping their feet, and opening their mouth.

Foundational to this study was testing the following null hypothesis. There will be no effect of auditory-motor mapping training on the speech output of nonverbal elementary children with ASD. This null hypothesis was tested at the .05 level of significance.

A secondary purpose of this study was to examine the development of pre-linguistic gestural communication demonstrated by the independent 'High-Five' gesture of participants in the concluding song of each session ($p \leq .05$). Gestures are one of three nonverbal behaviors that should emerge in typical early development of communication and continue after the onset of spoken or linguistic communication is achieved (Franco et al., 2013). Gestures, along with vocalizations and eye gaze are the basic components of pre-linguistic communication that are formative for the future development of symbolic language. Pre-linguistic gestural communication emerges in typically developing children between the ages of 18-24 months. However, this precursor to spoken language is typically absent or impoverished in children with ASD (Crais et al., 2009). The 'High Five' gesture in the concluding song for each session provided a means to observe the development of this pre-linguistic gesture.

Additionally, the researcher systematically reviewed the data in to create conceptual categories that formed a framework for descriptive analysis about each participant in this study. Individual narratives for each participant gave particular attention to confounding variables that may have influenced growth from auditory-motor mapping training sessions.

CHAPTER III

PROCEDURES

To examine the effects of Auditory-Motor Mapping Training (AMMT) on the expressive language abilities of elementary age students who have the primary diagnosis of autism spectrum disorder (ASD), a single-subject design was used. This research design allowed each participant to serve as his or her own control. The AMMT components of singing, drumming and presenting visual cues combined to serve as the independent variable. The production of words and phrases was the dependent variable. Seven nonverbal students ages five to eight years with a primary diagnosis of autism spectrum disorder (ASD) participated in the study. Identification of children with ASD was made by the special education teachers of Guilford County Public Schools and by medical and other educational professionals prior to initiation of the study. This chapter includes descriptions of the participants in the study, treatment procedures, data collection instruments and procedures, and data analysis procedures.

Recruitment and Selection of Participants

Eight participants were recruited from one elementary school in the Guilford County Public School System. Students, ages five to eight years with a primary diagnosis of ASD with minimal speech output, participated in the present study. All students were identified by the teachers of students with ASD who teach in compliance with the IDEA (USDE, 1997). The Individuals with Disabilities Education Act (1997) stipulates that school systems:

1. Use technically sound instruments to assess cognitive and behavioral factors and physical or developmental factors;
2. Use assessment tools that provide relevant information that directly assists persons in determining the educational needs of the child; and,
3. Review existing evaluation data on the child, parent information, class assessments and observations, and teacher-related service providers. (p. 50-58)

The Autism Diagnostic Observation Schedule (ADOS) was the primary instrument used to assess and determine the diagnosis of ASD for participants prior to their recruitment to participate in this study. This assessment is the commonly used instrument by the Guilford County Schools (GCS) when the parents or guardians and/or educational personnel deem that a student needs to be evaluated for Autism Spectrum Disorder (ASD). The Autism Diagnostic Observation Schedule includes four modules for observing the social and communicative behaviors of individuals with ASD. Internal consistency for all domains and modules ranges from .47 to .94. Inter-rater reliability within each module is considered excellent, ranging from .65–.78. The test-retest reliability over an average period of nine months ranges from .59-.82.
The strong reliability and validity of this diagnostic instrument provides clear differentiation between children with ASD and verbally matched children with non-spectrum disorders.

As required and specified by IDEA, the ADOS was a technically sound instrument to assess the cognitive and behavioral factors for a student to receive services in GCS for ASD. Consistent with item three from the aforementioned IDEA, parent information of the referred individual was obtained through a structured interview, along with class assessments and observations that aided in the diagnosis of the participants as being on the autism spectrum.

The researcher consulted the classroom teachers of the students with ASD to gain information about which students matched the nonverbal participant protocol of the current study. Conversations with teachers identified the characteristics that have diagnosed minimal speech output. Clarification was provided to teachers that the term 'nonverbal' was used interchangeably with minimal speech output in research literature and within this study. These two terms were defined operationally as children with ASD who have made minimal progress in speech acquisition based on speech-language pathology, parent reports, and teachers' observations. Recruitment letters were sent to ten students; nine consent forms initially were returned. Two out of nine responses from parents or guardians of children beyond five-to-eight years of age were eliminated as eligible participants. A follow-up recruitment letter was sent to the parents of a child who had not responded to the first recruitment letter. A signed consent form was returned after this second request.

Eight children with diagnoses of minimal speech output were administered the pre-assessment of the *Expressive One-Word Vocabulary Test* (Academic Therapy Publications, 2000) to confirm participants' diagnoses. The EOWVT is a measurement instrument that commonly is used by the Guilford County Public School System to assess language skills of students with ASD. The test has strong reliability and validity based on a standardization sample that closely resembled the demographics of the United States populations and included more than 2,400 children and adults ages 2 years, 0 months — 103 years. It has a high degree of reliability for internal consistency, ranging from 0.93 to 0.97 for the various age groups, with a median of 0.95 across all ages. The test-retest correlation for raw scores is 0.98 and 0.97 for standard scores.

One child was disqualified from the study based on the EOWVT pre-assessment because his speech output exceeded the threshold for the operational definition of nonverbal specified for the present study; therefore, he did not participate in the AMMT intervention sessions of this study. Seven children participated in three baseline assessments, 12 training sessions, and two probe assessments to determine the effects of AMMT on the participants' expressive language abilities.

Table 1 shows general characteristics of each participant in the study. The "Age at Initiation of the Study" indicates the age of each participant when the *Expressive One-Word Vocabulary Test* (EOWVT) was administered (Academic Therapy Publications, 2000). All participants scored 0 on this standardized EOWVT that was used to pre-assess and verify each participant's nonverbal diagnosis.

Table 1. Participant General Characteristics

Participant	Gender	Ethnicity	Primary Language in Spoken in Home	Age at Initiation of Study
M1	Male	Indian	English	5 years, 10 months
F1	Female	Afghanistani	English (parents also spoke Pushto)	6 years, 6 months
M2	Male	African-American	English	7 years, 3 months
M3	Male	Caucasian father, Hispanic mother	English	7 years, 4 months
M4	Male	Caucasian	English	5 years, 7 months
M5	Male	Guatemalan	English	8 years, 7 months
F2	Female	African-American	English	8 years, 1 month

Prior to the study, the researcher completed the *Collaborative Institutional Training Initiative* to be informed regarding responsible conduct of research. The Office of Research Integrity of the University of North Carolina at Greensboro granted Institutional Review Board (IRB) approval for this research project (Appendix A). Written permission to conduct the study also was obtained from the Research Review Committee of the Data and Evaluation Department and the Autism Coordinator of Guilford County Public School System (Appendix B). Parents and guardians of potential participants were sent a packet of information about the study including a "Recruitment Letter" (Appendix C), a brochure explaining the nature of the study, entitled "Effects of Auditory-Motor Mapping Training on Speech Output of Individuals with Autism" (Appendix D), and a "Parent/Guardian Research Consent Form" form granting permission for his or her child to participate in the study (Appendix E). The "Parent/Guardian Research Consent Form" also included the required permission giving consent for the child to serve as a "Human Subject for Research". When consent forms were received from interested parents/guardians, they were asked to complete a "Student Information Form" with each participants' first name, last initial, and essential information in case of emergency (Appendix F). All procedures were conducted according to the IRB-approved protocol.

To determine the therapeutic potential of Auditory-Motor Mapping Training (AMMT), the ages of the participants were beyond the typical age of initial speech development. Participants in the present study were heterogeneous with regard to gender and race. All participants had the primary diagnosis of ASD, and no other major medical conditions, such as motor disabilities (e.g. cerebral palsy, or tuberous sclerosis) or genetic disorders (e.g. Down's Syndrome). Expressive language development was confirmed by the EOWVT (Academic Therapy Publications, 2000) for seven out of eight children who were originally recruited. The expressive language output of one male student was beyond the operational definition of nonverbal specified for this study as measured by the EOWVT; therefore, he did not participate in the AMMT intervention sessions of this study.

While receiving the AMMT treatment in the present study, participants continued with their regular school activity, but no other new treatments were initiated that could confound the potential effect of AMMT on participants' expressive language abilities. Inclusion criteria for participants also included their ability to: (1) sit in a chair for more than 15 minutes, (2) follow one-step directions without multiple prompts, and (3) imitate simple gross-motor and oral motor movements such as clapping their hands, stomping their feet, and opening their mouth.

Treatment Procedures

The treatment sessions and probe-assessment sessions were conducted in a room adjacent to the elementary general music classroom. During the 20-minute session, the participant sat facing the experimenter with a pair of tuned drums placed between them. Each session began with a "Hello Song" and concluded with a "Goodbye" song to establish rapport and structure in the treatment environment. The "Goodbye" song included a 'High Five' hand gesture that encouraged a physical and social interaction between the participant and researcher (Crais, Watson, & Baranek, 2009). Inclusion of this gesture supported the secondary research question that examined the development of pre-linguistic gestural communication that is evidenced in typical language development between the ages of 18-24 months. The independent demonstration of the 'High-Five' gesture by participants during the concluding song of each session was noted and analyzed to discern if there was growth in pre-linguistic gestural communication over the course of the intervention sessions. Pre-linguistic gestural communication typically is absent or minimal among children with ASD.

Fifteen words relevant to the participants' activities of daily living served as target words for treatment sessions, baseline, midpoint and post-assessment probe sessions. These words were high-frequency objects, actions, social words or phrases, such as 'Apple,' 'Bus,' or 'Wash hands.'

Target words or phrases were introduced using Pics for Pecs pictures (Bondy & Frost, 2011) as visual cues while the experimenter intoned (sang) the words on two pitches and simultaneously tapped the drum (on the same two pitches). This simultaneous action was designed to facilitate bimanual sound-motor mapping. Table 2 shows the structure of an auditory-motor mapping intervention session.

Table 2. Structure of Auditory-Motor Mapping Training (AMMT) Sequence

Step	Procedure
1. Listening	Therapist introduces the target word/phrase by showing a picture and then intoning (singing) the phrase at a rate of one syllable per second. "Apple"
2. Unison Production	Therapist and participant intone the target word/phrase together. Therapist intone "Let's sing it together" and in unison with participant "Apple"
3. Partially-supported production	Therapist and participant begin to intone the target word together, but halfway through, the therapist fades out while the participant continues to sing the rest of the word/phrase "Ap(ple)"
4. Immediate repetition	Therapist intones and taps the target word/phrase while the participant listens. The participant immediately repeats the word/phrase. "My turn: apple. Your turn (Apple)"
5. Own production	The participant produces the target word/phrase on his/her own: one more time "(Apple)"

Treatment Sessions

Participants received twelve bi-weekly AMMT treatment sessions of 20 minutes in length. If a participant was absent for a session, then the researcher scheduled three sessions the following week. The goal of this scheduling procedure was so that sessions could be spaced in such a manner that the lapse of time between sessions was approximately the same for all participants, thus allowing for the rate of retention to be approximately the same. During the treatment sessions, they engaged with 15 predetermined target words through imitation, singing, and motor activity—all components of AMMT. The researcher introduced 15 target words or phrases in each treatment session by intoning (i.e., singing) the words on two pitches. Words and phrases presented during the treatment sessions were considered 'trained' words because participants received practice in learning how to use the AMMT intervention to master these words in the treatment sessions. Steps of the AMMT sequence could be repeated based on the participant's progress toward intoning the target word or phrase. The repetition provided training, so the words presented in treatment sessions were considered 'trained' words.

Prior to the presentation of the word or phrase in the 'Listening' step, the researcher put her hand to her ear and sang "Listen" on the 'sol-mi' pitches. Immediately following this prompt to listen, the researcher pointed to the picture card and intoned the target word or phrase on 'sol-mi' pitches at the rate of one syllable per second (See Table 2, Step 1). The researcher introduced words or phrases while simultaneously tapping the drums on the same two pitches.

After intoning the word or phrase twice, the researcher moved to step two and said, "Let's sing it together," inviting the participant to intone the word or phrase in unison with the researcher. If a participant was unable to produce the word after hearing the researcher intone it a few times, then the intervention sequence moved to the next word or phrase without proceeding through steps three, four and five. If a participant correctly intoned the word or phrase in unison with the researcher as specified in step two, then the sequence moved to step three and the participant was asked, "Let's sing it again." The researcher supported the participant in initiating the word or phrase and then faded out as the participant completed the word (see Table 2, Step 3).

Moving to step four of 'immediate repetition', the researcher said "My turn," intoned the word or phrase, then said "Your turn," gesturing for the participant to repeat the word or phrase (see Table 1, Step 4). Finally, in step five the participant was asked to intone the word "One more time" (see Table 2, Step 5). Each step was repeated several times during the treatment sessions depending on the participant's progress toward the mastery of the target word or phrase.

Words or phrases were selected randomly prior to treatment session one. Words or phrases that were produced by participants during treatment sessions were removed from the set, and new words or phrases were added so that 15 words or phrases that had not been mastered were presented in each treatment session. Correctly intoned words were removed from the set and replaced by another randomly selected word for the next treatment session. In this way, fifteen words that had not been intoned correctly were presented in each treatment session.

Participants were presented and practiced the same word or phrase during successive treatment sessions until the word or phrase was 'mastered' with a correct approximation. All participants were presented with Set One words or phrases shown in

Table 3 in treatment session one. Mastered words or phrases were removed and new words were put in their place for the succeeding session. For example, M5 correctly intoned the words 'Bus', 'Lunch', and 'Pizza' in session one, so these three words were replaced with ‘Color,’ ‘Change Clothes,’ and ‘Pig’ for treatment session two (see Table 3).

Table 3. Sample Treatment Session Words

SET 1	**SET 2**
Bus	Wash hands
Wash hands	Pants
Pants	Music
Music	Salad
Lunch	Apple
Pizza	Hungry
Salad	Puzzle
Apple	Recess
Hungry	French Fries
Puzzle	Eyes
Recess	Sandwich
French fries	Desk
Eyes	Color
Sandwich	Change clothes
Desk	Pig

All treatment sessions were videotaped to monitor the fidelity of the intervention and the adherence to protocol. Treatment sessions were referred to as ‘trained sessions’ because steps could be repeated many times for training in using the intervention as participants progressed toward word or phrase production.

Probe Assessments

Probe assessments were conducted during three baseline sessions, during a mid-point session (i.e., after treatment session six), and during a final post-treatment session. The same fifteen words were presented to all participants in baseline session one. These fifteen words were randomly selected prior to this baseline session. If a word was correctly intoned in a baseline session, then the word was removed from the set and replaced by another randomly selected word.

During each probe assessment, the participant's intoned responses to 15 'untrained' words or phrases that had not been presented in any of the treatment sessions. The participants had not been presented with any of the probe words during twelve treatment sessions. The twelve treatment sessions were called 'trained' sessions because participants received training and practice with the AMMT intervention for speech production during these sessions. In contrast, probe sessions were considered 'untrained' sessions because words were not practiced and repeated as they were during treatment sessions. Participants did not receive any training in mastering probe assessment words or phrases as they did with the repeated practice in the trained sessions (i.e., treatment sessions). Untrained words were presented during the probe sessions in a randomized manner.

