# CHARACTERISTICS OF VOCAL INTERACTIONS BETWEEN 9-MONTH OLD INFANTS AT HIGH AND LOW RISK FOR AUTISM AND THEIR MOTHERS

by

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Submitted to the Graduate Faculty of the Kenneth P. Dietrich

School of Arts and Sciences in partial fulfillment

of the requirements for the degree of

Master of Science

University of Pittsburgh

2013

UNIVERSITY OF PITTSBURGH

DIETRICH SCHOOL OF ARTS AND SCIENCES

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The current study aims to better understand the development of infants at heightened risk for autism (high risk infants; HR) as well as the common occurrence of language delays in this population by examining the vocal characteristics of early caregiver-infant interactions in a sample of mothers and younger siblings of children with autism spectrum disorder (ASD). HR infants and infants at low risk (LR) for ASD were videotaped playing with their mothers in their homes near their 9 month birthdays. These five-minute naturalistic toy play interactions were coded for the frequency and timing of infant and mother vocalizations. While risk status of infants (HR or LR) had little influence on the characteristics of these vocal interactions, infants who went on to have language delays in toddlerhood (language delayed infants; LD) had more non-linguistic vocalizations, were more likely to interrupt and be interrupted by their mothers, and were less coordinated with their mothers in the duration of time left before responding to their partner (switching pause duration) relative to infants who did not go on to have language delays (non-delayed infants; ND). Furthermore, the coordination of switching pause durations was found to predict language development and symptom severity on a diagnostic evaluation of ASD in toddlerhood among HR infants. These findings call attention to the importance of studying the subset of HR infants who go on to have language delays as well as understanding infant development in the context of social interactions.

**TABLE OF CONTENTS**

## LIST OF TABLES

## LIST OF FIGURES

## PREFACE

I would like to thank my advisor, Dr. Jana Iverson for her support and guidance throughout the process. I would also like to thank the staff and graduate students in the Infant Communication Lab for their help and encouragement, as well as my undergraduate coders, Marykate Viola, Timothy Barthelmes, and Alison Charles. Finally, I am grateful to the infants and families who participated in the project.

# 1.0 INTRODUCTION

Interactions between infants and their caregivers are fundamental to social learning and development. Research on typical development suggests that beginning in the first days of life these interactions are a coordinated and bidirectional experience characterized by a mutual synchronization of body, voice, and gaze (Condon & Sander, 1974; Crown, Feldstein, Jasnow, Beebe, & Jaffe, 2002; Jasnow & Feldstein, 1986; Kato et al., 1983). Although the character of this coordination changes as infants develop, the rhythm and flow of the interaction remain essential aspects of social engagement into adulthood.

Individuals with autism spectrum disorder (ASD) display difficulties with communication and social interaction, two skills that are deeply embedded in the coordinated experience of caregivers and infants. In addition, due to a strong genetic etiology, first-degree relatives of individuals with autism have been shown to display higher rates of social and communication deficits that are milder, but qualitatively similar to their relatives with ASD (Hurley, Losh, Parlier, Reznick, & Piven, 2007). Moreover, younger siblings of these individuals are at heightened risk for being diagnosed with the disorder itself as well as related disorders, such as language delays (Messinger et al., 2013; Zwaigenbaum et al., 2005). The proposed study aims to better understand the development of infants at risk for autism as well as the common occurrence of language delays in this population by examining the vocal characteristics of early caregiver-infant interactions in a sample of mothers and younger siblings of children with ASD.

## 1.1 LITERATURE REVIEW

### 1.1.1 Coordinated interpersonal timing.

A large body of research amassed over several decades has detailed the development and characteristics of what is often called "coordinated interpersonal timing" (CIT) or the mutual influence of the temporal patterning of behavior (typically vocal) of two participants in an interaction (Jaffe et al., 2001). When two individuals engage in conversation, they coordinate the timing of periods of sound and silence with their interlocutors (Capella, 1981; Jaffe et al., 2001; Jaffe & Feldstein, 1970). Jaffe and Feldstein (1970) characterize the temporal patterning of dyadic vocal interactions using a description of conversational states: vocalizations, intrapersonal pauses (silences between two vocalizations of the same speaker), switching pauses (silences occurring between two speaker), and simultaneous speech (see Appendix A for a visual representation of the characteristics of a dyadic vocal interaction).

The characteristics of these states, as well as their temporal coordination, have implications for both the individual and the dyad. Speakers who produce fewer vocalizations will provide their interlocutors fewer opportunities to follow those vocalizations with contingent responses, hence reducing the flow and coordination of the conversation. In addition to producing a sufficient number of vocalizations, speakers must also time these vocalizations properly. For example, individuals must leave sufficient time for a partner to respond before speaking again. This pause between when an individual stops speaking and when that same individual speaks again is called an intrapersonal pause. Individuals must also respond in a timely manner to their conversational partners: this pause—the pause between when a partner stops speaking and an individual responds—is referred to as a switching pause.

The duration of switching pauses has been consistently implicated as one of the most informative aspects of CIT. Research on a variety of dyads, from infant-adult to adult-adult, has repeatedly shown that individuals match their switching-pause durations to their partners on a global level, averaged across an entire interaction, as well as on a moment-to-moment basis, becoming more congruent as an interaction continues (Crown, 1991; Jaffe et al., 2001; Jaffe & Feldstein, 1970). This means that in general, caregivers who are quick to respond to their infants have infants who are also quick to respond, and caregivers who are slower to respond have infants who are slower to respond. In conversations between adults, the degree of congruence of switching-pause durations has been associated with individual perception of, liking of, and empathy for conversation partners (Crown, 1991; Feldstein & Welkowitz, 1978).

Finally, individuals tend to inhibit their vocalizations while other speakers are talking, so that instances of simultaneous speech, which we will refer to as "interruptions," are rare in typical conversation (Feldstein & Welkowitz, 1978; Jaffe et al., 2001; Jaffe & Feldstein, 1970). The frequency of interruptions during the course of a conversation is therefore often used as a proxy for the degree to which partners are engaging in vocal turn-taking (Jaffe et al., 2001).

