# EXAMINATION OF JOINT ATTENTION AND OROMOTOR IMITATION IN YOUNG CHILDREN

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ABSTRACT

JENNIFER C. DALTON: Examination of Joint Attention and Oromotor Imitation in Young Children
(Under the direction of Elizabeth R. Crais)

*Purpose:* This study examined the relationship between joint attention ability and oromotor imitation skill in three groups of young children using both nonverbal oral and verbal motor imitation tasks. Research questions addressed a) differences among joint attention and oromotor imitation abilities; b) the relationship between independently measured joint attention and oromotor imitation, both nonverbal oral and verbal motor; c) the relationship between concurrent joint attention and verbal motor imitation during interpersonal interaction; and d) the relationship between the sensory input demands (auditory, visual, and tactile) and oromotor imitation, both nonverbal oral and verbal motor.

*Method:* A descriptive, nonexperimental design (Johnson & Christensen, 2000) was used to compare joint attention and oromotor skills of 3 groups of preschool-aged children: a group of 10 children with Autism Spectrum Disorder (ASD), a group of 6 children who were typically developing (TD), and a group of 6 children with suspected Childhood Apraxia of Speech (sCAS) or apraxic-like symptoms.

*Results:* Concurrent joint attention, but not independently measured joint attention, and total verbal motor imitation were strong predictors of group membership. Children with ASD demonstrated a significantly lower group mean on the measure of concurrent joint

attention as compared to typically developing children and children with suspected CAS. On nonverbal oral tasks, the highest group means were in the tactile (auditory + visual + tactile) modality while the lowest group means were in the auditory modality (auditory only). Children with suspected CAS demonstrated a significantly lower group mean on the measure of verbal motor imitation as compared to typically developing children. Although not significant, other predicted patterns of abilities across groups of children were observed.

*Conclusions:* The current study results indicate that children with ASD had difficulties with both social and cognitive demands of oromotor imitation within a natural environment that demanded cross-modal processing of incoming stimuli within an interpersonal interaction. Patterns of joint attention ability and oromotor imitation skill generally supported the hypotheses of group differences. Further research is needed to determine whether these findings will generalize more broadly.

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# CHAPTER 1: INTRODUCTION

The research questions of the current study addressed the relationships between joint attention ability and oromotor imitation, both nonverbal oral and verbal motor abilities, in young children, including children with ASD, typically developing children, and children with suspected CAS. In order to achieve these purposes, this investigation looked at overall joint attention abilities and oromotor performance across groups. Secondly, joint attention abilities and oromotor abilities were examined within a structured context. Third, these abilities were also examined concurrently within a naturalistic and socially interactive context. Finally, consideration of prompts in three sensory modalities, including auditory, visual, and tactile prompts, were compared across groups to determine the unique contributions of each sensory modality to oromotor imitation, in both nonverbal oral and verbal motor tasks.

*Statement of the Problem*

Researchers have been studying deficits in joint attention ability and language development in children with ASD for several decades. Deficits in the development of joint attention and communication and language development comprise two-thirds of the internationally recognized diagnostic criteria for ASD (American Psychological Association [APA], 2000). Joint attention behaviors include following the attention of another or directing the attention of another for the purpose of sharing objects or events (Mundy, Sigman, Ungerer, & Sherman, 1986). Children with ASD have demonstrated difficulties with orienting and attending to a social partner, shifting gaze between people and objects, as well as initiating or responding to bids for attention to objects or events for the purpose of sharing the experience (National Research Council [NRC], 2001). Deficits in language development emerge early on in a young child's life as deficits in symbol use. Symbol use is the comprehension or use of a relationship between a sign and its referent (Bates, 1979). The developmental interaction of joint attention and symbol use facilitates a young child's ability to become an active partner in reciprocal social communication with caregivers (Wetherby, 2006). One area of social communication that is absent from current ASD diagnostic criteria (APA, 2000), but serves an important milestone in language development by laying the ground work for symbol use (Nadel, 2002), is the development of imitation. Imitation deficits have commonly been cited in the literature in children with ASD. Studies have found that children with ASD have difficulty imitating actions on objects, imitating of body movements, and imitating oral-facial postures and movements. Some researchers have hypothesized that a specific oromotor deficit may serve to negatively impact speech development in some children with ASD.

Oromotor imitation also may help to explain the relationship between joint attention abilities and later language development, as it serves as a precursor to language development, is related to the development of speech production, and its development occurs within a socially interactive context (Meltzoff & Moore, 1999; Nadel, 2002; Rogers, Cook, & Meryl, 2005). For young children, joint attention and oromotor imitation begin their development within the socially interactive context of the caregiver-child relationship and both serve regulatory functions in interpersonal situations to communicate mutuality and sharing of understanding (Mundy, et al, 1986; Užgiris, 1981). Oromotor imitation includes the skills of nonverbal oral movements, such as puckering lips, and verbal motor movements, such as the speech-motor production of simple consonants (e.g., [m]). Research exploring the possibility of an oromotor imitation deficit in children with ASD has examined both nonverbal oral and verbal motor imitation. The extant literature supports the contribution of joint attention ability to later language development in children with ASD. Literature to date also supports the contribution of oromotor imitation to speech development, which is one domain of overall language development. Therefore, past research supports the contributions of joint attention ability and oromotor imitation to later language competence. However, no research studies to date have examined the relationship between these two precursors of language development.

*Summary*

The purpose of the current study was to elucidate the relationship between the two developmental constructs of joint attention and oromotor imitation among three groups of children: children with ASD (n=10), typically developing children (n=6), and children with suspected CAS (n=6). In addition, the relative contributions of joint attention and oromotor imitation in predicting group membership were assessed. The information gained from this investigation will further our understanding of overall language competence in young children.

# CHAPTER 2: REVIEW OF THE LITERATURE

The overall aim of this study is to elucidate the relationship between joint attention and oromotor imitation in children with autism spectrum disorder (ASD). To accomplish this, several areas of the literature are reviewed in the following chapter. First, the literature pertaining to the nature of socio-communicative impairments in children with ASD will be reviewed. Next, an exploration of theoretical perspectives on imitation development is presented that includes an examination of the role of imitation in the first year and a consideration of a neural network model of speech acquisition and production that recognizes the developmental stages of imitative learning. An appraisal of the available research on factors related to general motor imitation skill in children with ASD follows, with an emphasis on motor imitation deficits specific to nonverbal oral and verbal motor imitation. Next, these deficits are further explored within the context of Childhood Apraxia of Speech (CAS), a distinct type of pediatric speech sound disorder (American Speech-Language-Hearing Association [ASHA], 2007). In the next section of the chapter, the role of imitation in the development of language and joint attention in children with ASD is considered. A conceptual framework for this study is then proposed that illustrates the connection between the concepts of joint attention and oromotor imitation, which are the central factors under inquiry in this study. Finally, the research questions that were addressed in the current investigation are explicated.

*Socio-Communicative Impairments in Children with ASD*

Children with ASD present with a number of impairments in social communication that are both used in the initial diagnosis of the disorder and influence the course of development and outcomes throughout childhood. Research to date in young children with and without ASD has consistently found a developmental link between the emergence of joint attention behaviors, such as social reciprocity, and the emergence of early speech milestones, such as canonical babbling (Bloom, 1993; de Laguna, 1927/1963; NRC, 2001). A substantial achievement in the development of communication occurs when a young infant demonstrates joint attention, successfully attending to a person and an object together, looking to one and then to the other (Bloom, 1993). This developmental achievement allows a young child to engage in a number of language-learning interactions. For example, a young child will attend to an object of interest, such as a ball, with the shared experience of their adult caregiver who models the name of the object, “ball.” The young child then repeats an approximation of the name of the object, points to it, and looks to their caregiver for approval (de Laguna, 1927/1963).

Mundy, et al. (1986) defined *joint attention* as the ability to coordinate attention between interactive social partners with respect to objects or events in order to share an awareness of the objects or events. Joint attention behaviors include following the attention of another or directing the attention of another for the purpose of sharing objects or events (Mundy, et al., 1986). Children with ASD have demonstrated difficulty coordinating attention between people and objects as evidenced by: deficits in orienting and attending to a social partner; shifting gaze between people and objects; following the gaze and point of another person; and being able to draw another persons' attention to objects or events for the purpose of sharing the experience (NRC, 2001). Deficits in the development of joint attention are used as part of the diagnostic criteria for ASD (APA, 2000). Children diagnosed with ASD also have qualitative impairments in communication and other types of symbol use, as well as joint attention (APA, 2000; Wetherby, 2006).

The developmental interaction of joint attention and symbol use facilitates a young child's ability to become an active partner in reciprocal social communication with caregivers (Wetherby, 2006). Symbol use is defined as the comprehension or use of a relationship between a sign and its referent (Bates, 1979). Symbol use indicates the emergence of the referential use of language, facilitating the development of language comprehension (Vihman, 1996; Wetherby, 2006). Symbolic usage presages the completion of a two-stage shift in communicative function from the natural use of gestures and vocal forms within the action context of a familiar routine to transitional use and then to referential use (Vihman, 1996). The first stage shift is defined by transitional use, such as the gesture of hand waving to indicate 'bye bye'. The second stage shift is defined by symbolic, referential use, such as when a performative word is used, as in the use of the one-word command, "Go," which would be used to announce an intention to act, prior to the act itself (Bates, 1979; Vihman, 1996). With the emergence of the referential use of language, a young child is able to produce words to symbolize an object, action, or event (Bates, 1979; Bloom, 1993). The deficits in symbol use demonstrated by children with ASD include difficulty learning conventional or shared meanings for symbols as evidenced by a child's decreased ability to acquire gestures, words, and imitation (NRC, 2001; Wetherby, 2006). Instead of acquiring these conventional gestures and words, children with ASD primarily use primitive motoric gestures to communicate their wants and needs, such as leading an adult to a desired object or manipulating the hands of a caregiver to obtain a desired outcome (Stone, Ousley, Yoder, Hogan, & Hepburn, 1997).

These deficits in social communication in young children with ASD have a direct influence on language learning in the long term (Marans, Rubin, & Laurent, 2005). For example, joint attention ability combined with parental responsivity in social interactions has been found to be a significant predictor of language growth over time for children with ASD (NRC, 2001; Siller & Sigman, 2008). In general, children with ASD have difficulty with overall language production and comprehension, although there are varying degrees of difficulty that may be related to general cognitive ability (Wetherby, 2006).

One area of social communication that is absent from current ASD diagnostic criteria (APA, 2000), but has an important role in language development by laying the ground work for symbol use (Nadel, 2002) is the development of imitation. Imitation refers to the transfer of forms of behavior between subjects (Trevarthen, Kokkinaki, & Fiamenghi, 1999) and serves a regulatory function in interpersonal situations to communicate mutuality and sharing of understanding (Užgiris, 1981). Past research has established that children with ASD generally perform worse on imitative tasks than both typically developing children and children with other developmental disabilities (Rogers & Williams, 2006).

Difficulty imitating other people's movements has been studied using a variety of imitative tasks, including actions on objects (Charman, Swettenham, Baron-Cohen, Cox, Baird, & Drew, 1997), imitation of body movements (Aldridge, Stone, Sweeney, & Bower, 2000), and oral-facial imitations (Rogers, Hepburn, Stackhouse, & Wehner, 2003). A consistent finding of difficulties with oral-facial imitation and the strong relationship of oral-facial imitation to speech development have led some researchers to hypothesize that a specific oral-motor or speech dyspraxia may underlie deficits in speech development for a subgroup of children with ASD (Dzuik, Larson, Apostu, Mahone, Denckla, & Mostofsky, 2007; Page & Boucher, 1998; Rogers, 1999; Rogers, Cook, & Meryl, 2005; Velleman, Andrianopoulos, Boucher, Perkins, Marili, & Currier, et al., 2009). Childhood Apraxia of Speech (CAS), previously referred to as dyspraxia, is characterized by impairments in the ability to plan and execute movements in the absence of other motor symptoms (ASHA, 2007). Available data have reported evidence of potential oromotor impairments in children with ASD, specifically in the areas of oromotor deficits relating to both nonverbal oral motor movements (Amato & Slavin, 1998; Marili, Andrianopoulos, Velleman, & Foreman, 2004; Page & Boucher, 1998) and verbal motor movements (Amato & Slavin, 1998; Marili, et al, 2004; Velleman, et al., 2009).

Conceptually, oromotor imitation could help to explain the relationship between joint attention abilities and later language development, as it serves as a precursor to language development, is related to the development of speech production, and its development occurs within a socially interactive context (Meltzoff & Moore, 1999; Nadel, 2002; Rogers, Cook, & Meryl, 2005). Oromotor imitation includes the skills of verbal motor and nonverbal oral imitation abilities. Verbal motor imitation refers to the ability to reproduce various phonemic and syllabic structures such as simple consonants (e.g., [m]), more complex syllabic productions (e.g., [p]- [t]- [k]), or words (e.g., “aluminum”), given a verbal model, possibly accompanied by a visual model or a tactile cue. Nonverbal oral imitation refers to the ability to reproduce oral motor movements, e.g., pucker lips, given a verbal model, possibly accompanied by a visual model or a tactile cue. In children with ASD, verbal motor imitation has been associated with expressive vocabulary growth over time (Smith, Mirenda, & Zaidman-Zait, 2007) and later language ability, and thus is a positive predictor of long-term academic and social success in children with ASD (Sigman & Ruskin, 1999; Toth, Munson, Meltzof, & Dawson, 2006).

While the independent relationships of joint attention and verbal motor imitation to later language outcomes in children with ASD have received growing, but still limited, consideration in the research literature, the relationship between joint attention and nonverbal oral imitation, has not received the same amount of consideration. This study seeks to elucidate the relationships between joint attention and oromotor imitation in children with ASD across verbal motor and nonverbal oral imitation abilities.

*Theoretical Perspectives of Imitation Development*

The concept of imitation has been studied for several decades, yet it has received an inconsistent operational definition (Sevlever & Gillis, 2010). In this section, two major theories of imitation development are reviewed and applied to the interpersonal development of the young child during the first two years of life within the context of the child-caregiver relationship. Next, research supporting a link between deficits in imitation and deficits in interpersonal development in children with ASD is explored. Finally, a theory that proposes a neural network framework of speech acquisition and production and that takes into account the dyadic and triadic phases of language learning is examined.

Two major theories have largely impacted inquiry into the development of imitation over the last fifty years. Piaget (1962) proposed a theory of imitation that viewed the child as an experimenter, learning the skill of imitation in order to gain representational meaning and consequently achieve symbolic thought over time. Meltzoff (1985) proposed an alternative theory of imitation that considered imitation an innate ability in human infants. While there are similarities and differences between the two theories, the efforts of researchers to substantiate the similarities or to resolve the differences have generated a substantial amount of attention and research in the area of imitation development. The extensive amount of research that has been conducted and reported relating to the examination of imitation development and its role in the overall development of the human infant is much too large to be fully elaborated in the current work. Therefore, the main points are extracted from the extant research and discussed within the context of the present study.

*Piaget's Theory of Imitation Development*

Piaget (1962) suggested that the young infant learns imitation through behavioral reinforcement of reflex actions at the earliest stage within the context of the child-caregiver relationship. The highest achievement of the sensorimotor stage is the emergence of mental representation, which allows for the awareness of the infant that objects remain permanent even when absent from the infant's immediate visual field (Bremner, 2001). In Piaget's view (1962), the sensorimotor period of development comprises the first of four stages in cognitive development, and extends from birth to the acquisition of language. The sensorimotor period includes a six-stage, sequential progression of imitation development during which an infant progresses from reflexive, instinctual action at birth to the beginning of symbolic thought toward the end of the stage, at around two years of age. During the sensorimotor period, the young infant constructs a progressively more complex understanding of the world by coordinating sensory experiences (e.g., auditory, visual, tactile) with physical and motoric actions, such that infants gain knowledge of the world from the physical actions they perform on it (Bremner, 2001). Stages 1 through 3 of the sensorimotor period occur from birth to 8 months of age and are characterized by the immediate imitation of simple hand movements and vocalizations. During this period, the infant is beginning to match perceptual information, such as visual cues with physical movements to enact, for example, a hand-opening gesture. Stages 4 through 5 of the sensorimotor period occur from between 8 to 18 months of age and are characterized by an infant's ability to imitate facial expressions and novel acts. These stages are also characterized by the development of logic and the coordination between means and ends. Stage 6 of the sensorimotor period occurs between 18 and 24 months of age and is characterized by the appearance of deferred imitation and culminates with the acquisition of object permanence (Piaget, 1962). Deferred imitation refers to the infant's ability to imitate actions they have seen others perform after a period of time ranging from a few hours to several days later (Piaget, 1962). In summary, Piaget's theory of imitation development proposes that infants are gradually able to imitate events that are farther and farther removed from the immediate sensory field because they learn to coordinate their sensory experiences with physical actions through a stage-like, developmental progression.

*Meltzoff's Developmental Theory of Imitation*

Meltzoff (1985) proposed an alternative view of imitation development that suggested infants are capable of early forms of imitation at birth, indicating an innate ability, and that experience over time serves to refine and develop functional use of imitation skill. His thesis is that motor imitation is a foundation for the later development of empathy and for theory of mind (Meltzoff, 2002). In his view, the development of imitation provides perspectives on both cognitive and social areas of an infant's development. Within the cognitive domain, cross-modal mapping enables the infant to perform immediate, deferred, and facial imitation. Within the social domain, imitation occurs within a context where the infant becomes aware that their caregiver is 'like-me' and that they themselves are 'like-you (caregiver)' (Meltzoff, 2010). This awareness supports bidirectional learning effects such that the infant is able to engage in interpersonal relations and, later, develop theory of mind (Meltzoff, 2010). Furthermore, Meltzoff (1985) recognizes that the act of imitation is neither a separate cognitive or social skill, but rather a combined act of social cognition. Within a social cognitive perspective, the social and cognitive domains converge and interact to enable the infant to use his representational capacity to practice imitation by linking observed and executed acts (Meltzoff, 2002). He suggests that infants use a 'supramodal' code that allows them to unite information from separate perceptual modalities into one framework, rather than organizing visual, auditory, and other sensory information into separate categories of information (Meltzoff & Moore, 1999). This cross-modal organizational framework allows the infant to process a variety of incoming sensory cues and to imitate a diverse array of stimuli. He suggests that infants also use this framework to vary their imitative attempts until the intended target is achieved (Meltzoff & Moore, 1999).

These theories highlight the influence of imitation development in both cognitive and social domains and are consistent in their conclusion that imitation appears to serve different cognitive functions across development (Fenstermacher & Saudino, 2006). Additionally, the developmental progression of imitative actions appears to be consistent across both theories, although there is less rigidity in Meltzoff's description (Meltzoff & Moore, 1999). However, two key misconceptions within Piaget's theory have been identified by Meltzoff and Moore (1999). First, Piaget (1962) proposed that infants learn to imitate through positive reinforcement of imitation behaviors that follow a stage-like progression. It has now been shown that newborns only a few minutes old can imitate human acts (Meltzoff, 2002). Therefore, from this perspective, imitation is innate to the human species, and is not a learned behavior as Piaget (1962) proposed. Moreover, imitation of facial acts has been documented as early as 42 minutes after birth, indicating an innate neural mapping between observed and executed movement in human infants (Meltzoff & Moore, 1999). In contrast, Piaget (1962) observed imitation of facial gestures only after 8 months of age.

The second Piagetian misconception identified by Meltzoff and Moore (1999) is that imitation had been thought to be rote, mindless, and automatic. Instead, they argue that imitation consists of effortful, intentional acts that are evidenced by infants' efforts to shape their own approximations of stimuli until a match is achieved between stimulus and target. Ultimately, the focus of scrutiny should not be on whether infants imitate or not. Rather, they contend that investigators should focus on the manner in which babies do imitate so that we may come to discover what mediates imitation and what functions it serves (Meltzoff & Moore, 1999).

*Role of Imitation in Infancy*

Defined in its most simplistic form, imitation occurs when an infant voluntarily reproduces behavior modeled by another person (Butterworth, 1999). Imitation serves as a tool for communication, role taking, and language (Trevarthen, 1999). Imitation also serves the infant as a means of identifying people and establishing whether they are a familiar person, with whom the infant has a history of imitating, or if the person is someone new (Meltzoff & Moore, 1999). In a single act of visual imitation, the infant uses visual perception to form an action plan and then performs a motor act (Meltzoff, 2002). The infant uses vision, cross-modal coordination, and motor control to accomplish this act. Imitation also recruits memory processes and the representation of action in order to imitate after a significant delay (Meltzoff, 2002).

Infant imitation provides a lens to examine linkages between perception and action. (Meltzoff & Moore, 1999). Forms of imitation include imitation of body movements (i.e., motor imitation), imitation with objects (i.e., symbolic imitation), and vocal imitation (Ozonoff & South, 2001). In the case of a typically developing infant, human speech is presented by another person, usually the caregiver initially, using auditory and visual modes. The infant perceives the auditory signal and tends to look in the direction of the source of sound, which effectively engages the infant's visual perception (Meltzoff, 2002). The construct of imitation is not easily defined, however, and should be considered in the larger context of social-cognitive development. Infants are able to use imitation in order to establish the beginnings of intersubjectivity through their understanding that their caregivers are 'like them" (Meltzoff & Moore, 1999). The development of the interpersonal aspects of imitation between infant and caregiver help to establish symbolic processes and the acquisition of speech (Butterworth, 1999).

Development of imitation begins as early as infancy (Meltzoff, 1985; Užgiris, 1981) and serves several social and cognitive functions, including but not limited to understanding the correspondence between self and others, engaging in reciprocal interaction, and serving as a semantic foundation for language development (Nadel, 2002; Trevarthen, Kokkinaki, & Fiamenghi, 1999; Užgiris, 1981). Imitation is also a means of learning new skills within the child-caregiver relationship (Butterworth, 1999). These interactions with caregivers and their broader sensorimotor development, including actions with objects, in the first year of life enables the infant to develop the knowledge necessary to transition to language in the second year (Bloom, 1993). The interpersonal nature and context of imitation development are inherently bidirectional and reciprocal (Užgiris, 1981).

Within a combined social cognitive perspective, imitation emphasizes both the understanding of the observed act as well as the interpersonal aspect of the interaction (Užgiris, 1981). The cognitive view is concerned with the imitator, such that the imitative model presents a cognitive challenge for the infant imitator, and the imitative act is a way of handling that challenge so as to gain a better understanding of the model (Užgiris, 1981). In the view of Bloom & Capatides (1991), children imitate what they already understand to some extent. These observations are consistent with Piaget who deduced that imitation is always a continuation of understanding (Piaget, 1962). Cognitively, to learn a word is to learn how to express a mental representation of meaning with regard to something the infant has in mind that is directed to objects, events, and relations in the world (Bloom, 1993).

Expanding on the social cognitive perspective, the interpersonal view approaches imitation with a focus on communicating mutuality and shared understanding with others (Užgiris, 1981). Socially, learning a word equips the infant with knowledge of how people make public what is internal to themselves so as to influence the thoughts, feelings, and actions of one another (Bloom, 1993). Beginning at birth, by gazing into each other's eyes, social awareness influences shared understanding between infant and caregiver (Bloom, 1993). These two views of imitation serve different functions in the course of infant development by emphasizing not only the understanding of specific acts but also of their larger context within which there is an interplay of the child's understanding of the modeled act and of the interpersonal situation (Užgiris, 1981). Thus, imitation is a form of encoding that allows for the processing of information that is necessary for the representation of linguistic schemas (both semantic and syntactic) in memory (Bloom & Capatides et al., 1991).

Trevarthen (1979) posits that in order for infants under one year of age to engage with others, they must possess the ability to exhibit their own intentions as well as show that they understand the intentions of others. By the age of one year, young children attend to and imitate vocalizations and gestures, and are motivated to regulate joint attention within the context of an interpersonal, social interaction (Trevarthen & Aitken, 2001). The highlight of this interaction is the bidirectional, reciprocal nature of turn taking, which involves coordinated looking, vocalizing, and playing (Bloom, 1993). Within this interpersonal and intersubjective context of social cognitive development, infants utilize two primary non-verbal social-communication acts that serve to facilitate the bidirectional and reciprocal nature of the infant-caregiver relationship. *Social interaction* behaviors involve the use of non-verbal acts (e.g., reaching to others) to elicit or maintain face-to-face interaction where the focus of the social partner is on the child. *Joint attention*, including both indicating an understanding or initiating, involves the use of behaviors (e.g., showing a toy) to coordinate attention with interactive social partners on objects or events in order to share an awareness of the object or event (Mundy, et al., 1986). These nonverbal social communication acts are linked to the emergence of social cognitive skills such as the ability to discriminate self and others and the ability to perceive others as intentional communication partners. The attentional demands of *social interaction* behaviors are dyadic (self and other), whereas the attentional demands of joint attention are triadic (self, other, in relation to an object/event) (Mundy, et al., 1986).

During the dyadic phase, beginning at birth and lasting to approximately 6 months of age, infants are learning the prosody of language first as a passive recipient, then later as a more active partner (Locke, 1997). During this phase, infants initially orient to people who are talking and then begin later to respond to such behavior by babbling and vocal play (Locke, 1997). Children actively seek knowledge of language from the input they receive in interactions with caregivers (Bloom & Capatides, 1991). This social cognitive phase sets the stage for later language development (Locke, 1997). During the triadic phase, beginning around 6-8 months of age, caregivers introduce the infant to objects and actions through labeling them; joint attention is necessary for the child to connect the correct referent with the spoken word (Locke, 1997). Infants begin to switch their gaze back and forth between caregiver and object so as to share attention with regard to the object (Adamson & Bakeman, 1984). Also during the triadic phase, infants are beginning to understand words and simple phrases from listening to others and imitating sounds and actions with objects (Locke, 1997). Infants who attempt to engage their caregiver the most in the dyadic stage are also more likely to show the most signs of joint engagement, attention following, and attention monitoring in the triadic stage (Striano & Rochat, 1999). Thus, there is a developmental link between dyadic and triadic socio-communicative competence in infancy (Striano & Rochat, 1999) as well as in later childhood development (Wetherby, 2006).