Table 4. Sample Probe Session Words

PROBE SESSION WORDS
Pancake
Tummy
Ketchup
Party
Line up
Jelly
Sick
Tired
Syrup
Sausage
Socks
Shirt
Pickle
Song
Happy

Both the sequence of steps for AMMT in probe sessions (see Table 4) were identical to those detailed in Table 2, but no practice, prompts, or feedback were included in the intervention procedure. These probe sessions provided foundational data showing the effects of AMMT, if any, on participants' abilities to produce words or phrases (i.e., expressive communication abilities). Untrained words were presented during the probe sessions in a randomized manner. Words presented during trained (i.e., treatment) and untrained (i.e., probe) sessions contained bi-syllabic words of phrases that were matched on: frequency in early language, and difficulty.

Data Collection Equipment

Equipment used for AMMT treatment sessions included a pair of tuned drums, Pics for Pecs visual cue cards (Bondy & Frost, 2011), and video equipment for recording each session. Each drum was tuned to a fixed pitch. One drum was tuned to C4 or 261.626 Hz, and the other drum was tuned to E*b*4 or 311.127 Hz). Pics for Pecs (Bondy & Frost, 2011) were used to provide visual cues to the participants while the experimenter intoned (i.e., sung) the words on two pitches and simultaneously tapped the drum (on the same two pitches).

The researcher used three forms of video recording equipment to record intervention sessions, an IPhone 5S, an iPad mini, and a MacBook Pro. Two out of three types of video recording equipment were present during each session. One was being used to video, and the other was available in the event that there was a malfunction of the original video recording device.

Data Analysis Procedures

The present study was designed to examine the effects of AMMT on expressive language abilities of nonverbal children with autism aged five to eight years old. A single-subject design was employed to analyze the therapeutic effect of this AMMT intervention on: (a) expressive language output, and (b) pre-linguistic gestural communication (e.g., high five gesture). This single-subject design allowed for each participant to serve as his or her own control.

A Friedman Rank Order One-way Analysis of Variance with repeated measures (ANOVA) was performed to test the null hypothesis. Each participant's utterances were transcribed and analyzed based on the best production of the target word or phrase within a trial. The participants' speech production when presented with the picture stimuli (trained and untrained sets) during the probe assessment sessions was the outcome measure of interest. Comparisons were made between the percentages of correct approximations produced by each child during the baseline, intervention, and follow-up probe assessments. Experimental control was attained through the administration of three baseline assessments prior to AMMT.

McNemar's Chi Square analyses were used to test the secondary purpose of this study. This statistical procedure was used to examine changes in the participants' social interaction as measured by their initiation of the 'High-Five' gesture in the concluding Goodbye song.

The *International Phonetic Alphabet* (Brown, 2012) was used to analyze speech sounds. The researcher viewed videotapes and analyzed whether the participant had intoned a correct approximation, based on the number of correctly produced consonants and vowels (CV). After the researcher reviewed the video recordings and documented the points of correct approximations, the services of a speech/language pathologist were enlisted who also reviewed the video recordings. Attention was given to whether the participant had produced a correct vowel combined with an approximation of the consonant, fulfilling the criterion for acceptable CV production. Criterion for a correct consonant approximation was met if the sound produced contained two out of three production dimensions of the target phoneme. Production dimensions include voicing (+ and – voice), place (bilabial, labiodental, interdental, alveolar, palatal, velar, and glottal) and manner (stop, nasal, fricative, affricative, liquid, glide). For example, a correct CV approximation for the word "he-llo" would be "he-wo." The researcher and speech/language pathologist determined the number of correct word approximations and then the number of correct CV approximation was documented.

The collected data were analyzed using descriptive and inferential statistics. Statistical analyses were conducted using the *Statistical Package for the Social Sciences* (IBM, 2013). A Friedman Rank Order One-way Analysis of Variance with repeated measures was used to compare correct consonant-vowel approximations from the best baseline probe, through untrained probe session one (P1), and two (P2) with growth in speech production indicating a positive effect of the intervention on expressive communication abilities. Probe one was conducted at the mid-point of all trained sessions on the same day as session six, and probe two was conducted after all trained sessions were complete. Growth in speech production or increased communication abilities was indicated by an increase in the number of correct approximation of words across the measures taken at the best baseline, probe one, and probe two sessions. The null hypothesis was tested with an alpha level equal to or less than .05 as the level of significance. McNemar's chi-square was used to examine the growth of participants' social interactions (i.e., increased pre-lingual gestural communication), as measured by their initiation of the 'High-Five' gesture in the concluding "Goodbye" song.

Results of the study were reported to the researchers Doctoral Committee at the University of North Carolina at Greensboro, to the Research Review Committee and the Autism Coordinator of the Guilford County Public School System, and to the parents of the participants in the study. Additionally, a copy of this dissertation will be presented to the Scholarship Committee of the Delta Kappa Gamma Education Society International and presented in an oral report to the Biennial International Convention of this Society in July 2016.

CHAPTER IV

RESULTS

The primary purpose of this study was to investigate the effect of Auditory-Motor Mapping Training (AMMT) on the expressive language abilities of nonverbal elementary age students who have the primary diagnosis of Autism Spectrum Disorder (ASD). "Nonverbal" was defined operationally as children with ASD who have demonstrated minimal progress in speech acquisition based on speech-language pathology and parent reports. Results of the study were determined by testing the following null hypothesis at a significance level of less than or equal to .05. There will be no effect of auditory-motor mapping training (AMMT) on speech output of nonverbal elementary children with autism.

The researcher systematically reviewed the data to create conceptual categories that formed a framework for descriptive analysis about each participant in this study. Individual narratives for each participant provided important information regarding confounding variables that possibly influenced the effects of AMMT sessions on participants' expressive communication abilities and pre-linguistic gestural communication.

To test the null hypotheses, a Friedman Rank Order One-way Analysis of Variance with repeated measures (ANOVA) was used to analyze participants' correct approximations of target words in the trained and untrained AMMT intervention sessions. The baseline and two probe assessment sessions served as the repeated measure. To fulfill the secondary purpose of this study, McNemar's Chi-square analyses were used to examine changes in participants' social interaction or pre-linguistic gestural communication as measured by their initiation of the 'High-Five' gesture in the concluding "Goodbye" song. McNemar's test was a one-way goodness-of-fit chi-square for a binary dependent variable for within-subjects' designs, and the alpha level was set at equal to or less than .05. According to Howell (2013), this analysis often is appropriate when the researcher expects an intervention to be effective, resulting in participants moving from a "No" response to a "Yes" response, rather than from an affirmative to negative response.

The researcher began each session with a "Hello Song" and concluded each session with a "Goodbye" song to establish a comfortable environment and routine for participants. The "High Five' gesture included in the "Goodbye" song exemplified a pre-linguistic gesture that develops in typical children between 18 months and 24 months of age. For nonverbal children with ASD, this gesture may be minimal or absent. The researcher observed and documented if the 'High Five' gesture occurred across all the AMMT sessions.

Descriptive Narratives of Participants

A systematic review of the data for each participant provided a framework for describing each participant in this study. The descriptive narratives also highlighted various individual components of the study where participants' communication abilities increased, but the increase was not statistically different from their baseline responses ($p > .05$). Although these discrete components were not significant according to the research protocol, they were important for two primary reasons. First, the demonstration of adherence and responsiveness to distinct features of the AMMT intervention sequence represented a measure of success for each participant. Additionally, the descriptions of positive growth toward speech output by participants was informative about the overall merits of this AMMT intervention strategy and its efficacy for developing speech output for nonverbal children with ASD.

Qualitative Analysis and Descriptive Narrative for M1

Participant M1 was a male of Indian descent that was five years ten months of age at the time of pre-assessment, but turned six during the course of intervention sessions. Pre-assessment scores yielded an age equivalent of two years eight months, placing him at a percentile rank of 0 for his expressive language vocabulary. His eager behavior throughout the intervention sessions can be exemplified in session five when the participant wanted to reverse roles with the researcher. He reached out to hold the Pics for Pecs cards (Bondy & Frost, 2011) and attempted to adhere to the session routine just as he had witnessed from the researcher in previous sessions. He intoned "Listen" on sol-mi as he presented a new Pics for Pecs visual card (Bondy & Frost, 2011), and then waited for the researcher to intone the word. He attempted to repeat the word, and then followed his word attempt with the affirmation "Good." This pattern of the participant attempting to reverse roles with the researcher continued for the remainder of the intervention sessions.

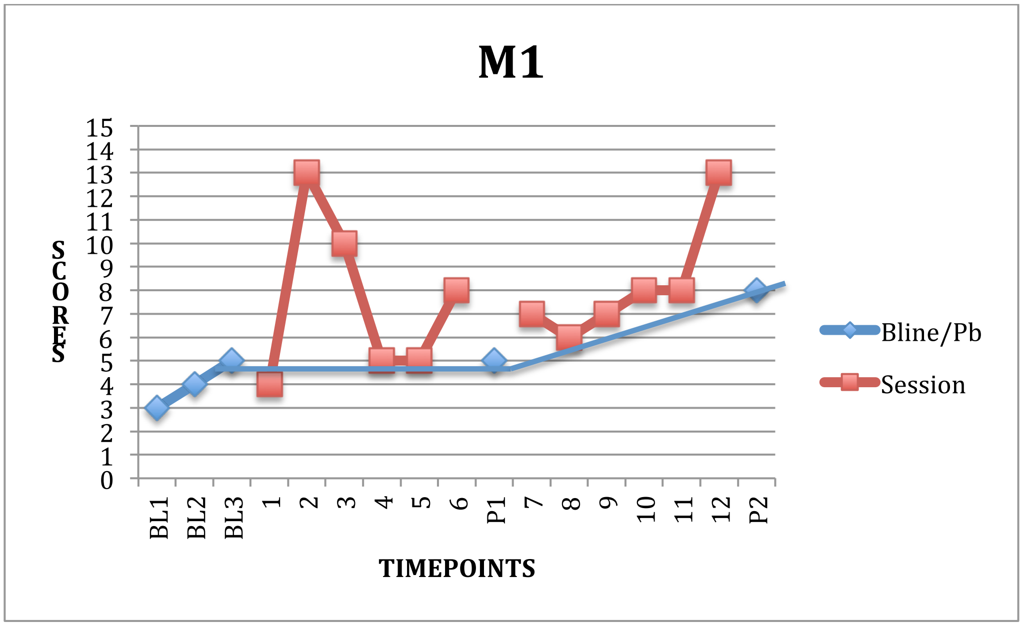

Figure 1. Scores for M1 Baseline/Probe Untrained and Trained Sessions

Results of words learned during AMMT sessions for participant M1 are shown in Figure 1. He demonstrated steady growth in scores indicated by the blue line from the first baseline session (BL1=3) to the final probe session (P2). Although M1's scores for correctly intoned words during trained sessions was more erratic, participant M1 produced a total of 83 correct approximations of words during the 12 trained sessions. Adding this number to the 25 total correct approximations of words during the five untrained probe sessions (three baselines, mid-point probe P1, and post treatment probe P2) sums to 108 total words that were correctly produced by M1. Given this positive response to AMMT, the researcher questioned why the participant's score on session 12 was low with only two correct approximations compared to the relatively strong response in other sessions. In answering this question, the researcher examined the difficulty of the 15 words presented in session 12 relative to those presented in other sessions. Selection of words for each session were randomized and matched for difficulty, but M1 may have lacked an experiential framework for recognizing the Pic for Pec visual (Bondy& Frost, 2011) and/or the word that represented the picture. This lack of contextual relevancy may have impacted understanding, therefore influencing the participant's desire to replicate the word. For example, a pair of exercise shoes were called "sneakers" according to the creators of Pics for Pec (Bondy & Frost, 2011), but the participant may have been confused by this terminology if it was outside his realm of experience. Food words such as cucumber and cantaloupe were presented, but perhaps the student had not had exposure to these foods, thus affecting his desire to replicate them in the session.

The correct production of 108 words during AMMT sessions indicated great progress for this participant, but the success of the intervention extended beyond treatment sessions. Reports from teachers and after-school care givers indicated participant M1 speech output continued to increase both while he was attending AMMT sessions and after treatment sessions were completed. The researcher also witnessed this improvement in speech output when she encountered the participant at other times during the school day outside of treatment sessions.

Participant M1 consistently demonstrated an independent 'High Five' gesture in each of the twelve sessions. This consistent response confirmed that this pre-linguistic skill had developed for M1, which was further confirmed by the high number of total words intoned by this participant throughout the AMMT sessions.

Qualitative Analysis and Descriptive Narrative for F1

Participant F1 was an Afghanistani female aged six years six months at the time of pre-assessment. She did not produce any verbal responses during the EOWVT yielding a raw score of 0. English was the language spoken in her home although her parents were also fluent in their native Pushto language. She was diagnosed with Pervasive Developmental Disorder at 34 months of age. Further developmental evaluation indicated that she demonstrated skills appropriate for her age in terms of her gross motor skills, but significant delays in her fine motor, cognitive, self-help, social-emotional, receptive and expressive language development were noted.

Vocalizations of any kind were rare for participant F1 during AMMT sessions. Figure 2 shows that she did not demonstrate any correct approximations of words during baseline, probe, or trained intervention sessions. She made no attempts to imitate the intoning of words, but during the first three minutes of session five she had a few delightful vocalizations of "ah." These responses seemed to stem from her interest in seeing her facial gestures in the camera and were not in response to the words and visual cues that were being presented. She was relatively still throughout the sessions, and rarely made eye contact with the researcher.

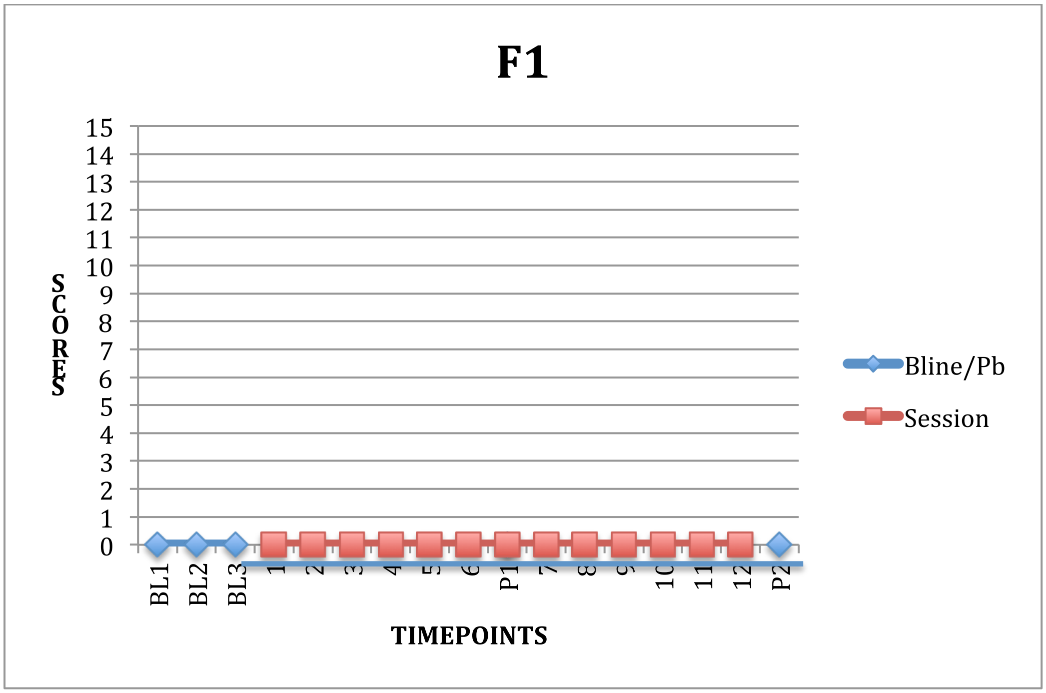

Figure 2. Scores for F1 Baseline/Probe Untrained and Trained Sessions

Participant F1 had one other instance of vocalization during session twelve when she said "mmm" at the presentation of the word 'pizza'. She wanted to hold the Pic for Pec card (Bondy & Frost, 2011) as she did this vocalization. When presented with the word 'eyes' during this session, she responded by pointing to her eyes but made no vocalization. Session twelve also included an independent 'High Five' gesture during the concluding "Goodbye Song." Considering F1 did not produce any speech output seen in Figure 2, and demonstrated a weakly moderate response to the 'High Five' gesture seen in Figure 3, session twelve was her strongest session. Even though she did not make any correct approximation of any words, she did communicate a response to the words 'pizza' and 'eyes' and did an independent 'High Five' gesture during session twelve.