### 1.1.2 Development of coordinated interpersonal timing.

The coordination of timing of behavior between infants and their caregivers begins in the very first days of life. Microanalysis of the movements of 1- to 6-day-old newborns has revealed a precise synchronization between adult speech and infant motor behavior (Condon & Sander, 1974; Kato et al., 1983). Kato et al. (1983) showed not only that infants' movements seem to be entrained by incoming adult speech, but also that adult speech is coordinated in response to infant movement. As infants develop more sophisticated sensory abilities, the dyadic interaction itself becomes more sophisticated. By 6 weeks of age, infants coordinate their eye-gaze behavior with adults' vocal behavior. Using time-series regression analysis, Crown et al. (2002) demonstrated that 6-week-old infants and adults alter their behavior (visual in the case of infants, vocal in the case of adults) in coordination with the behavior of their partners at levels significantly different from chance.

As infants begin to vocalize and produce more speech-like sounds, this same dyadic coordination can be found in the conversational patterns of infants and adults. Four-month-old infants and their caregivers show vocal coordination that is temporally similar to adult conversation (Beebe, Alson, Jaffe, Feldstein, & Crown, 1988). In particular, as mentioned previously, mother-infant dyads are coordinated in the mean duration of their switching pauses. Jasnow and Feldstein (1986) found the same coordination of switching pause duration in interactions between 9-month-old infants and their mothers. They used time-series regression analysis to show that the coordination of switching pauses was occurring not only globally—as an average across the entire interaction—but also on a moment-to moment basis mutually influential over the period of the interaction. The study also reported a high ratio of non-simultaneous speech to simultaneous speech for both mothers and infants, suggesting that dyad members inhibit their vocalizations when their partners are speaking and engage primarily in alternating speech.

Outside of the research focused specifically on CIT, caregiver switching-pause duration is often referred to as “response time” or “latency to respond” and has been implicated as an important factor in infant learning and development. Research has shown not only that mothers are quite good at providing prompt and contingent responses—responding within 2 seconds of their infants’ pre-linguistic vocalizations over 70% of the time—but also that infants are able to recognize this contingent behavior from a young age (Gros-Louis, West, Goldstein, & King, 2006; Millar & Watson, 1979). A study by Goldstein, Schwade, and Bornstein (2009) that utilized a face-to-face/still-face procedure demonstrates that when adults temporarily stop responding to infants during a still-face episode, infants exhibit an extinction burst—or rapid increase—in vocalizations. This extinction burst provides evidence that by 5 months of age, infants have established expectations about the influence of their own vocalizations on others.

Furthermore, research by Bigelow (1998) suggests that 4- and 5-month-old infants are sufficiently sensitive to the individual characteristics of their own caregivers’ synchronous behavior that they prefer strangers who match that level of contingency. These studies provide clear evidence that the timing of caregiver responses is a salient part of the infant’s interactive experience from a young age and affects the way the infant, in turn, responds to his or her interlocutor.

### 1.1.3 Coordinated interpersonal timing and contingency: Implications for development.

The consistent presence and growing maturity of mutually synchronous dyadic interaction from birth through the first year suggests that this coordination of interpersonal timing plays a significant role in development. An interactionist perspective on development suggests that infants learn through a dyadic process that involves both their own behavior and the input they receive from adults around them. A disruption in this dyadic process could therefore have cascading effects in multiple modalities. Research on typical development is consistent with the theory that dyadic processes are related to future competency in several areas.

Jaffe et al. (2001) found that the level of CIT in interactions between 4-month-old infants and their mothers (as well as strangers) was positively correlated with infants' scores on the Mental Development Index of the Bayley Scales at 12 months. This suggests that CIT specifically may be relevant to learning and cognition. In addition, numerous studies have shown that caregivers' contingent responses to their infants' vocalizations can have both short- and long-term positive effects on children's language abilities (Goldstein & Schwade, 2008; Tamis-LeMonda, Bornstein, & Baumwell, 2001). For example, naturalistic maternal responsiveness—the degree to which mothers respond contingently to their infants vocalizations—is predictive of later language development and achievement of language milestones (Tamis-LeMonda et al., 2001). The role of prompt and contingent responsiveness in facilitating infant vocal development has even been demonstrated within the context of a 10-minute laboratory play session. Goldstein and Schwade (2008) instructed caregivers to provide contingent responses to their infant's vocalizations while playing with toys in the lab. They found that the infants quickly began producing more advanced, speech-like vocalizations than they had in the naturalistic play period prior to the manipulation. The infant's own understanding of and participation in this dyadic process also has implications for later development. The previously mentioned still-face study by Goldstein et al. (2009) showed that the magnitude of a 5-month-old's extinction burst in response to a still-faced experimenter predicted language comprehension at 13 months.

In a busy, noisy, and confusing world, infants must learn to make sense of their environment. When infants experience prompt and contingent responses to their behavior, they develop a sense of agency and learn that they can interact with and affect the world around them (Nadel, Prepin, & Okanda, 2005). As their own actions become more sophisticated, so do the responses they receive (Gros-Louis et al., 2006), and through this interactive and ever-changing process, infants are able to expand and refine the way they interact and communicate.

### 1.1.4 Coordinated interpersonal timing: Infants at heightened risk for autism spectrum disorders.

Studies of the later-born siblings of children already diagnosed with ASD (high risk infants; HR) reveal that, as a group, these infants show delays in a number of areas throughout infancy and toddlerhood (Presmanes, Walden, Stone, & Yoder, 2007; Yirmiya et al., 2006). Given the predictive value of characteristics of infant-caregiver vocal coordination and contingency in typical development, there is reason to believe that delays in HR infants may be a result of disruptions in interactive processes important for learning. While there has been very little research specifically on vocal interactions between caregivers and their HR infants, research on language development, attention, and parent-infant interactions in this population provide evidence for potential disruptions in vocal coordination.

Several studies have found delays in spontaneous social communication in HR infants (Goldberg et al., 2005; Paul, Fuerst, Ramsay, Chawarska, & Klin, 2011; Toth, Dawson, Meltzoff, Greenson, & Fein, 2007). For example, a recent study by Paul et al. (2011) found that HR infants produced fewer "speech-like" vocalizations (defined as "…vocalizations characterized by the production of consonants and/or vowels that could be represented by phonetic symbols and contained speech-like vocal quality…") and more "non-speech" vocalizations during toy play interactions with their caregivers than did their LR counterparts at 6, 9, and 12 months of age (although the differences were only significant at 12 months). Given the importance of spontaneous vocal production to dyadic coordination of vocal behavior, this finding suggests the possibility that CIT may differ for HR infants.