*Developmental Discontinuity in Imitation in Children with ASD*

Infants later diagnosed with ASD have demonstrated difficulties maintaining similar developmental trajectories compared to typically developing infants with regards to the development of imitation (Rogers, 1999) and social cognition (APA, 2000). There are different hypotheses as to the underlying deficit in the imitation difficulties experienced by some children with ASD. Dawson (1991) has hypothesized that infants with ASD may become overaroused in social interactions and seek greater amounts of time outside of the context of social interaction. This social withdrawal can result in a lack of attention to any available social partners and preclude the development of imitation, which can further affect the infant's development of interpersonal skills, including joint attention and engagement (Dawson, 1991). Thus, Dawson (1991) proposes that attentional difficulties are the underlying mechanism for the imitation deficits in infants later diagnosed with ASD. An alternative hypothesis by Smith and Bryson (1994) suggests that deficits in an infant's ability to process incoming stimuli cross-modally serves to undermine the development of imitation in infants later diagnosed with ASD. Yet another hypothesis was proposed by Rogers and Pennington (1991), who suggested that the imitation deficit in children with ASD may be due to a biological dysfunction that affects their ability to coordinate representations of self and other. These three theoretical perspectives were extended by Meltzoff and Gopnik (1993), who suggested that the deficits in imitation development in children with ASD may result from an impairment in their ability to map externally perceived bodily movements to internal proprioceptive sensations that is from a biological dysfunction that impacts cross-modal mapping of stimuli.

Researchers continue to seek evidence to better understand the underlying mechanisms of imitation deficits in children with ASD. While the underlying impairments may not yet be elucidated, we do know that during the first two years of life, the developmental trajectory of imitation development in children with ASD parallels the developmental path of typically developing children (Nadel, Revel, Andry, & Gaussier, 2004). Also, children with ASD successfully acquire varying degrees of imitation ability, but at a much slower rate than other typically developing children (Ozonoff & South, 2001).

The hypothesis that attentional difficulties result in imitation deficits in children with ASD may be supported, given the impact of dyadic and triadic behaviors in infancy on later social responsiveness. In a study by Clifford and Dissanayake (2009), measures of dyadic (eye contact and affect) and triadic (joint attention) behaviors in infants later diagnosed with ASD were obtained retrospectively via parental interview and home videos from birth to twenty-four months of age and examined in relationship to social responsiveness at preschool age. Results revealed that both early dyadic and triadic behaviors, particularly sharing attention, were associated with the development of later social responsiveness (Clifford & Dissanayake, 2009). Consistent with the hypothesis that difficulties with sharing attention may be indicated in the imitation deficits exhibited by infants later diagnosed with ASD (Dawson, 1991), these results emphasize the role that imitation development has in the broader development of social-communicative competence. Applying this hypothesis, if a child with ASD has difficulty orienting to interactive caregivers during the dyadic phase, then there may be a disadvantageous cascade effect during the triadic phase, as the impoverished early experiences then provide an inadequate basis for later developing social-cognitive skills (Dawson, 1991; Smith & Bryson, 1994).

Extending Smith and Bryson's (1994) hypothesis that deficits in an infant's ability to process incoming stimuli cross-modally may undermine the development of imitation in infants later diagnosed with ASD, some researchers have attempted to model articulatory control within the transition from dyadic and triadic interactions. The DIVA (Directions Into Velocities of Articulators) is a neural theory of speech motor control and production focusing on the sensorimotor transformation underlying the control of articulatory movements (Guenther & Vladusich, 2009; Terband, Maassen, Guenther, & Brumberg, 2009). This theory provides a neural network framework of speech acquisition and production that takes into account the dyadic and triadic phases of language learning. During the dyadic phase human infants learn to produce speech sounds by babbling through a combination of motor, auditory, and somatosensory information acquired through face-to-face, or dyadic, interactions. At this stage, only a target auditory "trace" is stored in the brain (Guenther & Vladusich, 2009). Through subsequent triadic interactions with the adult showing the object or action and saying the word, the infant produces the newly learned sound. These newly learned sound "traces" become more finely tuned and corrected over repeated attempts to produce the sound and are stored in the child's "speech sound map," which provides a mental link between the sensory representation of a speech sound and the motor program for that sound. The DIVA model compares these speech sound map neurons to "mirror neurons" and posits that they share key properties including communicative mouth movements. These "mirror neurons" are believed to work together with Broca's area in the brain to promote imitation learning and the production and perception of human speech (Guenther & Vlasudich, 2009). Mattingly suggested (1973) that vocal play during the interactive triadic phase serves to map the vocal tract, allowing the infant to update sensory information about oral and pharyngeal spaces by touch, pressure, and activity within these spaces. Vihman (1996) further suggests that visual as well as auditory factors enter into the child's first production of features of the 'ambient language' (p. 120), as typically developing infants attend to the faces of their caregivers. Thus, the infant's perceptual abilities and levels of awareness enable the infant to orient to and process the necessary sensory information in order to imitate a given model (Southgate, Gergely, & Csibra, 2009). According to the DIVA model, mirror neurons emerge as a consequence of imitation learning, rather than driving the imitation learning process (Guenther & Vladusich, 2009). This developmental sequence further supports the finding of Striano and Rochat (1999) that there is a developmental link between the dyadic (face-to-face) and triadic (person-object-person) stages of socio-communicative development.

Studies of deficits in imitation development in children with ASD have been varied and, in most cases, have not primarily focused on oromotor imitation difficulties, but rather on general motor imitation difficulties. Addressing this gap is important because an underlying deficit in imitation development may negatively affect the development of speech, and subsequent language development, given that the development of imitation provides the infant with opportunities to practice skills relevant to language competence before they are needed for that purpose (Iverson, 2010). Furthermore, if the development of oromotor imitation is also related to the development of joint attention within triadic social interactions, then both of these essential developmental processes may be impacted, compromising the development of overall socio-communicative competence in children with ASD (Siller & Sigman, 2008).

*Motor Imitation Skill in Children with ASD*

In a review of the literature on the imitative deficits in children with ASD, Smith and Bryson (1994) concluded that there is a consistent finding that children with ASD do not readily imitate the actions of others. The authors compared studies that had examined a variety of imitation behaviors that were concerned primarily with action-object imitation, pantomime tasks, and gestures. Rogers (1999) and Ozonoff & South (2001) arrived at similar conclusions that a primary deficit in motor imitation exists in children with ASD across all ages, both relative to comparison groups and to other imitation skills. Theories as to the origins of the imitation deficit in children with ASD are not solidified and continue to be debated. As discussed above, three primary and longstanding explanations for the deficit are proposed to be attentional (Dawson, 1991), praxic (Rogers & Pennington, 1991), and representational (Smith & Bryson, 1994).

Studies of motor imitation deficits have examined a broad range of motor functioning in children with ASD including limb apraxia (Page & Boucher, 1998; Seal & Bonvillian, 1997; Stone & Yoder, 2001), oral apraxia (Amato & Slavin, 1998; Page & Boucher, 1998; Marili, et al., 2004), and apraxia of speech (Amato & Slavin, 1998; Marili, et al., 2004; Velleman, et al., 2009). Examining the nature of motor imitation in children with ASD is important because motor imitation abilities have been found to predict both language and play skills in children with ASD (Stone & Yoder, 2001). Furthermore, this area of research may provide insights into the emerging language system and the foundations of the processes underlying language achievement in children with ASD (Iverson, 2010).

Several studies have examined limb apraxia in children with ASD. Seal and Bonvillian (1997) examined sign language production in children with ASD to ascertain whether the motor production difficulties observed in the children's manual signs would be related to their performance on measures of apraxia. Fourteen students with ASD in a residential educational facility for children and adolescents with developmental disorders ranging in age from 9 years, 2 months to 20 years, 4 months participated in the study. Participants were videotaped interacting with their teachers in their regular education classrooms. A variety of different materials and activities were used in the sessions to provide sufficient contextual variation to elicit as many signs from each student as possible. A total of 348 signs were transcribed and coded across all participants, ranging from 2 different signs to 59 different signs individually. Two measures of apraxia ability were also collected for each participant. The authors found that those participants who obtained higher scores on the apraxia measures, indicating better performance and lower levels of apraxic deficit, also tended to be those students who were more successful in their sign language acquisition. Additionally, the participants' combined scores from the apraxia measures were positively correlated with their scores on measures of cognitive age, gross motor age, and fine motor age, though only those involving gross motor age and fine motor age were statistically significant. The findings of this study underscore the possibility of a connection between limb apraxia and sign language learning in children with ASD (Seal & Bonvillian, 1997).

In another study examining the range of motor imitation ability, including fine motor skills, Page and Boucher (1998) collected ratings of oromotor, manual (fine motor), and gross motor skills to evaluate if oromotor and manual "dyspraxia," (p. 236) coincide in some children with ASD, causing or contributing to impaired ability to acquire either speech or fluent signing. Thirty-three children with ASD who were classified as nonverbal, ranging in age from 5 years, 0 months to 16 years, 6 months, participated in the study. The assessment battery consisted of 25 measures divided into assessments of nonverbal, oromotor, manual (fine motor), and gross motor functions observed within both formal and informal settings of children in everyday situations over three months. The authors calculated the prevalence and distribution of motor impairments across all participants in two ways. They found that rates of motor impairment were high, with nearly 80% of the children having at least one area receiving 50% or more negative ratings. Oromotor and manual impairments were more prevalent than gross motor impairments. The authors concluded that the obtained results provide weak evidence that manual, or fine motor, impairments were “dyspraxic,” (p. 254) in quality, due to negative ratings that were characterized as ‘groping.’ These results extend our understanding of a general motor deficit present in some children with ASD and, further suggest that there may be a connection between “dyspraxic” motor movements and impaired speech abilities in children with ASD (Page & Boucher, 1998).

These findings support the presence of fine motor as well as nonverbal oral imitation deficits in children with ASD. However, given the ages of the children in both of these studies, we can only guess at the levels of imitation ability that the children in both of the studies would have demonstrated at an earlier age, prior to their diagnosis of ASD. In an effort to further explore the abilities of children with ASD at an earlier age, Stone and Yoder (2001) examined specific child and environmental variables present at the age of 2 years to explore the possibility that language outcomes at the age of 4 years could be predicted. Thirty-five children with ASD, ranging in age from 23 to 31 months, participated in the study. Each child received an initial evaluation and annual clinic re-evaluations for 2 years. Environmental variables included socioeconomic level and amount of speech-language therapy received. Child variables included an imitation battery that consisted of 16 imitation acts requiring the imitation of actions either with objects or body movements, a play assessment scale, a parent interview for ASD, and the MacArthur Communicative Development Inventory (MCDI: Fenson, et al., 1993). The results of the study by Stone and Yoder (2001) revealed that stronger motor imitation skills at age 2 and more hours of participation in speech-language therapy between ages 2 and 3 were associated with better expressive language outcomes at age 4 years. They conclude that these findings support the importance and existence of the representational aspect of motor imitation.

Given the findings that general imitation deficits are present in children with ASD (Page & Boucher, 1998; Seal & Bonvillian, 1997) and that these deficits may impact later language competence (Stone & Yoder, 2001), further research is needed that will clarify which specific imitation deficits are related to speech and language competence. Oral-motor skills, including both verbal and nonverbal tasks as well as intelligibility tasks, have been found to be strongly associated with speech fluency in typically developing children as well as children with ASD (Gernsbacher, Sauer, Geye, Schweigert, & Goldsmith, 2008). As it is well established that a significant percentage of children with ASD do not acquire speech (Rogers, Cook, & Meryl, 2005), understanding the underlying processes that may contribute to difficulties with speech development is imperative.

Some researchers have suggested that the underlying imitative deficits demonstrated by some children with ASD may be attributed to a suspected developmental apraxia, or Childhood Apraxia of Speech (Dziuk, et al., 2007) or CAS (ASHA, 2007). In a study of 47 children with ASD, ranging in age from 8 to 14 years of age, Dziuk, et al. (2007) found that praxis, or motor, ability in children with ASD was strongly correlated with the social, communicative, and behavioral impairments that served as the basis for the initial diagnosis of the disorder. The authors further concluded that apraxia may be a core feature of ASD. While the causes of the imitative deficit in children with ASD continue to be debated, the speech characteristics of children with ASD have become a means to examine and explore the nature of the imitative deficit, including a specific aim to test whether CAS is an adequate explanation for the lack of speech development in at least some children with ASD (Shriberg, Paul, Black, & van Santen, 2011).

In a recent study, Shriberg et al. (2011) present both a weak and a strong form of this hypothesis. The strong form of the hypothesis posits that suspected CAS may underlie the imitative deficits demonstrated by children with ASD. The weak form of the hypothesis postulates that CAS contributes to the inappropriate speech, prosody, and/or voice features in some children with ASD. The findings from their study did not support the weak form of the hypothesis. Rather, they suggest that children with ASD have normal to enhanced auditory-perceptual and auditory-monitoring skills but have affective, social reciprocity challenges that mediate the acquisition and performance, and monitoring of appropriate speech, prosody, and voice in discourse. However, half of the participants in the study did not meet criteria for the diagnosis of ASD and were older and higher functioning than the participants in the present study. Continued exploration of any plausible theories advances our understanding, given the paucity of data in this area of research.

CAS is a neurological speech sound disorder involving the inability or difficulty with the ability to perform purposeful voluntary movements for speech, in the absence of a paralysis or weakness of the speech musculature (ASHA, 2007). ASHA (2007) further specifically states that, to date, no validated list of *diagnostic* features of CAS differentiates this symptom complex from other speech sound disorders. However, there are features that are consistent with a deficit in the planning and programming of movements for speech that have gained some consensus among researchers. These features include difficulty positioning and sequencing movements of muscles specifically for speech (ASHA, 2007; Velleman, 2003); inappropriate prosody (ASHA, 2007; Davis, 1998; Shriberg, Aram, Kwiatkowski, 1997b); and lengthened and disrupted coarticulatory transitions between sounds and syllables (ASHA, 2007; Davis, Jakielski, & Marquardt, 1998). There are also contextual influences on speech production that are frequently noted to occur, including (1) errors that increase as length of word or utterance increase; (2) movements for specific phonetic segments that are more easily produced in single word production than in sentences or conversational speech; (3) errors that vary with the phonetic complexity of the utterance; and (4) well practiced utterances that are produced or imitated more easily than unfamiliar utterances (Caruso & Strand, 1999; Davis, Jakielski, & Marquardt, 1998; Velleman, 2003). In a large-scale review of the literature, ASHA (2007) described six behavioral variables that have been studied in association with CAS including nonspeech motor behaviors (e.g., impaired volitional oral movements); speech production (e.g., productions of alternating syllables); prosody (i.e., inappropriate stress); speech perception (e.g., deficits in auditory perception); language characteristics (e.g., receptive/expressive language deficits); and metalinguistic/literacy characteristics (e.g., phonological awareness). As part of the larger technical report on CAS in the general population, ASHA (2007) suggested that an increased number of well-controlled studies are needed to establish reliably the increased prevalence of CAS in children with ASD compared to the general population of children. This recommendation clearly indicates the need for more studies that fully explore the implications of CAS for the socio-communicative development of young children with ASD.

*Oromotor Imitation in Children with ASD*

A review of twelve empirical studies examining motor imitation in children with ASD was completed with an emphasis on the methodologies used to study CAS in preschool-aged children with ASD and is briefly reported in this paper. Of these studies, only seven examined motor impairment in preschool-aged children with ASD or their siblings. The remaining five studies looked at older children and focused on general motor (Ming, Brimacombe, & Wagner, 2007), gross motor (Vanvuchelen, Royeurs, & Weerdt, 2007), fine motor (Mostofsky, Dubey, Jerath, Jansiewicz, Goldberg, Denckla, 2006; Seal & Bonvillian, 1997), or nonspeech measures (Gernsbacher et al., 2008; Page & Boucher, 1998). Only four of the seven studies examined speech behaviors specifically (Amato & Slavin, 1998; Iverson & Wozniak, 2007; Landa & Garrett-Mayer, 2006; Marili, et al., 2004). These studies represent a broad-stroke approach that attempts to address a severely underexplored area of research. In a child with ASD, deficits in oromotor imitation may be ultimately associated with deficits in later language development. These combined deficits may predispose a child to severely decreased verbalization and prohibit full participation in social-communication opportunities, where interpersonal communication occurs as a basis for ongoing interaction and language development (Dawson, 1991; Iverson, 2010).

In one of the few studies examining oromotor imitation difficulties in preschool-aged children with ASD, Amato and Slavin (1998) conducted a study of twenty preschoolers with ASD between the ages of two and one-half and four years in their preschool setting. The authors hypothesized that nonverbal preschool-aged children with ASD would demonstrate poorer oromotor skills than verbal preschool-aged children with ASD. Ten of the children were verbal and ten were nonverbal. Measures of mental age or IQ were not reported for the participants in the study. Children were considered verbal when they produced, vocalized, and integrated consonant-vowel syllables during communicative attempts. One assessment, the Pediatric Oral Motor Examination (P.O.M.E.: Sheppard, 1990), was used to evaluate oromotor status in the areas of a) musculoskeletal anatomy, b) basic oral motor functions, c) eating behaviors, d) voluntary nonverbal oral abilities, and e) prespeech and speech behaviors. Results revealed that the verbal group scored significantly better than the nonverbal group on three of the oromotor tasks, including eating behaviors, voluntary nonverbal oral ability, and prespeech and speech behavior. However, both groups scored well within the impaired range of oral motor functions, including oral postural control, control of oral secretions, and presence or absence of infantile oral reflexes. These findings lend support for more sensitivity to oral-motor screening of children recently diagnosed with ASD. If these children are identified with deficits in oral-motor development early, then specialized therapy can be initiated. Notable weaknesses of this study are that they did not report any measures of language or cognitive ability and relied only on the P.O.M.E. to draw conclusions regarding the speech abilities of these children.

Marili, et al. (2004) extended this research by reporting a sixty percent (60%) incidence rate of positive symptomology consistent with apraxia, dysarthria, or both among forty individuals with ASD, ranging in age from 22 months to 21 years and having a mean age of 8.05 years. The authors collected extensive information from parents regarding their participant's developmental milestones and general abilities, modes of communication, and specific motor-related milestones and abilities. These findings lend support to the existence of an underlying speech motor impairment in at least some individuals with ASD. Unfortunately, the participants ranged in age from twenty-two months to twenty-one years. With some of the participants being of adult age, the reliability of their parental reports is brought into question as the parents were asked to report retrospectively on their developmental milestones, as well as general abilities; modes of communication; medical, educational, and communication histories; activities of daily living; and specific motor-related milestones and abilities. However, the persistence of motor speech impairments in these participants into adulthood further supports the hypothesis of an underlying speech motor impairment in at least some children and adults with ASD.

The studies by Amato & Slavin (1998) and Marili et al. (2004) each provide only a small amount of evidence for an underlying speech motor impairment in preschoolers with ASD. Together, they highlight the need for more research, an ongoing theme of these and other studies. One application of these findings to the clinical treatment of preschool children with autism is that a child's oromotor functioning should be given careful consideration following an initial diagnosis of autism so that targeted interventions can begin. A second application of these findings to the clinical treatment of preschool children with autism is the potential of parents to contribute information about their child's unique developmental history and play an important role in the diagnostic process of speech impairment. Additionally, parents can provide details regarding the history of speech sound disorders within the child's immediate family.

An innovative method for exploring familial patterns of symptoms of ASD has been used with infant siblings of children with ASD. Two studies have been conducted using infant siblings of children with ASD specifically exploring early motor development (Iverson & Wozniak, 2007; Landa & Garrett-Mayer, 2006). Landa & Garrett-Mayer (2006) prospectively examined eighty-seven infants across a range of developmental domains. Infants were assessed at six, fourteen, and twenty-four months of age using the Mullen Scales of Early Learning (MSEL; Mullen, 1992). The MacArthur Communicative Development Inventory (MCDI; Fenson et al., 1993) was given at the fourteen and twenty-four month visits. Finally, the Autism Diagnostic Observation Scale (ADOS; Lord, Rutter, DiLavore, &

Risi, 2002) and Preschool Language Scale (PLS-III; Zimmerman, Steiner, & Pond, 1992) were given at the twenty-four month visit. Based on the authors' clinical judgment at the twenty-four month visit, infants were assigned to one of three groups and classified as: children with ASD (*n*=24), children with language delay (*n*=11), and children who did not meet criteria for either ASD or language delay (*n*=52). This study was the first to provide findings of a longitudinal study of general development in infant siblings of children with ASD from six to twenty-four months of age. Notably, infant siblings later identified as having ASD scored significantly worse than the unaffected group at the fourteen month visit on all scales of the MSEL, including gross and fine motor domains, and worse than the language delayed group in MSEL subtest domains of gross motor, fine motor, and receptive language. These data add to the earlier work in the areas of general motor impairment as previously mentioned. However, the study group did not collect any measures that were related specifically to oromotor functioning in these infants. Longitudinal data of this sort would have invaluably informed this area of research. Landa & Garrett-Mayer (2006) emphasize the need for more research to understand motor development in children with autism and the implications of early motor dysfunction for language and social development.

In another infant sibling study, Iverson and Wozniak (2007) examined early motor, vocal, and communicative development in a group of younger siblings of children with ASD. They included a group of typically developing infants with little to no risk of ASD. The researchers videotaped the infants with their caregivers each month from age five months through age fourteen months, with one follow-up observation at eighteen months. At each visit, the MCDI (Fenson, 1993) was administered as an early measure of communicative and language development. Videotaped interactions with caregivers were analyzed for observations of rhythmic limb movements, occurrences of milestone behaviors, and posture change during the interchange. Hypothesizing that a correlation would exist between speech-language and motor difficulties in infant siblings of children with ASD, the researchers found that infant siblings exhibited delays in both language production and comprehension at eighteen months as well as delays in motor development.

Together with Amato and Slavin (1998), as well as Marili et al. (2004), these findings clarify the need for and add validity to the continued investigation of impaired motor development, and specifically the impact of speech disorders such as CAS, in preschoolers with ASD. These findings are very promising but lack specificity in their implications for clinical practice. The research to date strongly associates broad motor impairment with language development (Stone & Yoder, 2001). The future of research in this area holds a great deal of promise if greater consensus in methodology is achieved. Several studies have examined the role of motor development of infants and toddlers in predicting spoken language level (Stone & Yoder, 2001) and later speech development (Gernsbacher, et al., 2008). However, only a few studies have examined verbal motor imitation ability specifically in a preschool-age population of children with ASD (Amato & Slavin, 1998; Marili et al., 2004). Furthermore, too few studies have taken a more specific approach to examine the influence of a suspected speech sound disorder such as CAS in preschool-aged children with ASD. These studies have also inadequately addressed the implications of a suspected CAS on the developmental progression and impact of socio-communicative interactions of young children with ASD and their caregivers, where imitation plays a crucial role.

*Oromotor Imitation and Joint Attention in Children with ASD*

Given the potential connection of oromotor imitation and later language skills, it is important to look at skills that may serve to facilitate development in both areas. Three skills that may be key components are verbal motor imitation, nonverbal oral motor imitation, and joint attention. Motor imitation with objects (McDuffie, Turner, Stone, Yoder, Wolery, & Ulman, 2007), as well as elicited nonverbal oral movement imitation tasks, e.g., extend tongue and wiggle sideways (Rogers, Hepburn, Stackhouse, and Wehner, 2003), are both correlated significantly and positively with early developing joint attention skills. Thus, joint attention abilities may facilitate or hinder the development of nonverbal oral movements.

In children with ASD, responsiveness to bids for joint attention (RJA) may serve a critical role in early intervention responsiveness in children with ASD (Mundy & Sigman, 2006). Mundy and Sigman's 2006 study examined nonverbal indicating behaviors, such as showing a toy, as a framework to examine social-communication skills in young children with autism compared to children with intellectual disability and typically developing children. While the authors did not explore the children's use of verbal, intentional communicating behaviors with regards to their use of joint attention, their findings highlighted the need to further explore the social skills deficits exhibited by young children with ASD.

Recent research examining the effects of concurrent motor, linguistic, and cognitive tasks on verbal motor production in typical adults indicates that distracter tasks during verbal motor production can have a significant influence on overall verbal motor production. This suggests that attentional focus is critical and that the balance of neural resources allocated to different aspects of human communication may shift according to situational demands

(Dromey & Benson, 2003). Further research suggests that verbal motor activity can influence linguistic production as well as be influenced by it in typical adults (Dromey & Bates, 2005). For children, the modality of task administration i.e., whether items are provided through auditory, visual, or tactile means may differentially influence the degree of engagement and attentional focus the child demonstrates during verbal motor and nonverbal oral imitative tasks. For children with limited joint attention and language abilities such as in ASD, however, it is not clear which type of imitative task would be more difficult. Further, the relationship between joint attention ability and verbal motor imitation in children has not been explored in the extant research literature. Determining this information may add to our understanding of early links between joint attention and oromotor development, as well as links to later language development.

In sum, we know that joint attention ability as well as oromotor imitation ability is related to later language outcomes. However, we do not know the relationship between joint attention and oromotor imitation, or how this relationship is affected by overall oromotor development or vice versa.

*Summary and Research Questions*

In conclusion, this review has discussed several aspects of the development of imitation during the first two years of life and its potential influence on the greater social and cognitive development of the human infant. Piaget (1962) posited that infants learn to imitate as a result of behavioral reinforcement of reflex actions that occur along an invariable, developmental sequence via coordination of sensory experiences. Alternatively, Meltzoff (1985) posited that the ability to imitate is an innate capacity in infants and that experience over time serves to refine and develop the functional use of imitation. Meltzoff

(2002) further proposed that the ability to imitate serves both cognitive and social purposes by championing cross-modal mapping to process incoming stimuli within an interpersonal context. Dawson (1991) has suggested that, in children with ASD, overarousal leads to social withdrawal in children with ASD, resulting in fewer opportunities for interpersonal engagement, including joint attention. Smith & Bryson (1994) have offered an alternative view, hypothesizing that children with ASD have difficulty processing stimuli cross-modally. Additionally, Rogers & Pennington (1991) proposed that children with ASD experience a praxis deficit that manifests as difficulty relating themselves to others. This view has been extended by Meltzoff and Gopnik (1993) to suggest that children with ASD may have an impairment in their ability to map externally perceived bodily movements to internal sensations.