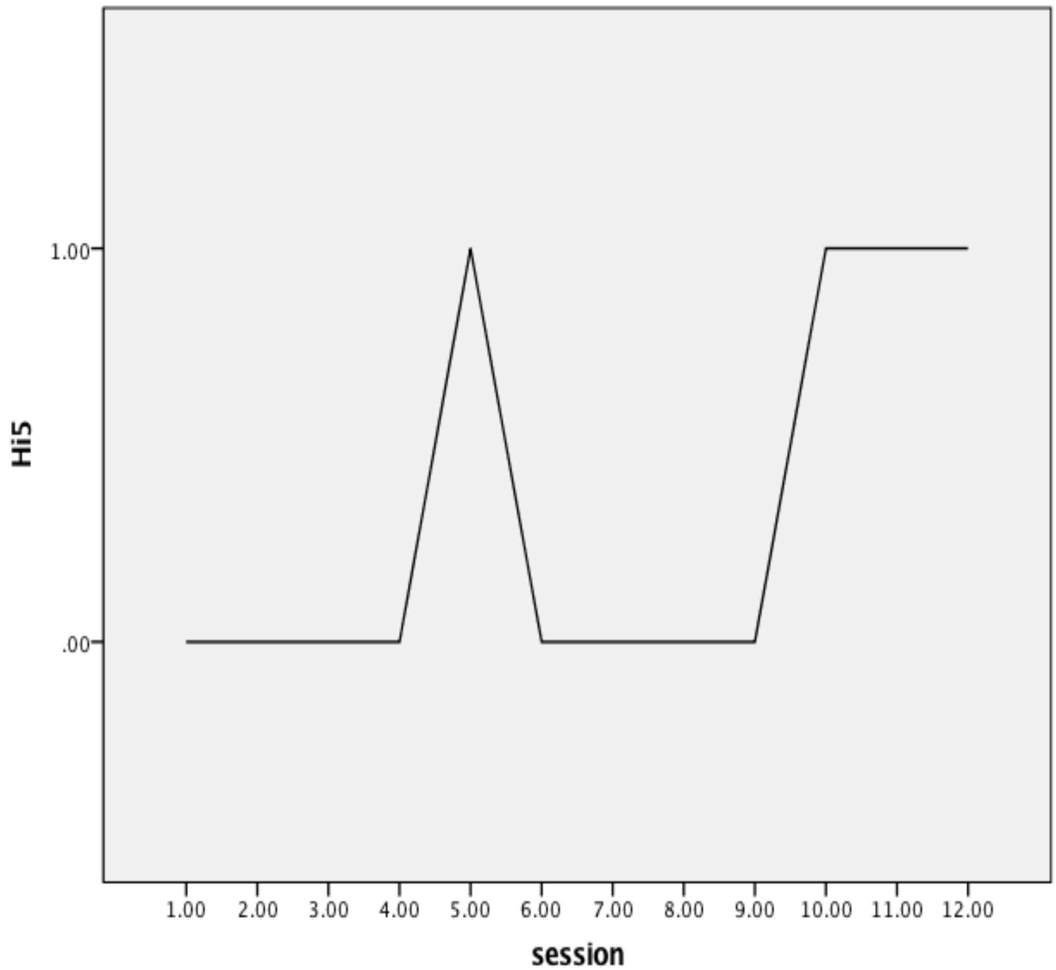

Figure 3. F1 Independent High 5 Gesture

Figure 3 shows a developing independent ‘High Five’ gesture for participant F1. The trend toward a consistent positive response in sessions ten, eleven and twelve were encouraging given the minimal response of this participant to developing speech output. Pre-linguistic communication such as ‘High Five’ should emerge around 18-24 months of age in typically development, so F1’s independent demonstration gave support to the notion that pre-linguistic communication was developing for her. This small measure of success provided some tangible evidence of the development of pre-linguistic communication for F1 that may eventually be foundational for speech development for this individual.

Qualitative Analysis and Descriptive Narrative for M2

Participant M2 was an African-American male who was seven years three months of age at the time of pre-assessment. He did not produce any verbal responses during the (Academic Therapy Publications, 2000) yielding a raw score of 0. He was being reared by his mother and grandmother; his father had infrequent contact with him. His mother, a public school counselor, had been thorough in early diagnosis and intervention for participant M2, her only child. According to his ADOS (Lord & Rutter, 2000) dated May 20, 2011, he spontaneously offered no words or word approximations, and occasionally whined or responded with brief echolalia during the ADOS assessment session. These communication and language behaviors were also witnessed by the researcher during AMMT sessions.

Figure 4 shows that participant M2 had no correct approximations of words during baseline, probe or trained sessions. However, he established good eye contact with the researcher throughout all sessions, and moved the Pic for Pecs cards (Bondy & Frost, 2011) if they impeded his eye contact with the researcher. He was generally attentive and made some vocalizations that seemed to be related to events during the intervention sessions. For example, he held his hands over his ears, shook his head, and made nonsensical agitated vocalizations during the initial "Hello" song of the first two baseline sessions. By the third baseline session, he was much more acclimated to the session environment, so he was smiling and making pleasant vocalizations during the

“Hello” song without covering his ears. He keenly watched the formation of the researcher’s mouth as she presented the word ‘Bus,’ and moved his mouth to form the sounds for this word, but never vocalized a correct approximation. This participant was a regular bus rider, so this word seemingly held significant meaning for him. Again in session one participant M2 expressed particular interest in the word ‘Bus’ as he attempted to touch my mouth as I intoned the word.

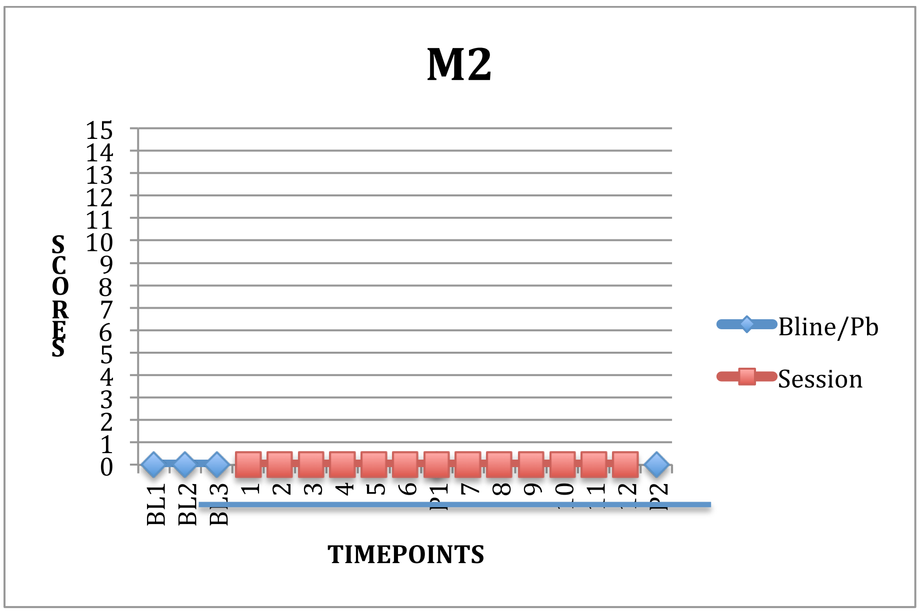

Figure 4. Scores for M2 Baseline/Probe Untrained and Trained Sessions

Sessions three, four and seven included other demonstrations of understanding and meaningful vocalization attempts by this participant. When presented with ‘Wash hands’ during session three and seven, he looked toward the sink located in the session room. During session four, he continued to vocalize the ‘m’ sound when presented with the word ‘Music.’

Sessions eight, ten and twelve were marked by negative behaviors for participant M2. During the “Hello” song, he groaned and put his hands over his ears or in his ears. He seemed agitated, demonstrating avoidance behaviors such as ducking and shaking his head, and attempts to wrestle with the researcher’s hands. Conversations with his teachers after these sessions indicated that his off-task behavior in AMMT sessions corresponded with similar off-task behaviors during school on those days. Although the researcher made efforts to ensure a calm consistent environment, confounding variables outside the control of the researcher may have impacted the behavior of this participant, particularly during sessions eight, ten and twelve.

Figure 5 shows that participant M2 made gradual, but somewhat erratic progress in showing an independent ‘High Five’ gesture. During session one, four and five, the participant rested his hands over the researcher’s hands while she played a steady beat to the “Goodbye Song,” but he did not respond to the initiation of the ‘High Five’ gesture. However, by sessions six and seven, he excitedly responded with an independent gesture. The overall positive trend in his initiation of an independent ‘High Five’ gesture indicated that this pre-linguistic skill was likely developing. With the promise of continued practice of this gesture by participant M2 with his mother and grandmother after the AMMT sessions were completed, the foundation for the eventual emergence of meaningful speech output will be in place so that spoken language will be evidenced.

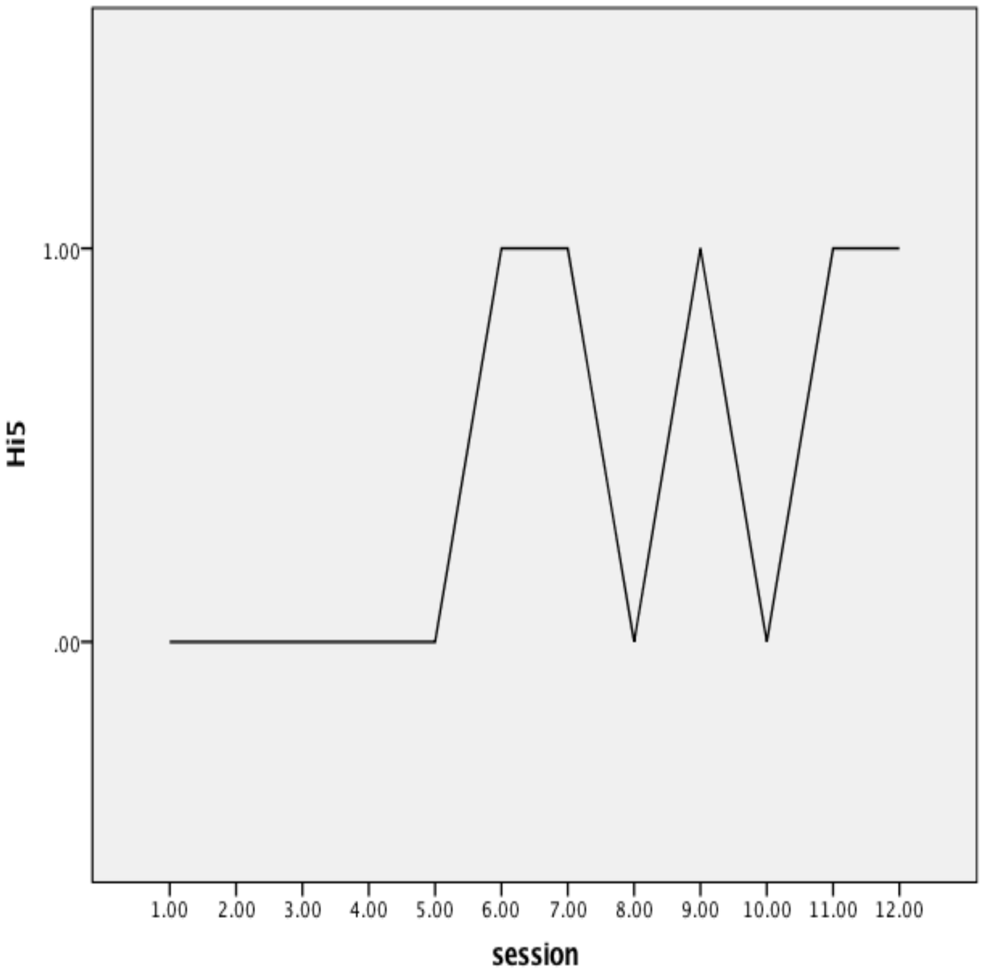

Figure 5. M2 Independent High 5 Gesture

Qualitative Analysis and Descriptive Narrative for M3

Participant M3 was a male who was seven years four months of age at the time of pre-assessment. He did not produce any verbal responses during the EOWVT (Academic Therapy Publications, 2000) yielding a raw score of 0. He lived with his Caucasian father and Hispanic mother, and had an older sister and brother also living in the home. Teacher and parent reports prior to AMMT sessions indicated that negative behaviors were likely to occur during transitions and in new situations. Given the potential for particularly negative and adverse behaviors, the researcher strategically planned for easing the transition from his classroom to his after school intervention sessions. In spite of careful planning and adjustments throughout the duration of intervention sessions, erratic behaviors were commonly exhibited by M3 during interactions with the researcher.

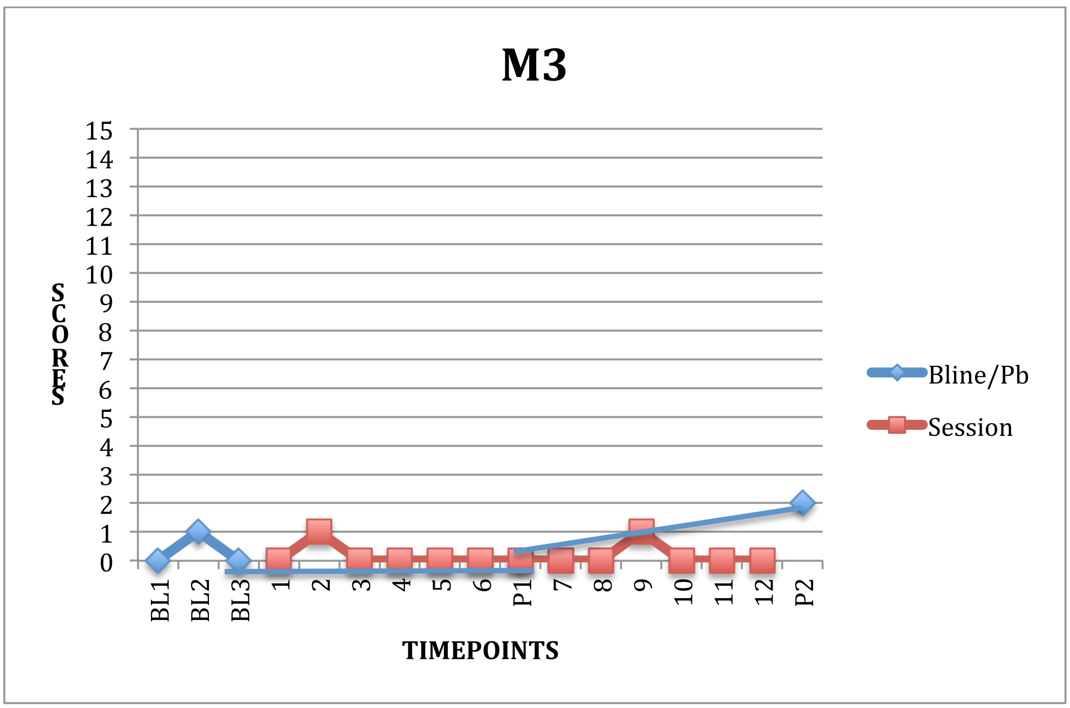

Figure 6. Scores for M3 Baseline/Probe Untrained and Trained Sessions

As shown in Figure 6, participant M3 demonstrated a correct approximation of the word ‘Apple’ during the second baseline session (B2), and two correct approximations of the words ‘Happy’ and ‘Lemon’ in the post-assessment probe session P2). He also correctly produced the word ‘Pants’ in session two and the word ‘Bus’ in session nine. Although the correct vocalization of five total words seemed minimal in terms of statistical significance, this measure of progress toward speech development was significant in light of the challenging behaviors demonstrated by this participant.