Along similar lines, Yirmiya et al. (2006) reported differences in spontaneous non-verbal communication at 14 months, with HR infants producing fewer higher-level requesting behaviors during the Early Social Communication Scales (ESCS), a semi-structured assessment. Cassel et al. (2007) also reported lower rates of initiated joint attention in HR infants at 15 months using the same assessment. These studies provide evidence that as a group, HR infants are delayed in non-verbal communication important for engaging with an interactive partner. While this behavior is not specifically vocal, verbal and non-verbal communication are closely intertwined in such a way that delays in non-verbal communication could have important implications for parent-infant interactions in multiple domains.

Differences in where infants allocate their attention could also have implications for parent-infant interactions in dyads with HR siblings. From the moment TD infants are born, they show a preference for attending to their mother's voice, for human faces, and for human biological motion (DeCasper & Fifer, 1980; Simion, Regolin, & Bulf, 2008; Valenza, Simion, Cassia, & Umilta, 1996). These types of early preferences have implications for coordination in parent-infant interactions, which requires attention to one's interactive partner and the complementary disregard of distractions. A study by Nadig et al. (2007) found a marginal group difference in preference for infant-directed speech over adult-directed speech in 6-month-old infants at high risk for ASD, with HR infants showing a less robust preference. In addition, a recent study by Droucker, Curtin, & Vouloumanos (2013) provides evidence that HR siblings' preference for faces is not as strong as that of LR infants, and that attentional preferences in HR infant siblings relates to later language development. Specifically, this group found that attention to faces over checkerboards between 6 and 12 months was predictive of 18 month expressive vocabulary. It is important to note that both of these studies found that HR infants still allocate preferential attention to infant-directed speech and faces over adult-directed speech and checkerboards respectively, but that this preference is less strong than that shown by LR infants. Nonetheless, even subtle differences in attentional preferences could have cascading effects on how infants interact and communicate with others.

Finally, one study has found differences specifically in parent-infant interactions in infancy among HR infants and their mothers. Yirmiya et al. (2006) reported that HR dyads were less synchronous—as measured by the time-series correlation of phases of caregiver and infant engagement (e.g. avert, object attend, social attend)—in a parent-infant interaction than LR dyads at 6 months. While this study did not look at vocal coordination specifically, it suggests that HR dyads are, on average, somewhat less coordinated in their play than LR dyads, a finding that may extend to vocal coordination.

Infant-caregiver interactions are, of course, dyadic, and examination of caregiver behavior in an HR population is equally essential. When considering interactive styles of caregivers of HR infants, it is important to keep in mind that these caregivers all have an older child with ASD. While research on responsiveness in caregivers of children with ASD is very limited, there is some evidence to suggest that these caregivers may coordinate their vocalizations with their infants differently from the caregivers of TD children. Warlaumont et al. (2010) analyzed in-home recordings of caregiver-child interactions involving children with versus without ASD aged 16-48 months and found that caregiver median response time (a measure essentially identical to switching-pause duration) to children with ASD was significantly longer than caregiver median response time to TD children. While this study looked specifically at interactions with children who had ASD, not their younger siblings, it is possible that interactions with an older child could affect interactions with a younger child.

Moreover, research suggests that characteristics of switching pauses in parent-infant interactions relate to caregiver mood. Specifically, depressed mothers have longer and more variable switching pause durations when interacting with their infants than non-depressed mothers (Bettes, 1988; Zlochower & Cohn, 1996). In combination with research indicating that raising a child with ASD puts parents at risk for high levels of stress and depressive symptoms (Gray & Holden, 1992; Koegel et al., 1992; Sanders & Morgan, 1997), this literature suggests that caregivers of children with ASD might have different interaction styles from caregivers of TD children. Zlochower and Cohn (1996) hypothesize that longer and more variable caregiver switching pauses may lead to less predictable caregiver behavior, and hence, less synchronous interactions.

Finally, caregiver expectations about development may be altered by the experience of raising a child with ASD. Given the particular experience of these parents, in combination with the increased risk for social and communicative deficits in the first-degree relatives of individuals with ASD, it is not unreasonable to expect that there may be differences in the way parents of children with ASD interact with their younger infants.

## 1.2 PRESENT STUDY

The present study is an extension and elaboration of previous work on vocal coordination in typical development to a population of infants at high risk for ASD. While this is the first study to specifically examine vocal interactions between HR infants and their mothers, the literature reviewed above provides evidence that HR infants and caregivers may differ in several areas important for coordination.

Furthermore, previous literature describes group level differences between HR and LR infants and their caregivers without regard to the vast heterogeneity apparent in this population. While much research has been done on HR infants who go on to develop ASD, very little research to date has looked specifically at HR infants who go on to have language delays. Given the high incidence of social-communicative and language delays in this population, and the importance of CIT throughout development, examination of early vocal interactions has the potential to provide insight into the ontogeny of delay.

Accordingly, this research aims to characterize caregiver-infant vocal coordination in HR dyads to determine whether and how these interactions may be altered in this population; it will also explore this behavior as a potential predictor of later language delays and ASD symptomatology among HR infants. Nine-month old infants and their mothers were chosen as participants, as vocal coordination in TD infants at this age has been well documented and characterized. Infants in the present study were followed to 36 months of age, at which time a subgroup received a diagnosis of ASD and/or were characterized as having a language delay (see Methods). The study has three primary aims:

### 1.2.1 Aim 1: Examine the effect of Risk Status on characteristics of vocal interactions.

Given the dearth of literature on HR mother-infant interactions in infancy, the first goal of this study is to characterize mother and infant behavior during a vocal interaction for a HR sample and to compare it to that of a LR sample. This will involve an examination of the frequency of vocalizations (for infants, we will examine linguistic and non-linguistic sounds separately), the duration of intrapersonal pauses, the duration and variability of switching pauses, and the frequency of interruptions for infants and mothers. Two dyadic variables will also be analyzed, namely the average duration of interruptions and the coordination of switching pause durations.