Deficits in general motor imitation ability have been well-established (Rogers, 1999; Smith & Bryson, 1994). Research has shown that motor imitation ability in children with ASD is predictive of language and play skills later in childhood (Stone & Yoder, 2001). Further research is crucial that will ascertain which specific motor imitation skills are predictive of language skills, especially speech acquisition. Some researchers have suggested that speech-related motor imitation difficulties in children with ASD may be related to an underlying suspected CAS. Some evidence has been presented that supports the potential for an overall oromotor deficit in children with ASD (Amato & Slavin, 1998) and that speech and language skills are related to motor difficulties, at least in infant siblings later diagnosed with ASD (Iverson & Wozniak, 2007). The DIVA model (Guenther & Vladusich, 2009) provides a neural network framework that supports the developmental progression of imitation across the dyadic and triadic phases of social-cognitive development and is consistent with the theories of Smith and Bryson (1994) and Meltzoff and Moore (1999). Too few studies have directly examined oromotor imitation in preschool aged children with ASD and its potential impact on the child's social and cognitive development. One study found that nonverbal oral imitation ability was related to joint attention ability (Rogers, et al., 2003). However, no studies to date have examined the relationship between verbal motor imitation and joint attention ability in children with ASD.

The current study extends the research literature by examining joint attention ability in relation to both nonverbal oral imitation and verbal motor imitation. The purpose of the current study is to examine the relationships between joint attention and oromotor imitation in children with ASD, typically developing children, and children with suspected Childhood Apraxia of Speech or apraxic-like symptoms. Additionally, this study sought to explore the effects of administration modality on oromotor imitation in young children with ASD, including both nonverbal and verbal motor tasks. In an effort to elucidate relationships between these variables, two comparison groups were utilized. Typically developing children (TD) served as a control for joint attention, oromotor imitation ability, and motor development. Children with suspected Childhood Apraxia of Speech or apraxic-like symptoms (sCAS) served as a control for joint attention and motor development, but not oromotor imitation ability. Children with ASD represented a group of children with potential deficits in both joint attention and oromotor imitation, while still being controlled for motoric maturation. *Oromotor* variables consisted of a modified version of the Verbal Motor Production Assessment for Children (VMPAC: Hayden & Square, 1999) that included an equal number of tasks across nonverbal oral and verbal motor imitation, as well as a connected speech sample. *Joint Attention* variables consisted of an interactive protocol that was designed to elicit both response to and initiation of joint attention behaviors such as three point gaze or looking at the examiner. A second joint attention variable was examined concurrently during the connected speech sample during a shared story activity in order to simulate a natural, interpersonal interaction.

Given the extant literature, it was hypothesized that some children with ASD may demonstrate poor joint attention abilities but have mid-range abilities to imitate oromotor movements, while other children with ASD may demonstrate poor joint attention abilities and have low-range oromotor abilities. Typically developing children tend to demonstrate high levels of oromotor imitation ability as well as high levels of ability to engage in joint attention. Children with suspected CAS may demonstrate high levels of ability to engage in joint attention, but have low to moderate abilities to imitate oromotor movements. However, joint attention for these children may be impacted during more difficult verbal motor tasks if the child is hesitant to look at an adult during speech production. In addition, children with sCAS are likely to be more facile at nonverbal oral motor tasks and have more difficulty with verbal oral motor tasks.

The conceptual model presented in Figure 2.1 takes into account the theoretical implications of the convergence of the two developmental processes of oromotor imitation and joint attention and the relative behaviors of the groups of study children in both areas.

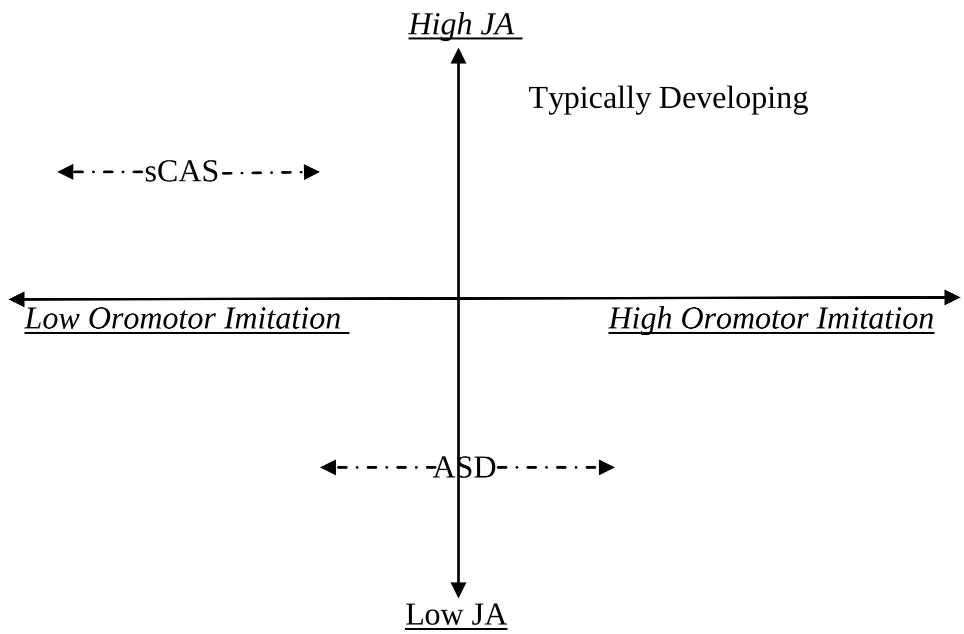


Fig 2.1. Schematic of the theorized relationship between joint attention and oromotor imitation.

The current study addressed the following research questions by examining five variables, including joint attention, nonverbal oral imitation, verbal motor imitation, concurrent joint attention, and concurrent verbal imitation among three groups of children.

1. Are the group means for the scores on five variables of interest the same or different for groups of children with ASD, typically developing children, and children with sCAS?
    a. Will typically developing children have the highest group mean across the three groups on joint attention and oromotor imitation, including both nonverbal oral and verbal motor tasks?
    b. Will typically developing children have the highest group means on concurrent verbal motor imitation and concurrent joint attention tasks compared to the other two groups?

c. Will children with suspected CAS have a higher group mean on joint attention but tend to have a low to moderate group mean on verbal motor imitation?

d. Will children with suspected CAS have a nonverbal oral imitation group mean in the moderate range, but still have a high joint attention group mean?

e. Will children with suspected CAS perform more poorly on both concurrent joint attention and concurrent verbal imitation than the group of typically developing children?

f. Will children with ASD have a low to mid-range joint attention group mean, as well as a low to mid-range verbal motor imitation group mean?

g. Will children with ASD have a low to mid-range joint attention group mean, but also have a mid-range nonverbal oral imitation group mean?

h. Will children with ASD have a low to mid-range concurrent joint attention group mean and concurrent verbal motor group mean?

2. How is joint attention ability related to oromotor production for both imitative nonverbal oral and verbal tasks in children with ASD, typically developing children, and children with suspected CAS?

    a. Will children with ASD have a significant positive correlation between group means on joint attention and nonverbal oral tasks, as well as joint attention and verbal motor tasks?

    b. Will typically developing children have a significant positive correlation between group means on joint attention and nonverbal oral tasks, as well as joint attention and verbal motor tasks?

c. Will children with sCAS have a significant positive correlation between group means on joint attention and nonverbal oral tasks, as well as joint attention and verbal motor tasks?

3. How is joint attention related to verbal motor imitation in a more naturalistic context, such as shared story experience where the child has to attend concurrently to both sets of skills?

   a. Will children with ASD have a significant positive correlation between group means on concurrent joint attention and concurrent verbal motor imitation?

   b. Will typically developing children have a significant positive correlation between group means on concurrent joint attention and concurrent verbal motor imitation?

   c. Will children with suspected CAS have a significant positive correlation between group means on concurrent joint attention and concurrent verbal motor imitation?

4. Across the three groups, what impact do the sensory demands of task administration modality (auditory, visual, and tactile) have on children's ability to correctly imitate verbal and nonverbal oral stimuli?

   a. Will typically developing children have high and equal group means on all six conditions of administration modality and output modality?

   b. Will children with suspected CAS have moderate nonverbal oral imitation group means and somewhat lower verbal motor imitation group means given auditory, visual, or tactile instruction, but have lower group means compared to the typically developing group?

c. Will children with ASD have low group means on both types of tasks administered with auditory, visual, or tactile instruction, and will their nonverbal oral imitation be higher than their verbal motor imitation group means, especially with the auditory and visual modalities?

# CHAPTER 3: METHODS

The purposes of this study were to (1) examine differences between groups on total scores across all variables; (2) investigate the relationships between joint attention scores and two types of oral motor tasks administered separately (a) verbal motor imitation, and (b) nonverbal oral imitation; (3) measure the interrelationship of concurrent joint attention behaviors and verbal motor scores during the same task; and (4) examine the effects of administration modality (auditory, visual, or tactile) on verbal motor and nonverbal oral tasks. Twenty-two children participated in the study and were grouped based on current developmental status. One group consisted of 10 children with an autism spectrum disorder (ASD). A second group consisted of 6 children who were typically developing (TD). A third group consisted of 6 children who had a suspected Childhood Apraxia of Speech or apraxic-like symptoms (sCAS).

*Sample Size*

G* Power 3.1.2 (Faul, Erdfelder, Buchner, & Lang, 2009) power analysis software was used to compute the appropriate sample size for the planned analyses. The projected MANOVA and discriminant analyses required a sample of 30 participants to provide high power (.95) to detect moderate (r = .40) effects between the measures (alpha = .05) and this number (10 in each group) was proposed for the current study. Recruitment efforts were intensive, involving cooperation with many agencies and individuals across a four-state area of the southeastern United States, although the study was funded solely with personal funds. Data collection lasted for twelve months (January, 2010 – January, 2011) and then data collection was ceased due to a shift in study priorities from the data collection phase to the completion of the study. As a result, 10 children were recruited to participate in the first group (ASD). Unfortunately, only 6 children in the second group (TD) and 6 children in the third group (sCAS) were recruited, although extensive attempts to locate more children for the third group (sCAS) had been underway for six months (September, 2010 – February, 2011). The resulting sample size of 22 participants provided an acceptable level of power (.83) to detect moderate (r=.40) effects between the measures (alpha = .05).

Previous studies comparing children with a suspected Childhood Apraxia of Speech to other groups of children, as reported in the American Speech-Language-Hearing Association (ASHA) Technical report on Childhood Apraxia of Speech (CAS) (ASHA, 2007), have included between five and nineteen participants, with an average of eleven participants within a single group of children with suspected CAS. These studies were published in peer-reviewed journals, such as *Journal of Speech, Language, and Hearing Research* and *Clinical Linguistics and Phonetics,* and used inferential statistics to derive their findings. The sample size of 22 (and 6 with CAS) in the current study, therefore, appears to be acceptable given the precedent established by these previously published studies.

*Recruitment*

Approval from the UNC's Behavioral Institutional Review Board was obtained. Data were collected and analyzed from a nonrandom, self-selected sample of 22 young children in a four-state catchment area of the southeastern region of the United States, including Georgia, North Carolina, Tennessee, and Virginia.

Applications were filed with the appropriate agencies governing research study participant recruitment. Children were recruited initially for the study by distribution of a family recruitment letter describing the study and the type of participants that the principal investigator was seeking. These family recruitment letters were accompanied by a letter addressed to professionals containing information about the study and distributed to professionals to give to any parents who had a child that they thought would be eligible for the study. Agencies represented by these professionals included *public schools, private practices, and university clinics*, as well as *personal and professional contacts* serving children with autism spectrum disorders and suspected childhood apraxia of speech in Georgia, North Carolina, Tennessee, and Virginia. Additional means included using *mass email* at the University of North Carolina at Chapel Hill; contacting *advocacy organizations* including the Autism Society of North Carolina and the Guilford County (NC), Mecklenburg County (NC), and Norfolk, VA chapters of Autism Speaks; and *web-based advertisement* on www.apraxia-kids.org. Once appropriate local agency approval was given, a parent information letter was distributed to parents of children with autism spectrum disorders first and then later to parents of typically developing children, as well as parents of children with suspected Childhood Apraxia of Speech, through teachers, school personnel, private clinicians, and staff. Additionally, parent information letters were sent directly to parents who contacted the principal investigator regarding the study after learning about the study through email, internet, or word of mouth.

The Parent Information Letter briefly described the purpose and rationale of the study, the amount of time necessary for participation, and the amount of incentive. In addition, in recruiting children with a suspected Childhood Apraxia of Speech, an Information Letter was distributed to speech-language pathologists (SLPs), with prior local agency approval, which included the same information as the Parent Information Letter and a Checklist for Suspected Childhood Apraxia of Speech (CAS) (Appendix). The SLPs were asked to use the checklist to screen for children on their caseloads who might have characteristics consistent with CAS. If an SLP found that a child on their caseload fit the criteria, they were instructed to provide the Parent Information Letter to the parents of the child. If the child ultimately qualified for the study, the participating SLP was given a financial incentive of a $20 giftcard of their choice to either Target or Walmart stores for taking the time to complete the Checklist of Characteristics of Childhood Apraxia of Speech and recruit the child.

*Design, Matching, and Participant Characteristics*

To address the research questions, this study utilized a descriptive, nonexperimental design using cross-sectional data collection (Johnson & Chrstensen, 2000) from three comparison groups. The groups were matched on Mean Length of Utterance (MLU: Brown, 1973) and mean receptive language ability as measured by standard scores derived from the Peabody Picture Vocabulary Test, Fourth Edition (PPVT-IV: Dunn & Dunn, 2007). Additionally, participant groups were matched on non-verbal cognitive ability and fine motor ability derived from the Visual Reception and Fine Motor scales, respectively, of the Mullen Scales of Early Learning (MSEL: Mullen, 1992**).** Groups were also broadly matched with a chronological age range to control for maturational effects attributed to overall motor development**.**

Group membership was determined based on each child's current developmental status including (1) children diagnosed with an Autism Spectrum Disorder (ASD), (2) typically developing children (TD), and (3) children with suspected Childhood Apraxia of Speech or apraxic-like speech symptoms (sCAS). In order to control for maturational effects attributed to overall motor development across large age spans, this study was limited to children ranging in age from 3 to 5 ½ years of age. Comparing children outside of this age range to children within this age range would have posed a potential disadvantage to the younger children, who are at a different stage of motoric development based on neurodevelopmental features that seem to be primary aspects of the neural organization for speech (Kent, 1999). The Group 1 (ASD) mean age in months was 57.30, with a range of 51.24 to 63.36. The Group 2 (TD) mean age in months was 44.83, with a range of 38.89 to 50.77. The Group 3 (sCAS) mean age in months was 59.17, with a range of 54.81 to 63.53.

Group One (ASD) included 10 children diagnosed with an ASD who had an MLU of at least 3.0 derived from asking the child's parent to list "three of the longest sentences you have heard your child say recently" and calculating the MLU. This parent report measure is part of Section D of the MacArthur-Bates Communicative Development Inventories: Words and Sentences (CDIs: Fenson, Marchman, Thal, Dale, Reznick, & Bates, 2006). The use of parent report to derive MLU is supported by the work of Dale (1991) who found that the three longest sentences as reported by the parent was highly correlated ($r = .74$, $p < .01$) with actual MLU and therefore, was a valid participant matching variable. Groups Two (TD) and Three (sCAS) were group-matched to Group One (ASD) based on MLU and mean receptive language scores that were within one standard deviation above or below the mean for Group One (ASD). The Group 1 (ASD) mean MLU was 6.09, with a range of 3.66 to 11.30; the standard deviation was 3.09. The Group 2 (TD) mean MLU was 6.08, with a range of 4.30 to 9.00; the standard deviation was 1.80. The Group 3 (sCAS) mean MLU was 5.08, with a range of 3.25 to 7.60; the standard deviation was 1.55.

Receptive language scores were derived from the Peabody Picture Vocabulary Test-Fourth Edition (PPVT-IV: Dunn & Dunn, 2007), which was administered individually to each child in all three groups. The Group 1 (ASD) mean PPVT-IV (Dunn & Dunn, 2007) standard score was 97.00, with a range of 62 to 139. The Group 2 (TD) mean PPVT-IV (Dunn & Dunn, 2007) standard score was 110.17, with a range of 105 to 120. The Group 3 (sCAS) mean PPVT-IV (Dunn & Dunn, 2007) standard score was 106.33, with a range of 96 to 129.

Portions of the Mullen Scales of Early Learning (MSEL: Mullen, 1992) were administered to further describe the groups, including the Visual Reception (MSEL-VR) and Fine Motor (MSEL-FM) scales. The MSEL Visual Reception scale age-equivalency scores, rather than the T-scores, were used to measure non-verbal cognitive ability because of the insensitivity of standard scores among low functioning children (Akshoomoff, 2006). To be consistent with this approach, only the age-equivalency scores of the MSEL Fine Motor scale also are reported here. Participant characteristics and demographics are reported in Table 3.1.

Table 3.1

*Characteristics and Test Results of Children by Group (N=22)*

| **Participant Characteristics** | **ASD (N=10)** | **TD (N=6)** | **sCAS (N=6)** |
|---|---|---|---|
| Gender (% Male) | 66 | 33 | 67 |
| Race (% Caucasian) | 66 | 83 | 83 |
| Mean Age (Months) | 57.30 | 44.83 | 59.17 |
| s.d. | 6.06 | 5.95 | 4.35 |
| Range | 46.00 – 66.00 | 39.00 – 53.00 | 55.00 – 64.00 |
| Mean Length Utterance | 6.09 | 6.08 | 5.08 |
| s.d. | 3.09 | 1.80 | 1.55 |
| Range | 3.66 – 11.30 | 4.30 – 9.00 | 3.25 – 7.60 |

| **Test Results** | **ASD (N=10)** | **TD (N=6)** | **sCAS (N=6)** |
|---|---|---|---|
| PPVT-IV | 97.00 | 110.17 | 106.33 |
| s.d. | 24.35 | 5.71 | 12.26 |
| Range | 62.00 – 139.00 | 105.00 – 120.00 | 96.00 – 129.00 |
| MSEL-VR (Age Equivalent in Months) | 58.17 | 49.83 | 56.83 |
| s.d. | 15.60 | 10.15 | 7.76 |
| Range | 27.00 – 69.00 | 39.00 – 69.00 | 48.00 – 69.00 |
| MSEL-FM (Age Equivalent in Months) | 52.17 | 41.00 | 50.50 |
| s.d. | 9.13 | 10.02 | 12.58 |
| Range | 39.00 – 68.00 | 31.00 – 53.00 | 31.00 – 68.00 |

As is evidenced in Table 1, participants in Groups 1 (ASD) and 3 (sCAS) were primarily male and participants in Group 2 (TD) were primarily female. When averaged together across all groups, there was a relatively even distribution of gender, with male children comprising 55% of the sample. Participants across all groups were primarily Caucasian, comprising 77% of the overall sample. Other ethnicities represented included Multi-ethnic (10%), Asian (4%), Black (4%) and Pacific-Islander (4%).

One-way analyses of variance were conducted to evaluate the relationships between group membership (ASD, TD, sCAS) and mean scores on study design controls for chronological age (in months), expressive language (MLU: Brown, 1973), receptive language (PPVT-IV: Dunn & Dunn, 2007), non-verbal cognitive ability (MSEL-VR: Mullen, 1992), and fine motor ability (MSEL-FM: Mullen, 1992). The independent variable was group membership (ASD, TD, sCAS). The dependent variable in each analysis was one of the above listed controls. All but one ANOVA (chronological age) yielded nonsignificant differences between each of the dependent variables, indicating that the groups were statistically matched with each other. The only significant test was between group membership and chronological age, $F(2, 19) = 12.15$, $p = .00$. The strength of the relationship between group membership and chronological age, as assessed by $\eta^2$, was strong, with the group membership accounting for 56% of the variance of the dependent variable (chronological age in months).

Follow-up tests were conducted to evaluate pairwise differences among the means. Because the variances among the three groups ranged from 18.97 to 36.68, the assumption was made that the variances were not homogenous and post hoc comparisons were conducted with the use of the Dunnett’s C test, a test that does not assume equal variances among the three groups. There was a significant difference in the means between Group 2 (TD) and both Groups 1 (ASD) and 3 (sCAS), but no significant differences between Group 1 (ASD) and Group 3 (sCAS). As expected, Group 2 (TD) showed a lower mean chronological age in months in comparison to the other two groups. The 95% confidence intervals for the pairwise differences, as well as the means and standard deviations for the three groups, are reported in Table 3.2.

Table 3.2

*95% Confidence Intervals of Pairwise Differences in Mean Chronological Age in Months*

| Developmental Group | M | SD | ASD | TD |
|---|---|---|---|---|
| ASD | 57.30 | 6.06 | | |
| TD | 44.83 | 5.95 | 2.95 to 21.98* | |
| sCAS | 59.17 | 4.35 | -5.99 to 9.72 | 4.54 to 24.13* |

Note: An asterisk indicates that the 95% confidence interval does not contain zero, and therefore the difference in means is significant at the .05 significance using Dunnett's C procedure.

The significant difference among groups on the basis of age is not unexpected. In order to qualify typically developing control participants for the study matched by MLU, it was necessary to screen typically developing children who were younger than many of the children in Group 1 (ASD). The difference in age does not violate the developmental age range of 3 to 5 ½ years, which controls for maturational effects attributed to overall motor development across large age spans (Kent, 1999). Furthermore, given that there were no significant differences by group membership on the remaining control variables, the three groups were considered to be well-matched and interpretation of performance on research data measures is thought to be valid.

In terms of the characteristics of the primary caregivers, all primary caregivers were female and indicated a total number of years of maternal education. These characteristics are reported in Table 3.3.

Table 3.3

*Characteristics of Primary Caregivers (N=22)*

| **Characteristics of Primary Caregivers** | **ASD (N=10)** | **TD (N=6)** | **sCAS (N=6)** |
|---|---|---|---|
| Gender (% Female) | 100 | 100 | 100 |
| Education - % Completion of High School | 30 | 0 | 17 |
| Education - % One year of College | 0 | 0 | 0 |
| Education - % Two Years of College | 30 | 50 | 0 |
| Education - % Three years of College | 0 | 17 | 0 |
| Education - % Four Years of College | 40 | 33 | 50 |
| Education - % Master's Degree | 0 | 0 | 33 |

Maternal education levels ranged from completion of high school to master's level education. Caregivers in Group 1 (ASD) varied from 30% having a high school degree or two years of college to 40% having a Bachelor's degree. Caregivers in Group 2 (TD) had more consistent education levels from 50% (three mothers) who had had two years of college to 33% (two mothers) who had a Bachelor's degree. Caregivers in Group 3 (sCAS) tended to have more divergent education levels than the other two groups with 17% (one mother) having only a high school diploma, while the remainder of the group had completed either Bachelor's or Master's degrees. A one-way analysis of variance was conducted to evaluate the relationships between group membership (ASD, TD, sCAS) and levels of maternal education. Each level of maternal education was assigned a number representing the maximum years of higher education such that '0' = High School degree, '1' = 1 year of college, '2' = 2 years of college, '3' = 3 years of college, '4' = 4 years of college, and '5' = Master's Degree. The independent variable was group membership (ASD, TD, sCAS). The dependent variable was maternal education. The one-way ANOVA yielded nonsignificant differences between maternal education, indicating that the groups were not statistically different from one another, $F(2, 19) = 1.54$, $p = .24$. Follow-up tests were conducted to evaluate pairwise differences among the means. There were no significant differences in the means among all the groups. The 95% confidence intervals for the pairwise differences, as well as the means and standard deviations for the three groups, are reported in Table 3.4.

Table 3.4

*95% Confidence Intervals of Pairwise Differences in Mean Maternal Education*

| Developmental Group | M | SD | ASD | TD |
|---|---|---|---|---|
| ASD | 2.20 | 1.75 | | |
| TD | 2.83 | 0.98 | -2.65 to 1.38 | |
| sCAS | 3.67 | 1.86 | -4.38 to 1.44 | -3.63 to 1.96 |

Note: An asterisk indicates that the 95% confidence interval does not contain zero, and therefore the difference in means is significant at the .05 significance using Dunnett's C procedure.

*Participant Inclusion and Exclusion Criteria*

All participants met criteria to receive a PASS rating on a hearing screening within the last two years indicating normal hearing acuity at 1k, 2k, and 4k at a 20 dB hearing level. Also, all were from a family in which English was the primary language of the home, were chronologically aged between 3 to 5 ½ years, and had an MLU derived from Section D of the

CDI (CDI: Fenson, et al., 2006) of at least 3.0. Potential participants in all groups were excluded if they had not passed a hearing screening within the last two years, if English was not the primary language of the home, if they were outside of the chronological age range of 3 – 5 ½ years, or if a parent reported the child had identified metabolic, genetic, or progressive neurological disorders (e.g., Rett syndrome, tuberous sclerosis, PKU, fragile X). Additionally, potential participants in Group 2 (TD) and Group 3 (sCAS) were excluded if participants met criteria for autism spectrum disorder by parent report on the Social Responsiveness Scale (SRS: Constantino, 2005) or if the child had identified or reported symptoms (or history) of developmental delay or disorders per parent report, with the exception of a diagnosis of suspected Childhood Apraxia of Speech in the case of Group 3 (sCAS).

Additional inclusion criteria were applied to Groups 1 (ASD) and 3 (sCAS) to more fully define the focal developmental disorder area of those groups. In Group 1 (ASD), all participants met the criteria for autism or a related pervasive developmental disorder (PDD) diagnosis, as confirmed by the Social Responsiveness Scale (SRS: Constantino, 2005) completed by a parent, as well as by parent and/or profession report. In Group 3 (sCAS), all participants had suspected Childhood Apraxia of Speech (CAS) or apraxic-like speech symptoms as confirmed by completion by a treating SLP of the Checklist for Suspected Childhood Apraxia of Speech, developed by the PI based on the research of Velleman (2003), Davis, Jakielski, & Marquardt (1998), and Strand (2002). An individual met criteria for having a suspected Childhood Apraxia if the first three characteristics on the Checklist for Suspected Childhood Apraxia of Speech were checked. These characteristics on the Checklist were: 1) difficulty achieving and maintaining articulatory configurations, 2) presence of vowel distortions (especially simplification/ reduction of dipthongs), and 3) gap in the child's ability to produce the same sound in a simple context versus in a longer or more complex context (i.e., number of errors increases as length of word/phrase increases). Additional checked items contributed more description of their disorder but did not contribute to the likelihood of being included in Group 3 (sCAS).