Behaviors exhibited by participant M3 during baseline sessions included crying, screaming, hitting, kicking, picking his nose, putting his fingers in his mouth, spitting, and biting his arm, leg, and shirt. He also hit, kicked, and bit the researcher, and also spat upon the researcher. In spite of these negative behaviors, he remained in his chair throughout the baseline sessions. He displayed intermittent moments of silence. He became relatively still and quiet when I intoned the word 'Apple' during the first baseline session (B1). The same attentive response occurred in baseline session two (B2) when the words 'Lunch,' 'Hungry,' and 'Apple' were intoned by the researcher. He demonstrated a correct approximation for the word 'Apple' during this session, and also performed the American Sign Language gesture for this word. The researcher deduced that he could be hungry during his afternoon sessions, so his mother complied with the request that a snack be provided for him to eat prior to his sessions.

When participant M3 arrived for session one, his positive demeanor stood in stark contrast to the negative behaviors he exhibited during the baseline sessions. His positive behavior contributed to more focused attention and stronger attempts at words, although he had only one correct approximation in session two of the word 'Pants.' For example, he verbalized the initial sounds of the word 'Puzzle' and 'French fries', but did not articulate either of these words in their entirety. He screamed and smiled excitedly when I offered him the drum to play bimanually while attempting to imitate the researcher's intoning of these two words. Similarly, during session two, he uttered the initial sounds of ‘Bus,’ ‘Music,’ ‘Puzzle, and ‘French fries’ and was thrilled with the opportunity to bimanually drum while attempting to intone these words correctly. He shaped his mouth to form the sounds of the word ‘Hungry,’ but did not articulate any sounds for this word. When the word ‘Eyes’ was presented, he pointed to his eyes demonstrating understanding, but did not attempt to intone this word.

Participant M3 was absent from school for a vacation for eleven days between sessions three and four. When he returned, he was particularly unruly, most likely because he had been out of his school routine for several days. His teacher and assistants were very frustrated after experiencing aggressive behaviors in the classroom, and while escorting him to the session room for sessions four, five and six following his return to school. They asked to excuse themselves from escorting him to the session room, so I escorted him by myself from session seven until the end of the AMMT process. He was generally resistant, but had intermittent moments of focus where he made strong attempts of correct word approximations. The researcher noted that if he articulated a correct sound in the word presented, it was always the initial sound. For example, in session five he articulated the ‘D’ in ‘Desk,’ in the first probe session he articulated the ‘P’ in ‘Pancake,’ and the ‘N’ in ‘Nose’ in session 11 while pointing to his nose.

The researcher contended that participant M3 was more responsive to the AMMT intervention than his scores would indicate. Since the scores only reflected correct approximation of entire words, there was no partial credit for his many correct approximations of initial sounds. The researcher also believes that the eleven day absence from school and intervention sessions had a confounding effect on this participant's general behavior. Resuming progress toward acclimation to the AMMT routine was difficult, therefore his sporadic engagement with the researcher may have compromised the scores reflecting the words he correctly intoned.

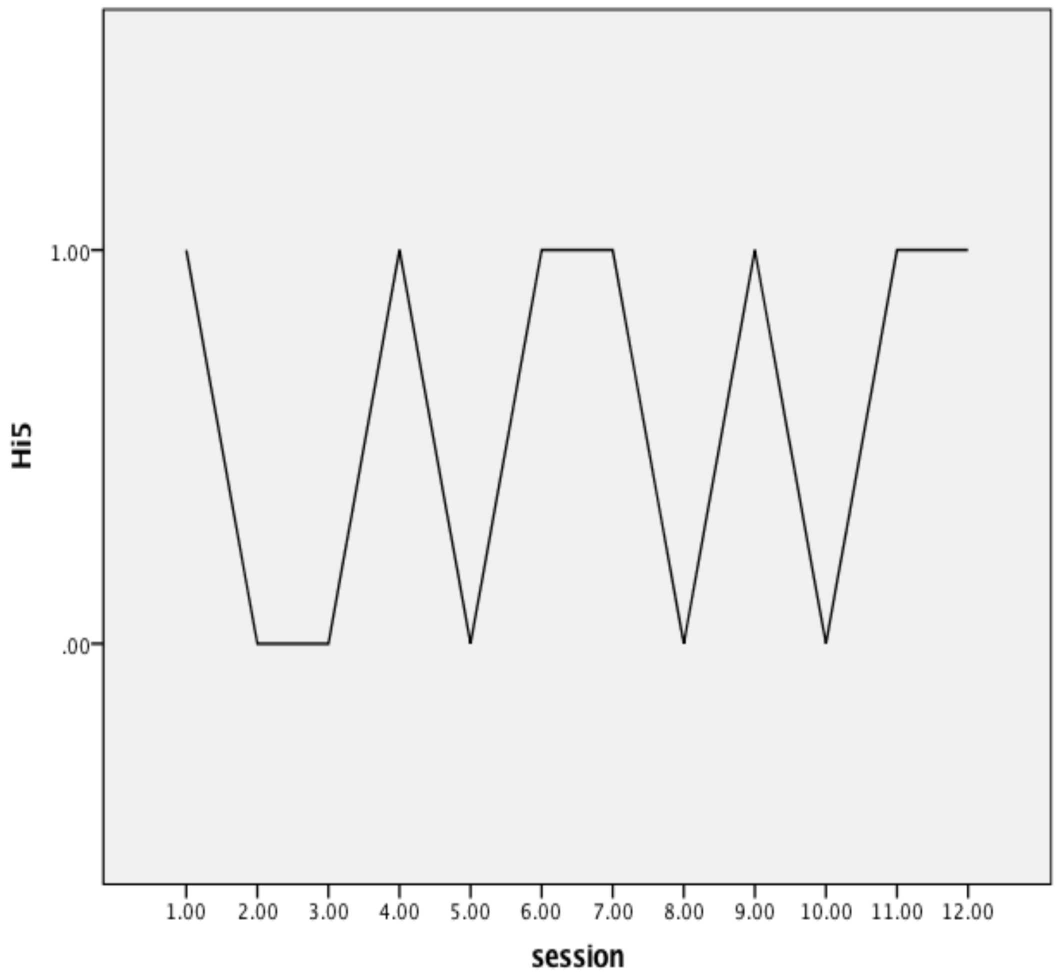

Figure 7. M3 Independent High 5 Gesture

Figure 7 shows that pre-linguistic communication evidenced by an independent 'High Five' gesture was moderately developed at the time of AMMT intervention sessions for participant M3. He lacked absolute consistency in demonstrating this gesture, but the inconsistency in his 'High Five' response seemed to be in keeping with his inconsistent behavior throughout the sessions. For example, session nine is one of several sessions where he kicked, hit and spat on the researcher, but also got up from his chair to hug me. At the conclusion of session nine, he happily initiated an independent 'High Five' gesture.

Qualitative Analysis and Descriptive Narrative for M4

Participant M4 was five years seven months of age at the time of pre-assessment. This Caucasian male was the youngest participant in this research study. He did not produce any verbal responses during the EOWVT (Academic Therapy Publications, 2000) yielding a raw score of 0. He lived with his biological parents and typical younger brother. While at school, he sat in a wheelchair for about half of the time in his classroom. The wheelchair had two purposes. First, he lacked stability while standing, so the wheelchair provided a means for him to interact in his classroom environment while protecting him from students who could potentially knock him off balance. The wheelchair also served the purpose of keeping him confined since he was a 'runner,' and was inclined to leave the room unexpectedly. When participant M4 came to his after school sessions, I often took him out of his wheelchair. This did not compromise his ability to participate and he maintained a pleasant and compliant demeanor throughout the duration of the intervention sessions. Participant M4 was assessed using the *Trans-disciplinary Play-Based Assessment* (Linder et al, n.d.) just prior to his recruitment into this AMMT study. Results of this assessment indicated that participant M4's language comprehension and production skills cluster at the eight month level, and his pragmatic skills cluster at the seven month level.

Participant M4 demonstrated many shifts in focus throughout AMMT sessions. He enjoyed making faces into the camera, but also demonstrated strong eye contact with the researcher and intent focus on the Pic for Pec visual cards (Bondy & Frost, 2011). When focused on the picture cards, he studied them carefully and frequently wanted to hold them. He exhibited occasional rhythmic, repetitive behaviors (RRBs), and enjoyed spontaneous drumming between presentation of words that seemed to be an extension of these RRBs. Often nonsensical vocalizations accompanied his drumming. He frequently did hand over hand drumming to the steady beat of the "Hello" song. As shown in Figure 8, participant M4 vocalized only two words during the trained sessions: 'Apple' in session five, and 'Happy' in session nine. However, he performed physical gestures that seemed to indicate understanding of a few other words that were presented. For example, when the word 'Eyes' was intoned in sessions five and ten, he pointed to his eyes. In sessions one, five, nine and twelve he looked at the sink when the words 'Wash hands' were intoned. When presented with the word 'Nose' in session ten, he reached out to touch the researcher's nose. He seemed to enjoy the intervention sessions, and frequently reached out his hand to interlock his fingers with the researcher.

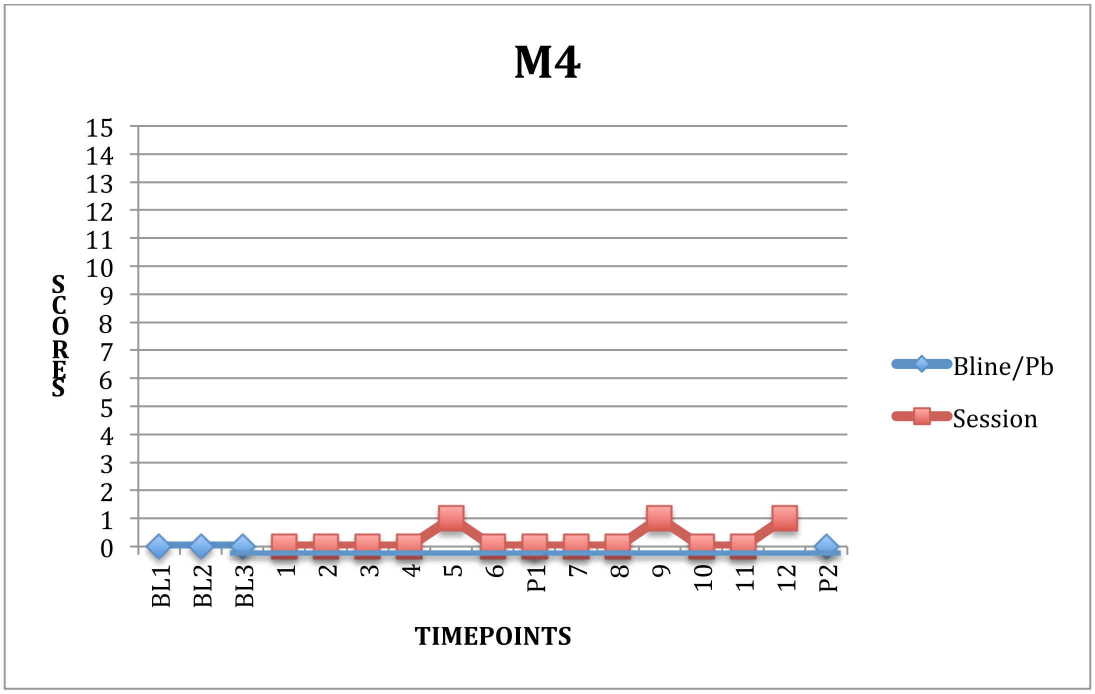

Figure 8. Scores for M4 Baseline/Probe Untrained and Trained Sessions

Figure 9 shows that pre-linguistic communication evidenced by an independent 'High Five' gesture was likely developing prior to participant M4's recruitment in this AMMT research study, and continued to develop during the course of intervention sessions. Independent gestures were produced in four out of six treatment sessions in the last half of this study (7-12). By comparison, two out of six 'High Five' gestures were performed independently during the first half of treatment sessions (1-6). The greater frequency of independent gestures in the final sessions indicated a trend in stronger development of this pre-linguistic communicative skill as participant M4 was exposed to this gestural response throughout this study. Figure 8 shows that correct word approximations were produced only in sessions five, nine and twelve, but these three correct responses were also accompanied by an independent 'High Five' gesture in sessions nine and twelve. These two sessions of correct word approximations along with independent gestures were close to the end of the study. This correlation in the final AMMT sessions may be indicative that positive growth may have continued for this participant if he had continued with AMMT beyond the duration of this study.

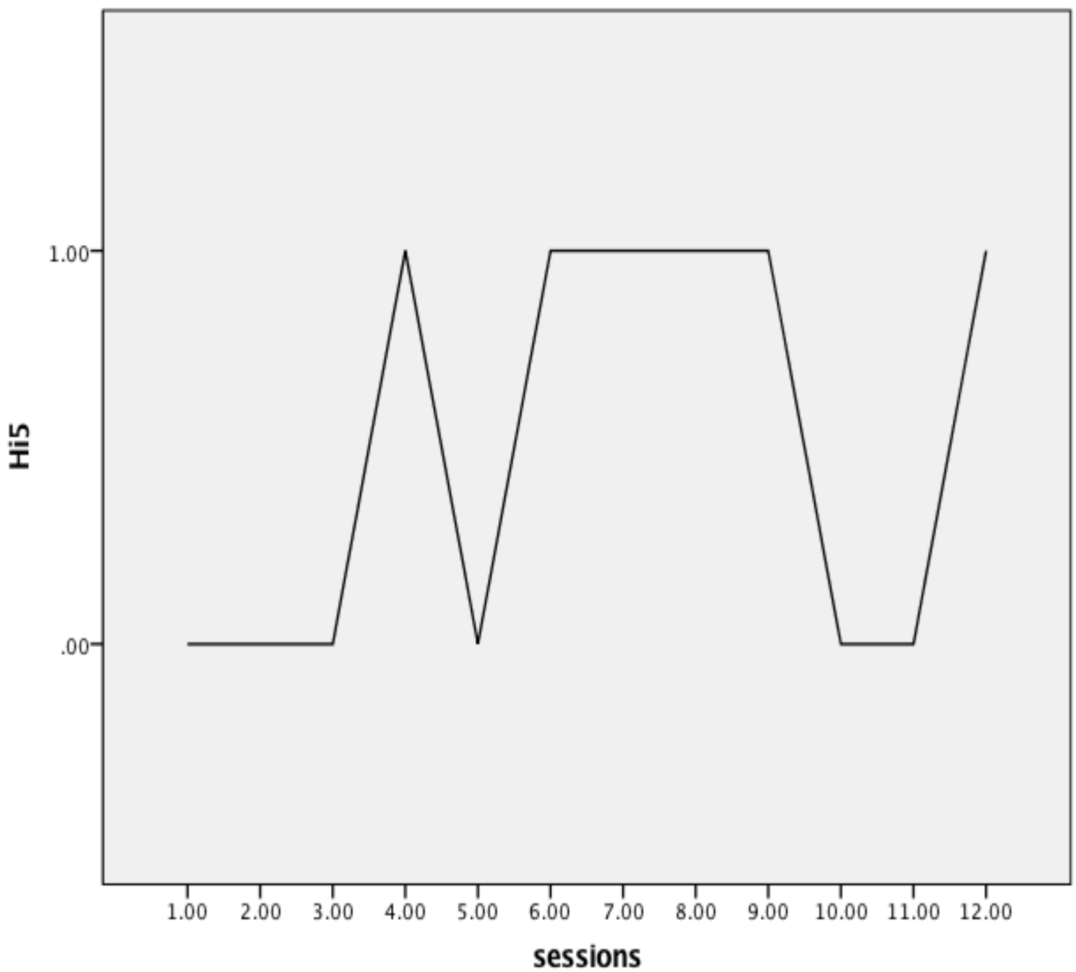

Figure 9. M4 Independent High 5 Gesture

Qualitative Analysis and Descriptive Narrative for M5

Participant M5 was Guatemalan male who was eight years seven months of age at the time of pre-assessment. He did not produce any verbal responses during the EOWVT (Academic Therapy Publications, 2000) yielding a raw score of 0. He was adopted as an infant by his two female parents. He had four other adopted siblings: a typically developing older brother and sister, and a handicapped younger brother and sister. Participant M5 wore a global positioning satellite (GPS) device any time he was away from home in order for his location to be tracked due to his tendency to run. Knowledge of this tendency informed the researcher to be deliberate in establishing and maintaining a positive and secure atmosphere while escorting him from his classroom to the treatment session room. During this transition that occurred during the school day, the researcher encouraged engagement with things that participant M5 heard and saw during this transition. Initially he tended to be volatile during these transitions, however, these negative behaviors diminished as treatment sessions progressed. He attempted to run out of the session room during the first baseline session (BL1) and then again in sessions two and three. He did not repeat this behavior after sessions three, most likely because he had acclimated to the intervention session routine. By contrast, his classroom behaviors became more adverse and non-compliant as the school year progressed until its conclusion in June.