Although this aim is primarily descriptive in nature, several hypotheses have been generated based on the literature described above. First, consistent with Paul et al. (2011), we hypothesize that HR infants will have fewer linguistic and more non-linguistic vocalizations than LR infants. Based on research on the relationship between mood and switching pause variability described above, we hypothesize that HR mothers will have greater switching pause durations and variability than LR mothers. In addition, based on previous reports of socio-communicative delays, as well as differences in attention and interactive synchrony in HR infants, we hypothesize that HR infants will have more interruptions, and that HR dyads will be less coordinated in switching pause durations than LR dyads.

### 1.2.2 Aim 2: Examine the effect of Outcome on characteristics of vocal interactions.

The second aim of this study is to examine whether and how language delay at 36 months is related to the characteristics of vocal interactions described above. Three hypotheses are suggested by the existing literature. First, infants who go on to have language delays will have fewer linguistic vocalizations and more non-linguistic vocalizations than infants who do not go on to have a delay. Second, infants who go on to have a language delay will exhibit more infant interruptions than infants who do not. Finally, it is expected that infants who go on to have a language delay will be less coordinated with their mothers in mean duration of switching pause.

### 1.2.3 Aim 3: Examine how individual differences in characteristics of vocal interactions at 9 months relate to individual differences in language development at 24 & 36 months and ASD Symptom Severity at 36 months among HR infants.

The final aim is to examine whether and how individual differences in characteristics of vocal interactions at 9 months that are related to language delay relate to individual differences in continuous measures of language and ASD symptom severity in HR infants in toddlerhood. We expect that variables that relate to language delay (Aim 2) will also be related to a continuous measure of language. Analyses exploring the relationship between characteristics of vocal interactions and ASD symptom severity will be exploratory.

# 2.0 METHOD

## 2.1 PARTICIPANTS

Thirty-two mother-infant dyads participated in this study. They were drawn from two larger longitudinal studies investigating language and motor development over the first years of life. Dyads were included in the current study if they had completed a full, uninterrupted 5-minute toy play session at 9 months (see more on visit procedures below) and if they had reached their 36 month birthday by the time coding for the present study was completed (January 2013).

Twenty-three infants (12 male) were high risk (HR; have an older sibling with a confirmed diagnosis of ASD), while 9 (4 male) were low risk (LR; have no first- or second-degree relatives diagnosed with ASD). Families in the HR group were recruited through the Autism Research Program at the University of Pittsburgh, parent support organizations, and local agencies and schools serving families of children with ASD. Prior to enrollment, all older siblings were administered the Autism Diagnostic Observation Schedule (ADOS; Lord et al., 2000) by a trained clinician to confirm their diagnosis. Families in the LR group were recruited from two separate sites, a small Midwestern city and a Northeastern city, through local newspaper birth announcements and word of mouth. Eligible families were contacted by an introductory letter and follow-up phone call.

All infant participants in both samples were full-term, from uncomplicated pregnancies and deliveries, and came from monolingual, English-speaking homes. Twenty-eight (19 HR infants, 9 LR infants) were Caucasian, 3 (all HR infants) were Hispanic, and 1 HR infant was Asian American. The education levels of mothers and fathers in both groups were comparable, with the majority of parents either holding college degrees or having completed some college. Although information on family income was unavailable, parental occupations were identified for the purpose of providing a general index of social class. Because many of the mothers were home raising their children, Nakao-Teas occupational prestige scores (Nakao & Treas, 1994) were calculated for fathers' occupation. For 6 cases (4 HR; 2 LR), it was impossible to identify the father's occupation with enough precision to assign a prestige score. Results from the remaining families indicated that the mean prestige scores did not differ between groups ($M_{HR}$ = 55.71, SD = 16.4; $M_{LR}$ = 48.45, SD = 12.03). Mean maternal ($M_{HR}$ = 33.43, SD = 4.11; $M_{LR}$ = 31.55, SD = 3.39) and paternal ($M_{HR}$ =35.52, SD = 3.94; $M_{LR}$ = 35.55, SD = 3.82) ages also did not differ significantly by group.

HR infants were visited monthly at home between the ages of 5 and 14 months and at 18, 24, and 36 months, yielding 13 home visits per child. Visits were conducted to coincide with the monthly anniversary of the infant's birthday. LR infants were followed bi-monthly from 2 to 19 months of age. One visit was conducted to coincide with the monthly anniversary of the infant's birthday, and the second monthly visit was scheduled for the midpoint between birthday anniversaries.

## 2.2 MEASURES AND OUTCOME CLASSIFICATION

### 2.2.1 Language.

Parents of HR and LR children completed the Words and Sentences Form of the MacArthur-Bates Communicative Development Inventory (CDI; Fenson et al., 1993) at 18 months. Parents of HR children also completed the CDI at 24 months and the CDI-III at 36 months. The CDI is a widely used measure of expressive and receptive vocabulary and grammar. It has excellent internal consistency and test-retest reliability, as well as concurrent validity with tester-administered measures (Fenson et al., 1993). The Words and Sentences Form is designed for use with children 16 to 30 months of age and consists of two parts. Part I is a 680-word vocabulary checklist organized into 22 semantic categories that asks parents to indicate words that their child says. The second section consists of questions relating to children's use of English morphology and syntax. The CDI-III, which is designed for children aged 30-37 months, consists of three parts: a 100-item vocabulary checklist, 12 sentence pairs assessing grammatical complexity, and 12 yes/no questions concerning semantics, pragmatics, and comprehension. For the present study, only the vocabulary checklist (Words Produced) was utilized from these assessments.

Children in the HR group were also administered the Mullen Scales of Early Learning (MSEL; Mullen, 1995) at 18, 24, and 36 months. The MSEL is a normed, standardized developmental assessment of language, cognitive and motor functioning. For the purposes of the current study, only the Receptive (RL) and Expressive (EL) Language subscales were utilized.

A standardized language composite was created in order to generate a continuous measure of language in toddlerhood for HR infants. This was done by standardizing into z-scores and then averaging 24- and 36-month CDI percentile scores and 24- and 36-month RL and EL MSEL t-scores. CDI percentile scores were used because parents filled out two different forms at these time points—the CDI at 24 months and the CDI-III at 36 months. Level of internal consistency for the composite was more than adequate (Cronbach's $\alpha = .858$).