*Procedures*

Upon being contacted by the interested parent of a preschooler, a telephone screening interview was conducted to provide more detailed information to the parent about the study and to assess the appropriateness of the child for the study. If the child was found to be eligible for the study and the parent wished to enroll the child in the study, then the interviewer reviewed the consent information and requested that the parent orally consent to the child's participation. After the parent had an opportunity to discuss any questions they may have had regarding the study and their child's participation, and oral consent had been given, a written copy of the consent form was mailed along with a background questionnaire for the parent to complete and bring to the assessment visit.

If the child was not found to be eligible for the study, then the PI thanked the parent for his/her time. The PI then shredded the written information that had been gathered. Children were excluded from the study for a variety of reasons, including (1) not meeting the age range requirement, (2) not meeting the MLU range requirement, (3) not meeting the English as a First Language requirement, and (4) having a known genetic condition. In the case of the fourth reason for exclusion, appropriate referrals were made at the request of the parent. One child was found to not be eligible based on an affirmative answer to the question, "Does the child have any known genetic conditions?" Upon further exploration, the parent reported that the child had been diagnosed with Fragile X syndrome. The parent verbalized understanding of the child's ineligibility, but inquired if the PI knew of other studies that may involve children with Fragile X syndrome. The PI informed the mother of the UNC Fragile X Research Registry and provided contact information for the Registry.

*Assessment Context and Procedure*

Once verbal consent was obtained during the initial telephone screening interview, the PI contacted families and set up a single behavioral assessment session scheduled at the family's convenience. Written consent was received from the parent at the time of the initial assessment before any research procedures were conducted. Each child was tested in a quiet room, free of distraction. Most of the children were tested in their homes, with only one child being tested in their speech clinic facility afterhours, per parent request. The assessments were provided in more than one session for only one child, who was a participant in Group 1 (ASD). In that instance, the child's attention was challenging to maintain and the parent and PI decided to schedule a second session in order to complete the testing.

Caregivers of each child participant were asked when the child's hearing was last tested and formal hearing screening procedures were offered. If the participant's hearing had not been formally screened or evaluated within the last two calendar years from the date of the research visit, then the PI attempted a formal hearing screening using otoacoustic emission testing procedures endorsed by the American Speech-Language-Hearing Association (ASHA, 1997). Successful hearing screenings were conducted with 14 participants. Hearing screenings were attempted with 4 other participants but were unsuccessful due to inconsistent responses or difficulty being conditioned to the screening procedure.  In all 4 of these cases, the mother reported having no concerns regarding her child's hearing.  Additionally, these four mothers reported that the child had either passed the auditory brainstem response (ABR) procedure at birth or had passed recent testing at a 3-year-old well-child pediatric check-up.  Hearing screening was not attempted on four participants because the mother reported that the child had recently undergone and passed a hearing screening as part of either a speech-language evaluation or well-child pediatric visit.

Children were administered the matching instruments and experimental tasks for 1 ½ - 2 hours across the session(s) with breaks as needed.  All instruments and experimental tasks were counterbalanced (see descriptions in next section).  Additionally all blocks of the modified-VMPAC were counterbalanced within groups.  Administration of the Joint Attention Protocol (Watson, Baranek, & Poston, 2003) and all trial blocks of the modified-VMPAC (Hayden & Square, 1999) were digitally recorded, including both video and audio, for the purposes of reviewing for accuracy of scoring and inter-rater reliability.

*Descriptive Data Collection Instruments*

Descriptive data collection instruments consisted of a background questionnaire, the Social Responsiveness Scale (SRS: Constantino, 2005), the Peabody Picture Vocabulary Test, Fourth edition (PPVT-IV: Dunn & Dunn, 2007), and two scales of the Mullen Scales of Early Learning (MSEL: Mullen, 1992).  All matching measures were administered to all participants.  Descriptive data collection instruments were counterbalanced across all participants to control for sequence effects, such as boredom or fatigue.

*Background questionnaire.* A background questionnaire was given to the parents of all participants.  The questionnaire requested information including the child's date of birth, gender, ethnicity, parent occupation, address, mother's highest level of education, family structure/siblings/birth order, handedness, and general developmental milestones. For Group 1 (ASD), the questionnaire also requested the age of first diagnosis, the age of first concern related to the diagnosis of ASD, and the reason(s) for the parent's initial concern.

*Social Responsiveness Scale (SRS: Constantino, 2005).* The SRS is a standardized parent rating scale that distinguishes autism spectrum conditions from other child psychiatric conditions by identifying the presence and extent of autistic social impairment. The SRS is appropriate for children ages 4 years to 18 years of age as a screener in clinical or educational settings. Parents completed the SRS to either confirm (ASD) or rule out (TD and sCAS) the presence of autistic social impairment.

*Peabody Picture Vocabulary Test, Fourth Edition (PPVT-IV: Dunn & Dunn, 2007).* The PPVT-IV is a norm-referenced, wide-range instrument for measuring the receptive (listening) single word vocabulary of children. Each test item consists of four full-color pictures as response options on a page. For each item, the examiner says a word, and the examinee responds by selecting the picture that best illustrates that word's meaning. The PPVT-IV is appropriate for participants ages 2 years, 6 months of age to 90 years of age. One standard deviation above or below the representative group score of Group 1 (mean = 97.00) was used as a matching criterion for Groups 2 and 3.

Components of the *Mullen Scales of Early Learning (MSEL: Mullen, 1992).* The MSEL is a standardized measure of cognitive and motor functioning that consists of a gross motor scale along with four cognitive scales, including fine motor, receptive language, expressive language, and visual reception. The MSEL is appropriate and provides norms for children ranging in age from birth through 8 years. Only the Fine Motor and Visual Reception scales were administered. The Fine Motor and Visual Reception scales were collected as descriptive data on all participants. The Fine Motor scale was used to rule out any overarching fine motor deficits. The Visual Reception scale is a measure of nonverbal cognitive ability (Mullen, 1992) and is reported as descriptive data for all groups.

*Research Data Measures*

Research data measures included the Joint Attention Protocol (Watson, Baranek, & Poston, 2003) and components of the Verbal Motor Production Assessment for Children (VMPAC: Hayden & Square, 1999). All experimental tasks were administered to all participants using a counterbalancing technique to control for sequence effects, such as fatigue or boredom.

*Attention-Following and Initiating Joint Attention Protocol (Watson, Baranek, & Poston, 2003).* This protocol measures the extent to which children will follow the attentional cues of the examiner, and the extent to which they will initiate and respond to bids for joint attention in communicating with the examiner. In order to examine the child's ability to respond to bids for joint attention (RJA), eight elicitations for RJA are attempted by the examiner. The child was given credit for RJA if they demonstrated one or more of four types of child behaviors: (1) head turn without any other cues; (2) head turn plus pointing gesture only; (3) head turn plus pointing gestures plus verbalization: "Look," and (4) head turn plus pointing gesture plus verbalization: "Look, (name object)". Colorful posters and toys were used as targets and displayed at 90-degree angles to the left and right of the child, out of the child's reach. In order to examine the child's ability to initiate bids for joint attention (IJA), eight opportunities for IJA are provided by the examiner. The child was given credit for IJA if they demonstrated one or more of six types of child behaviors: (1) looks from the examiner to the object/event and back to the examiner, or looks from the object/event to the examiner and back to the toy, i.e., 3-part gaze; (2) holds an object up, extending it toward the examiner; (3) points to an object or event; (4) vocalizes in conjunction with looking at the examiner, and then looks back at the object or event; (5) vocalizes in conjunction with holding up an object or pointing; and/or (6) verbalizes an intelligible comment about the object or event in conjunction with holding an object up, pointing, or eye gaze directed to another person. Each opportunity for IJA or RJA was coded as "+", indicating that the joint attention behavior was present or "--", indicating that the joint attention behavior was not present. The positive scores were totaled to arrive at a total number of joint attention behaviors present across 16 opportunities.

Components of the *Verbal Motor Production Assessment for Children (VMPAC: Hayden & Square, 1999).* The VMPAC (Hayden & Square, 1999) is a standardized assessment of the neuromotor integrity of the oromotor system for children ranging in age from 3 to 12 years. The VMPAC was modified for the purposes of this study with the permission of the first author of the test. The modified version includes only those test items that are administered using multiple modalities, including auditory, visual, and tactile, as well as a story recast task. Test items represent nonverbal oral and verbal motor stimuli. Tasks were administered in three blocks of tasks. In order to control for sequence effects including fatigue or boredom, the protocol was counterbalanced within groups such that one-half of the participants in each group (N=3 or 5) was given Block 1, then Block 2, followed by Block 3, in that order. The remaining participants in each group (N=3 or 5) were given Block 3, then Block 2, followed by Block 1.

Block 1 included 10 nonverbal oral tasks to be completed by the child (e.g., 'Show me how you open your mouth.') given once for each of three administration modalities (i.e., auditory, visual, and tactile), and Block 2 included 10 verbal motor tasks to be completed by the child (e.g., 'Say, /a-u/.') given once for each of the three administration modalities. For example, the auditory instruction for a non-verbal item included the command, "Open your mouth." The child would then be expected to perform the motor action. Visual administration for the same non-verbal item included the examiner physically performing the action by lowering her jaw in view of the participant and then saying, "Now you do it." Tactile administration for the same non-verbal item had the examiner say, "Now I'm going to help you open your mouth." Then the examiner placed her thumb on the participant's chin, and placed her index finger along the side of the participant's jaw in order to encourage jaw opening. All three modalities were administered even if the child performed well with an auditory cue only.

In Blocks 1 and 2 of the modified-VMPAC (Hayden & Square, 1999), the criteria for scoring of imitative utterances across administration modalities were consistent with the coding system in the published VMPAC (Hayden & Square, 1999) manual. Specifically, each utterance was scored as either a "0," "1," or a "2." A score of "0" indicated that one or both movements were severely imprecise in one or more parameters, the child substituted one phoneme for another, or the child did not say all the phonemes. A score of "1," indicated that one or both movements were partially imprecise in one or more parameters. A score of "2," indicated that both movements were precise in every parameter. These scoring criteria were consistent across all Blocks.

Block 3 of the Modified-VMPAC (Hayden & Square, 1999) represented a concurrent sampling of connected speech (as in the published version of the test) and joint attention behaviors (not typically measured during administration of the published version of the test).

Each of 10 items in Block 3-Connected Speech was administered up to three times to provide adequate opportunity for the child to respond or engage in the task with the examiner. Only the best trial was included in behavioral data scoring. Each of the same 10 items in Block 3-Joint Attention was administered and attempted in the same manner, while embedding 10 opportunities for initiating joint attention (IJA) and 10 opportunities for responding to joint attention (RJA).

Block 3 (Connected Speech) included ten connected speech items that ranged from simple to complex along a continuum of syllabic complexity. The first six of ten tasks in Block 3 provided opportunities for the child to imitate single words through simple sentences given a picture card cue and verbal instructions from the examiner (ex., 'Say, pea, tea, key.'). These six connected speech utterances were given a score that indicated whether the child's utterance was precise, partially imprecise, or severely imprecise. The criteria for the scoring of imitative utterances across administration modalities were consistent with the coding system in the published VMPAC (Hayden & Square, 1999) manual and were the same criteria as for Blocks 1 and 2.

The remaining four of the ten Block 3 tasks provided the child with an opportunity to retell a four-card picture story sequence given a verbal and visual model using a simple sentence structure. In the picture story sequence portion of Block 3 of the modified-VMPAC (Hayden & Square, 1999), scoring criteria served two purposes. The first score was based on the child's utterances to recast the 4-card picture story sequence. Each child's utterance was judged across a range between "0," and "6." A score of "0," for example, indicated that the child gave no response or that the response was unintelligible (i.e., no meaning can be derived). A score of "3," in contrast, indicated that the child's utterance resembled a chain of single words (e.g., “a dog, shoe”; “bone and shoe”; “dog, bone”). A score of “6” indicated that the child’s utterance resembled a complete, grammatical sentence (e.g., “The dog found a bone”). The second score of the picture story sequence portion of Block 3 modified-VMPAC (Hayden & Square, 1999) evaluated the child’s motor control for the entire connected speech and language sample between “0” and “7.” A score of “0” indicated that the child gave no response or had severe motor control difficulties. A score of “4” indicated that the child primarily used his/her jaw and lip to make contact, with poor tongue use. A score of “7” indicated that the child demonstrated a well-coordinated, balanced, and aligned system with highly intelligible and prosodic speech.

The portion of Block 3 that is not included in the published version of the VMPAC (Joint Attention and Connected Speech) included twenty naturalistic opportunities for the child to engage in joint attention with the examiner with respect to an object or event, including 10 opportunities for initiating bids for joint attention and 10 opportunities for responding to bids for joint attention, embedded within the ten connected speech tasks. Each of these tasks involved a joint focus of attention between the examiner and the participant using blocks, picture cards, or other objects. For example, the shared story card activity was initiated by the examiner. The examiner announced to the child that she would tell him/her a story and that the child would be able to tell the story back to the examiner. The examiner then held the picture cards next to and parallel to her face and said one or two short sentences about the story card (e.g., ‘The boy is riding a bike.’) while providing bids for joint attention with the child by looking to the child and back to the picture several times. The examiner continued through each of four story cards, providing a naturalistic interaction for the shared story card activity. Once the examiner had shared all four cards, the examiner stacked them together again and passed them face down to the child. The examiner then requested that the child retell the story to her and instructed the child to hold the cards up so that they were visible to the examiner. If the child did not appear to understand the instructions, the examiner repeated the instructions and waited patiently for the child to respond. The child then retold the story to the examiner and the examiner responded naturalistically to any bids for joint attention initiated by the child.

The child was credited with initiating bids for joint attention according to the same criteria as in the Joint Attention Protocol (Watson, et al., 2003). Criteria for crediting the child with responding to bids for joint attention included the participant demonstrating a shift of gaze between an object of interest and the examiner or a triad of looking (i.e., object, person, object; or person, object, person) in addition to vocalizing or verbalizing. Participants who demonstrated either initiating bids for joint attention or responding to bids for joint attention were credited for each occurrence. The positive scores were totaled to arrive at a total number of joint attention behaviors present during connected speech across the 20 opportunities.

*Coding Process and Reliability*

Before coding any behavioral data for any participants, DVDs were randomly selected along with printed scoring protocols used during the real-time data collection session(s). A graduate research assistant who has an undergraduate degree in Psychology and is currently pursuing graduate study in Communication Disorders assisted with inter-rater reliability of the behavioral data scoring. The research assistant was trained on scoring procedures over a three week period using DVDs collected during the pilot phase of the dissertation study until inter-rater reliability was established with at least 80% agreement across all tasks.

Final scoring protocols were developed and behavioral data coding for the current study was initiated using the final scoring protocols, randomly selected DVDs, and the research assistant being blind to each participant's group assignment. The research assistant also checked the scoring of the descriptive data collection instruments for accuracy. The research assistant and the PI both coded all 22 of the participant's DVDs. The measures that were the primary focus of this study were the Joint Attention Protocol (Watson et al., 2003) and the three Blocks of the modified-VMPAC (Hayden & Square, 1999). These data were compiled through behavioral coding using criteria that were consistent with the scoring criteria in the published administration protocols for each instrument and were described earlier. Inter-rater reliability, assessed via kappa coefficients, ranged from .83 to 1.00. Table 3.5 lists the kappa coefficients for the variables of interest.

Table 3.5

*Kappa Coefficients for Independent Variables*

| | JA | Total NVO | Total VM | CJA | CVM |
|---|---|---|---|---|---|
| Kappa Coefficient | .83 | 1.00 | .95 | .95 | .95 |

# CHAPTER IV: RESULTS

The purpose of this study was to examine the relationships among five variables relating to joint attention and oromotor imitation abilities among three groups of children group-matched for receptive and expressive language and speech motor development. A non-random, self-selected sample of twenty-two (22) participating children was grouped according to developmental status. Groups included children with an autism spectrum disorder (Group 1: ASD), typically developing children (Group 2: TD), and children with a suspected Childhood Apraxia of Speech (Group 3: sCAS). All statistical analyses were completed using IBM SPSS Statistics 19.0, Windows edition. A table presenting a summary of remarkable results is included at the end of this chapter.

*Descriptive Statistics*

The scores in the dataset reflected continuous data on each of five variables for each child's performance during the assessment time and include joint attention ability (JA); nonverbal oral imitation ability (NVO); verbal motor imitation ability (VM); concurrent joint attention ability (CJA); and concurrent verbal motor imitation ability (CVM). The nonverbal oral and verbal motor imitation assessments were further subdivided according to the modality of administration, such that each of these variables had three levels plus a total overall score. The three levels of each variable were auditory, visual, and tactile scores.

Descriptive statistics were obtained for all variables using univariate analyses to examine the means and standard deviations of each variable. The JA measure represented the sum of positive scores present out of a total of 16 opportunities to demonstrate initiating or responding to bids for joint attention. The Total NVO measure represented the sum of scores on 10 nonverbal oral imitation tasks given 3 times, each with either an auditory, visual, or tactile prompt. The Total NVO score possible on this measure was 60. The Total VM measure represented the sum of scores on 10 verbal motor imitation tasks given 3 times, each with either an auditory, visual, or tactile prompt (each with a score of 0,1, or 2). The Total VM score possible on this measure was 60. The concurrent joint attention (CJA) measure represented the sum of positive scores present out of a total of 20 opportunities to demonstrate initiating or responding to bids for joint attention. The concurrent verbal motor (CVM) measure represented the sum scores on 6 connected speech items combined with a percentage score on 4 items, with a total score possible of 20. Table 4.1 presents the means and standard deviations of all five variables, as well as those of the three subtests for nonverbal oral and verbal motor imitation assessments.

Table 4.1

*Means and Standard Deviations for Joint Attention Ability and Oromotor Imitation (N=22)*

| | **ASD (N=10)** | **TD (N=6)** | **sCAS (N=6)** |
|---|---|---|---|
| Joint Attention (16) ☨ | 10.80 | 13.00 | 14.33 |
| s.d. | 2.25 | 2.76 | 0.82 |
| Range | 6.00 – 14.00 | 8.00 – 15.00 | 13.00 – 15.00 |
| Total Nonverbal Oral (60) ☨ | 46.30 | 54.00 | 53.33 |
| s.d. | 9.37 | 4.34 | 7.09 |
| Range | 31.00 – 60.00 | 46.00 – 58.00 | 41.00 – 60.00 |
| *Auditory Modality* (20) ☨ | 12.30 | 15.50 | 15.83 |
| s.d. | 5.76 | 1.87 | 3.43 |
| Range | 2.00 – 20.00 | 13.00 – 18.00 | 13.00 – 20.00 |
| *Visual Modality* (20) ☨ | 17.10 | 19.33 | 18.17 |
| s.d. | 2.28 | 1.63 | 2.40 |
| Range | 14.00 – 20.00 | 16.00 – 20.00 | 14.00 – 20.00 |
| *Tactile Modality* (20) ☨ | 16.50 | 19.17 | 19.33 |
| s.d. | 2.72 | 1.60 | 1.63 |
| Range | 12.00 – 20.00 | 16.00 – 20.00 | 16.00 – 20.00 |
| Total Verbal Motor (60) ☨ | 49.80 | 57.67 | 43.00 |
| s.d. | 10.28 | 2.42 | 7.80 |
| Range | 29.00 – 60.00 | 53.00 – 60.00 | 35.00 – 53.00 |
| *Auditory Modality* (20) ☨ | 16.00 | 18.83 | 13.67 |
| s.d. | 4.59 | 1.33 | 4.13 |
| Range | 6.00 – 20.00 | 17.00 – 20.00 | 8.00 – 19.00 |

| | | | |
|---|---|---|---|
| *Visual Modality* (20) † | 16.50 | 19.17 | 13.33 |
| s.d. | 2.76 | 1.33 | 3.01 |
| Range | 13.00 – 20.00 | 17.00 – 20.00 | 12.00 – 16.00 |
| *Tactile Modality* (20) † | 17.30 | 19.67 | 15.67 |
| s.d. | 3.97 | 0.52 | 2.58 |
| Range | 10.00 – 20.00 | 19.00 – 20.00 | 13.00 – 18.00 |
| Concurrent Joint Attention (20) † | 9.10 | 17.50 | 15.33 |
| s.d. | 4.63 | 2.35 | 1.63 |
| Range | 3.00 – 18.00 | 13.00 – 19.00 | 12.00 – 18.00 |
| Concurrent Verbal Motor (20) † | 13.43 | 16.80 | 10.65 |
| s.d. | 5.72 | 3.65 | 4.07 |
| Range | 2.00 – 19.70 | 11.80 – 20.00 | 6.40 – 16.70 |

† Total points possible for each variable.

*Differences between Groups across Research Measures*

The first research question in the study addressed differences in group means across all five research measures, including joint attention, total nonverbal oral imitation, verbal motor imitation, concurrent joint attention, and concurrent verbal motor imitation. The one-way multivariate analysis of variance (MANOVA) was conducted to evaluate the relationship between the independent variable of group membership (ASD, TD, sCAS) and mean scores on the five research measures serving as dependent variables.

Data were screened for unequal sample sizes and missing data; normality; outliers; homogeneity of variance-covariance matrices; and linearity. Sample sizes were different among the groups: There were 10 children with ASD, 6 typically developing children, and 6 children with sCAS in the sample. SPSS automatically adjusted for unequal *n*. There were at least more cases in any single group than the total number of variables. There were no missing data or outliers. The Box's *M* test was nonsignificant, $F$ (30, 745) = .84, $p > .05$, confirming homogeneity of variance-covariance matrices. Results of evaluation of assumptions of linearity were satisfactory. All twenty-two cases were included in the final analysis.

Significant differences were found among the three groups on the five variables, Wilks' $\Lambda = .15$, $F$ (10, 30) = 4.88, $p < .01$, indicating that the group means on the dependent variables were not the same for the three groups. The multivariate partial $\eta^2$ based on Wilks' $\Lambda$ was quite strong, .62, indicating that 62% of multivariate variance of the dependent variables was associated with the group factor. Results of the overall MANOVA are shown in Figure 4.1.

**Multivariate Tests[c]**

| Effect | | Value | F | Hypothesis df | Error df | Sig. | Partial Eta Squared |
|---|---|---|---|---|---|---|---|
| Intercept | Pillai's Trace | .989 | 264.139[a] | 5.000 | 15.000 | .000 | .989 |
| | Wilks' Lambda | .011 | 264.139[a] | 5.000 | 15.000 | .000 | .989 |
| | Hotelling's Trace | 88.046 | 264.139[a] | 5.000 | 15.000 | .000 | .989 |
| | Roy's Largest Root | 88.046 | 264.139[a] | 5.000 | 15.000 | .000 | .989 |
| Group | Pillai's Trace | 1.193 | 4.731 | 10.000 | 32.000 | .000 | .596 |
| | Wilks' Lambda | .145 | 4.877[a] | 10.000 | 30.000 | .000 | .619 |
| | Hotelling's Trace | 3.563 | 4.988 | 10.000 | 28.000 | .000 | .640 |
| | Roy's Largest Root | 2.700 | 8.640[b] | 5.000 | 16.000 | .000 | .730 |

a. Exact statistic

b. The statistic is an upper bound on F that yields a lower bound on the significance level.

c. Design: Intercept + group

***Figure 4.1 Results of the overall MANOVA.***

Analyses of variances (ANOVA) on each dependent variable were conducted as follow-up tests to the MANOVA. Each ANOVA was tested at the .05 level. The ANOVA on the concurrent joint attention group means was significant, $F$ (2, 19) = 12.44, $p < .01$. The strength of the relationship between group membership and concurrent joint attention, as assessed by partial $\eta^2$, was strong, with the group membership accounting for 56% of the variance of the dependent variable (concurrent joint attention).

Follow-up tests were conducted to evaluate pairwise differences among the group means for concurrent joint attention. Because the variances among the three groups ranged from 2.67 to 21.43, the assumption was made that the variances were not homogenous and post hoc comparisons were conducted with the use of the Dunnett's C test, a test that does not assume equal variances among the three groups. Examination of the means on the CJA variable indicated that Group 1 (ASD: M=9.10, SD=4.63,) scored significantly ($p$<.001) lower than Group 2 (TD: M=17.50, SD=2.35) and significantly ($p$=.003) lower than Group 3 (sCAS: M=15.33, SD=1.63), but there were no significant differences between group means for Group 2 (TD) and Group 3 (sCAS). On the measure of CJA, Group 1 (ASD) had the largest standard deviation. The 95% confidence intervals for the pairwise differences, as well as the means and standard deviations for the three groups, are reported in Table 4.2.

Table 4.2

*Means, standard deviations, and 95% Confidence Intervals of Pairwise Differences in Concurrent Joint Attention*

| Developmental Group | M | SD | ASD | TD |
|---|---|---|---|---|
| ASD | 9.10 | 4.63 | | |
| TD | 17.50 | 2.35 | 3.27 to 13.53* | |
| sCAS | 15.33 | 1.63 | 1.61 to 10.85* | -5.96 to 1.63 |

Note: An asterisk indicates that the 95% confidence interval does not contain zero, and therefore the difference in means is significant at the .05 significance using Dunnett's C procedure.

The ANOVA on the total verbal motor imitation group means was also significant, $F\ (2, 19) = 4.78$, $p < .05$. The strength of the relationship between group membership and total verbal motor imitation, as assessed by partial $\eta^2$, was medium, with the group membership accounting for 33% of the variance of the dependent variable (total verbal motor imitation).

Follow-up tests were also conducted to evaluate pairwise differences among the group means for total verbal motor imitation. Because the variances among the three groups ranged from 5.87 to 105.73, the assumption was made that the variances were not homogenous and post hoc comparisons were conducted with the use of the Dunnett's C test, a test that does not assume equal variances among the three groups. Examination of the means on the VM variable indicated that Group 2 (TD: M=57.67, SD=2.42) scored significantly higher ($p$=.006) than Group 3 (sCAS: M=43.00, SD=7.80), but no significant differences were found between Group 2 (TD) and Group 1 (ASD) or between Group 1

(ASD) and Group 3 (sCAS). The 95% confidence intervals for the pairwise differences, as well as the means and standard deviations for the three groups, are reported in Table 4.3.