Participant M5 produced 15 correct approximations of words during baseline, mid-point and post probe sessions. During the trained AMMT sessions, he correctly vocalized 33 words, with a total of 48 words that were correctly articulated and intoned during the entire AMMT study (see Figure 10). Although the pattern of progress was erratic, the measure of success was notable given the participant's verbal output prior to AMMT exposure.

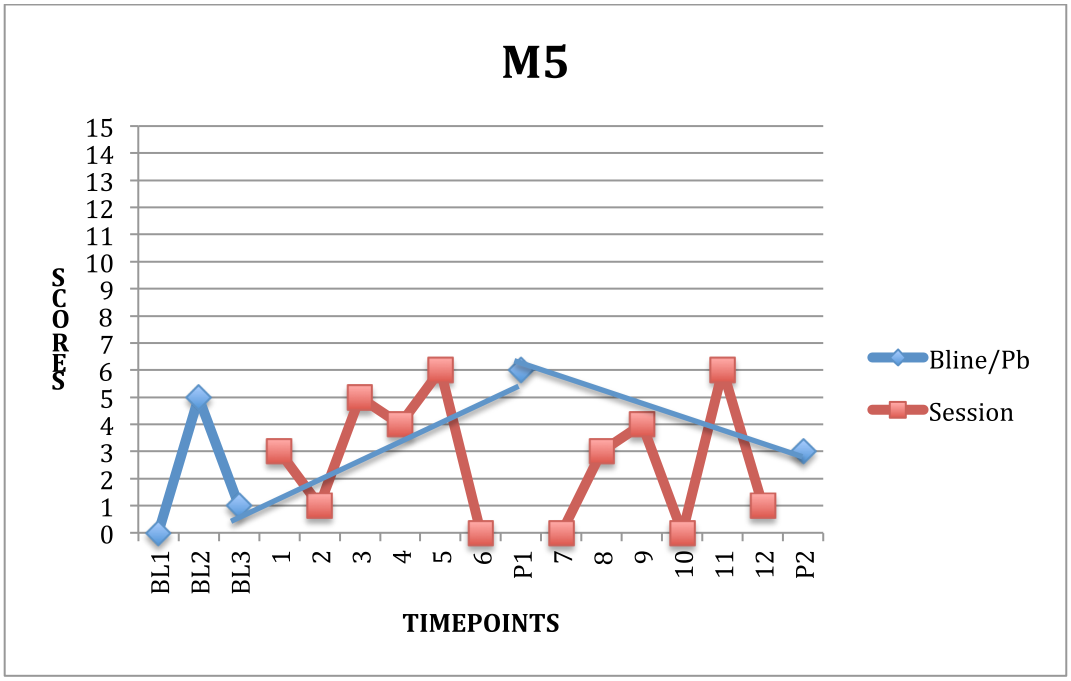

Figure 10. Scores for M5 Baseline/Probe Untrained and Trained Sessions

The fluctuating scores for this participant can likely be explained by extraneous factors that were outside the control of the researcher. The scores of zero during sessions six, seven and ten correspond with days that he was off-task during his regular school activities according to his classroom teacher. Session six occurred on a Thursday; his demeanor was calm, yet he seemed preoccupied throughout this AMMT session. Participant M5's classroom teacher observed similar lethargic behaviors during activities in her classroom on this day. Probe session one (P1) occurred on a Monday, four days after session six, so he was energized when he returned to school after the weekend; he intoned six words correctly during this session. However, his energy erupted into negative behaviors in his classroom at the end of the school day on Monday. His agitated vocalizations during session seven on Tuesday were likely influenced by the disciplinary consequences of his aggressive classroom behaviors the previous day. He bounced back and was successful in producing correct approximations of three words in session eight, and four words in session nine. But by session ten, occurring on a Thursday, he had zero correct word approximations. Once again the researcher observed that he seemed to be tired and uninterested, so his ability to focus on intoning correct approximations of words was compromised.

Negative behaviors in the classroom escalated as the school year drew to a close influencing the classroom teacher's decision to request that he not return to campus for the final days of school. The parent was willing to bring him to school only for AMMT sessions on these days, but she also desired to be sensitive to the teacher's request, so the parent complied and did not bring her child to campus as the classroom teacher requested. To complete session twelve and the final probe assessment (P2), the researcher met participant M5 in his home. The parent of participant M5 was accommodating in attempting to arrange an area of her home that was comparable to the session environment at school. Participant M5 seemed to be delighted when the researcher arrived for the AMMT sessions in his home. However, the behavior and scores of this participant for session twelve and the final probe assessment (P2) may have been compromised due to the change in session setting. For example, during the final probe assessment session, the participant abruptly ran out of the room and quickly returned with his tattered bear comfort toy. He proudly shared it with the researcher, but she attempted to resume the participant's focus on the intervention sequence rather than the toy in order to maintain the fidelity of the research protocol. The researcher's neutral reaction to the toy seemed confusing to the participant during the course of the probe session. However, once the session had actually concluded, the researcher gave attention to the participant and attempted to recognize the importance of this comfort toy to the participant.

A decision was made at an IEP conference at the conclusion of the school year to move this student to another school more specifically designed for ASD students who need more specialized attention than what was available at the school he attended while participating in this AMMT intervention. This researcher believes that the scores for M5 would have been stronger if our school could have provided the resources for students like M5 whose behavior is often characterized by mood extremes. However, in light of the severity of participant M5's challenging needs, his success in intoning 48 total correct approximations of words was quite an accomplishment. Incidentally, the relocation of the final sessions for this participant allowed his mother to hear the sounds of four words being correctly intoned in a beautiful sol-mi tone. This opportunity for the mother to hear her son sing was particularly rewarding for her since she had never heard her son use his singing voice.

Figure 11 shows that pre-linguistic communication evidenced by an independent 'High Five' gesture was likely moderately developed at the time of AMMT intervention sessions for participant M5. He observed the 'High Five' gesture being performed by the researcher during the three baseline sessions, so this likely prepared him to perform the gesture independently during session one.

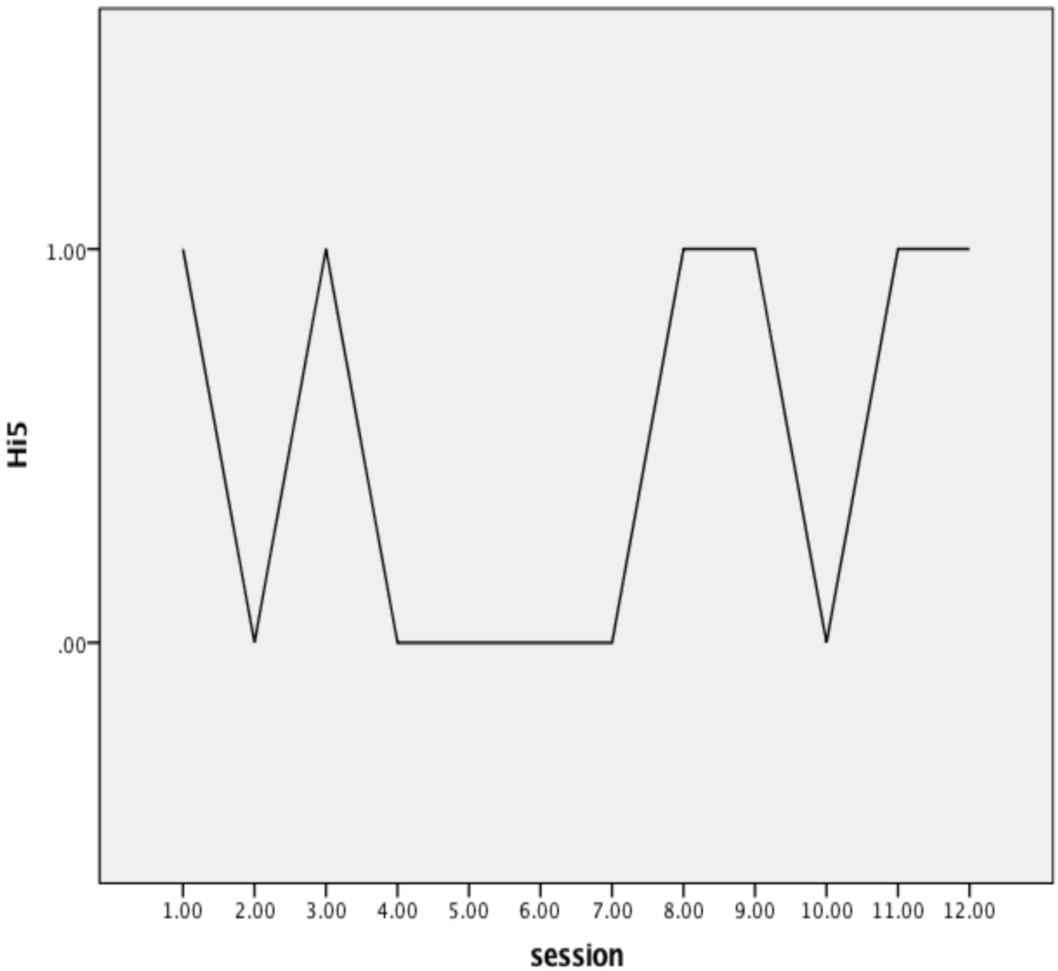

Figure 11. M5 Independent High 5 Gesture

A comparison of low scores from Figure 10 and no independent gesture from Figure 11 shows a strong correlation. In session two, only one word was correctly intoned, and the participant did not perform an independent gesture. The same pattern occurs in sessions six, seven and ten where there were no correct approximations of words and the participant was not successful in performing independent 'High Five' gestures. The only exception to this pattern was in session twelve where he correctly intoned only one word, yet he was successful in the independent 'High Five' gesture. Based on this pattern, the conclusion could be made that when he was unable to focus on producing correct word approximations, he was also unable or unwilling to perform the independent 'High Five' gesture. This points to the notion that when participant M5's physical or emotional state was compromised, he was also unable to learn new words via the AMMT intervention sequence.

Qualitative Analysis and Descriptive Narrative for F2

Participant F2 was an African-American female who was eight years one month of age at the time of pre-assessment. She did not produce any verbal responses during the EOWVT (Academic Therapy Publications, 2000) yielding a raw score of 0. She was a petite female being reared by her two working parents. Her general demeanor throughout the duration of this AMMT study was quiet and compliant. While being escorted to and from the intervention session room, she frequently gestured to be carried or held. This may have been an indication that she was often held or carried by her parents or other adult outside of the school setting. Standardized tests administered just prior to her recruitment into this AMMT study indicated that she was in the low range according to *Vineland II Adaptive Behavior Composite* (Sparrow, Cicchetti,, & Balla), and in the very low range according to the *Stanford – Binet Intelligence S*cale (Rold) with a nonverbal IQ of 43.

Throughout AMMT sessions, participant F2 was relatively still, but seemed to be in a daze. Occasional random vocalizations were repetitive 'duh, duh, duh' or 'buh, buh, buh' sounds. According to parent reports, she loved to listen to music, and frequently 'sang' while listening.

As seen in Figure 12, participant F2 vocalized correct approximations of the word 'Bus' during session four, 'Apple' in session eight, 'Hungry' in sessions eleven, and 'Lemon' in the post-assessment probe session. Several times throughout the AMMT sessions, participant F2's gestures demonstrated understanding of words as they were presented, although she did not actually intone the words. For example, during the first baseline (BL1) session, and in sessions three and five, she pointed to her eyes when the word 'Eyes' was presented. During session eight, she held up her hands when 'Wash hands' was intoned by the researcher.

Frequently she smiled or moved the Pics for Pecs cards (Bondy & Frost, 2011) to her mouth when food words were presented. This was the case in sessions two, six and seven when the word 'Pizza' was presented, and in sessions five and twelve when 'Apple' was presented. There were other single session responses to the words 'Ketchup' and 'Salad'. As mentioned previously, she was very petite and slender, and so the researcher wondered if the responses to food words indicated that she might be hungry.

There were instances when participant F2 vocalized the initial consonant of the word presented, but did not intone a complete approximation of the word. Examples of these attempts were in session six when she vocalized the initial consonant 'p' of 'Pants,' and during sessions eight and eleven when she uttered the 'd' of the word 'Desk.