#### 2.2.2 ASD.

At 36 months, children in the HR group attended a diagnostic outcome assessment at the University of Pittsburgh Research Program. Outcome status was determined by administration of the Autism Diagnostic Observation Schedule (ADOS) and clinical judgment using DSM-IV criteria by a clinician blind to all previous study data. The ADOS is a structured play schedule designed to elicit behaviors diagnostic of ASD. It reliably distinguishes children with ASD from typical children and children with other, non-ASD developmental disorders (Lord et al., 2000).

In addition, raw scores from the ADOS were used to calculate an ASD severity score based on work by Gotham, Pickles, and Lord (2009). The severity score is a standardized metric of severity of ASD-specific features across a range of developmental groups. The severity score ranges from 1 to 10 and encompasses non-spectrum children as well as children with ASD.

## 2.3 OUTCOME GROUPS

Mother-infant dyads were split into two Outcome groups based on whether or not the infant exhibited language delays at 36 months. Among HR infants, language delay was assessed using a combination of the MCDI and Mullen at 18, 24, and 36 months. Infants were categorized as language delayed (LD) if the following criteria were met:

1. Standardized scores on the CDI-II and CDI-III at or below the 10th percentile at *more than one* time point between 18 and 36 months (e.g., Ellis Weismer, & Evans, 2002; Gershkoff-Stowe, Thal, Smith, & Namy, 1997; Heilmann et al., 2005; Robertson & Ellis Weismer, 1999).
2. Standardized scores on the CDI-III at or below the 10th percentile *and* standardized scores on the Receptive and/or Expressive subscales of the MSEL equal to or greater than 1.5 standard deviation below the mean at 36 months (e.g., Landa & Garrett-Mayer, 2006; Ozonoff et al., 2010).

LR infants were not assessed after 18 months. However, no developmental concerns were ever reported for any of these infants during the course of their involvement in the study. We have remained in contact with these families since this time, and no children have subsequently received a diagnosis of a developmental disorder of any sort (e.g., ASD, language impairment).

Eleven HR infants (5 male) met the above criteria for language delay. Three of those 11 infants also met criteria for ASD at 36 months based on the ADOS and clinical judgment. While a future goal of this research is to examine vocal coordination in ASD specifically, given the small numbers at this time, the current study will focus on the commonality of delay in this group. Consequently, these 11 infants will form a language delay group (LD). The remaining 12 HR infants who did not meet criteria for a language delay at 36 months were combined with the 9 LR infants to form a no delay group (ND; n = 21; 11 male).

Descriptive statistics for study variables are shown for LR-ND, HR-ND, HR-LD, and each of the 3 ASD infants individually in Appendix B.

## 2.4 PROCEDURE

For both HR and LR infants, at each visit mother and infant were videotaped for approximately 45 minutes in various structured and unstructured activities (for further details describing the procedures employed in the two larger studies, see Iverson & Wozniak, 2007).

For purposes of the present study, a 5-minute period of unstructured, naturalistic toy play during the 9-month visit was coded. During this time, infants and mothers were seated on the floor and mothers were asked to play together with their infant and some favorite familiar toys. To enhance the audio component of the recordings, infants wore a small wireless microphone clipped to a cloth vest worn over their clothing during the session. Observations were scheduled for a time during the day when infants were expected to be alert and playful.

## 2.5 CODING

The videotaped mother-infant interactions were coded by four independent coders blind to infant Risk Status and Outcome. Coders were trained until they reached at least 85% reliability with a master coder (the author) on three consecutive videos. Coding was done using a time-locked annotation program (ELAN; Brugman & Russel, 2004) that allows coders to annotate and characterize data from an audio and video source. Waveform files of the audio were created from each video to provide an additional visual component for identifying durations of sounds and pauses. The following conversational state variables were coded (see Appendix C for the full coding manual; see Appendix D for zero-order correlations between all conversational state variables):

### 2.5.1 Vocalizations.

All sounds made by the mother and the infant were coded and attributed to the individual who produced them (the speaker). Sounds were categorized as either voluntary (e.g. raspberries, babbles, words, etc.) or involuntary (e.g. sneezes, coughs, etc.). For infants, voluntary sounds were further categorized as either linguistic (e.g., vocalizations, babbles, words) or non-linguistic (e.g. raspberries, squeals, grunts, fusses). For analysis, we calculated the frequency of mother voluntary vocalizations and the frequency of infant linguistic and non-linguistic vocalizations.

### 2.5.2 Intrapersonal pauses.

An intrapersonal pause was coded as a period of silence between when one speaker stops a voluntary vocalization and the same speaker begins another voluntary vocalization (e.g. Jasnow & Feldstein, 1986). It is attributed to the speaker who speaks before and after the pause. For analysis, we calculated the average duration of mother and infant intrapersonal pauses.

### 2.5.3 Switching pauses.

A switching pause was coded as a period of silence between when one speaker stops a voluntary vocalization and the other speaker begins a voluntary vocalization (e.g. Jasnow & Feldstein, 1986). It is attributed to the speaker who breaks the pause. For analysis we calculated both the average duration and the coefficient of variance (CV; the mean divided by the standard deviation) of mother and infant switching pauses. The CV indicates the variability of switching pause durations with the effect of mean differences in length of switching pause removed.

### 2.5.4 Simultaneous speech.

Simultaneous speech was coded when both speakers were vocalizing at the same time. Both speakers' vocalizations had to be voluntary (i.e. not a cough, sneeze, etc.) for simultaneous speech to be coded. Instances of simultaneous speech will be referred to hereafter as "interruptions" for the ease of discussing this variable; however, we acknowledge that simultaneous speech occurs for a variety of reasons. Interruptions are attributed to the "interrupting" speaker. For analysis, we calculated the frequency of infant and mother interruptions and the average duration of interruptions.

## 2.6 RELIABILITY

To assess inter-coder reliability, approximately 30% of the videotaped data were double coded by the author (N = 10 sessions). Sessions were chosen at random with the constraint that both risk groups and all raters were equally represented.  Using this procedure, mean percent agreement for identification of vocalizations was 85% (range: 80-89%).  Mean Cohen's Kappa statistic for identification of vocalization type (voluntary vs. involuntary) was .94 (range: .90-.96).  Mean Cohen's Kappa statistic for identification of voluntary vocalization type (linguistic vs. non-linguistic was .86 (range: .84-.89).  Pearson's statistics for average durations of conversational states (vocalizations, intrapersonal pauses, switching pauses, interruptions) ranged from .77 (for infant intrapersonal pauses) to .97 (for interruptions).