Table 4.3

*Means, standard deviations, and 95% Confidence Intervals of Pairwise Differences in Total Verbal Motor Imitation*

| Developmental Group | M | SD | ASD | TD |
|---|---|---|---|---|
| ASD | 49.80 | 10.28 | | |
| TD | 57.67 | 2.42 | -1.76 to 17.49 | |
| sCAS | 43.00 | 7.80 | -20.53 to 6.93 | -25.51 to -3.82* |

Note: An asterisk indicates that the 95% confidence interval does not contain zero, and therefore the difference in means is significant at the .05 significance using Dunnett's C procedure.

The ANOVA on the joint attention group means was also significant, $F$ (2, 19) = 5.48, $p < .05$. The strength of the relationship between group membership joint attention, as assessed by partial $\eta^2$, was medium, with the group membership accounting for 36% of the variance of the dependent variable (joint attention).

Follow-up tests were also conducted to evaluate pairwise differences among the group means for joint attention. Because the variances among the three groups ranged from 0.67 to 7.60, the assumption was made that the variances were not homogenous and post hoc comparisons were conducted with the use of the Dunnett's C test, a test that does not assume equal variances among the three groups. Examination of the means on the JA variable indicated that Group 3 (sCAS: M=14.33, SD=0.82) scored significantly higher ($p$ <.05) than Group 1 (ASD: M=10.80, SD=2.25), but no significant differences were found between Group 3 (sCAS) and Group 2 (TD) or between Group 1 (ASD) and Group 2 (TD). The 95%

confidence intervals for the pairwise differences, as well as the means and standard deviations for the three groups, are reported in Table 4.4.

Table 4.4

*Means, standard deviations, and 95% Confidence Intervals of Pairwise Differences in Joint Attention*

| Developmental Group | M | SD | ASD | TD |
|---|---|---|---|---|
| ASD | 10.80 | 2.25 | | |
| TD | 13.00 | 2.76 | -1.96 to 6.36 | |
| sCAS | 14.33 | 0.82 | 1.27 to 5.79* | -2.49 to 5.15 |

Note: An asterisk indicates that the 95% confidence interval does not contain zero, and therefore the difference in means is significant at the .05 significance using Dunnett's C procedure.

The remaining ANOVA results were nonsignificant and were greater than $p$=.05, including the total nonverbal oral imitation, $F$ (2, 19) = 2.49, $p$=.11, and concurrent verbal motor ability, $F$ (2, 19) = 2.44, $p$=.11. With a larger total number of participants and, thus, greater variability in scores, these measures may have achieved statistical significance.

*Relationship between Joint Attention Ability and Oromotor Imitation*

The second research question in the study addressed the relationships between total scores of joint attention (JA) and total scores derived from (a) imitative, non-verbal oral tasks (NVO), and (b) imitative verbal motor tasks (VM) among the three groups of children. The correlational analysis sought to assess the degree that JA scores were linearly related to total NVO or to total VM scores.

Data were screened for normality, independence, reasonable means, standard deviations, minimum and maximum in range, skewness, kurtosis, and outliers for each group.

The distribution of scores was positively skewed. A significance test for skewness was conducted that tested the obtained value of skewness against the null hypothesis of zero. The result was nonsignificant, indicating that the obtained skewness was not significantly different than zero. Any skewness in the distribution was well within the range of random error. Thus, the assumption of normality was met. The cases represented a non-random sample from the population and the scores on variables for one case were independent of scores on the variables for other cases. Therefore, the independence assumption was met. All other descriptive statistics, including means, standard deviations, minimum and maximum in range, kurtosis, and outliers were acceptable. All twenty-two cases were included in the final analysis.

Correlation coefficients were computed among the three variables of interest. A *p* value of .05 was required for significance. Due to sample size limitations, statistics were not corrected for Type I errors in an effort to reduce Type II errors. The results of the correlational analyses are presented in Table 4.4.

Table 4.5

*Correlations between Joint Attention, Nonverbal Oral Imitation, and Verbal Motor Imitation (N=22)*

| | *Nonverbal Oral Imitation* | | | *Verbal Motor Imitation* | | |
|---|---|---|---|---|---|---|
| | ASD | TD | sCAS | ASD | TD | sCAS |
| Joint Attention | .59 | -.32 | -.09 | .57 | .27 | -.03 |
| (*p*-value) | (.07) | (.53) | (.86) | (.08) | (.60) | (.95) |

** No significant correlations at the $p < .05$ level for any of the variables.

Correlation coefficients for the ASD group were large and positive for both pairs of variables, but were not significant at the $p < .05$ level. The p levels of .07 and .08, however, may indicate a trend that nonverbal oral and verbal motor imitation skills may increase with concomitant increases in joint attention, or vice versa for this group. The correlation coefficients for the TD group were both nonsignificant, as were the correlations for the sCAS group; none of these correlations approached significance.

*Relationship between Concurrent Joint Attention Ability and Concurrent Verbal Motor Imitation*

The third research question in the study addressed the relationship between total scores of concurrent joint attention (CJA) and of concurrent verbal motor imitation (CVM) across all three groups. The correlational analysis sought to assess the degree that CJA scores were linearly related to CVM scores.

Data were screened for normality, independence, reasonable means, standard deviations, minimum and maximum in range, skewness, kurtosis, and outliers for each group. The distribution of scores was positively skewed. A significance test for skewness was conducted that tested the obtained value of skewness against the null hypothesis of zero. The result was nonsignificant, indicating that the obtained skewness was not significantly different than zero. Any skewness in the distribution was well within the range of random error. Thus, the assumption of normality was met. The cases represented a non-random sample from the population and the scores on variables for one case were independent of scores on the variables for other cases. Therefore, the independence assumption was met. All other descriptive statistics, including means, standard deviations, minimum and maximum in range, kurtosis, and outliers were reasonable. All twenty-two cases were included in the final analysis.

Correlation coefficients were computed among the three variables of interest. A *p* value of .05 was required for significance. Due to sample size limitations, statistics were not corrected for Type I errors in an effort to reduce Type II errors. The results of the correlational analyses are presented in Table 4.5.

Table 4.6

*Correlations between Concurrent Joint Attention and Concurrent Verbal Motor Imitation (N=22)*

| | *Concurrent Verbal Motor Imitation* | | |
|---|---|---|---|
| | ASD | TD | sCAS |
| Concurrent Joint Attention | .34 | -.29 | -.078 |
| (*p*-value) | (.34) | (.57) | (.88) |

* No significant correlations at the $p < .05$ for any group.

The correlation coefficient for the ASD group was positive and of medium strength but not significant. Although nonsignificant, it mirrored the finding between the total scores of joint attention and verbal motor imitation (which approached significance). There is no context for interpreting the nonsignificant correlations seen in the TD and sCAS groups.

As a follow-up to both correlational analyses for research questions 1 and 2, a secondary analysis using discriminant function analysis was conducted to determine if group membership could be predicted on the basis of quantitative predictive variables.

*Discriminant Function Analysis to Predict Developmental Status (Group Membership)*

A discriminant function analysis was conducted to see if the twenty-two (22) participants could be classified into groups on the basis of one or more measures. The discriminant analysis procedure was selected because it is a statistical analysis method used to predict membership of participants in predefined groups (Tabachnick & Fidell, 2001). Discriminant function analysis involves two main procedures: (1) testing the significance of a set of discriminant functions, and (2) classification. The first procedure involves performing a multivariate test. If this is statistically significant, further analysis is performed to determine which of the variables have significantly different means across the groups. Once group means are found to be statistically significant, the second procedure is undertaken involving classification of variables into discriminant functions. Participants are classified into the groups in which they had the highest classification scores. These classification scores indicate if scores on the variables of interest will predict which participants will fall into the three groups. Thus, this analysis explores the dimensions on which the groups differed, the predictors contributing to differences among groups on these dimensions, and the degree to which members of groups are accurately classified into their own groups.

A discriminant function analysis was performed using five behavioral variables as predictors of membership in the three groups. Predictors were the joint attention protocol (JA), total nonverbal oral imitation (NVO), total verbal motor imitation (VM), concurrent joint attention (CJA), and concurrent verbal motor imitation (CVM). Groups were children who have an autism spectrum disorder (ASD: n = 10), children who are typically developing (TD: n= 6), and children with a suspected Childhood Apraxia of Speech (sCAS: n =6). The number of predictors is deemed appropriate because discriminant function analysis is robust despite the small sample size in the present study.

First, the data were evaluated with respect to the practical limitations of discriminant function analysis. Data were screened for missing data, outliers, linearity, homogeneity of variance-covariance matrices, normality, and multicollinearity and singularity. Of the original 22 cases, there were no missing data or outliers. Additionally, in discriminant analysis, no special problems are posed by unequal sample sizes in groups (Tabachnick & Fidell, 2001). Additional screening statistics were calculated to determine the means and standard deviations of the predictors within groups, the ANOVAs assessing differences among the five predictors, the covariance matrices, and a test of equality of the within-group covariance matrices. These additional screening statistics indicated significant differences in means on the predictors among the three groups (*p* values range from .00 to .11). There were no significant differences in the covariance matrices among the three groups (p value of .71 for the Box’s M test), indicating that the population variances and covariances among the dependent variables were the same across all levels of the factor. However, some of the covariances did appear to differ across groups. For example, the covariance between concurrent joint attention and total verbal motor ability varied from -5.20 in the sCAS group to -2.60 in the TD group. The covariances in these two groups were negative, indicating that scores on these variables tended to move in opposite directions. That is, as the group mean on concurrent joint attention went up, the group mean on total verbal motor ability went down, or vice versa. However, the covariance of 21.80 in the ASD group was positive, indicating that the scores tended to covary in a positive way. That is, as the group mean on concurrent joint attention went up, the group mean on total verbal motor ability also went up, or vice versa. After careful screening of the data, it was determined that the evaluation of assumptions of linearity, homogeneity of variance-covariance matrices, normality, and multicollinearity or singularity revealed no threats to multivariate analysis. The output for additional screening statistics is provided in Figure 4.2.

**Tests of Equality of Group Means**

| | Wilks' Lambda | F | df1 | df2 | Sig. |
|---|---|---|---|---|---|
| Joint Attention Protocol | .634 | 5.481 | 2 | 19 | .013 |
| Total Nonverbal Oral Imitation | .792 | 2.488 | 2 | 19 | .110 |
| Total Verbal Motor Imitation | .665 | 4.783 | 2 | 19 | .021 |
| Concurrent Joint Attention Ability | .433 | 12.441 | 2 | 19 | .000 |
| Concurrent Verbal Motor Ability | .796 | 2.439 | 2 | 19 | .114 |

**Test Results**

| | | |
|---|---|---|
| Box's M | | 45.622 |
| F | Approx. | .840 |
| | df1 | 30 |
| | df2 | 745.521 |
| | Sig. | .713 |

Tests null hypothesis of equal population covariance matrices.

***Figure 4.2.*** **Screening statistics of the discriminant analysis.**

Results of the first step of discriminant analysis involving test of significance and strength-of-relationship statistics are shown in Figure 4.3. In the box labeled Wilks' Lambda, a series of chi-square significance tests are reported. These tests assess whether there are significant differences among groups across the predictor variables, after removing the effects of any previous discriminant functions. In the first row, SPSS reported the overall Wilks' lambda, $\Lambda = .14$, $\chi^2(10, N = 22) = 32.82$, $p < .01$. This test is significant at the .05

level and indicates that there are differences among the groups across the five predictor variables in the population. In the second row, SPSS reports that the residual Wilks' lambda was significant, $\Lambda = .54$, $\chi^2(4, N = 22) = 10.58$, $p < .05$. This test indicates that there is a significant difference among groups across all predictor variables in the population, after removing the effects associated with the first discriminant function. Because both tests were significant, both discriminant functions are interpreted according to the chi-square tests.

**Wilks' Lambda**

| Test of Function(s) | Wilks' Lambda | Chi-square | Df | Sig. |
|---|---|---|---|---|
| 1 through 2 | .145 | 32.820 | 10 | .000 |
| 2 | .537 | 10.578 | 4 | .032 |

**Eigenvalues**

| **Function** | **Eigenvalue** | **% of Variance** | **Cumulative %** | **Canonical Correlation** |
|---|---|---|---|---|
| 1 | 2.700[a] | 75.8 | 75.8 | .854 |
| 2 | .863[a] | 24.2 | 100.0 | .681 |

a. First 2 canonical discriminant functions were used in the analysis.

***Figure 4.3.*** **Significance tests and strength-of-relationship statistics for discriminant analysis.**

A series of statistics associated with each discriminant function are reported in the box labeled Eigenvalues. The first discriminant function has an eigenvalue of 2.7 and a canonical correlation of .85. By squaring the canonical correlation for the first discriminant function ($.85^2 = .72$), the eta squared is obtained that would result from conducting a one-way ANOVA on the first discriminant function. This indicates that 72% of the variability of the scores for the first discriminant function was accounted for by differences among the three groups. In comparison, the second discriminant function has an eigenvalue of .86 and a canonical correlation of .68. Therefore, 46% ($.68^2 = .46$) of the variability of the scores for the second discriminant function was accounted for by group membership. The first discriminant function is that which maximally separates the groups. The second discriminant function, orthogonal to the first, maximally separates the groups on variance not yet explained by the first discriminant function.

The discriminant functions are shown in Table 4.6, and include the within-groups correlations between the predictors and the discriminant functions as well as the standardized coefficients (i.e., weights). Each discriminant function is named by determining which variables are most strongly related to it. Strength of relationship is assessed by appraising the correlation coefficients between the predictor variables and the function within a group with the magnitudes of the standardized coefficients for the predictor variables in the function. Discriminant functions are interpreted after examination of correlation coefficients and standardized coefficients. Correlation coefficients represent the correlations between the variables in the model and the discriminant functions. The larger the correlation coefficient, the greater the strength of relationship represented between the respective variable and the discriminant function. The standardized coefficients represent each respective variable's unique contribution to the discrimination specified by the respective discriminant function. The larger the standardized coefficient, the greater is the contribution of the respective variable to the discrimination between groups. The maximum number of discriminant functions is either (1) the number of predictors or (2) the degrees of freedom for groups, whichever is smaller. Because there are three groups (and five predictors) in this study, there are potentially two discriminant functions contributing to the overall relationship.

For the first discriminant function in the application, concurrent joint attention has a relatively large positive correlation coefficient (.53) and a standardized coefficient (i.e., weight) of .59. For the second discriminant function, the largest positive standardized coefficient is for total verbal motor imitation, while concurrent verbal motor ability has a weaker coefficient. On the basis of the standardized function and correlation coefficients, the first and second discriminant functions are named concurrent joint attention and total verbal motor imitation, respectively.

Table 4.7

*Results of Discriminant Function Analysis of Behavioral Variables*

| | Correlation coefficients With discriminant functions | | Standardized coefficients for discriminant functions | |
|---|---|---|---|---|
| Predictors | Function 1 | Function 2 | Function 1 | Function 2 |
| JA | .46 | .13 | .64 | -.17 |
| NVO | .26 | .29 | .73 | -.46 |
| VM | -.18 | .69* | -.92 | .81 |
| CJA | .53* | .80* | .59 | .68 |
| CVM | -.13 | .50 | -.26 | .09 |

*Loadings > .50

The loading matrix of correlation coefficients between predictors and discriminant functions suggests that the best predictor for distinguishing between children with ASD and the other two groups (first function) is concurrent joint attention. The group means on the discriminant functions are consistent with this interpretation. Children with an autism spectrum disorder have significantly lower mean scores on concurrent joint attention (M = 9.10, SD = 4.63) than typically developing children (M = 17.50, SD = 2.35) or children with a suspected Childhood Apraxia of Speech (M = 15.33, SD = 1.63). Loadings less than .50 were not interpreted.

Two predictors, concurrent joint attention ability and total verbal motor imitation, had loadings in excess of .50 on the second discriminant function, which separates typically developing children from the other two groups. Children with an autism spectrum disorder have significantly lower mean scores during concurrent joint attention than typically developing children and than children with a suspected Childhood Apraxia of Speech (means have already been cited). Typically developing children also have significantly higher mean total verbal motor imitation scores (M = 57.67, SD = 2.42) than children with an autism spectrum disorder (M = 49.80, SD = 10.28) or children with a suspected Childhood Apraxia of Speech (M = 43.00, SD = 7.80).

It is interesting to note the patterns of percent correct between groups among the total verbal motor and concurrent verbal motor imitation tasks when computed by hand. Although not significant ($F$ (2, 19) = 2.44, $p$=.11), all groups had a lower percent correct on the concurrent verbal motor imitation tasks compared to the percent correct on the total verbal motor imitation tasks. For example, Group 1 (ASD) achieved 83% correct (M=49.80 (SD=10.28) / Total=60) on the total verbal motor imitation task, whereas they achieved only 67% correct (M=13.43 (SD=5.72) / Total=20) on the concurrent verbal motor imitation task. Group 3 (sCAS) indicated the most change in percent correct with 71% correct (M=43.00 (SD=7.80) / Total=60) on the total verbal motor imitation task and, only 53% correct

(M=10.65 (SD=4.07) / Total=20) on the concurrent verbal motor imitation task. Group 2 (TD) indicated the least amount of change in percent correct with 96% correct (M=57.67 (SD=2.42) / Total=60) on the total verbal motor imitation task and 84% correct (M=16.80 (SD=3.65) / Total=20) on the concurrent verbal motor imitation task. Though these differences were not significant, they may reveal a pattern and could hold some clinical relevance. The principal difference between the measures is represented by a continuum of syllabic complexity where tasks on the concurrent verbal motor imitation measure embodied the most syllabic complexity compared to tasks on the total verbal motor imitation task which embodied less syllabic complexity. This continuum is supported by the differences in performance across groups, most distinctly for Group 3 (sCAS). The difference in performance in Group 2 (TD), though not significant, may indicate that as syllabic complexity increased within the verbal motor tasks, a decrease in performance was noted to occur.

As a technique to visualize these results, a discriminant function plot of the group centroids is presented in Figure 4.4. Differences in the location of these centroids show the dimensions along which the groups differ. If there is a big difference between the centroid of one group and the centroid of another along a discriminant function axis, the discriminant function separates the two, or more, groups. If there is not a big distance, the discriminant function does not separate the two groups. The plot emphasizes the value of both discriminant functions in separating the three groups. On the first discriminant function (*X* axis: Concurrent Joint Attention), children with an ASD are maximally separated from children with a suspected Childhood Apraxia of Speech, with typically developing children falling between these two groups. On the second discriminant function (*Y* axis: Total Verbal

Motor), the typically developing children are some distance from the other two groups. It takes both discriminant functions, then, to separate the three groups from each other. The asterisks denote the three group centroids, while the square, triangle, and circle symbols indicate the individual participants from the group with that shape as indicated in the key.

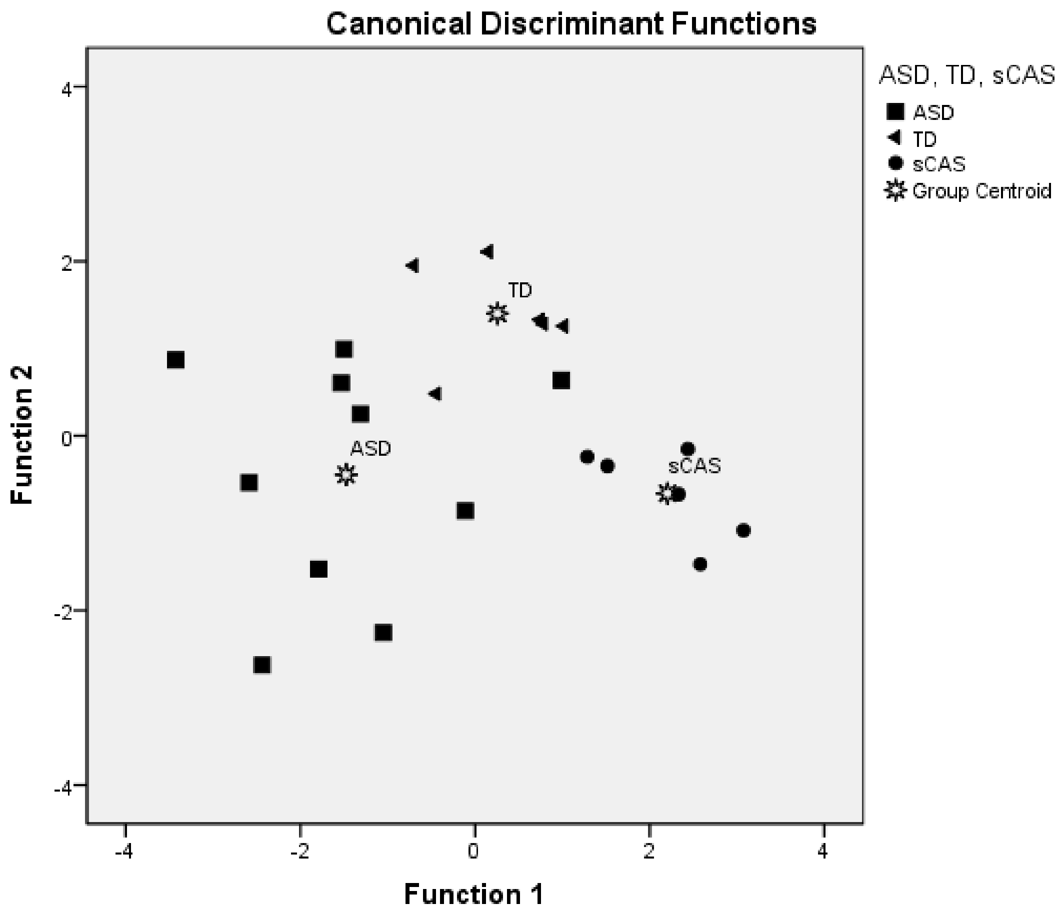


***Figure 4.4.*** **Plots of three group centroids on two discriminant functions.**

The output for group classification is shown in Figure 4.5. The classification results allow determination of how well group membership can be predicted by using the classification functions. The top part of the figure (labeled Original) indicates how well the classification functions predicted the sample. Correctly classified cases appear on the diagonal of the classification table. With the use of a group classification procedure for the total sample of 22 children, 20 (91%) were classified correctly. Prior probabilities, specified as .45 (ASD), .27 (TD), and .27 (sCAS), would predict that 4 children (.45 X 22) would be in the ASD group, 2 children in the TD group, and 2 children in the sCAS group. Therefore, 8 children (35%) would have been correctly classified by chance alone. Thus, the classification procedure correctly classified substantially more than that. Nine of 10 children with ASD, 5 of 6 typically developing children, and 6 of 6 children with sCAS were correctly classified.

**Classification Results[b,c]**

| | | | Predicted Group Membership | | | |
|---|---|---|---|---|---|---|
| | | ASD, TD, sCAS | ASD | TD | sCAS | Total |
| Original | Count | ASD | 9 | 1 | 0 | 10 |
| | | TD | 1 | 5 | 0 | 6 |
| | | sCAS | 0 | 0 | 6 | 6 |
| | % | ASD | 90.0 | 10.0 | .0 | 100.0 |
| | | TD | 16.7 | 83.3 | .0 | 100.0 |
| | | sCAS | .0 | .0 | 100.0 | 100.0 |
| Cross-validated[a] | Count | ASD | 9 | 1 | 0 | 10 |
| | | TD | 2 | 4 | 0 | 6 |
| | | sCAS | 0 | 1 | 5 | 6 |
| | % | ASD | 90.0 | 10.0 | .0 | 100.0 |
| | | TD | 33.3 | 66.7 | .0 | 100.0 |
| | | sCAS | .0 | 16.7 | 83.3 | 100.0 |

a. Cross validation is done only for those cases in the analysis. In cross validation, each case is classified by the functions derived from all cases other than that case.

b. 90.9% of original grouped cases correctly classified.

c. 81.8% of cross-validated grouped cases correctly classified.

***Figure 4.5.*** **Group classification for discriminant analysis.**

The stability of the classification procedure was checked by a cross-validation run. The bottom part of the table (labeled Cross-validated) is generated by choosing the leave-one-out option within the classification dialog box. With the leave-one-out option, classification functions are derived on the basis of all cases except one, and then the left out case is classified. This is repeated *N* times, until all cases have been left out once and classified based on classification functions for the *N* – 1 cases. The results for how well the classification functions predicted the *N* left out cases are reported in the cross-validated table. These results can be used to estimate how well the classification functions derived on all *N* cases should predict with a new sample. As shown in the cross-validated sample, 9 of 10 children with ASD, 4 of 6 typically developing children, and 5 of 6 children with a suspected Childhood Apraxia of Speech were correctly classified using both classification functions.

The overall percent of cases correctly classified is 91% in the sample. This value is affected by chance agreement. Kappa is an index that corrects for chance agreements. Kappa was computed to assess the accuracy in prediction of group membership. The output presenting the kappa coefficient is shown in Figure 4.6. Kappa ranges in value from -1 to +1. A value of 1 for kappa indicates perfect prediction, while a value of 0 indicates chance-level prediction. As shown in the figure, kappa was .86 and is very strong, indicating a better than chance-level prediction.

**Symmetric Measures**

| | | Value | Asymp. Std. Error[a] | Approx. T[b] | Approx. Sig. |
|---|---|---|---|---|---|
| Measure of Agreement | Kappa | .859 | .096 | 5.632 | .000 |
| N of Valid Cases | | 22 | | | |

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

***Figure 4.6.*** **Results of kappa analysis.**

*Oromotor Imitation and Administration Modality*

The fourth research question of the study addressed differences among all three groups on scores of oromotor production as a function of six conditions: three sensory administration modalities (auditory, visual, and tactile) and two output modalities (Nonverbal Oral versus Verbal Motor). Each of ten stimuli targeting each output modality was administered in succession across the three sensory modalities, beginning with auditory, then visual, and, finally, tactile. Each output modality (nonverbal oral and verbal motor) consisted of 30 tasks, 10 in each of the sensory modalities. Each sensory task (auditory, visual, or tactile) was scored with either a ‘0’, ‘1’, or ‘2’, and each output modality (nonverbal oral or verbal motor) had a possible range of scores between 0 and 60. Two profile analyses sought to assess whether the three groups had the same pattern of means on the subscales for nonverbal oral stimuli and for verbal motor stimuli. Profile Analysis is a multivariate approach to analyzing repeated measures data (Tabachnick & Fidell, 2001).