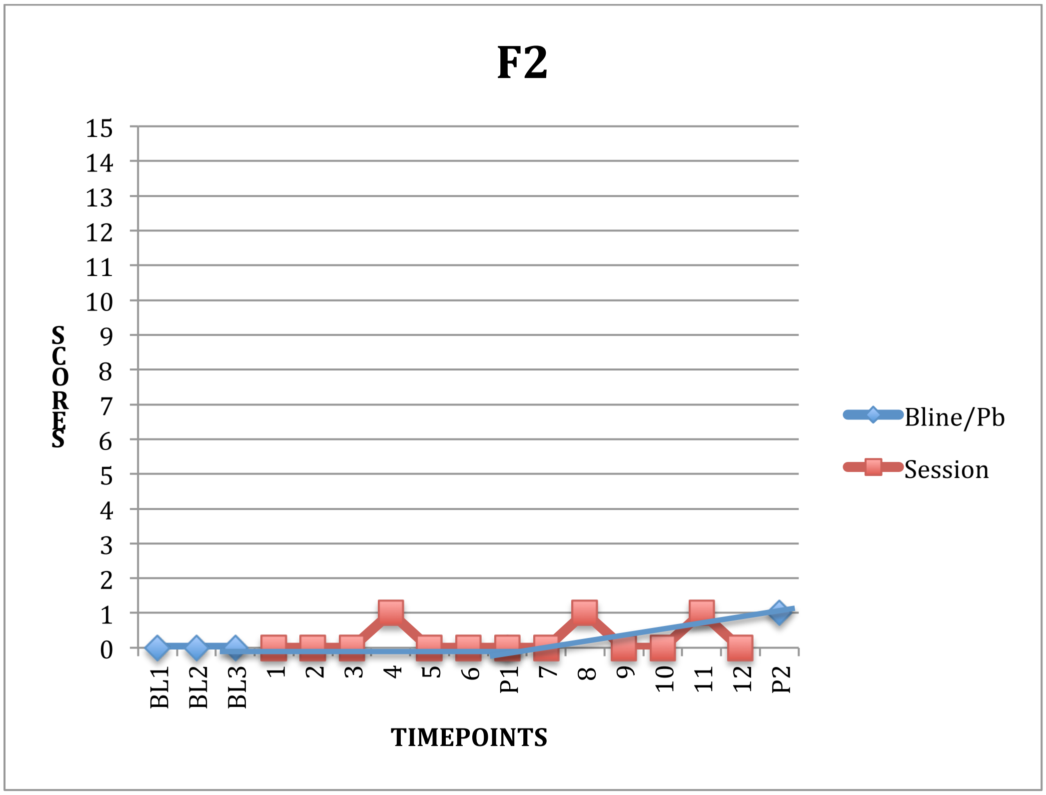

Figure 12. Scores for F2 Baseline/Probe Untrained and Trained Sessions

When participant F2 produced the four correct approximations of words, these vocalizations were intoned in a beautiful singing tone with vibrato. The researcher was a bit surprised when this sound was produced by such a small female child. Given the standardized test scores for this participant, the four correct approximations likely required great effort for this participant. Most often, she had a dull and unresponsive affect during the AMMT sessions, so these responses were encouraging and seemed to indicate good degree of understanding for this participant.

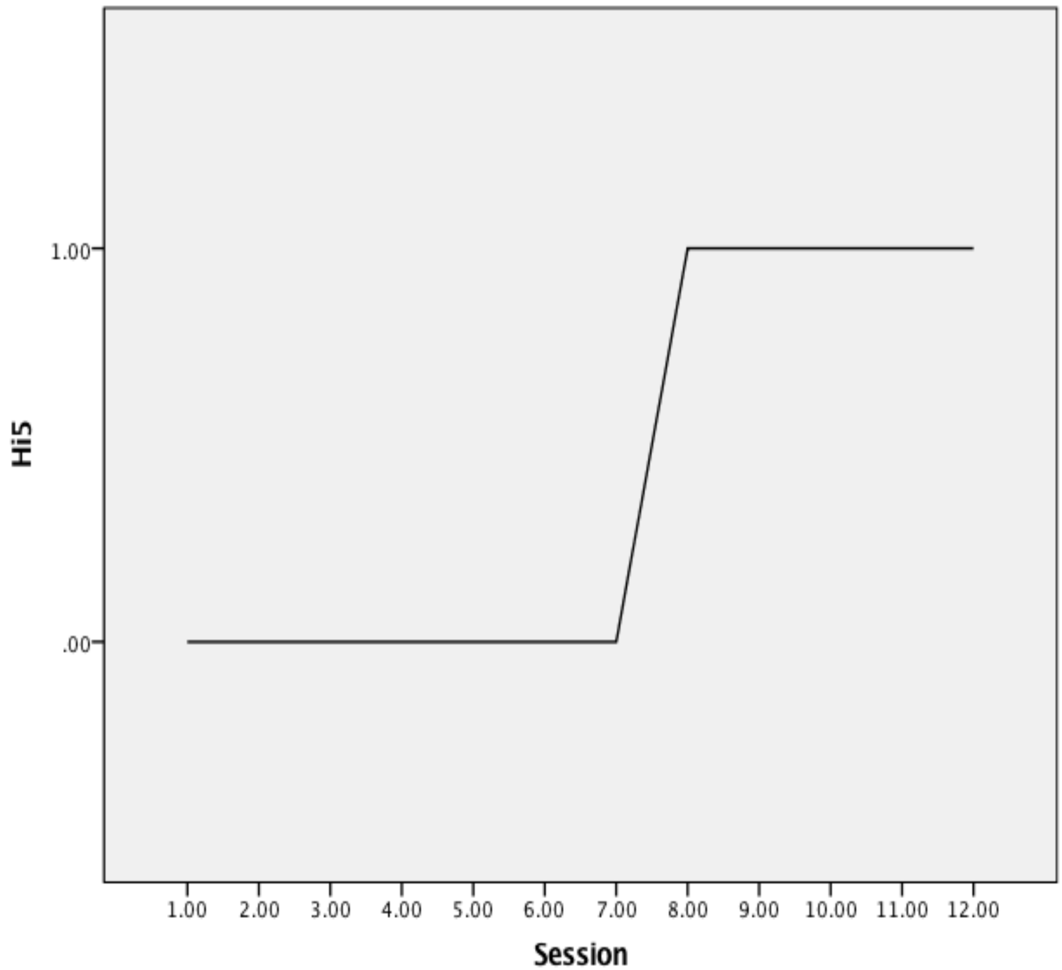

Figure 13. F2 Independent High 5 Gesture

Figure 13 shows that pre-linguistic communication evidenced by an independent ‘High Five’ gesture showed a trend toward development during the last five sessions of AMMT intervention sessions for participant F2. The consistent independent ‘High Five’ response from session eight until the end of AMMT sessions likely indicated a strong trend toward pre-linguistic development as demonstrated by this gesture. Furthermore, the cluster of correct approximations of words in sessions eight, eleven and probe session two (P2) correspond with the consistent ‘High Five’ gestures from sessions eight until the conclusion of the AMMT sessions (See Figures 12 and 13).

Primary Purpose of the Study

The null hypothesis was tested to determine the effect of auditory-motor mapping training (AMMT) on speech output of nonverbal elementary children with ASD ($p \leq .05$). A Friedman Rank Order Oneway Analysis of Variance with repeated measures (ANOVA) was performed to compare scores from the best baseline to probe one and probe two. There was no significance effect of the AMMT sessions on the participants' expressive communication abilities (*p* = .424). Therefore, was no difference between the participants’ word production from the baseline measurement session through the measurements during the two probe assessment sessions. The null hypothesis that there would be no effect of auditory-motor mapping training (AMMT) on speech output of nonverbal elementary children with ASD was retained (See Table 5).

Table 5. Comparison of AMMT Effect Across Best Baseline, Probe One, and Probe Two

Effect	N	X^2	df	Significance
	7	1.714	2	.424

The Friedman Rank Order One-way Analysis of Variance with repeated measures (ANOVA) test was selected as the most appropriate statistical test to analyze data to answer the primary research question. This test is a non-parametric equivalent to the repeated measures ANOVA, but this test does not assume normality or sphericity. Scores simply must be repeated by the same participant across time points. Fractional ranking was used to handle tied scores within each subject's responses. The highest word count or score, within each subject's baseline, probe 1 and probe 2 responses, was represented by the rank with the highest number.

For example, M1 correctly intoned eight words during probe 2, which was the highest word count compared to his best baseline and probe 1, so his rank for probe 2 was three. Participant M1 correctly intoned five words in both the best baseline probe assessment and in probe 1. Since the number of correctly intoned words was tied (*n = 5),* then the rank order was represented by the fraction 1.5. Friedman ranking is for *within* subjects effect, so the same ranking pattern may hold true for different participants, even if their scores were very different. Participant F2 had the identical ranking pattern as M1 with her highest score of one correctly intoned word in probe 2, and 0 intoned words in the best baseline and in probe 1.

The ranking for words correctly intoned is best demonstrated by participant M5. His highest scores for correct word approximations (*N*=6) was in probe 1, yielding a rank of 3 for this session. The best baseline was his second highest score (*N*=5), yielding a rank of 2, and his lowest score was in probe 2, yielding a rank for 1 for this session.

If the participant had the same score for the best baseline, probe 1 and probe 2 sessions, then their rank was 2 for each session. This was true even if the participant intoned 0 words for each session, as was the case for participant F1, M2 and M4.

Examining the value of the mean ranks in Table 6 shows the overall improvement of participants from probe one ($\bar{x}$=1.8571) to probe two ($\bar{x}$=2.29). Although this increase in the number of words correctly produced was not statistically significant (*p*=.424; see

Table 5), this improvement in speech output is important given that all participants had no speech output according to the operational definition of nonverbal measured by the Expressive One Word Vocabulary Test (Academic Therapy Publications, 2000) administered prior to the AMMT intervention sessions. This improvement in expressive language could most likely be attributed to the effect of AMMT on these children with ASD.

Table 6. Participant Scores and Ranks Across Best Baseline, Probe One and Two

Participant	**Best Baseline**	**Probe 1**	**Probe 2**	**BB Ranks**	**P1 Ranks**	**P2 Ranks**
M1	5	5	8	1.5	1.5	3
F1	0	0	0	2	2	2
M2	0	0	0	2	2	2
M3	1	0	2	2	1	3
M4	0	0	0	2	2	2
M5	5	6	3	2	3	1
F2	0	0	1	1.5	1.5	3
Mean Words	1.57	1.57	2.00			
		Mean Ranks =		**1.8571**	**1.8571**	**2.29**

3 = highest word count
2 = second highest word count
1 = lowest word count
Fractions represent ties between two or three word counts

Words production by participants were measured and analyzed during the best baseline probe session, mid-point probe session, and post-assessment probe session to determine the effect of this AMMT intervention. Because there were only three sessions in which measures were collected to test the null hypothesis, the power of this test was limited. The power would have likely increased if data from additional sessions had been collected to test the effects of AMMT on the speech output of the participants (See Table 5).

As previously stated, the null hypothesis that there was no effect of auditory-motor mapping training on the speech output of nonverbal elementary children with ASD was retained. Table 7, however, shows that the improvement in speech output reflected in the mean scores from probe one to probe two was notable. Although this positive change in the speech output did not meet the bar of statistical significance, these scores show an overall positive effect for participants as a result of AMMT interventions.

Table 7. Descriptive Statistics for AMMT

Test Session	**Mean**	**Standard Deviation**	**Minimum**	**Maximum**
Best Baseline	1.57	2.37045	.00	5.00
Probe 1	1.57	2.69921	.00	6.00
Probe 2	2.00	2.88675	.00	8.00

Table 7 compares the means of the best baseline scores with the post-assessment probe scores. The improvement from 1.57 to 2.00 reflects some growth of expressive communication abilities by four participants. Although three out of seven participants did not produce any words during AMMT sessions, reflected by the minimum of 0 shown in Table 7. However, all participants progressed in the development of their pre-linguistic gestural communication that will be discussed in the next section of Chapter IV as a secondary purpose of this study. The development of this gesture was one evidence of growth toward eventual development of speech output;

Pre-assessment scores of 0 according to the *Expressive Language Vocabulary Test* (Academic Therapy Publications, 2000) confirmed that all participants were nonverbal prior to their exposure to the AMMT intervention. Given the non-existent speech output of participants prior to AMMT, the growth from the mean word production of 1.57 words in the best baseline and probe one sessions, to 2.0 in the probe two post-assessment was notable.

Secondary Purpose of the Study

Participants increased social interaction as measured by their initiation of the 'High-Five' gesture in the concluding song was examined. McNemar's chi-square analysis was used to determine if participants' social interaction significantly increased. The presence of this gesture was used as a means of viewing the development of pre-linguistic skills that are necessary for expressive language development.

Table 8 shows the number of participants who demonstrated this gesture independently in each session. The researcher performed the 'High Five' gesture as part of the 'Good-bye Song' that concluded each session. She assisted the participants to perform this gesture in response to her gesture if they did not initiate the 'High Five' independently. If the participant responded to the researcher's 'High Five' gesture at the appropriate point in the song without assistance from the researcher, this was considered an independent 'High Five' gesture.

Table 8. 'High Five' Gestures Per Session

S1	S2	S3	S4	S5	S6	P1		S7	S8	S9	S10	S11	S12	P2
2	1	2	4	2	3	4		3	3	5	3	6	5	4

Table 9 shows a comparison of responses of participants during session one with session four yielding an asymptotic significance of .147. Although there was growth from session one where only two participants responded independently with a 'High-Five' gesture to session four where four participants demonstrated an independent 'High-Five' gesture, the value of .147 did not show statistical significance (p>. 05).

Table 9. McNemar Chi-Square Test for 'High Five' Gestures

Crosstabulation	**Probability**
Sessions 1 & 4	.147
Sessions 2 & 11	.063

A comparison of only one participant demonstrating the 'High Five' gesture in sessions two with six participants in session eleven yielded a marked difference between subjects use of the 'High-Five' gesture (p = .063; See Table 9). Although the probability was not significantly different (p = .063), there was a positive increase of participants' pre-linguistic gestural communication, and the difference approached significance. Comparing the differences between participants in sessions one and four, and between sessions two and eleven revealed that there was increased independence in the demonstration of 'High Five' as the participants were exposed to uses of this pre-linguistic gesture as the AMMT sessions progressed. The inclusion of increased participants in this study likely would generate statistically significant results ($p \leq .05$), particularly as related to the development of pre-linguistic gestural communication of non-verbal children with ASD, and possibly as related to expressive communication abilities, measured by speech output during AMMT sessions.

Summary

This study was designed to examine the effect of a music intervention called auditory-motor mapping training (AMMT) on the speech output of seven nonverbal participants with ASD. All participants were beyond the age for the typical emergence of speech, and their pre-assessment score of 0 confirmed their nonverbal diagnoses. The primary purpose of the study was tested using an Friedman Rank Order One-way Analysis of Variance with repeated measures (ANOVA) to compare the scores from the best baseline to probe one and probe two assessments. This analysis yielded a results show no significant effect on participants' speech output (p =.424). The null hypothesis that there will be no effect of auditory-motor mapping training (AMMT) on the speech output of nonverbal elementary children with ASD was retained.

The study also was designed to examine changes in participants' pre-linguistic gestural communication, as measured by participants' initiation of the 'High-Five' gesture during the concluding Goodbye song. McNemar's chi-square tests showed no significant difference in the elementary children's use the 'High-Five' gesture between sessions one and four (p = .147), and between sessions two and eleven (p = .063). There was, however, marked increases in participants' uses of the 'High-Five' gestures during AMMT Treatment Session 11 as compared to Session 2 that warrants additional research.

Descriptive participant narratives, included at the beginning of the results discussions, provided qualitative analyses that highlighted areas of growth for all participants in this study. These qualitative analyses also addressed confounding variables that possibly affected participants' scores. Although data analyses associated with the primary and secondary purposes did not reveal significant effects of AMMT on the communication abilities of elementary children with autism spectrum disorder, the merits of applying AMMT were positive, evidenced by the overall growth in word production and development of pre-linguistic gesture of the study's participants.

CHAPTER V

DISCUSSION

The primary purpose of this study was to determine the effect of auditory-motor mapping training on the speech output of nonverbal elementary children with ASD. The following null hypothesis, associated with the primary purpose of the study, was tested. There will be no effect of auditory-motor mapping training (AMMT) on speech output of nonverbal elementary children with autism.

To address the primary purpose of the study, seven nonverbal children with ASD participated in 17 total AMMT sessions (three untrained baseline probe assessments, 12 trained sessions, one untrained mid-point probe session, and one untrained post-assessment probe session). A Friedman Rank Order One-way Analysis of Variance with repeated measures (ANOVA) was used to compare scores of participants' correct approximations of target words from the untrained sessions: best baseline, probe one, and probe two ($p \leq .05$).