# 3.0 RESULTS

The present study was designed to explore characteristics of mother-infant vocal interactions at 9 months in the hopes of understanding the influence of risk on these interactions and the predictive value of these characteristics for the development of subsequent language delays and for continuous measures of language development and ASD symptom severity in HR infants in toddlerhood. Vocalizations, pauses, and interruptions were coded from videotapes of mother-infant interactions when infants were 9 months old.

Following presentation of preliminary analyses, results relevant to each of the three study aims will be presented in turn. First, analyses exploring differences in conversational state variables between LR and HR dyads will be presented. This will be followed by analyses examining the relationship between conversational state variables and subsequent language delay. Finally, I explore whether conversational state variables that are related to language delay predict continuous measures of language in toddlerhood and of ASD symptom severity at 36 months in HR infants. All analyses were carried out using version 20.0 of SPSS for Windows (SPSS, Inc., 2013).

## 3.1 PRELIMINARY ANALYSES

A series of preliminary analyses was conducted to assess the potential effects of Gender on conversational state variables. Table 1 displays descriptive statistics (means and standard deviations) organized by infant gender for frequency of mother voluntary vocalizations, frequency of infant linguistic and non-linguistic vocalizations, average duration of infant and mother intrapersonal pauses, average duration and coefficient of variance (CV; standard deviation divided by the mean) of infant and mother switching pauses, frequency of infant and mother interruptions, and average duration of interruptions. Independent samples t tests revealed significant differences between male and female infants for frequency of non-linguistic vocalizations ($t(30) = 3.09$, $p < .01$) and average duration of infant switching pause ($t(30) = -2.12$, $p < .05$). Male infants produced non-linguistic vocalizations significantly more frequently than female infants, and female infants had significantly longer switching pauses than male infants. No other comparisons were statistically significant.

**Table 1.** Conversational state variables by Gender

| | Male | | Female | |
|---|---|---|---|---|
| | M | SD | M | SD |
| F Caregiver Voc | 72.19 | 18.88 | 65.44 | 25.19 |
| F Infant L | 24.88 | 11.75 | 24.38 | 24.77 |
| F Infant NL | 11.50 | 8.90 | 4.06 | 3.71 |
| M Caregiver IP | 2.67 | 1.75 | 3.19 | 1.63 |
| M Infant IP | 1.39 | .84 | 2.39 | 2.07 |
| M Caregiver SP | 1.86 | .94 | 2.53 | 1.82 |
| CV Caregiver SP | 1.36 | .26 | 1.30 | .40 |
| M Infant SP | 1.93 | .95 | 3.15 | 2.10 |
| CV Infant SP | 1.54 | .98 | 2.01 | 4.35 |
| F Caregiver Interrupt | 5.56 | 5.03 | 3.31 | 3.63 |
| F Infant Interrupt | 7.81 | 6.85 | 4.25 | 3.66 |
| Mean Interrupt | .48 | .23 | .44 | .27 |

*Note*. F = Frequency; M = Mean; Voc = Voluntary Vocalization; L = Linguistic; NL = Non-Linguistic; IP = Intrapersonal Pause; SP = Switching Pause; CV = Coefficient of Variance.

A chi-square analysis revealed that the distributions of male and female participants did not vary by Risk Status ($X^2$ (1, N = 32) = 0.155, $p$ > .05). Furthermore, a regression analysis predicting Outcome with Gender revealed that Gender was not a significant predictor of future language delay ($B$ = .062, t(30) = 2.554, p = .721). Thus, Gender is not expected to impact the analyses of interest, except in the case of an interaction effect. Therefore, for analyses that include frequency of infant non-linguistic vocalizations and average duration of infant switching pause, an interaction term will be entered into the regression model to examine the interaction between Gender and Risk Status or Gender and Outcome on the variable of interest.

## 3.2 THE EFFECT OF RISK STATUS ON THE CHARACTERISTICS OF VOCAL INTERACTIONS

The first aim of this study was to explore whether mother and infant vocal behavior in dyadic interactions is related to Risk Status. Table 2 displays the means and standard deviations for mother and infant conversational state variables for LR and HR dyads. I begin by presenting analyses of mother and infant vocal behavior examining the influence of Risk Status on the four conversational state behaviors of interest: vocalizations, intrapersonal pauses, switching pauses, and interruptions. To determine whether Risk Status had a significant effect on these conversational state variables, separate linear regressions were conducted for each variable with Risk Status as a predictor. I then examine whether the relationship between mother and infant average duration of switching pause differed for HR and LR dyads by analyzing the moderating effect of Risk Status on the coordination of switching pause durations.

**Table 2.** Conversational state variables by Risk Status

| | LR | | HR | |
|---|---|---|---|---|
| | M | SD | M | SD |
| F Caregiver Voc | 75.00 | 29.43 | 66.39 | 18.85 |
| F Infant L | 25.89 | 15.16 | 24.13 | 20.69 |
| F Infant NL | 4.11 | 2.85 | 9.22 | 8.54 |
| M Caregiver IP | 2.95 | 2.41 | 2.92 | 1.38 |
| M Infant IP | 2.04 | 2.18 | 1.83 | 1.42 |
| M Caregiver SP | 1.90 | 1.24 | 2.31 | 1.55 |
| CV Caregiver SP | 1.13 | .23 | 1.41 | .34 |
| M Infant SP | 2.23 | 1.59 | 2.66 | 1.78 |
| CV Infant SP | 1.10 | .66 | 2.03 | 3.63 |
| F Caregiver Interrupt | 4.33 | 5.05 | 4.48 | 4.34 |
| F Infant Interrupt | 5.22 | 4.44 | 6.35 | 6.18 |
| Mean SS | .47 | .25 | .46 | .25 |

*Note.* F = Frequency; M = Mean; Voc = Voluntary Vocalization; L = Linguistic; NL = Non-Linguistic; IP = Intrapersonal Pause; SP = Switching Pause; CV = Coefficient of Variance.

### 3.2.1 Vocalizations.

As is evident in Table 2, mothers of LR infants produced approximately 10 more voluntary vocalizations on average during the 5-minute interaction than did mothers of HR infants ($M_{LR}$ = 75, SD = 29.43; $M_{HR}$ = 66.39, SD = 18.85). However, Risk Status was not a significant predictor of this variable. This was likely due to substantial variability in frequency of vocalizations for both HR and LR mothers.