All measures had the same range of possible scores, with the same score value having the same meaning on all the measures. Three test constructs were evaluated as part of the profile analysis protocol, including parallelism of profiles, overall differences among groups (i.e., levels), and flatness of profiles. Profile analysis tests of parallelism and flatness are multivariate and involve sum-of-squares and cross-products matrices. The levels test, however, is a univariate test, equivalent to the between-subjects main effect in repeated-measures ANOVA (Tabachnick & Fidell, 2001).

Though the sample sizes differed among groups, unequal sample sizes typically do not provide any difficulty because each hypothesis is tested as if in a one-way design and an unequal *n* creates difficulties in interpretation only in designs with more than one between-subjects independent variable. Data were screened for multivariate normality, outliers, homogeneity of variance-covariance matrices, linearity, and multicollinearity and singularity for each output modality across groups. Data screen findings and analyses are presented separately for nonverbal oral imitation and for verbal motor imitation.

*Profile Analysis of Nonverbal Oral Imitation Across Administration Modality*

A profile analysis was performed on three subtests of the Nonverbal Oral Imitation tasks representing the three input modalities (auditory, visual, and tactile). The grouping variable was current developmental status, divided into children who (1) were diagnosed with an autism spectrum disorder (ASD), (2) were typically developing (TD), and (3) were diagnosed with suspected Childhood Apraxia of Speech or apraxic-like symptoms (sCAS). The distributions of scores were negatively skewed across all three input modalities (auditory, visual, and tactile) indicating that there were more high scores than low scores on these subtests, suggesting possible ceiling effects. No univariate or multivariate outliers were detected among the children, although two extreme low scores were noted only on tasks involving the nonverbal oral imitation – auditory modality. Both of these low scores were found in Group 1 (ASD). These scores were included in the final analyses in order to conserve all data points. Assumptions regarding homogeneity of variance-covariance matrices, linearity, and multicollinearity and singularity were also met. SPSS GLM was used for the major analyses.

The first test construct was the test of parallelism and is the primary question addressed by profile analysis. The parallelism test is the test of interaction which assesses whether the profiles for the three groups are the same. Using Wilks' criterion, the profiles, seen in Figure 4.7, did not deviate significantly from parallelism, $F(4, 36) = 1.09$, $p = .37$, partial $\eta^2 = .11$. Only eleven percent of the variance in the segments as combined for this test was accounted for by the difference in shape of the profiles for the three groups. Each segment represented the differences between the dependent variables, such as the difference between auditory and visual modalities, and then compares these differences between the three groups. The test of parallelism was not significant and indicated that the profiles for the three groups were roughly the same. However, from visual inspection of Figure 4.7, ASD and TD groups had fairly equivalent scores in the visual and tactile modalities, whereas the highest scores for the sCAS group were in the tactile modality. With this small number of participants, significant differences may not have been possible. However, although not significant, these patterns may have clinical relevance. The small number of participants in this study resulted in low power to detect small to medium differences between groups.

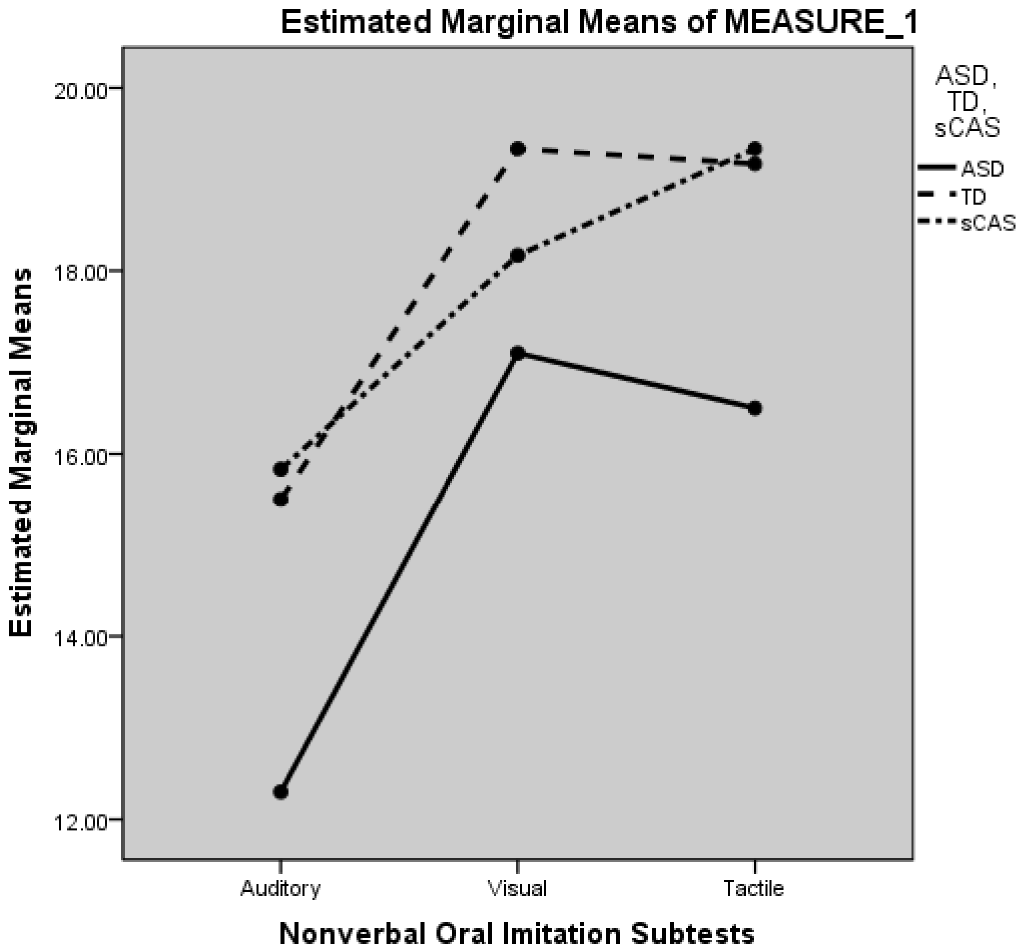


***Figure 4.7.*** **Profiles of nonverbal oral subtest scores for three developmental groups.**

The second test construct was the “levels” hypothesis, which addresses whether one group, on average, scores higher on the collected set of measures than another. For the levels test, no reliable differences were found among the groups when scores were averaged across all subtests, $F(2,19) = 2.58$, $p = .10$. That is, no one group scored reliably higher overall than any other group, although the p value (p = .10) may indicate a possible trend in differences. An observed trend from visual inspection suggested that children with ASD may have scored lower across the sensory modalities compared to the other two groups.

The third test construct is the "flatness" hypothesis, which addresses whether the dependent variables elicit the same average response from the groups. The flatness null hypothesis is that the segments (e.g., from auditory to visual, visual to tactile) are both 0, i.e. the slope of each line segment is zero and the profile is flat. This is then evaluated independently for each group, making this a within-subjects test. If the line is not flat (either of the segments varies significantly from 0), then there is a within groups main effect of the dependent variables (Connor, 2008). When averaged across groups to look at the flatness of scores, subtests were found by Hotelling's criterion to deviate significantly from flatness, $F(2, 18) = 14.71$, $p < .001$, partial $\eta^2 = .62$. That is, the participants, as a whole, demonstrated differing responses to the dependent variables (auditory, visual, and tactile). Sixty-two percent (62%) of the variance in this combination of segments is accounted for by the non-flatness of the profile collapsed over all participants groups. The partial $\eta^2 = .62$ is a medium effect size and indicates a strong relationship between the groups and the variables of interest.

Deviation from flatness was then evaluated by conducting a simple effects analysis. SPSS MANOVA was used for the simple effects analysis with simple contrasts. The simple contrasts compared the means for the auditory, visual, and tactile sensory modalities of the nonverbal oral tasks. Results of the simple contrasts revealed a significant difference between the auditory modality compared to the tactile modality ($p$=.00). Across the groups, the lowest scores were in the auditory modality and the highest were in the tactile modality.

*Profile Analysis of Verbal Motor Imitation Across Administration Modality*

A second profile analysis was performed on three subtests of the Verbal Motor Imitation tasks representing 3 input modalities (auditory, visual, and tactile). The grouping

variable was current developmental status, divided into children who (1) are diagnosed with an autism spectrum disorder (ASD), (2) are typically developing (TD), and (3) are diagnosed with suspected Childhood Apraxia of Speech or apraxic-like symptoms (sCAS).
The distributions of scores were negatively skewed across all three input modalities, (auditory, visual, and tactile) indicating that there were more high scores than low scores on these subtests, suggesting possible ceiling effects. No univariate or multivariate outliers were detected among the children, although two extreme low scores were noted only on the tasks involving the verbal motor – tactile modality. Both of these low scores were found in Group 1 (ASD). These scores were included in the final analyses in order to conserve all data points. Assumptions regarding homogeneity of variance-covariance matrices, linearity, and multicollinearity and singularity were also met. SPSS GLM was used for the major analyses.

The first test construct was the test of parallelism and is the primary question addressed by profile analysis. The parallelism test is the test of interaction which assesses whether the profiles for the three groups are the same. Using Wilks' criterion, the profiles, seen in Figure 4.8, did not deviate significantly from parallelism, $F(4, 36) = .451$, $p = .77$, partial $\eta^2 = .05$. Only five percent of the variance in the segments as combined for this test is accounted for by the difference in shape of the profiles for the three groups. Each segment represents the differences between the dependent variables (such as the difference between auditory and visual modalities) and then compares these differences between the three groups. Thus, the test of parallelism indicates that the profiles for the three groups are the same. However, visual inspection of the segments of the sCAS group may suggest that there may be a depression in group means in the visual modality as compared to the means of the other two groups. With this small number of participants, significant differences may not have been possible. However, whereas the differences were not significantly different, the pattern for the sCAS group may be clinically relevant.

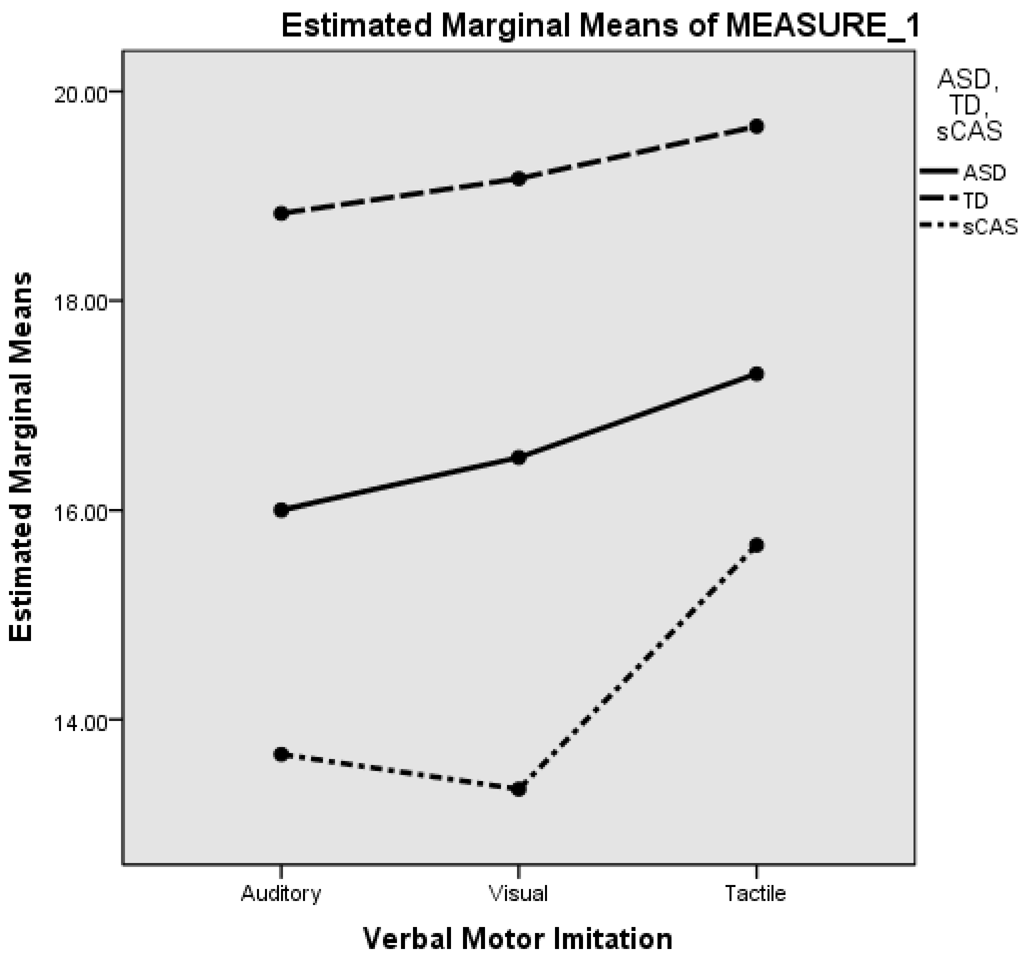


***Figure 4.8*** **Profiles of verbal motor subtest scores for three developmental groups.**

The second test construct was the "levels" hypothesis, which addresses whether one group, on average, scores higher on the collected set of measures than another. For the levels test, significant differences were found among the groups when the scores were averaged over all subtests, $F(2,19) = 4.94$, $p < .05$. Overall differences among groups (i.e., levels) were evaluated using a one-way ANOVA to examine pairwise comparisons and assess whether one group scored higher than any other group or groups. Results revealed there were significant differences between the groups. For the Verbal Motor Imitation tasks, Group 2 (TD) had a reliably higher ($p$=.003) mean score than Group 3 (sCAS).

The third test construct is the "flatness" hypothesis, which addresses whether the dependent variables elicit the same average response from the groups. For the flatness test, no reliable differences were found among subtests using Hotelling's criterion, $F(2, 18) = 3.14$, $p = .07$, partial $\eta^2 = .26$. Twenty-six percent (26%) of the variance in this combination of segments was accounted for by the non-flatness of the profile collapsed over groups. From visual inspection of the data (and the p level approaching significance), it appeared that all of the groups tended to perform more poorly in the auditory context.

*Conclusion*

Data from twenty-two children among three groups of children classified according to their current developmental status were analyzed. Group 1 consisted of 10 children with ASD (ASD). Group 2 consisted of 6 typically developing children (TD). Group 3 consisted of 6 children with a suspected CAS or apraxic-like symptoms (sCAS).

Four main research questions were addressed in an attempt to elucidate the relationship between joint attention and oromotor imitation in young children. There were no significant differences between groups on the matching variables of MLU, receptive language using the PPVT-IV (Dunn & Dunn, 2007), and the fine and gross motor scales of the MSEL (Mullen, 1992). As to chronological age, there were no significant differences between Groups 1 (ASD) and 3 (sCAS). However as expected, Group 2 (TD) was significantly younger than the other two groups in mean age in months with a group mean age of 44.83 months, compared to 57.30 months in Group 1 (ASD) and 59.17 months in

Group 3 (sCAS). This resulted from the deliberate group matching on the basis of MLU and PPVT-IV scores.

Analyses revealed the following significant findings. A strong relationship between group membership and concurrent joint attention, a medium-strength relationship between group membership and total verbal motor imitation, and a medium-strength relationship between group membership and joint attention was found using multivariate analysis of variance (MANOVA). A correlation between joint attention and nonverbal oral imitation was found to approach significance ($p$=.07) for Group 1 (ASD), while no other correlations between these measures were significant. Discriminant function analysis revealed two functions, concurrent joint attention and total verbal imitation that showed differences between the groups. The first discriminant function, concurrent joint attention, was found to account for 72% of the variability of the group means while maximally separating Group 1 (ASD) from Group 3 (sCAS), with Group 2 (TD) falling between these two groups. The second discriminant function, total verbal imitation, was found to account for 46% of the variability of the group means while maximally separating Group 2 (TD) from the other two groups. The nonverbal oral imitation profile analysis revealed a significant difference between participants across groups, indicating that they responded differently (and more poorly) in the auditory modality compared to the tactile modality. Further, the verbal motor imitation profile analysis indicated that Group 2 (TD) had a reliably higher mean score compared to Group 3 (sCAS). A summary of the original research questions, predictions, and findings, both significant and nonsignificant, is provided in Table 4.7.

Table 4.8

*Summary of Results*

<table>
<tr><td>Design: N = 22, *k* = 3<br><br>Group 1 (ASD), n = 10<br>Group 2 (TD), n = 6<br>Group 3 (sCAS), n = 6</td><td colspan="2">Variables:<br>Joint Attention (JA)<br><br>Nonverbal Oral Imitation (NVO) ⎤ Subtests: Auditory,<br>Verbal Motor Imitation (VM) ⎦ Visual, Tactile<br><br>Concurrent Joint Attention (CJA)<br>Concurrent Verbal Motor Imitation (CVM)</td></tr>
<tr><th>Research Questions</th><th>Predictions</th><th>Findings</th></tr>
<tr><td>1. Are the group means for the scores on five variables of interest the same or different for groups of children with ASD, typically developing children, and children with sCAS?<br><br>Statistic: MANOVA</td><td>Children with Autism Spectrum Disorders (ASD) will have lower group means on all dependent variables compared to the other two groups.<br><br>Typically Developing (TD) children will have the highest group means on all dependent variables compared to the other two groups.<br><br>Children with suspected Childhood Apraxia of Speech (sCAS) will a) have comparable group means on the independent joint attention measure,<br>b) have higher nonverbal oral imitation than verbal motor imitation,<br>c) have lower concurrent joint attention and concurrent verbal imitation compared to (TD).</td><td>a) Significant strong relationship between group membership and concurrent joint attention (CJA, *p*<.01);<br>b) Group 1 (ASD) had a significantly lower (*p*<.001) group mean on the measure of CJA compared to Group 2 (TD) and significantly lower (*p*=.003) compared to Group 3 (sCAS);<br>c) Significant medium relationship between group membership and verbal motor imitation (VM);<br>d) Group 2 (TD) had a significantly higher (*p*=.006) group mean on the measure of VM compared to Group 3 (sCAS).<br>e) Significant medium relationship between group membership and joint attention (JA);</td></tr>
</table>

| | | |
|---|---|---|
| | | f) Group 3 (sCAS) had a significantly higher ($p$ > .05) group mean on the measure of JA compared to Group 1 (ASD).<br><br>Appraisal: These results were expected and support some, but not all, of the predictions. |
| 2. How is joint attention ability related to oromotor production for both imitative nonverbal oral and verbal tasks in children with ASD, typically developing children, and children with suspected CAS?<br><br>Statistic: Correlational Analysis | Children with Autism Spectrum Disorders (ASD), Typically Developing (TD), and Children with suspected Childhood Apraxia of Speech (sCAS) will have a significant positive correlation between total group means on joint attention and nonverbal oral tasks, as well as joint attention and verbal motor tasks. | a) No significant correlations (at $p$<.05 level)<br>b) Correlation (r = .59) approaching significance ($p$ = .07) for Group 1 (ASD) between joint attention and nonverbal oral imitation<br>c) Correlation (r = .57) approaching significance ($p$ = .08) for Group 1 (ASD) between joint attention and verbal motor imitation<br><br>Appraisal: These results were expected for Group 1 (ASD). However, the lack of significant results for the other two groups was not expected. |
| 3. How is joint attention related to verbal motor imitation in a more naturalistic context, such as shared story experience where the child has to attend concurrently to both sets of skills?<br><br>Statistic: Correlational Analysis | Children with Autism Spectrum Disorders (ASD), Typically Developing (TD), and Children with suspected Childhood Apraxia of Speech (sCAS) will have a significant positive correlation between total group means on concurrent joint attention tasks and | No significant correlations.<br><br>Appraisal: These results were unexpected. |

| | | |
|---|---|---|
| | concurrent verbal motor imitation tasks. | |
| Can group membership be predicted on the basis of the five dependent variables?<br><br>Statistic: Discriminant Function Analysis | Joint attention variable(s) will be stronger predictors of group membership than any of the other variables.<br><br>Concurrent Verbal Motor Imitation will potentially be a moderate predictor of group membership. | Two functions emerged:<br>1. Concurrent Joint Attention (72% of variability in group differences)<br>2. Verbal Motor Imitation<br>(46% of variability in group differences)<br>Classification results indicated 20 of 22 children (91%) were classified correctly using these two variables.<br>Appraisal: These results were partially expected. The second discriminant function was not expected to be Total Verbal Imitation. |
| 4. Across the three groups, what impact do the sensory demands of task administration modality (auditory, visual, and tactile) have on children's ability to correctly imitate verbal and nonverbal oral stimuli?<br><br>Statistic: Profile Analysis | Children with Autism Spectrum Disorders (ASD) will a) have low group means on both types of imitation tasks across modalities compared to the other two groups, and b) have higher nonverbal oral than verbal motor imitation group means.<br><br>Typically Developing (TD) will have the highest group mean and equal scores on both imitation tasks across modalities.<br><br>Children with suspected Childhood Apraxia of | A strong reliable difference between the auditory modality compared to the tactile modality on nonverbal oral tasks across subtests ($p$<.01).<br>• Lowest group means were in the Auditory modality<br>• Highest group means were in the Tactile modality<br><br>A reliable difference between groups on verbal motor tasks ($p$=.02).<br>• TD had a reliably higher ($p$=.003) group mean than sCAS<br>• Trend: (p = .07) Lowest |

| | | |
|---|---|---|
| | Speech (sCAS) will have a mid-range nonverbal oral imitation group mean and a lower verbal motor imitation group mean across modalities compared to (TD). | group means were in the auditory modality<br><br>Appraisal: Results were expected for nonverbal oral tasks. Results for verbal motor tasks were somewhat expected. |

# CHAPTER 5: DISCUSSION

The current study examined the relationships between joint attention ability and oromotor imitation, including nonverbal oral and verbal motor imitation, in young children. Twenty-two children participated in the study and were classified into one of three groups based on their current developmental status, including children with ASD (n=10), typically developing children (n=6), and children with a suspected CAS (n=6). Research questions addressed a) differences in the groups in joint attention and oromotor imitation abilities; b) the relationship between independently measured joint attention and oromotor imitation, both nonverbal oral and verbal motor; c) the relationship between concurrent joint attention and verbal motor imitation during interpersonal interaction; and d) the relationship between the sensory input demands (auditory, visual, and tactile) and oromotor imitation, both nonverbal oral and verbal motor across the groups.

Data obtained from the discriminant function analyses in the present study indicate that concurrent joint attention (CJA) tasks as well as verbal motor (VM) imitation tasks are positive predictors of group membership. Specifically, CJA significantly differentiated Group 1 (ASD) from Group 3 (sCAS), and with the addition of VM, Group 2 (TD) emerged. Results of MANOVA analyses indicated that Group 1 (ASD) had a significantly lower group mean on the measure of CJA compared to both Group 2 (TD) and Group 3 (sCAS). On the VM measure, Group 2 (TD) had a significantly higher group mean compared to Group 3 (sCAS). On the JA measure, Group 1 (ASD) had a significantly lower group mean compared to Group 3 (sCAS). Further, data from the profile analyses indicate that auditory stimuli are less facilitative than stimuli that possess a combination of auditory, visual, and tactile cues. Furthermore, nonsignificant data trends suggest that a potential relationship exists between joint attention and both nonverbal oral imitation tasks, as well as between joint attention and verbal motor imitation tasks in at least some children with ASD.

*Differences in Groups between Joint Attention and Oromotor Imitation Abilities*

The first research question sought to obtain an understanding of differences in performance in the three groups of participants on all measures. A significant strong relationship was found between group membership and concurrent joint attention (CJA), a significant medium strength relationship was found between group membership and total verbal motor imitation (VM), and a significant medium relationship was found between group membership and joint attention (JA). Group 1 (ASD: M= 9.10, SD=4.63) had a significantly lower group mean on the CJA (Total = 20) measure compared to Group 2 (TD: M=17.50, SD=2.35) and compared to Group 3 (sCAS: M=15.33, SD=1.63). No significant differences were found between typically developing children and children with suspected CAS on the CJA measure. Group 1 (ASD: M=10.80, SD=2.25) also had a significantly lower group mean on the JA (Total = 16) measure compared to Group 3 (sCAS: M=14.33, SD=0.82). These results were expected, and support some, but not all, of the predictions.

The extant literature supports the finding that Group 1 (ASD) had a significantly lower group mean on the CJA and JA measures. Qualitative impairments in social interaction, including joint attention, serve as a partial basis for the diagnosis of ASD (APA, 2000). Deficits in joint attention in children with ASD have been consistently reported and documented. Within the current study, both tasks involved every description of joint attention behavior described by the NRC (2001). For example as a group, children with ASD had difficulty coordinating attention and shifting gaze between the examiner and objects and materials, following the gaze of the examiner, and being able to draw the examiner's attention to objects and materials for the purposes of sharing (NRC, 2001). Therefore, this finding was expected.

It is interesting to note that both joint attention measures were significantly related to group membership, but at different levels of significance and differentially across the groups. Indeed, only the CJA task differentiated the children with ASD from both other groups. If the measures represented the same constructs, then both measures would have been expected to be related to group membership to a similar degree and similarly across groups. These discrepancies suggest that the two measures may be different in some way. There were more opportunities overall in the CJA measure (Total =20) for the participants to demonstrate joint attention behavior compared to the JA measure (Total=16). However, both measures represented the same and fairly even split between child behaviors that sought to initiate joint attention (IJA) with the examiner (IJA bids: CJA=10/ JA=8) and child behaviors that responded to joint attention (RJA) bids from the examiner (RJA bids: CJA=10/ JA= 8). Another difference was in the play setting with the independent joint attention measure utilizing simple tasks and numerous interesting toys within a child-directed context, whereas the concurrent joint attention measure primarily utilized story cards within an adult-directed context.  The story card setting may have presented with an additional burden on participants to utilize their joint attention skills, as the cards were placed next to the examiner's face during bids for RJA and the examiner modeled this placement for the children to use when they retold the story.  The differences in sensitivity between the two measures may be due to the level of complexity presented by the two measures.  Some children may have been at a developmental level where their joint attention difficulties were not tapped by the simpler tasks of the independent joint attention measure.  Rather, for some children, their joint attention difficulties were revealed by the more complex and less child-directed tasks of the concurrent joint attention measure.