The secondary purpose of this study was to examine the participants' increased social interaction as measured by their initiation of the 'High-Five' gesture in the concluding song. McNemar chi-square analyses were used to determine if the participants social interaction significantly increased during the course of the intervention evidenced by their "No" response moving to a "Yes" response ($p \leq .05$). The presence of this gesture was used as a means of viewing the development of pre-linguistic skills that are necessary for expressive language development.

Descriptive narratives served the purpose of highlighting areas of progress for each participant, and for identifying confounding variables that may have influenced the efficacy of this study. Areas of growth may not have been statistically significant according to research protocol, but were nonetheless important. Confounding variables that may have mitigated statistically significant results for each participant were also addressed. Additionally, these narratives provided a lens into the heterogeneity of autism, and specifically the diversity of these nonverbal participants.

Summary of Results

Participants (N = 7) were nonverbal children with autism ages five to eight years. At the time of pre-assessments for this study, participants' ages ranged from 5 years 8 months (68 months), to 8 years 10 months (106 months), with a mean age of 7 years. Five participants were male, and two participants were female. All participants were beyond the age for the typical emergence of speech, and consequently had participated in speech therapy with school therapists and with private speech pathologists and audiologists for at least two years prior to their participation in this study.

The primary purpose of the study was to determine the effect of auditory-motor mapping training (AMMT) on the speech output of nonverbal elementary children with ASD. A Friedman Rank Order One-way Analysis of Variance with repeated measures (ANOVA) was used to analyze participants' correct approximations of target words in the trained and untrained AMMT intervention sessions. A comparison of participants' speech output scores from the best baseline to probe one and probe two did not reveal significant differences between these three assessment periods (p = .424). The null hypothesis that there was no significant effect of auditory-motor mapping training (AMMT) on speech output of nonverbal elementary children with ASD was retained.

The secondary purpose of the study was to determine if there were changes in participants' pre-linguistic gestural communication, as measured by their initiation of the ‘High-Five’ gesture during the concluding “Goodbye” song during each AMMT treatment and probe session. A comparison of the independent ‘High Five’ gesture in session one to session four using McNemar’s chi-square yielded no significant differences between participants' uses of 'High-Five' gestures ($p = .147$). Although not significantly different ($p = .063$), a comparison of participants' independent uses of this gestural response between session two and session eleven showed trends toward positive growth that warrants additional research.

Qualitative analysis and descriptive narratives addressed confounding variables that possibly affected participants’ speech output and uses of 'High-Five' gestures during the AMMT treatment and probe sessions. These participant narratives also highlighted areas of growth for all children in this study, even though most of the children's responses were not significantly different between the baseline assessments and the final probe session.

Discussion of Results and Conclusions

Autism spectrum disorder (ASD) is estimated to affect 1 in 68 children, and is reported to occur in all racial, ethnic, and socioeconomic groups (Center for Disease

Control [CDC], 2014; corresponding author – Baio, J.). Symptoms and severity of individuals with ASD varies greatly, but up to 25% of those with ASD lack the ability to communicate with others using speech sounds (Tager-Flusberg & Caronna, 2007). The ability to communicate verbally is considered one of the most important positive outcome indicators for children with ASD (Lord et al., 2006).

Language proficiency is one of the most important factors in predicting outcomes for people with ASD, with the other critical factor being IQ (National Institutes of Health [NIH], 2012). Since language deficit can be so disabling, the acquisition of language is a priority for outcomes leading to interventions that help children with ASD acquire language (Rogers, 2006).

Relatively few studies have focused on speech development for nonverbal children with ASD. As a consequence, interventions for increasing speech output in nonverbal children are very limited. The music intervention of auditory-motor mapping training (AMMT) uses motoric movement, intoning words, and visual picture cues to address some of the persistent deficits that are evidenced in persons with ASD. The potential for AMMT to facilitate language development via overlap between brain regions with the putative mirror neuron system (MNS) that is considered to be dysfunctional in individuals with ASD is based on evidence from prior research (Koelsch et al., 2002; Patel, Gibson, Ratner, Besson, & Holcomb, 1998; Ozdemir, Norton & Schlaug, 2006). The primary purpose of the current study was to determine the effect of auditory-motor mapping training on the speech output of nonverbal elementary children with autism spectrum disorder.

Music as a Vehicle for Developing Speech for Children with ASD

As determined by previous researchers (e.g., Applebaum, Egel, Koegel, and Imhoff, 1979; Armstrong & Darrow, 1999; Gfeller, 1986; Grandin, 1988; Gordon, 2007a, 2007b; Heaton, Hermelin, & Pring, 1998; Heaton, Hermelin & Pring, 1999; Wan, 2010), results of the current study confirm that individuals with ASD have a keen interest in music, and may have strong musical abilities. Participants engaged with the researcher during musical interactions of the AMMT sessions through singing and drumming as they were simultaneously presented with Pics for Pecs (Bondy and Frost, 2011) visual cue cards. The researcher observed that the participants were also particularly attentive to communication outside AMMT sessions when words were intoned by the researcher rather than spoken. This heightened interest in music was key in appealing to the children who served as participants in the present study examining the efficacy of auditory-motor mapping training (AMMT) on the speech output of nonverbal elementary children with autism spectrum disorder.

According to Carnahan, Musti-Rao, and Bailey, (2009), social interactions or skills of persons with ASD may improve when music materials are combined with other interventions. The use of music through singing and drumming combined with the presentation of visual cue cards that is characteristic of AMMT is supported by the research of Carnahan et al. (2009).

Although the effect of AMMT on the speech output of nonverbal elementary children with ASD in the current study was not significant, all participants demonstrated growth in word production and/or in developing pre-linguistic skill demonstrated by the

‘High Five’ gesture. Scores for the number of words correctly intoned ranged from 0 by two participants to 108 with an average score of 24 words learned by all participants. All participants demonstrated the independent ‘High Five’ gesture at least four times during the course of the study, with one participant responding independently with 'High Five' during the “Goodbye” Song at the end of each AMMT treatment and probe session. The average number of times the ‘High Five’ gesture was used was 6.28 times.

Singing more than speaking is known to engage a bilateral reciprocal network between frontal and temporal regions, which contain some components of the putative mirror neuron system (Brown, Martinez, Hodges, Fox, & Parsons, 2004). Autism hypothetically is linked with mirror neuron system dysfunction. Although the current study did not employ non-invasive neuroimaging such as fMRI or CAT scan technology to view the engagement of neural regions during the AMMT intervention, this researcher observed keen engagement of participants when music was present in the intervention sessions. In addition to the intoning of words that was a feature of the AMMT intervention, the researcher also intoned directions to the participants during transitions to and from their classroom to the session room. In concurrence with Edgerton (1994), using the modality of music for communication seemed to captivate the interest of participants and maintain their interest during times of giving directions and transitions which are frequently challenging for children with ASD.

Musical elements of rhythm, pitch, timbre, and texture were combined in the AMMT intervention. This combination made music a functional tool to facilitate growth of their social communicative behavior demonstrated by correctly intoning words and independent ‘High Five’ gesture. According to Chou (2008) and Edgerton (1994), as children with ASD gain social-communicative skills through music, they may begin to apply them independently without the use of music as a vehicle for learning speech. At that point, music can be faded with the goal of executing the skill without the facilitation of music. One participant demonstrated this type of independence in the present study, and two other participants exhibited growth toward independence. Growth and independence among these children were observed by the researcher, as well as by the children's parents and teachers.

The observations of Pickett, Pullara, O’Grady, and Gordon (2009), regarding the variability of the initiation of speech for nonverbal individuals with ASD, is relevant to understanding results of the current study. The review of 64 papers by Pickett et al. (2009), focused on speech acquisition by nonverbal individuals with ASD, provides an important and invaluable synthesis of research on this topic. Among the studies reviewed, most participants developed speech between the ages of 5 and 7 years, but some participants initiated speech up to 13 years of age. The variability of the initiation of speech was substantial, despite continuing efforts to facilitate speech initiation of individuals with ASD. Pickett et al., (2009), however, also maintained that once speech began, improvements in speech often were rapid, leading researchers to speculate that achieving initial speech competence is key. Learning of the elements of speech may occur efficiently once the individual with ASD experiences foundational success with sound production and words.

Using Pickett et al. (2009) as a window to view the progress of participants in the current study enlightens the results. All participants were nonverbal according to the *Expressive One-Word Vocabulary Test* (Academic Therapy Publications, 2000) given as a pre-assessment, yet substantial gains were experienced by participant M1 intoning 108 total words, and modest gains by participant M5 who intoned 48 total words correctly. Constant consistent efforts to achieve were made for all participants, yet these two participants achieved initial competence, and consequently their progress accelerated after their initial successes. Participant M1 was 5 years, 11 months of age, and M5 was 8 years, 9 months of age the initiation of this study. The age of these participants concur with the age range observed by Pickett et al. (2009).

As previously stated, the null hypothesis that there was no effect of auditory-motor mapping training on the speech output of nonverbal elementary children with ASD was retained. However, improvement in speech output reflected in the mean scores from probe one ($\bar{x}$=1.57) to probe two ($\bar{x}$=2.00) was notable. Although this positive change in the speech output did not meet the bar of statistical significance, these scores show an overall positive effect for participants as a result of AMMT interventions. The improvement from 1.57 to 2.00 was due to the growth of expressive communication abilities demonstrated by the number of words correctly intoned by four participants. Although three out of seven participants did not produce any words during AMMT sessions, all participants progressed in the development of their pre-linguistic gestural communication. The development of this gesture was one evidence of growth toward eventual development of speech output. A thorough discussion of this gestural development is provided in the section entitled 'Secondary Purpose of the Study' in Chapter IV.

Pre-assessment scores of 0 according to the *Expressive Language Vocabulary Test* (Academic Therapy Publications, 2000) confirmed that all participants were nonverbal prior to their exposure to the AMMT intervention. Given the non-existent speech output of participants prior to AMMT, the growth from the mean word production of 1.57 words in the best baseline and probe one sessions, to 2.0 in the probe two post-assessment was notable.

The Importance of Rhythm, Metricity, and Motoric Activity in Developing Speech

Rhythm organizes music into tonal and rhythmic patterns and forms. This characteristic and importance of music's rhythmic qualities is central to understanding and experiencing music. Metrical structure functions to organize the phonology of language via speech prosody. Rhythmic repetitive behaviors of persons with ASD tend to give stability in the frequency at which these behaviors occur (Edgerton, 1994). The use of drumming in the AMMT intervention sequence supported the importance of rhythm, metricity, and motoric activity for developing speech for persons with ASD. The motoric activity of bimanual drumming captured the participants' interest, which engaged the sensorimotor network that controlled the orofacial and articulatory movements in speech for those participants who were able to intone words.

Thaut (2005) suggests that rhythm may be absorbed on a physiological level while bypassing the cognitive deficits of children with ASD. Due to the fundamentally rhythmic behaviors of children with ASD demonstrated by their rhythmic repetitive behaviors, all participants were able to experience some measure of success in the intervention session using this communicative modality on the "Goodbye" song. The tuned drums supported the notion that metrical structure is essential in organizing the phonology of language and speech production (Koelsch, Gunter, Wittforth & Sammler, 2005).

The gestural response of 'High Five' gave the participants the opportunity to demonstrate the steady beat during the "Goodbye" song. The affirming lyric to this song, "Good job, good bye, good job, high five" were high points for participants because they enjoyed playing the drum and doing the 'High Five' gesture. The enjoyment of drumming, singing, gesturing, and affirmation for a job well done was motivational for the students evidenced by the fact that all participants were able to demonstrate growth in the demonstration of the 'High Five' gesture. As this gesture developed, the number of words produced also increased for participants M1, M3, M4, M5, and F2. If the duration of this study had been longer, participants may have been more successful in intoning correct words. All were able to progress in developing the pre-linguistic gesture, so speech production may have followed.

A comparison of responses of participants during session one with session four yielding an asymptotic significance of .147. Although there was growth from session one where only two participants *(n* = 2) responded independently with a 'High-Five' gesture, to session four where four participants (n = 4) demonstrated an independent 'High-Five' gesture, the value of .147 did not show statistical significance ($p > .05$).

Comparing the single participant demonstrating the 'High Five' gesture in sessions two with six participants in session eleven yielded a marked difference between subjects use of the 'High-Five' gesture ($p = .063$). Although the probability was not significantly different ($p = .063$), there was a positive increase of participants' pre-linguistic gestural communication, and the difference approached significance. Comparing the differences between participants in sessions one and four, with the differences between sessions two and eleven revealed that there was increased independence in the demonstration of 'High Five' as the participants were exposed to uses of this pre-linguistic gesture as the AMMT sessions progressed. The inclusion of increased participants in the present study likely would have generated statistically significant results ($p \leq .05$), particularly as related to the development of pre-linguistic gestural communication of nonverbal children with ASD, and possibly as related to expressive communication abilities, measured by speech output during AMMT sessions.

Corriveau and Goswami (2009) found that children with speech and language difficulties demonstrated significant impairment with a metronome tapping task compared to both age-matched and younger language-matched control children. Results of the current study do not necessarily support the findings of Corriveau and Goswami. The "Hello Song" at the beginning and the "Goodbye" song at the conclusion of each session included the opportunity for participants to wave their hands back and forth to the beat, matching the gesture of the researcher. Participants were allowed to play the steady beat on the drum while we sang if they preferred. Once the participants were acclimated to this routine, most were very successful at maintaining a steady drumming beat or gesture. Participants' ability to maintain a steady beat may have been due to the dyadic nature of the intervention session. Since all session were one-on-one, participants could look to the researcher for guidance, and attempt to mirror the researcher's steady beat movements. If participants had been required to demonstrate a steady beat in a group or class setting without the close proximity of the beat-competent leader to guide them, their ability to demonstrate an independent steady beat may have been weaker. However, in support of Corriveau and Goswami's findings, this researcher has frequently observed the purported comorbidity between language and motor impairment in children with specific language impairment in her work as an elementary educator and general music teacher.

Implications for Future Research

Limitations

Although up to 25% of those with ASD lack the ability to communicate with others using speech sounds (Tager-Flusberg & Caronna, 2007), the ability to communicate verbally is considered one of the most important positive outcome indicators for children with ASD (Lord et al., 2006). Recruiting a large sample of nonverbal elementary-aged children with ASD was difficult due to the limited number of students who met these characteristics in the School System providing approval for the study to be conducted within its elementary schools. All students who met the operational definition of nonverbal were sent recruitment materials. Two of those who were willing to participate did not meet the age requirement. Another student who met the age criteria was disqualified from the study because his speech output exceeded the definition of non-verbal specified for participation in this study. To reduce the limitation of the current study, the recruitment of more participants to increase the sample size is essential for productive and generalizable results in future studies.

Confounding variables of history and maturation also were limitations in this study. Participant narratives contained in chapter four provide descriptive details that possibly accounted for confounding variables that affected the internal validity of this study. Effects due to history and maturation were the most likely confounding variables. The history effect possibly confounded the results of this study. History effects include events that possibly intervened with participants' behaviors during the course of research, thus diminishing or increasing the effects of independent variable on the dependent variable in biased fashion. Maturation effect also possibly confounded the results of this study because maturation possibly affected participants' behaviors across time.

The researcher attempted to control for the effects of history and maturation in several ways. Among the features of this study that the researcher attempted to control were scheduling sessions in a timely manner. Initiating the study after spring break and concluding before the summer break was logical. Parents or guardians of a few participants, however, did not inform the researcher that participants would be out-of-town on regular school days. The researcher was able to reschedule missed intervention sessions so that all participants were able to complete all of the intervention sessions. Results, however, for individual participants who missed a week or more of AMMT sessions possibly were impacted by the break in exposure to the AMMT intervention. Consequently, the overall results of the study possibly were affected by interruptions in the normal bi-weekly schedule of sessions.