There were two primary hypotheses related to the frequency of infant linguistic and non-linguistic vocalizations. Consistent with Paul et al (2011), we hypothesized that HR infants would produce fewer linguistic and more non-linguistic vocalizations than LR infants. Data were not consistent with this prediction: LR and HR infants were quite similar in the frequency of linguistic vocalizations they produced ($M_{LR}$ = 25.89, SD = 15.16; $M_{HR}$ = 24.13, SD = 20.69). Analyses confirmed that Risk Status was not a significant predictor of the variable.

However, consistent with our prediction, HR infants produced more than twice as many non-linguistic vocalizations on average than did LR infants ($M_{LR}$ = 4.11, SD = 2.85; $M_{HR}$ = 9.22, SD = 8.54). Owing to the significant gender differences reported above, analyses examined the influence of Risk Status as well as the possibility of a Risk-by-Gender interaction on the frequency of non-linguistic vocalizations. Table 3 displays the summary of this regression model.

**Table 3.** Frequency infant non-linguistic vocalizations and Risk Status

| | DV: Frequency Infant Non-Linguistic Vocalizations | | |
|---|---|---|---|
| *Variables* | *B* | *SE B* | $\beta$ |
| Risk | 9.14** | 2.91 | .54 |
| Gender*Risk | -8.43** | 2.75 | -.53 |
| Constant | 4.11 | 2.20 | |
| $R^2$ | .31** | | |

*Note. B* = unstandardized regression coefficient; $\beta$ = standardized regression coefficient; **p < .01

There was a significant main effect of Risk Status (*B* = 9.14, t (29) = 3.14, p <.01) as well as a significant Risk-by-Gender interaction (*B* = -8.432, t (29) = -3.06, p <.01). This model explained 31% of the variance in frequency of non-linguistic vocalizations ($R^2$ = .31, $F(2, 29)$ = 6.63, $p$ = .004). Figure 1 displays the means and 95% confidence intervals for the Risk-by-Gender effect. The data in the figure indicate that HR males had a particularly high frequency of non-linguistic vocalizations (M = 13.25, SD = 9.61), but that HR females (M = 4.82, SD = 4.24) did not differ substantially from LR male (M = 6.25, SD = 2.87) or female (M = 2.40, SD = 1.34) infants. Note that there was substantial variability among HR males in the frequency of non-linguistic vocalizations, so this interaction should be interpreted with caution.

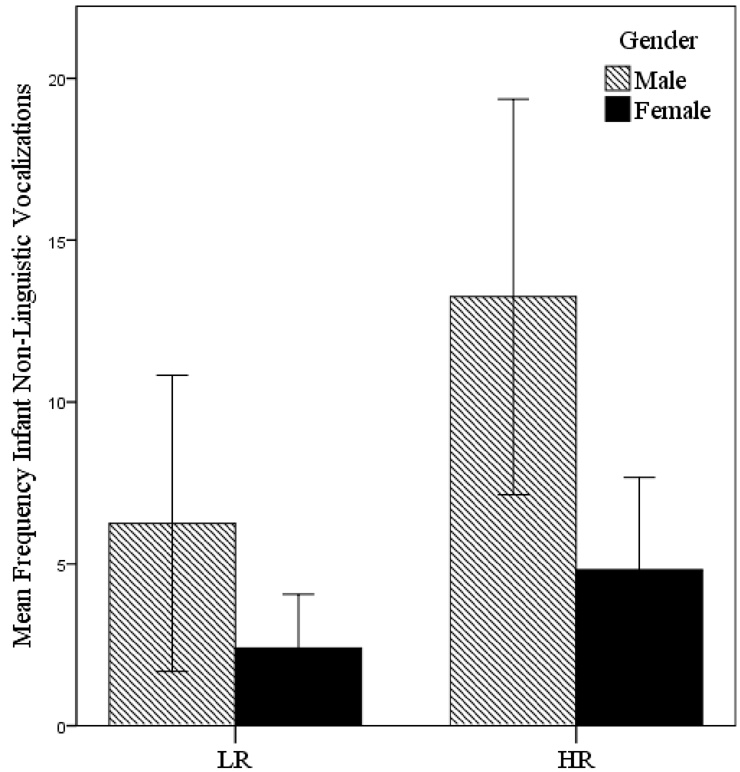



**Figure 1.** Frequency infant non-linguistic vocalizations, Risk-by-Gender interaction

### 3.2.2 Intrapersonal pauses.

The intrapersonal pause is the period of silence between two vocalizations of the same speaker. It is the length of time an individual leaves after speaking before speaking again. As is apparent in Table 2, LR and HR mothers were very similar in the average duration of intrapersonal pauses, pausing for a little less than 3 seconds on average between two of their own vocalizations ($M_{LR}$ = 2.95, SD = 2.41; $M_{HR}$ = 2.92, SD = 1.38). LR and HR infants were also very similar in the average duration of intrapersonal pauses, pausing for approximately 2 seconds on average between two of their own vocalizations ($M_{LR}$ = 2.04, SD = 2.18; $M_{HR}$ = 1.83, SD = 1.42). Risk Status was not a significant predictor of either of these variables.

### 3.2.3 Switching pauses.

The switching pause, or latency to respond, marks the time between when one speaker stops speaking and the next speaker begins speaking. Based on research on response timing in mothers with increased stress and depressive symptoms (Bettes, 1988; Zlochower & Cohn, 1996), we hypothesized that HR mothers would have longer and more variable switching pauses than LR mothers. The data were consistent with this hypothesis. As can be seen in Table 2, HR mothers' switching pauses lasted 2.32 seconds (SD = 1.55) on average, with a CV of 1.41 (SD = 0.43), while LR mothers' switching pauses lasted only 1.90 seconds (SD = 1.24) on average, with a CV of 1.13 (SD = 0.23). Analyses revealed that while Risk Status was not a significant predictor of the *average duration* of mother switching pause, it was a significant predictor of the *variability* of switching pause duration ($B$ = .28, $t(30) = 2.27$, $p < .05$). Results for this latter regression model are presented in Table 4 and depicted in Figure 2. As can be seen, HR mothers were significantly more variable in their switching pause durations over the course of the interaction than were LR mothers.