Another interesting observation is related to the significant age difference between Group 2 (TD) and both Group 1 (ASD) and Group 3 (sCAS).  Group 2 (TD) was 12 and 14 months younger than Group 1 (ASD) and Group 3 (sCAS), respectively.  Despite these age differences, Group 2 (TD) had a significantly higher group mean than Group 1 (ASD), and Group 2 (TD) and Group 3 (sCAS) were not significantly different from one another.  The data demonstrate that typically developing children and children with suspected CAS demonstrated an apparent strength in joint attention during interpersonal engagement on the concurrent joint attention task compared to children with ASD.  Indeed, these findings were predicted from what has been seen in the research literature and supported the use of these specific comparison groups.

On the VM (Total = 60) measure, Group 2 (TD: M=57.67, SD=2.42) had a significantly higher group mean compared to Group 3 (sCAS: M=43.00, SD=7.80). No significant differences were found between Group 1 (ASD: M=49.80, SD=10.28) and Group 2 (TD) or between Group 1 (ASD) and Group 3 (sCAS) on the VM measure. The significant difference was expected, but the remainder of the findings did not support all of the predictions. As part of the study design, Group 3 (sCAS) was selected because they possessed specific characteristics of verbal motor difficulties as indicated on the checklist of Characteristics of Childhood Apraxia of Speech (Appendix I), including a) difficulty achieving and maintaining articulatory configurations, b) presence of vowel distortions, especially simplification/reduction of dipthongs, and c) a gap in the child's ability to produce the same sound in a simple context versus in a longer or more complex context (i.e., number of errors increases as length of word/phrase increases) (Davis, et al., 1998; Strand, 2002; & Velleman, 2003). Thus, it was expected that this group would have more difficulty on the verbal motor imitation measures compared to the children with typical development. Each one of these speech characteristics could have negatively impacted the group's performance and each one of the six participants in the group had all three of these characteristics as indicated by their current speech-language pathologist. Even with a 13 month chronological age gap, the typically developing children were able to perform significantly better than children with suspected CAS on the verbal motor imitation tasks. The achievement of the typically developing children over their older peers further emphasizes the extent to which the characteristics of suspected CAS can persist and diminish the overall communication abilities of these children.

The prediction that Group 1 (ASD) would have significantly lower group means than Group 2 (TD) on the VM measure was not statistically supported; however, their overall mean scores were somewhat lower with a much larger standard deviation. Thus, with additional participants these nonsignificant differences may have reached significance. Although past research has established that children with ASD perform worse on imitative tasks than typically developing children (Rogers & Williams, 2006), the differences were not large enough to reach significance in this study. Further, whereas some researchers have suggested that a specific dyspraxic deficit may underlie deficits in speech development for a subgroup of children with ASD (Dzuik, et al., 2007), it was not statistically supported in this study. One potential reason for the lack of significant difference may be related to the inclusion criteria, which required that all children with ASD be combining words in utterances (MLU $\geq$ 3.0). Children with ASD had the largest range of mean length of utterance (3.00 – 9.18) compared to the other two groups. Additionally, participants with ASD demonstrated a wide range of severity of symptoms. Some participants needed maximum supports in order to participate and frequent breaks, whereas another participant with ASD, age 4 years, read a book aloud to the examiner without being prompted. This range of low and high verbal behaviors may have skewed the results of the verbal motor imitation measure. Thus the predictions that Group 2 (TD) would have high scores, with Groups 1(ASD) and 3( SCAS) having low to moderate scores on verbal motor imitation were upheld with the approaching significance trends in the results.

*Correlations between Joint Attention and Oromotor Imitation (Nonverbal Oral Imitation and Verbal Motor Imitation)*

The second research question sought to ascertain the relationship between joint attention (JA) and oromotor imitation, including nonverbal oral (NVO) and verbal motor (VM) imitation. No significant correlations were found at the $p \leq .05$ level of significance. However, two correlations were found to be significant at the $p \leq .10$ level. Both correlations were found for Group 1 (ASD). A large and positive correlation (r = .59, $p = .07$) was found between JA and NVO. A second large and positive correlation (r = .57, $p = .08$) was found between JA and VM. These results were expected for Group 1 (ASD). However, the same pattern of association was not found, although it was expected, for Group 2 (TD) and Group 3 (sCAS).

The extant literature supports the finding for Group 1 (ASD), but given the pattern of results does not fully explain why the correlation coefficients approached significance only for Group 1 (ASD) and not for either Group 2 (TD) or Group 3 (sCAS). Within the social cognitive view of the typical path of imitation development, there is an emphasis on increasing the understanding of the observed act as well as increasing the understanding of the interpersonal aspect of the interaction within which the observed act occurs (Užgiris, 1981). Put more dynamically, Piaget (1962) suggests that imitation is always a continuation of understanding. Further, Užgiris (1981) functionally defines the cognitive operation at hand such that the imitative model presents the young typically developing child with a cognitive challenge. The imitative act serves to accommodate that challenge so that a better understanding of the model can be achieved. Presumably, once the understanding of the model is achieved, there is reduced need to imitate the same model as the challenge no longer exists (Užgiris, 1981).

Children with ASD have demonstrated difficulties following the same developmental trajectory of social cognition compared to their typically developing peers (APA, 2000). More specifically, attentional difficulties have been identified as a potential underlying mechanism for the imitation deficits in children with ASD (Dawson, 1991). Group 2 (TD) and Group 3 (sCAS) did not have any known or observable attentional difficulties, and, based on the results, there was no relationship between JA and NVO. These results lend support to Dawson's (1991) hypothesis that children with ASD may have persistent difficulties with later-developing social-cognitive skills, such as those necessary for imitation and joint attention. The typically developing age of mastery for joint attention and imitation is well below the actual age of the participants in Group 1 (ASD), and is supported by the lack of significant correlations for the other two groups (one of whom was significantly younger). Perhaps Group 2 (TD) and Group 3 (sCAS) no longer rely on the social cognitive act of imitation to understand the imitative models around them, whereas Group 1 (ASD) continues to use this mechanism in order to solve the challenge of the imitative models that they do not fully understand without the use of the imitative act to accommodate the challenge presented (Užgiris, 1981). The continuation of the use of this mechanism by Group 1 (ASD) may have also hindered their performance on the concurrent joint attention task. With lowered social and attentional capabilities, as suggested by Dawson (1991), these children then show difficulties in both imitation and concurrent joint attention.

While the correlation coefficients are only approaching significance for Group 1 (ASD), the results are promising. The current results suggest that for some children with ASD, there is a potentially positive relationship between joint attention skills and nonverbal oral abilities. The nonsignificant trend in these data supports past research by Rogers, et al. (2003) who found a relationship between nonverbal oral imitation and joint attention ability. Finally, a potentially positive relationship between joint attention skills and verbal motor abilities also emerged as a nonsignificant trend. This trend has not been reported in the extant literature and, therefore, suggests that further research is needed.

*Correlations Between Concurrent Joint Attention Ability and Concurrent Verbal Motor Ability*

The third research question sought to ascertain the relationship between concurrent joint attention (CJA) and concurrent verbal motor (CVM) imitation. No significant correlations were found at the $p \leq .05$ level of significance, nor did correlations approach significance for any of the groups. These results were unexpected as strong positive correlations were predicted for all groups. The constructs of the CJA and CVM variables were designed to capture a dynamic interpersonal interaction as a direct comparison to the independent constructs represented in the second analysis of the JA, NVO, and VM variables. Therefore, the predicted relationship was expected to be the same. However, not only was the relationship not present for both comparisons, it was also not present for Group 1 (ASD) in the present analysis (unlike the approaching significance results for this group between JA and NVO and VM tasks). If the theorized relationship of joint attention and oromotor imitation does, indeed, persist for some children with ASD, as was proposed in the discussion of the second analysis (Dawson, 1991), then the same pattern would have been expected in the present analysis.

In the absence of any strong positive correlations, it can be concluded that these constructs are clearly not related for the participants in this study. Additionally, the CJA and CVM constructs were not entirely consistent with their independent measure counterparts JA and VM. Whereas the CJA measure had 20 total opportunities, further divided into 10 opportunities to respond to joint attention bids and 10 opportunities to initiate joint attention, the independent JA measure had a total of 16 opportunities, further divided into 8 opportunities to respond to joint attention bids and 8 opportunities to initiate joint attention. The context of the two measures was also quite different. The CJA measure was designed as a shared story telling experience using picture cards exclusively, whereas the independent JA measure utilized a play-based setting, with a variety of toys. The role of the examiner was different across the two measures as well. In the CJA measure, the role of the examiner was more structured in providing targeted stimuli, demonstrating the task and then asking each participant to imitate the same task. The role of the examiner in the independent JA measure was less structured and more child-directed where the examiner presented some tasks but also included instances where the examiner was to remain silent. Anecdotally, during one instance of the independent JA measure, the examiner had presented one child with ASD with a bid to initiate joint attention by presenting a bag of musical toys and then waiting in silence while pretending to write on a clipboard. The child sat and looked at the bag of toys for a bit, and finally asked, “You want me to do something with these don’t you?” The design of the task may have appeared unnatural to some children, although it was easy to measure and record by the examiner. In this case, both JA and CJA constructs have an identical goal, that is, to measure a child's ability to engage in social interactions using joint attention skills. However, these two constructs differ across several dimensions, including number of opportunities, context, and the role of the examiner.

Likewise, the CVM measure was quite different from the VM measure which was analyzed in the second analysis. First, the CVM measure had a total of 20 stimulus items, all of which were within a combined auditory and visual modality, and without tactile prompts. The independent VM measure consisted of 20 items overall that were each given three times for a total of 60, once in the auditory modality only, then in the auditory plus visual modalities combined, and then in the auditory plus visual plus tactile modalities combined. The role of the examiner was the same for the CVM measure as it was for the CJA measure, as it was concurrent. The role of the examiner for the independent VM measure was more structured.

There are more differences than similarities between the independent versus the concurrent measures of joint attention and oromotor imitation. Even with these identified differences, however, there is no clear indication of why, given the results of the MANOVA analysis, the concurrent joint attention measure (CJA) and the independent verbal imitation measure (VM) were most associated with group membership but were not significantly related to any other constructs across the variables in the second and third analyses. As has already been stated, some potential reasons for this puzzling set of results across analyses are the range of severity, ASD behaviors, and verbal skills within Group 1 (ASD) which may be obscuring individual patterns of performance.

*Discriminant Function Analysis of All Variables*

Given that the measure of CJA was significantly related to group membership in the first analysis, a lack of a significant relationship in the third analysis was unexpected. Further, the unexpected lack of significance across most of the correlational analyses suggested that further analysis of all the variables could yield a clearer understanding of how the variables represented the three groups overall. Therefore, in an effort to gain a greater understanding of these findings, a discriminant function analysis was conducted to determine whether group membership could be predicted on the basis of the five quantitative predictive variables, including (1) joint attention, (2) total nonverbal oral imitation, (3) total verbal motor imitation, (4) concurrent joint attention, and (5) concurrent verbal motor imitation.

As noted, two discriminant functions emerged and revealed that two of the five variables, concurrent joint attention (CJA) and total verbal motor imitation (VM), were significant predictor variables of group membership. Concurrent joint attention group means were found to maximally differentiate between children with ASD and children with suspected CAS. Typically developing children were not as easily differentiated from the other two groups based on this one variable. Only when the total verbal motor imitation variable was added to the predictive function, did the typically developing children emerge as a clearly defined group. The combination of these factors had a strong predictive value as the classification procedure indicated that 90% of children with ASD, 66% of typically developing children, and 83% of children with suspected CAS were correctly classified. The overall classification rate was 90%. This is an exciting finding and suggests that the combined measures of concurrent joint attention and total verbal motor imitation warrant further investigation to examine how the oromotor demands of interpersonal communication affect joint attention behaviors and vice versa.

Further, the finding that total verbal motor imitation (VM), and not concurrent verbal motor imitation (CVM), held predictive value was surprising. Just as the concurrent joint attention (CJA) task appears to have posed significant challenges for children with ASD, similar challenges were expected to appear with concurrent verbal motor imitation. However, CVM did not hold the predictive value held by the VM variable.

As has already been stated, the design of the measures was different and may have contributed to the lack of predictive value of the CVM measure. An additional difference between these two variables that may have contributed to the predictive nature of VM measure may lie in the range of syllabic complexity that was captured by the variable. CVM imitation tasks consisted of meaningful short phrases and age-appropriate conversational utterances, whereas the VM imitation tasks consisted of sequences of single vowels to simple consonant-vowel sequences. A child's ability to produce conversational-style utterances, even in imitation, is built upon a progression of learned syllabic forms that gradually increase along a continuum of complexity (Pollock and Schwartz, 1988). Thus, the CVM measure represents a higher level of motor speech achievement that could be more sensitive to the difficulties that a child may have, while the VM measure would represent the emerging set of motor speech mastery.

In order to understand this discrepancy, raw group means for the VM and CVM variable were considered more closely. Davis, et al. (1998) found that children who have a suspected CAS tend to have a performance gap in their ability to produce the same sound in a simple context versus in a longer, more complex context. This suggests that any participant in the current study who had difficulty with simpler forms in the VM measure would have greater difficulty with more complex forms in the CVM measure. Upon further inspection of raw group means, though not significant in the MANOVA analysis, an observed trend suggested that all groups had lower percentage correct per group on the more complex CVM measure compared to the percentage correct on the VM measure. These raw data suggest that there was some degree of difficulty with the CVM measure that the groups were challenged with. The raw data provides some understanding of how the groups actually performed outside of statistical significance.

For the purposes of the current discussion, however, the data show that the predictive power of the VM imitation variable emerged when imitative tasks were reduced to simple forms, as well as more conscious effort on the part of Group 1 (ASD) and Group 3 (sCAS) participants to imitate sequences they may not have been used to producing. Group 2 (TD) may have experienced a ceiling effect particularly as evidenced by their high group mean and low standard deviation. It is important to note that the VM and CVM subtests were counterbalanced across participants such that participants were evenly and randomly given verbal motor tasks that ranged from simple syllables, then to complex syllables, and finally, conversational-level imitation. This order was reversed for exactly half of the entire sample of 22 participants. Therefore, the effects of fatigue or varying stages of mastery were controlled.

Ultimately, this difference warrants further investigation to clarify how the progressive development of syllable shapes impacts conversational level imitation skills, especially within the naturalistic context of social interaction, and how sensitive each developmental stage is in determining mastery of motoric forms.

*Profile Analyses of Oromotor Imitation Across Administration Modalities*

The fourth research question sought to examine how the sensory demands involved with task administration modality (auditory, visual, and tactile) impacted each participant's ability to imitate nonverbal oral and verbal motor stimuli. Each analysis addressed three dimensions, including parallelism, levels, and flatness. The test of parallelism assessed whether the profiles for the three groups were the same or parallel. The levels test assessed whether one group, on average, scored higher on a set of measures than another group. The test of flatness assessed whether the independent variables elicited the same response across all participants. Results are briefly presented below across these three dimensions for nonverbal oral imitation tasks and for verbal motor imitation tasks. Then, an appraisal of both profile analyses follows.

*Nonverbal Oral Imitation Ability.* The tests of parallelism and levels were both nonsignificant, indicating that the nonverbal oral imitation profiles for the three groups were roughly the same and no one group scored reliably higher on any one subtest than any other group. Within the levels test an observed trend ($p<.10$), though nonsignificant, in the raw group mean data suggested that Group 1 (ASD) had the lowest raw group means across all modalities compared to the other two groups. This result was predicted and is consistent with past research that reports oromotor deficits relating to nonverbal oral movements in children with ASD (Amato & Slavin, 1998; Page & Boucher, 1998; Marili, et al., 2004; Rogers & Williams, 2006).

The test of flatness revealed a significant difference in performance across participants such that scores in the auditory modality were significantly lower than scores in the tactile modality. An additional observed trend, though nonsignificant, suggested that the profiles all had an upward trend across all modalities, suggesting that the additional sensory inputs provided some benefit to performance accuracy. However, Groups 1 (ASD) and 2 (TD) appeared to have a slight downward trend (or at least no improvement) in the tactile modality (although not significant), suggesting that the combination of sensory inputs did not yield the same beneficial factor to Groups 1 (ASD) and 2 (TD) as it may have yielded to Group 3 (sCAS). These results were both expected and unexpected. Group 2 (TD) was expected to have the highest raw group mean across modalities due to the lack of reported nonverbal oral difficulty. However, with the ceiling effect for Group 2 (TD) on the visual and tactile modalities, there was no clear benefit with added tactile sensory input. For Group 3 (sCAS), the tactile seemed to benefit their performance, whereas for Group 1 (ASD), it did not.

*Verbal Motor Imitation Ability.* The test of parallelism was not significant and indicated that the profiles for the three groups for verbal motor imitation across modalities were the same. The flatness test was also not significant and indicated that participants responded similarly within each modality across participants.

The levels test revealed significant ($p$=.003) differences between Group 2 (TD) and Group 3 (sCAS), such that Group 2 (TD) had a significantly higher group mean compared to Group 3 (sCAS). Closer inspection of raw group means across all three modalities suggested a nonsignificant trend of Group 2 (TD) having the highest raw group mean, Group 1 (ASD) having the next highest raw group mean, and Group 3 (sCAS) having the lowest raw group mean. Group 1 (ASD) was expected to have the lowest raw group mean across all modalities compared to the other two groups based on past research reporting the presence of oromotor deficits relating to verbal motor movements in children with ASD (Amato & Slavin, 1998; Page & Boucher, 1998; Marili, et al., 2004; Rogers & Williams, 2006). Also, Group 3 (sCAS) was also expected to have a lower raw group mean on verbal motor imitation given past research indicating a variety of contextual influences on speech production that are noted to occur (Davis, 1998; Caruso & Strand, 1999; Velleman, 2003).

*Appraisal of Oromotor Imitation Performance Across Administration Modalities.* In consideration of the findings from the profile analyses, two themes emerged that address the effects of sensory demands on children's ability to imitate nonverbal oral and verbal motor stimuli. There are both statistically significant findings and nonsignificant trends which characterize each theme in their totality, while holding relevance for both clinical and future research applications.

The first theme relates to the observation that performance on tasks based on raw group means generally improved across modalities, though not significantly, for both nonverbal oral and verbal motor stimuli, as indicated by a general upward trend across modalities on both subtests. This pattern of raw group means suggests that the added sensory input may have improved the ability of the child participants to process incoming stimuli cross-modally (Meltzoff, 2002; Smith & Bryson, 1994), at least from the auditory modality alone (and for the sCAS group with the addition of tactile cues).

On the nonverbal oral imitation test, raw group means for Group 1 (ASD) and Group 2 (TD) improved from auditory to visual sensory modalities but did not improve when tactile input was provided, suggesting that typically developing children found that tactile input was not helpful or salient and that children with ASD found the tactile input was, potentially, an annoyance. For Group 2 (TD), this may have occurred because their scores were close to a ceiling effect on visual and therefore they had little improvement possible when adding the tactile. On the other hand, Group 1's (ASD) performance did not improve with the addition of the tactile cues. Anecdotally, many typically developing children asked why the examiner was touching their face while they performed a task and remarked that it was funny. Many children with ASD turned their heads away from the examiner's hand or appeared to be flinching at the examiner's touch. There was a steady upward trend for Group 3 (sCAS), suggesting that the successive sensory inputs were more facilitative (see Figure 4.7).

In contrast, on the verbal motor imitation test, there was a steady upward trend of performance across modalities for Group 1 (ASD) and Group 2 (TD), whereas Group 3(sCAS) saw a slight decrease in performance from auditory to visual modalities, though not significant. These patterns of raw group means, though not significant, suggest that successive sensory inputs increase the helpfulness of the stimuli for at least some children (see Figure 4.8). Children in Group 3 (sCAS) demonstrated a tendency to avoid eye contact while trying to say verbal stimuli that were more difficult for them, which may explain why the raw group mean did not improve in the visual modality, though nonsignificant.

The nonverbal oral and verbal motor imitation tests were designed with a consideration of cross-modal sensory processing. Thus, stimuli were presented first in the auditory modality, then in the visual modality, and finally, in the tactile modality. This sequence was designed to challenge the child participant to rely first on only one sensory input (auditory), and then have the progressive benefit of the other two sensory modalities in succession; first auditory and visual, then auditory, visual, and tactile. It was expected that if there were any differences in performance between the groups across the sensory input progression, the differences should not have been attributed to language deficits, as all participants were group-matched on both receptive and expressive language. Therefore, differences in group means were predicted to indicate variability in sensory processing of incoming stimuli (Meltzoff, 2002; Smith & Bryson, 1994).

The second theme relates to the differences in total group performance, based on raw group means, between nonverbal oral tasks and verbal motor tasks. As predicted, Group 3 (sCAS) clearly had a lower percentage correct on verbal motor tasks (though not significant) compared to their percentage correct on nonverbal oral tasks. In contrast, Group 1 (ASD) and Group 2 (TD) had a pattern of increased percentage correct (although not significantly) on the verbal motor imitation test compared to the nonverbal oral test, but only for the auditory modality.

Difficulty processing visual stimuli appears to be a common finding across both the nonverbal oral and verbal motor subtest for Group 3 (sCAS). The most striking difference is the difference in scores from nonverbal oral to the verbal motor subtests. In fact, children with suspected CAS demonstrated the most difficulty across all sensory modalities for verbal motor imitation compared to the other two groups. The auditory and tactile processing strengths demonstrated by children with suspected CAS during nonverbal oral imitation tasks were not carried over into the performance on verbal motor tasks. These observations illustrate a clear difference in the patterns of scores for children with suspected CAS. These trends in differences in the group means for both nonverbal oral and verbal motor imitation subtests provide support to prior research suggesting that nonverbal oral movements are controlled by different neurological systems than verbal oral movements (Steeve & Moore, 2009; Bunton, 2008).

*Conclusions*

Four of five measures were utilized to match children with ASD to the comparison groups of typically developing children and children with suspected CAS. The group means for chronological age were significantly different between typically developing children and children with suspected CAS, but not significantly different from children with ASD. Whereas the typically developing children were younger than the children with suspected CAS, the age range represented by all of the children in the study was within the same age range of motoric development. Therefore, the groups were generally considered to be matched within the same stage of motoric development.

*Oromotor Imitation and Children with ASD.* Of the five research measures included in the study that could have potentially accounted for differences between the groups, the significant differences between groups were related to the research measures of concurrent joint attention, total verbal motor imitation, and joint attention, as well as nonsignificant but consistent patterns of scores that confirmed hypotheses across groups. As described earlier in the literature review, past research would suggest that children with ASD generally perform worse on imitative tasks than typically developing children (Rogers & Williams, 2006). The current study results indicate that the performance of children with ASD on nonverbal oral and verbal motor imitative tasks supports this finding. Children with ASD have different developmental trajectories compared to typically developing children with regards to the development of imitation (Rogers, 1999) and social cognition (APA, 2000).

The results of the current study tend to support this finding as children with ASD did demonstrate a nonsignificantly lower raw group mean on verbal motor imitation tasks, suggesting that they may have a different developmental trajectory, compared to typically developing children. This is consistent with past research by Rogers (1999) who found that infants later diagnosed with ASD have demonstrated difficulties maintaining similar developmental trajectories compared to typically developing infants with regards to the development of imitation. However, in this study, while the trajectory appears to be different, the patterns of their performance were at least to some degree parallel to the developmental trajectories of typically developing children. This suggests that the same mechanism for the development of imitation is being employed.

Deficits in nonverbal oral imitation have been found for children with ASD (Page & Boucher, 1998) and have been correlated with joint attention (Rogers, Hepburn, Stackhouse, & Wehner, 2003). Nonverbal oral imitation deficits were not statistically validated (although approached significance) and were not significantly correlated with joint attention in the study reported here (although approached significance). Not only did children with ASD tend to have the lowest group means for nonverbal oral imitation ability (approaching significance) and concurrent joint attention (significant), and joint attention (significant), but they also generally had larger standard deviations than the other two groups across most of the measures. Thus, it is possible that nonverbal oral imitation differences only hold for a subset of children with ASD. Given a larger sample size and a greater number of trials per tasks, the potential relationship between these two measures may be clearer. Further, on the verbal motor imitation task, although the correlation between joint attention and verbal motor imitation for the children with ASD only approached significance, this trend supports a possible relationship between the two for some children with ASD.

Meltzoff (2002) proposed that development of imitation provides perspectives on both cognitive and social areas of a child's development. Cognitively, cross modal mapping typically enables immediate imitation. Socially, imitation learning occurs within an interpersonal context. The convergence of these two creates within the child an ability to organize incoming stimuli cross-modally which allows the infant to fine tune their imitative attempts in a feedback loop until they achieve their intended target. In the current study, though only approaching significance, children with ASD demonstrated lower raw group means on all input modalities for nonverbal oral imitation. These findings suggest that children with ASD had difficulties with both social and cognitive demands in the structured tasks of the VM measure and in a more natural story-like environment of the CJA measure that demanded cross-modal processing of incoming stimuli within an interpersonal interaction. Further, the interpersonal and interactive context of the testing environment may have placed higher-level social cognitive demands on the child with ASD to engage in theory of mind (Meltzoff, 2010) as they had to interpret the examiner's intent in the tasks. The effect of this increased demand may have resulted in reduced overall attention to tasks which may have resulted in the lower scores (but not always significantly) demonstrated by children with ASD as compared to the other two groups. Research by Dromey & Benson (2003) suggests that, at least in adults, distractor tasks during verbal motor production can have a significant influence on overall verbal motor production. In the current study, it is plausible that joint attention demands had a competing influence on the children with ASD. If this is true, then children with ASD may have been doubly disadvantaged by deficits in both cognitive processing of imitative stimuli and social processing of joint attention cues. It is conceivable that with a greater sample size, the relationship between joint attention and oromotor imitation performance would have been stronger.