Conducting the present study between spring break and summer break limited the number of AMMT sessions for each participant. The researcher considered conducting intervention sessions three times per week, but two factors informed the decision to meet with participants twice weekly.

One of the factors that influenced the twice weekly schedule was the availability of parents to pick-up participants from sessions held after school. Five out of seven participants rode the bus to and from school with no alternative means of transportation should they stay after school, so it was mandatory that intervention sessions be held within the confines of the school-day schedule for these five students. The other factor that limited the number of intervention sessions was finding mutually agreeable times between the researcher's schedule and the participants' school schedule. The researcher also served as the music teacher in the school that the participants attended, so finding times outside of her music teaching schedule that fit with the times that participants were available limited the total number of sessions in the present study.

Another factor that possibly impacted the internal validity of the study was control of experimental isolation. The session room was a small room adjacent to the music room. The room was not sound proof, so sounds from the hallway outside the door perhaps distracted participants during intervention sessions. Additionally, one participant completed the last two sessions of the study with intervention sessions being presented at his home. Given the events surrounding the decision to move away from the campus, this situation was unavoidable, but regrettable nevertheless in that it possibly presented variables that confounded the effect of AMMT and the overall results for this participant.

Time constraints and scheduling also created limitations for this study. The duration of the study needed to be completed before the end of the school year. Finding consecutive weeks that were not interrupted by school breaks, such as those in the winter and spring, and that were conducive to the schedules of the participants was difficult. Standardized testing days are mandatory throughout the school building were also considered important days to avoid. Unfortunately, some of the sessions occurred during standardized testing, so transitioning to and from the session room was planned carefully to protect the environment for those who were testing in rooms adjacent to the session room or in hallways needed for transition.

Auditory-motor mapping training (AMMT) is a relatively new intervention for speech development for nonverbal children with ASD. This researcher attempted to be exhaustive in reading and reviewing all related research pertaining to AMMT for this study. The challenge of discerning the specifics of the intervention sequence reported by Wan in the proof of concept study (2011) prompted email correspondence with Gottfried Schlaug, the corresponding author. Ultimately, this researcher determined the features that each step of the AMMT would contain, but adhered to the AMMT protocol as best could be ascertained from reading the literature, email correspondence, and in consultation with her Dissertation Advisor. Any deviation from the AMMT sequence reported by Wan in her 2011 study was unintentional. The present research study, however, should be considered a modified version of AMMT because there were only 17 total sessions compared to the Wan study that contained 40 individual sessions 5 times per week, over an 8-week period. Additionally, the inclusion of the 'High Five' gesture at the conclusion of each session is not part of the AMMT intervention, as described in the 2011 proof of concept study. The study by Wan (2011) incorporated a hello and goodbye song to bookend each session, but using the pre-linguistic gesture that was included in the "Goodbye" song of the present study was a unique idea of this researcher.

Implications for Future Research and Music Education

Future research is needed to understand the value of incorporating the principles and practices of music making in the treatment of language disorders for children with ASD. Suggestions for future research include isolating the specific mechanisms of AMMT, such as (1) intoning of words, and (2) drumming. These suggestions, however, perhaps are practically difficult due to the challenge of recruiting participants that meet the research protocol. Using a control group that is presented with the same words and visual cards, but without the musical features of AMMT would beneficial in future research. While having a control group that is not exposed to the drumming and singing components may provide a means of comparison for the effectiveness of AMMT, but this consideration also practically may be challenging due to the difficulty of recruiting an adequate number of participants who are nonverbal with ASD.

Auditory-motor mapping training accentuates the prosody of speech through slow, pitched vocalizations, while participants are being presented with picture cues and drumming. The activation of the sensori-motor feedback regions and the auditory-motor mapping network with the association of hand tapping and intoned vocal output may lead to the production of speech for nonverbal children with ASD (Albert, Sparks & Helm, 1973; Norton, Zipse, Marchina & Schlaug, 2009). There is a growing body of research that provides foundations for supporting AMMT as beneficial neurologically, but time in refining and fine-tuning the actual methodology for using this musical intervention is necessary. Although the current study did not yield generalizable results, the growth that was made by the participants in this study supports the premise that auditory motor-mapping treatments or intervention should be studied in the future as a viable approach to developing the speech output of nonverbal elementary children with autism spectrum disorders.

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APPENDIX A

LETTER GRANTING IRB APPROVAL

THE UNIVERSITY *of* NORTH CAROLINA
GREENSBORO

OFFICE OF RESEARCH INTEGRITY
2718 Beverly Cooper Moore and Irene Mitchell Moore
Humanities and Research Administration Bldg.
PO Box 26170
Greensboro, NC 27402-6170
336.256.0253
Web site: www.uncg.edu/orc
Federalwide Assurance (FWA) #216

To: Sara Massey

masseys@gcsnc.com

From: UNCG IRB

____
Authorized signature on behalf of IRB

Approval Date: 1/05/2015
Expiration Date of Approval: 1/04/2016

RE: Notice of IRB Approval by Expedited Review (under 45 CFR 46.110)
Submission Type: Initial
Expedited Category: 7.Surveys/interviews/focus groups,6.Voice/image research recordings
Study #: 14-0189
Study Title: The Effects of Auditory-Motor Mapping Training on Speech Output of Students with Autism

This submission has been approved by the IRB for the period indicated. It has been determined that the risk involved in this research is no more than minimal.

Study Description:

I will investigate the effect of Auditory-Motor Mapping Training (AMMT) on the expressive language abilities of elementary-aged students with of autism. AMMT combines intoning (singing) target words and using tuned drums with high-low pitch capacity to facilitate speech output.

Probe assessment data will be collected for each participant before, during and after treatment sessions using the 15 'trained' words, and 15 'untrained' words not practiced during treatment sessions. Both sets of stimuli will contain bi-syllabic words that will be matched on early language frequency and difficulty. As the outcome measure of interest, the probe assessments will include the identical steps as the treatment sessions which include 1.) listening, 2.) unison production, 3.) partially-supported production, 4.) immendiate repetition, and 5.) own production, but no practice, prompts, or feedback will be permitted.

Regulatory and other findings:

- This research, which involves children, meets criteria at 45 CFR 46.404 (research involving no greater than minimal risk). Permission of one parent or guardian is sufficient.
- If your study is contingent upon approval from another site (school district), you will need to submit a modification at the time you receive that approval.

Investigator's Responsibilities

Federal regulations require that all research be reviewed at least annually. It is the Principal Investigator's responsibility to submit for renewal and obtain approval before the expiration date. You may not continue any research activity beyond the expiration date without IRB approval. Failure to receive approval for continuation before the expiration date will result in automatic termination of the approval for this study on the expiration date.

Signed letters, along with stamped copies of consent forms and other recruitment materials will be scanned to you in a separate email. **Stamped consent forms must be used unless the IRB has given you approval to waive this requirement.** Please notify the ORI office immediately if you have an issue with the stamped consents forms.

You are required to obtain IRB approval for any changes to any aspect of this study before they can be implemented (use the modification application available at http://integrity.uncg.edu/institutional-review-board/). Should any adverse event or unanticipated problem involving risks to subjects or others occur it must be reported immediately to the IRB using

page 1 of 2

the "Unanticipated Problem-Adverse Event Form" at the same website.
Please be aware that valid human subjects training and signed statements of confidentiality for all members of research team need to be kept on file with the lead investigator. Please note that you will also need to remain in compliance with the university "Access To and Retention of Research Data" Policy which can be found at http://policy.uncg.edu/research_data/.

CC:
Patricia Sink, Music Education
Sandra Teglas, Music Education

APPENDIX B

GUILFORD COUNTY SCHOOL RESEARCH APPROVAL LETTER

Guilford County Schools

September 24, 2015

Sara Massey
4204 Bitternut Trail
Greensboro, NC 27410

Re: 141545

Note: This research proposal application was ready for approval in fall 2014, pending documentation of UNCG IRB approval. We did not receive notice of UNCG IRB approval until 9/15/15. Based on the approval date of the UNCG IRB notice, the request to conduct research would have been approved in January, 2015.

Dear Sara Massey:

The Guilford County Schools Research Review committee has concluded that your proposal *The Effects of Auditory Motor Mapping Training on Speech Output of Students with Autism* meets the requirements of state legislation and the current research policy of Guilford County Schools. This decision does not constitute an establishment of a joint research program between the researchers/ university and Guilford County Schools.

Committee approval does not guarantee access to schools or to individuals, nor does it imply that a study can or will be conducted. School principals make the final decision regarding the participation of their school in the research. Parents/students cannot be contacted unless the principal grants permission to conduct the research in the school. Potential participants decide independently whether they wish to participate and they may withdraw at any time. The committee expects that the identities of individuals, schools, and the district will remain anonymous throughout all stages of the project and thereafter.

Please present this letter upon initial contact with principals. Thank you.

Sincerely,

CGilbert

Carolyn Gilbert
Co-Chair, Research Review Committee

STRIVING. ACHIEVING. EXCELLING.
501 West Washington Street Greensboro, NC 27401 P 336.370.8100

APPENDIX C

RECRUITMENT LETTER

Dear __________

I am Sara Massey, Colfax Elementary music teacher and a UNCG student pursuing a doctoral degree in music education. As a UNCG student, I am planning a research project that will be conducted at Colfax Elementary School that may help students with autism develop their ability to communicate using music. I received your name from your child's teacher at Colfax.

The purpose of this research study is to investigate the effect of a music intervention called Auditory-Motor Mapping Training on the language abilities of elementary age students who have the primary diagnosis of Autism Spectrum Disorder.

Your child may be eligible for this study if you he/she has a diagnosis of Autism Spectrum Disorder and has minimal verbal output. If your child has autism and is limited in his/her ability to communicate using words, he/she may benefit from their participation in this study.

Children in this study will participate in two 30 minute sessions per week, for a total of twelve sessions during a six-week period. During each session, they will engage with 15 words or phrases that are considered useful in daily activities. During the week before the treatment sessions begin, I will meet three times with your child for 10 minutes to assess their speech output. During the week after the six seeks of treatment sessions, I will have one more brief meeting with them to assess whether their speech output improved during the treatment period. The total amount of time for participation in this study will be seven weeks.

Learning to speak words or phrases that will be useful in daily activities will be the goal for participants in this study. These words will be introduced using pictures as visual cues while I sing the words and simultaneously tap on two pitched drums on the pitches that fit the natural intonation of these words or phrases in speech. The participants will be led from listening to the words being sung and played on the drum by me, then your child will join me in unison sound production, partially supported production of the word, immediate repetition, and finally producing the words or phrases independently. Each step may be repeated several times during the treatment session based on the participant's need and progress toward mastery of the target.

If you are interested in your child's participation this study, please complete the enclosed consent form, and mail it back to us in the pre-paid envelope. You can also call me at 336-549-2755. There will be no fees or other costs for your child to participate in this study. The only requirement for participation is the return of the completed consent form in the pre-paid envelope.

It is important to know that this letter is not to tell you to join this study. It is your decision. Your participation is voluntary. Whether or not you participate in this study will have no effect on you or your child's relationship with Colfax

Elementary School. Colfax Principal Thigpen, Assistant Principal Kimsey and Guilford County Schools are aware that I am conducting this research as a UNCG student, but Guilford County Schools is not sponsoring this research study. You do not have to respond if you are not interested in this study. If you do not respond, you may receive a follow-up contact to be certain of your interest for your child to participate (or not) in this study. Thank you for your time and consideration. I look forward to hearing from you.

Sincerely,

Sara Massey

Enclosures:

Music/Speech Study brochure, consent form

APPENDIX D

BROCHURE

Brochure Outside

“Effect of Auditory-Motor Mapping on Speech Output of Individuals with Autism”

Effect of
Auditory-Motor
Mapping Training
on Speech Output
for Individuals
with Autism

Music Research Institute

Sara Massey

University
of
North Carolina
at
Greensboro

THE UNIVERSITY of NORTH CAROLINA
GREENSBORO
School of
Music, Theatre and Dance

FACTS

doi:10.1371/journal.pne0025505.g001

*Communication difficulties are common symptoms of autism affecting up to 25% of persons with Autism Spectrum Disorder (ASD).

*Reported incidence of autism spectrum disorder (ASD) is increasing.

*About 1 in 68 children has been identified according to estimates from Center for Disease Control's Autism and Developmental Disabilities Monitoring (ADDM) Network.

Brochure Inside

What is Auditory-Motor Mapping Training?

Participants will receive twelve bi-weekly sessions of 30 minutes in length where they will engage with 15 target words using:

- **Singing** to encourage vocal output
- Interactive imitation and **music making** to enhance social interaction
- Motor activity of **drumming** to enhance auditory-motor mapping

Student is guided to speak target words while tapping drum.
(Eyes are covered in photo to maintain confidentiality. No blindfolds are used in sessions.)

The **GOAL** is to conduct research to determine if students will show **improvement** in:

- Expressive **language** function
- Verbal **communication**
- Social **interaction**

APPENDIX E

CONSENT FORM

GUILFORD COUNTY SCHOOLS
Guardian/Parent Research Consent Form

To be completed by the parent/legal guardian of a school-aged participant under 18 years.

Project Name: THE EFFECTS OF AUDITORY MOTOR MAPPING TRAINING ON SPEECH OUTPUT OF STUDENTS WITH AUTISM

Sponsoring Organization: University of North Carolina at Greensboro

Principal Researcher: Sara Massey Telephone: 336-549-2755

Project Location: Colfax Elementary School

Student's Name______________________________________

Home Address____

Telephone ____

Student's School____________________ Grade ___________Age__________

Participants/Parental Rights and Assurances

I have received a copy of the approved Guilford County Schools Research Application Form for the aforementioned research project. Having read the application, I am familiar with the purpose, methods, scope and intent of the research project.

____ I **am willing** for my child to participant in this research project.

____ I am **not willing** for my child to participate in this research project.

If I am willing for my child to participate in this research, I understand that during the course of this project my child's responses will be kept strictly confidential and that none of the data released in this study will identify my child by name or any other identifiable data, descriptions or characterizations. Furthermore, I understand that my child may discontinue his/her participation in this project at any time or refuse to respond to any questions to which he/she chooses not to answer. My child is a voluntary participant and has no liability or responsibility for the implementation, methodology, claims, substance or outcomes resulting from this research project. I am also aware that my child's decision not to participate will not result in any adverse consequences or disparate treatment due to that decision.

I fully understand that this research is being conducted for constructive educational purposes and that my signature gives consent for my child to voluntarily participate in this project.

Parent's Signature:

____ Date____________________

Student's Signature:

____ Date____________________
(When Age Appropriate)

APPENDIX F

STUDENT INFORMATION FORM

All information will remain confidential. Contact information will only be used in the event of an emergency.

Student Name: ______________________________________
(First name, last initial)

Student Age: _________________________

Best way to contact you in case of emergency. Only one form of contact is necessary. Place a check beside the form of contact you prefer, then add the information.

First name of parent/guardian's associated with contact information:

____

Cell phone: ____

Home phone: ____

Work phone: ____

Email: ____

Grade of student for the 2014-2015 year? _____________________________

School for the 2014-2015 school year? _______________________________

Is there anything that you would like for me to know about your child other then characteristics that are common for children with autism?
________________ Yes __________________ No

If yes, please describe: (Use back if additional space is needed.)

____

____