*Joint Attention.* This study utilized two measures of joint attention ability for the participants. The first measure was a protocol designed to measure the extent to which children will follow the attentional cues of the examiner and the extent to which they will initiate joint attention in communicating with the examiner (Watson, Baranek, & Poston, 2003). The second measure was less structured and involved a shared story card activity, the subject of which was used as the target stimuli for the concurrent verbal motor stimuli. The two types of joint attention behaviors were coded consistently. Conceptually, there should be no differences in the joint attention behaviors displayed by any individual child across the two measures. However, this was clearly not the case as the concurrent joint attention measure emerged ultimately as the strongest predictor of differences across the groups whereas joint attention, measured independently of verbal motor imitation, did not discriminate the children with ASD from those with typical development. The difference in sensitivity of these two measures suggests that the independent measure of joint attention may capture the child's ability to engage in child-directed joint attention, whereas the concurrent joint attention measure may capture more complex joint attention behaviors in more adult-directed situations.

As noted, the three groups were not significantly different from each other on the independent joint attention measure (JA). However, differences among group means on concurrent joint attention ability, discriminant function 1, were strongly predictive of group membership. One possible explanation for these differences could be contextually dependent; one could hypothesize that all participants had statistically the same level of joint attention capability, but did not consistently demonstrate their abilities within an interpersonal context that required additional demands as well as verbal motor imitation. Further examination of the raw group means for independent joint attention suggest otherwise. While not statistically significant, the pattern of raw group means for this measure suggests that children with ASD may have had more difficulty with joint attention than the other two groups and that this pattern was continued into the more interpersonal context of the concurrent joint attention measure, where social-cognitive and verbal motor imitation demands were greater and therefore a significant difference was observed. These nonsignificant trends are supported in the literature by consistent reports of deficits in joint attention and social orienting (APA, 2000; NRC, 2001)

A further possible explanation is that variability in scores in concurrent joint attention (CJA) is attributed to varying difficulties processing the incoming stimuli from the social demands of the joint attention tasks combined with the verbal motor demands of the imitation tasks. This explanation lends support to the works of Smith & Bryson (1994) and Meltzoff & Gopnik (1993) who suggested that cross-modal programming difficulties contribute to the imitative deficits observed in children with ASD.

Comparison of the group means on independent joint attention and CJA in children with suspected CAS also suggests that difficulty with cross-modal processing of social stimuli involved in joint attention is related to the ability to meet demands for verbal motor performance.  Whereas children with suspected CAS performed slightly better (although not significantly) than typically developing children on the independent joint attention task, their relative performance appeared to weaken (although not significantly) in comparison to children with typical development when demands for verbal motor imitation were introduced during the interpersonal CJA measure.

*Limitations of the Current Study*

This study has several limitations.  The original number of participants sought for this study was 30, with 10 being in each group.  However, after one year of data collection and limited resources, there were 10 children with ASD recruited, but only 6 children with sCAS and 6 typically developing children identified. The small sample size of the current study most likely limited the statistical sensitivity of finding significant results. Despite the sample size limitations, however, there were some significant findings in the expected directions as well as trends in the group means that supported the predictions of the study, thus supporting the possibility of significant findings with added numbers.  Additionally, increasing the number of items within subtests may have contributed to greater variability in group means.

An additional explanation for the fewer significant results than expected also may be attributed to the heterogeneity in Group 1 (ASD).  Though there were no significant differences between groups except in mean age, when standard deviations were compared across groups, Group 1 (ASD) had the greatest variability compared to the other two groups on all descriptive measures except the MSEL-Fine Motor subtest.  Further, whereas all the children in Group 1 (ASD) had diagnoses of ASD, the severity of symptoms varied widely among the individual participants.  All participants met the language and MLU requirements for matching, yet individual variability across scores was observed. Future studies would benefit from covarying children with ASD by severity of symptoms to ascertain if their performance specifically varied as a function of severity of ASD symptoms. For the research measures as well, the children with ASD had the greatest variability in standard deviations compared to the other two groups for total nonverbal oral tasks, total verbal motor tasks, concurrent joint attention tasks, and concurrent verbal motor tasks. Typically developing children demonstrated the highest amount of variability on the independent joint attention measure only, most likely due to their lower chronological ages.

The current study also only included verbal children with ASD who were group matched to the other two groups according to MLU. This expressive language measure served to control variability across the groups. However, including a group of children with ASD who were also classified as nonverbal would have greatly informed the extant research with regards to exploring the relationship between nonverbal oral motor imitation and joint attention abilities.

In addition, in terms of potential variability within the group of children with ASD, the Checklist of Characteristics of Suspected Childhood Apraxia of Speech (Appendix) could have been used with these children. Determining what, if any, difficulties with speech motor praxis they might have had, especially if parents or professionals were already aware of the presence of any of the characteristics could have been beneficial. The checklist was initially intended to standardize the screening and inclusion methods for children with sCAS, rather than to describe the speech praxis skills of children with ASD.

*Future Research*

First, future studies should have sufficient resources and organization to locate enough children to increase the overall statistical power of the study. Second, the Checklist for Characteristics of Childhood Apraxia of Speech (Appendix 1) could be used with a group of children with ASD who are nonverbal as well as a group of children with ASD who are verbal. Third, a future direction for this research is to examine the influence of syllabic complexity on verbal motor imitation performance as syllabic complexity may be related to joint attention. Few studies have looked at verbal motor imitation as a function of syllabic complexity. Fourth, trials should be greatly increased to increase variability in scores. Fifth, verbal motor stimuli could be more varied, including a greater number of words and syllable shapes, longer utterances, spontaneous speech productions, and automatic speech trials (i.e., counting from 1 to 10).

*Summary*

In summary, the overall aim of this study was to elucidate the relationship between joint attention and oromotor imitation in children with autism spectrum disorder (ASD). Concurrent joint attention and total verbal motor imitation ability served to be the strongest predictors of group membership. While the findings of this study did not indicate significant correlations between joint attention variables and oromotor imitation variables, expected patterns among means were observed for the children with ASD. The examination of the relationship between joint attention and oromotor imitation should continue with a focus on elucidating the processes underlying verbal motor imitation deficits in children with ASD.

APPENDIX: *Characteristics of Childhood Apraxia of Speech*

<u>*Three Essential Diagnostic Markers for sCAS:*</u> Please check any of the three that you think describe the child's speech.

_____ Difficulty achieving and maintaining articulatory configurations

_____ Presence of vowel distortions, especially simplification/reduction of diphthongs

_____ Gap in the child's ability to produce the same sound in a simple context versus in a longer or more complex context (i.e., number of errors increases as length of word/phrase increases)

<u>*Other Characteristics of sCAS:*</u> Please check any additional characteristics that you think describe the child's speech.

_____ Severely limited phonetic repertoires, with many omission errors: (1) Errors may include substitutions, omissions, additions, and repetitions; (2) Tendency for consonant omissions in initial position of words; (3) Tendency to centralize vowels to a "schwa"

_____ Use of simple/simplified syllable and word shapes

_____ Inconsistencies in articulation performance-the same word may be produced several different ways when repeated in a sequence. Ex. "boom, boom, boom, boom" may be produced as "buh, boo, bim, boom"

_____ Groping for articulatory targets

_____ Well-rehearsed, "automatic" speech (e.g., ABC's) is easiest to produce, and "on demand" speech is most difficult to produce

_____ Rate, rhythm, and stress of speech are disrupted

_____ No weakness, incoordination, or paralysis of speech musculature

_____ Little to no difficulty with involuntary motor control for chewing, swallowing, etc., unless there is also an oral apraxia

_____ Receptive language skills are usually significantly better than expressive skills

_____ Errors in prosody, but generally good control of pitch and loudness

_____ Age-appropriate voice quality

## REFERENCES


Akshoomoff, N. (2006). Use of the Mullen Scales of Early Learning for the assessment of young children with autism spectrum disorders. *Clinical Neuropsychology, 12*, 269-277.

Adams, L. (1998). Oral-motor and motor-speech characteristics of children with autism. *Focus on Autism and Other Developmental Disabilities, 13*(2), 108-112.

Adamson, L. B. & Bakeman, R. (1984) Coordinating attention to people and objects in mother-infant and peer-infant interaction. *Child Development*, 55, 1278-1289.

Aldridge, M. A., Stone, K. R., Sweeney, M. H., & Bower, T. G. (2000). Preverbal children with autism understand intentions of others. *Developmental Science, 3*, 294-301.

Amato, J. J., & Slavin, D. (1998). A preliminary investigation of oromotor function in young verbal and nonverbal children with autism. *Infant-Toddler Intervention, 8*(2), 175-184.

American Psychiatric Association, & American Psychiatric Association. (2000). *Diagnostic and statistical manual of mental disorders : DSM-IV-TR* (4th , text revision ed.). Washington, DC: American Psychiatric Association.

American Speech-Language-Hearing Association. (1997). *Guidelines for Audiologic Screening* [Guidelines]. Available from www.asha.org/policy.

American Speech-Language-Hearing Association. (2007). *Childhood Apraxia of Speech* [Technical Report]. Available from www.asha.org/policy.

Bates, E. (1979). *The emergence of symbols: cognition and communication in infancy (Language, thought, and culture).* New York, NY: Academic Press.

Bloom, L., & Capatides, J. B., Fiess, K., Gartner, B., Hafitz, J., Holzman, L. H., Lahey, M., Lifter, K., Lightbown, P., Merkin, S., Miller, P., Rispoli, M., Rocissano, L., Tackeff, J., & Wooten, J. (1991). Imitation and its role in language development. In L. Bloom, & J. B. Capatides (Eds.), *Language development from two to three*. New York, NY: Cambridge University Press.

Bloom, L. (1993). The expressive infant. In L. Bloom (Ed.), *The transition from infancy to language : acquiring the power of expression*. New York, NY: Cambridge University Press.

Bremner, J. G. (2001). Cognitive development: knowledge of the physical world. In J. G. Bremner & A. Fogel (Eds.), *Blackwell Handbook of Infant Development.* Malden, MA: Blackwell Publishers, Inc.

Brown, R. (1973). *A first language : The early stages*. Cambridge, MA: Harvard University Press.

Bunton, K. (2008). Speech versus nonspeech: different tasks, different neural organization. *Seminars in Speech and Language, 29*(4), 267-275.

Butterworth, G. (1999). Neonatal imitation: existence, mechanisms and motives. In J. Nadel & G. Butterworth (Eds.), *Imitation in infancy* (pp. 63-88). Cambridge, England: Cambridge University Press.

Caruso, A. J. & Strand, E. A. (1999). Motor speech disorders in children: definitions, background, and a theoretical framework. In A. J. Caruso & E. A. Strand (Eds.), *Clinical management of motor speech disorders in children* (pp. 1-28). New York: Thieme Medical Publishers, Inc.

Charman, T., Swettenham, J., Baron-Cohen, S., Cox, A., Baird, G., & Drew, A. (1997). Infants with autism: An investigation of empathy, pretend play, joint attention, and imitation. *Developmental Psychology, 33,* 781-789.

Clifford, S. & Dissanayake, C. (2009). Dyadic and triadic behaviors in infancy as precursors to later social responsiveness in young children with autistic disorder. *Journal of Autism and Developmental Disorders, 39* (10), 1369-80.

Connor, E. F. (2008). *Profile analysis* [PDF document]. Retrieved from http://userwww.sfsu.edu/%7Eefc/classes/biol710/manova/Profile-Analysis.pdf

Constantino, J. N. (2005). *Social Responsiveness Scale.* Los Angeles: Western Psychological Services.

Dale, P. S. (1991). The validity of a parent report measure of vocabulary and syntax at 24 months. *Journal of Speech and Hearing Research, 34*, 565-571.

Davis, B.L., Jakielski, K. J., and Marquardt, T.M. (1998). Developmental apraxia of speech: determiners of differential diagnosis. *Clinical Linguistics and Phonetics,* 12, 25-45.

Dawson, G. (1991). A psychobiological perspective on the early socio-emotional development of children with autism. In D. Cicchetti and S. L. Toth (Eds.), *Rochester Symposium on Developmental Psychopathology, vol. 3: models and intergrations* (pp. 207-34. Hillsdale, NJ: Erlbaum.

de Laguna, G. A. (1927/1963). *Speech: its function and development*. Bloomington, IN: Indiana University Press.

Dromey, C., & Bates, E. (2005). Speech interactions with linguistic, cognitive, and visuomotor tasks. *Journal of Speech, Language, and Hearing Research, 48*(2), 295-305.

Dromey, C., & Benson, A. (2003). Effects of concurrent motor, linguistic, or cognitive tasks on speech motor performance. *Journal of Speech, Language, and Hearing Research, 46*(5), 1234-1246.

Dunn, L.M. & Dunn, D. M. (2007). *Peabody Picture Vocabulary Test, Fourth Edition (PPVT-IV).* Bloomington, MN: Pearson Assessments.

Dzuik, M. A., Larson, J.C.G., Apostu, A., Mahone, E.M., Denckla, M.B., & Mostofsky. S.H. (2007). Dyspraxia in autism: association with motor, social, and communicative deficits. *Developmental Medicine & Child Neurology, 49,* 734-739.

Faul, F., Erdfelder, E., Lang, A.-G., & Buchner, A. (2007). G*Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavior Research Methods, 39,* 175-191.

Fenson, L., Marchman, V., Thal, D., Dale, P., Reznick, S., & Bates, E. (2007). *Communicative Development Inventories*. Baltimore: Brookes.

Fenstermacher, S.K. & Saudino, K.J. (2006). Understanding individual differences in young children's imitative behavior. Developmental Review, 26, 346-364.

Gernsbacher, M.A., Sauer, E.A., Geye, H.M., Schweigert, E.K., & Hill Goldsmith, H. (2008). Infant and toddler oral- and manual-motor skills predict later speech fluency in autism. *Journal of Child Psychology and Psychiatry, 49*(1), 43-50.

Guenther, F. H. & Vladusich, T., A neural theory of speech acquisition and production. *Journal of Neurolinguistics* (2009), doi:10.1016/j.jneuroling.2009.08.006.

Hayden, D. & Square, P. (1999). *Verbal Motor Production Assessment for Children.* San Antonio, TX: Pearson Education, Inc.

Iverson, J.M. & Wozniak, R.H. (2007). Variation in vocal-motor development in infant siblings of children with autism. *Journal of Autism and Developmental Disorders, 37*, 158-170.

Iverson, J.M. (2010). Developing language in a developing body: the relationship between motor development and language development. *Journal of Child Language* 37, 229-261.

Johnson, R. B. & Christensen, L. (2000). *Educational research: quantitative and qualitative approaches.* Boston, MA: Allyn & Bacon.

Kent, R. D. (1999). Motor control: neurophysiology and functional development. In A. J. Caruso & E. A. Strand (Eds.), *Clinical management of motor speech disorders in children* (pp. 1-28). New York: Thieme Medical Publishers, Inc.

Landa, R. & Garrett-Maye,r E. (2006). Development in infants with autism spectrum disorders: a prospective study. *Journal of Child Psychology and Psychiatry* 47:6 629.

Locke, J.L. (1997). A theory of neurolinguistic development. *Brain and Language*, 58, 265-326.

Lord, C., Rutter, M., DiLavore, P.C., & Risi, S. (2002). *Autism Diagnostic Observation Schedule*. Los Angeles, CA: Western Psychological Services.

Marans, W. D., Rubin, E., & Laurent, A. (2005). Addressing social communication skills in individuals with high-functioning autism and Asperger syndrome: critical priorities in educational programming. In F. R. Volkmar, R. Paul, A. Klin, & D. Cohen (Eds.), *Handbook of Autism and Pervasive Developmental Disorders, 3rd edition,* (pp. 977-1002). Hoboken, NJ: John Wiley & Sons, Inc.

Marili, K., Andrianopoulos, M., Velleman, S., & Foreman, C. (2004, November). Incidence of motor speech impairment in autism and asperger's disorders. *Poster Presented at the American Speech Language Hearing Association Annual Convention,* Philadelphia, PA.

Mattingly, I. G. (1973). Phonetic prerequisites for first-language acquisition. Status report on speech research. SR 341-5. Haskins Laboratories.

McDuffie, A., Turner, L., Stone, W., Yoder, P., Wolery, M., & Ulman, T. (2007). Developmental correlates of different types of motor imitation in young children with autism spectrum disorders. *Journal of Autism and Developmental Disorders, 37*(3), 401-412.

Meltzoff, A. N. (1985). The roots of social and cognitive development: models of man's original nature. In T. M. Field & N. A. Fox (Eds.), *Social perception in infants* (pp. 1-30). Norwood, NJ: Ablex.

Meltzoff , A. N., & Gopnik, A. (1993). The role of imitation in understanding persons and developing theories of mind. In S. Baron-Cohen & H. Tager-Flusberg (Eds.), *Understanding other minds: perspectives from autism.* Oxford: Oxford University Press.

Meltzoff, A. N., & Moore, M. K. (1999). Persons and representation: why infant imitation is important for theories of human development. In J. Nadel & G. Butterworth (Eds.), *Imitation in infancy* (pp. 9-35). Cambridge, England: Cambridge University Press.

Meltzoff, A.N. (2002). Elements of a developmental theory of imitation. In A.N. Meltzoff & W. Prinz (Eds.), *The imitative mind: development, evolution, and brain bases* (pp. 19-41). New York, NY: Cambridge University Press.

Meltzoff, A.N. (2010). Bridging between action representation and infant theory of mind. In P. A. Frensch & R. Schwarzer (Eds.), *Cognition and neuropsychology: Vol. 1.*

*International perspectives on psychological science* (pp. 15-33). New York: Psychology Press.

Ming, X., Brimacombe, M., & Wagner, G. (2007). Prevalence of motor impairment in autism spectrum disorders. *Brain Development, 29*(9), 565-570.

Mostofsky, S.H., Dubey, P., Jerath, V.K., Jansiewicz, E.M., Goldberg, M.C., & Denckla, M.B. (2006). Developmental dyspraxia is not limited to imitation in children with autism spectrum disorders. *Journal of the International Psychological Society, 12,* 314-326.

Mullen, E.M. (1992). *Mullen Scales of Early Learning.* Bloomington, MN: Pearson Assessments.

Mundy, P., Sigman, M., Ungerer, J., & Sherman, T. (1986). Defining the social deficits of autism: The contribution of non-verbal communication measures. *Journal of Child Psychology and Psychiatry and Allied Disciplines, 27*(5), 657-669.

Mundy, P., & Sigman, M. (2006). Joint attention, social competence, and developmental psychopathology. In D. Ciccheti, & D. J. Cohen (Eds.), *Developmental psychopathology, vol. 1: Theory and method* (2nd ed., pp. 293-332). Hoboken, NJ: John Wiley & Sons, Inc.

Nadel, J. (2002). Imitation and imitation recognition: functional use in preverbal infants and nonverbal children with autism. In A. Meltzoff & W. Prinz (Eds.), *The imitative mind: development, evolution, and brain bases.* New York: Cambridge University Press.

Nadel, J., Revel, A., Andry, P., & Gaussier, P. (2004). Toward communication: first imitations in infants, low-functioning children with autism and robots. *Interaction Studies: Social Behaviour and Communication in Biological and Artificial Systems, 5*(1), 45-74.

National Research Council. (2001). *Educating children with autism.* Washington, DC: National Academies Press.

Ozonoff, S., & South, M. (2001). Early social development in young children with autism: theoretical and clinical implicatons. In G. Bremner & A. Fogel (Eds.), *Blackwell handbook of infant development.* Malden, MA: Blackwell Publishers, Ltd.

Page, J., & Boucher, J. (1998). Motor impairments in children with autistic disorder. *Child Language Teaching & Therapy, 14*(3), 233-259.

Piaget, J. (1962). *Play, dreams, and imitation in childhood.* New York: Norton.

Rogers, S. J., & Pennington, B. F. (1991). A theoretical approach to the deficits in infantile autism. *Development and Psychopathology, 107,* 147-161.

Rogers, S. J. (1999). An examination of the imitation deficit in autism. In J. Nadel & G. Butterworth (Eds.), *Imitation in infancy.* Cambridge, England: Cambridge University Press.

Rogers, S. J., Hepburn, S. L., Stackhouse, T., & Wehner, E. (2003). Imitation performance in toddlers with autism and those with other developmental disorders. *Journal of Child Psychology and Psychiatry*, *44*(5), 763-781.

Rogers, S. J., Cook, I., & Meryl, A. (2005). Imitation and play in autism. In F. R. Volkmar, R. Paul, A. Klin, D. Cohen (Eds.), *Handbook of autism and pervasive developmental disorders, 3rd ed. Vol. 1.* Hoboken, NJ: John Wiley & Sons, Inc.

Rogers, S. J., & Williams, J. H. G. (2006). Imitation in autism: findings and controversies. In S. J. Rogers & J. H. G. Williams (Eds.), *Imitation and the social mind.* New York: The Guilford Press.

Seal, B. C., & Bonvillian, J. D. (1997). Sign language and motor functioning in students with autistic disorder. *Journal of Autism & Developmental Disorders*, *27*(4), 437-466.

Sevlever, M. & Gillis, J.M. (2010). An examination of the state of imitation research in children with autism: issues of definition and methodology. *Research in Developmental Disabilities*, *31,* 976-984.

Sheppard, J. (1990). *Pre-school oral motor examination.* Unpublished assessment. New York: Teachers College, Columbia University.

Shriberg, L. D., Aram, D.M., & Kwiatkowski, J. (1997b). Developmental apraxia of speech: II. toward a diagnostic marker. *Journal of Speech, Language, & Hearing Research, 40*(2), 286-312.

Shriberg, L. D., Paul, R., Black, L. M., & van Santen, J.P (2011). The hypothesis of apraxia of speech in children with autism spectrum disorder. *Journal of Autism and Developmental Disorders, 41*, 405-426.

Sigman, M., & Ruskin, E. (1999). Continuity and change in the social competence of children with autism, down syndrome, and developmental delays. *Monographs of the Society for Research in Child Development*, *64*(1), v-114.

Siller, M., & Sigman, M. (2008). Modeling longitudinal change in the language abilities of children with autism: Parent behaviors and child characteristics as predictors of change. *Developmental Psychology*, *44*(6), 1691-1704.

Smith, I. M. and Bryson, S. E. (1994). Imitation and action in autism a critical review. *Psychological Bulletin*, 116(2), 259-73.

Smith, V., Mirenda, P., & Zaidman-Zait, A. (2007). Predictors of expressive vocabulary growth in children with autism. *Journal of Speech, Language and Hearing Research, 50*(1), 149.

Southgate, V., Gergely, G., & Csibra, G. (2009). Does the mirror neuron system and its impairment explain human imitation and autism? In J. A. Pineda (Ed.), *Mirror neuron systems: the role of mirroring processes in social cognition,* (pp. 331 – 354). New York, NY: Humana Press.

Steeve, R. W. & Moore, C. A. (2009). Mandibular motor control during the early development of speech and nonspeech behaviors. *Journal of Speech, Language & Hearing Research*, *52*(6), 1530-1554.

Stone, W., O.Ousley, P.Yoder, K.Hogan, & S.Hepburn (1997). Nonverbal communication in 2- and 3-year old children with autism. *Journal of Autism and Developmental Disorders* 27:677–696.

Stone, W.L., & Yoder, P.J. (2001). Predicting spoken language level in children with autism spectrum disorders. *Autism*, *5*(4), 341-361.

Strand, E. (2002). Childhood apraxia of speech: suggested diagnostic markers for the younger child. Proceedings of the 2002 Childhood Apraxia of Speech Research Symposium, ed. by Lawrence D. Shriberg and Thomas F. Campbell. Carlsbad, CA: The Hendrix Foundation.

Striano, T. & Rochat, P. (1999). Developmental link between dyadic and triadic social competence in infancy. *British Journal of Developmental Psychology,17,* 551–562.

Tabachnick, B. G. & Fidell, L. S. (2001). *Using multivariate statistics.* Boston: Allyn and Bacon.

Terband, H., Maassen, B., Guenther, F.H., & Brumberg, J. (2009). Computational neural modeling of speech motor control in childhood apraxia of speech (CAS). *Journal of Speech, Language, and Hearing Research*, *52*, 1595-1609.

Toth, K., Munson, J., Meltzoff, A. N., & Dawson, G. (2006). Early predictors of communication development in young children with autism spectrum disorder: Joint attention, imitation, and toy play. *Journal of Autism and Developmental Disorders, 36*(8), 993-1005.

Trevarthen, C. (1979). Communication and cooperation in early infancy. A description of primary intersubjectivity. In M. Bullowa (Ed.), *Before speech: The beginning of human communication* (pp. 321-347). London: Cambridge University Press.

Trevarthen, C., Kokkinaki, T., & Fiamenghi, G. A. (1999). What infants' imitations communicate: With mothers, with fathers and with peers. In J. Nadel, & G. Butterworth (Eds.), *Imitation in infancy* (pp. 127-185). Cambridge, MA: Cambridge University Press.

Trevarthen, C. & Aitken, K.J. (2001). Infant intersubjectivity: research, theory, and clinical applications. *Journal of Child Psychology and Psychiatry, 42*, No. 1, pp. 3-48.

Uzgris, I.C. (1981). Two functions of imitation during infancy. *International Journal of Behavioral Development*, 4, 1-12.

Vanvuchelen, M., Royeurs, H., & De Weerdt, W. (2007). Nature of motor imitation problems in school-aged boys with autism: a motor or a cognitive problem? *Autism, 11 (3)*, 225-40.

Velleman, S. (2003). *Childhood Apraxia of Speech: Resource Guide.* New York: Thomson Delmar Learning.

Velleman, S. L., Andrianopoulos, M. V., Boucher, M., Perkins, J., Marili, K. E., Currier, A., et al. (2009). Motor speech disorders in children with autism. In R. Paul, & P. Flipsen (Eds.), *Speech sound disorders in children: Essays in honor of Lawrence D. Shriberg* (pp. 141-180). San Diego: Plural.

Vihman, M. M. (1996). *Phonological development: The origins of language in the child.* Cambridge, MA: Blackwell.

Watson, L. R., Baranek, G., & Poston, V. (2003). *Attention-Following and Initiating Joint Attention Protocol.* Chapel Hill: unpublished assessment.

Wetherby, A. M. (2006). Understanding and measuring social communication in children with autism spectrum disorders. In T. Charman & W. Stone (Eds.), *Social and communication development in autism spectrum disorders.* New York: The Guilford Press.

Zimmerman, I. L., Steiner, V. G., & Pond, R. E. (1992). PLS-3: Preschool Language Scale-3. San Antonio, TX : The Psychological Corporation.