**Table 4.** Caregiver switching pause CV and Risk Status

| | DV: Caregiver Switching Pause CV | | |
|---|---|---|---|
| *Variables* | *B* | *SE B* | *β* |
| Risk | .28* | .12 | .38 |
| Constant | 1.13 | .11 | |
| $R^2$ | .15* | | |

*Note. B* = unstandardized regression coefficient; *β* = standardized regression coefficient; *p <.05.

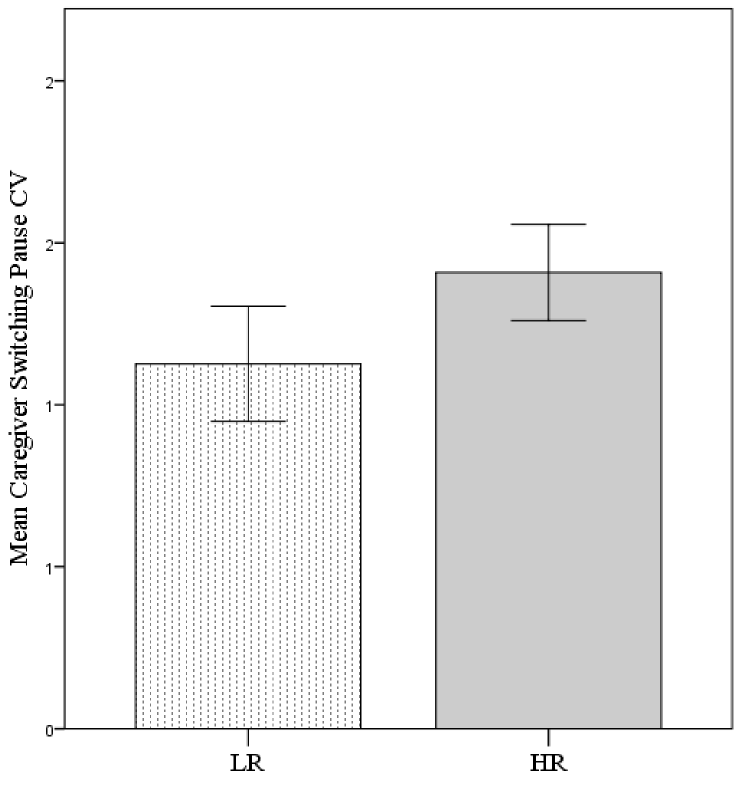



**Figure 2.** Caregiver switching pause CV by risk

Similarly, HR infants had somewhat longer (M = 2.66, SD = 1.78) and more variable ($M_{CV}$ = 2.03, SD = 3.63) switching pauses than their LR counterparts (M = 2.23, SD = 1.59; $M_{CV}$

= 1.10, SD = 0.66). Due to the previously described gender differences in average switching pause duration, regression models included both the main effect of Risk Status as well as a Risk-by-Gender interaction effect on this variable. Results from this regression analysis are displayed in Table 5. There was no main effect of Risk Status, but the Risk-by-Gender interaction was nearly significant (*B* =1.40, t(29) = 2.03, p = .052); this result is shown in Figure 3. As is evident in the figure, HR females had longer switching pause durations (M =3.39, SD = 2.25) than HR males (M = 1.99, SD = 0.86), and this difference was greater than that between LR female (M = 2.63, SD = 1.82) and LR male infants (M =1.74, SD = 1.32).

**Table 5.** Infant switching pause duration and Risk Status

| | DV: Infant Switching Pause Duration | | |
|---|---|---|---|
| *Variables* | *B* | *SE B* | *β* |
| Risk | -0.24 | 0.73 | -0.06 |
| Gender*Risk | 1.40° | 0.69 | 0.39 |
| Constant | 2.23 | 0.55 | |
| $R^2$ | 0.14 | | |

*Note*. *B* = unstandardized regression coefficient; *β* = standardized regression coefficient;
°p < .10

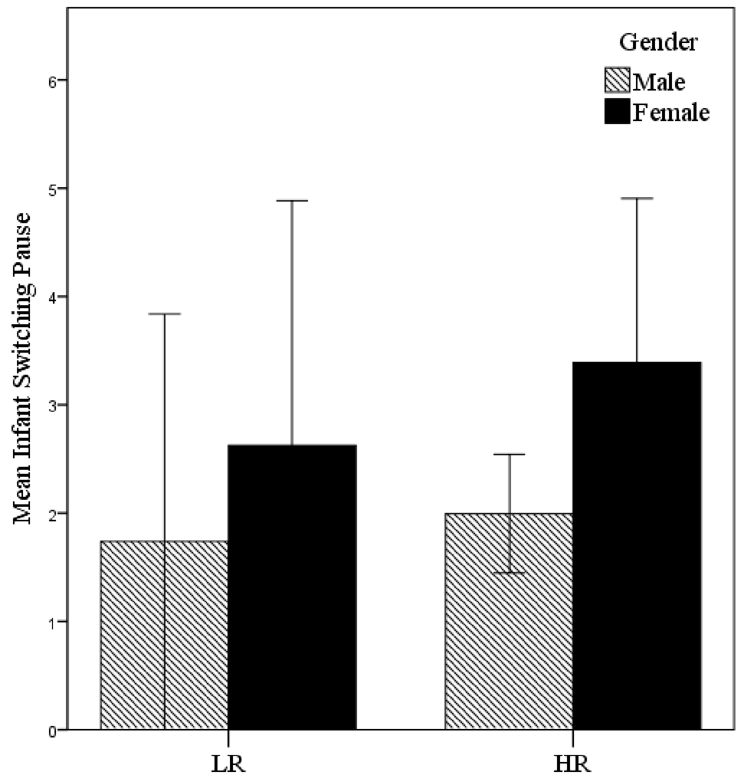



**Figure 3.** Infant switching pause duration, Risk-by-Gender interaction

Despite the apparent differences in infant switching pause CV described above, Risk Status was not a significant predictor of this variable. This is likely attributable to the considerable between-subject variability in switching pause CV for HR infants.

### 3.2.4 Interruptions.

Interruptions occur when one individual begins a vocalization during a partner's vocalization and are attributed to the interrupting speaker. Because differences in the frequency of infant and mother interruptions may reflect variation in the total amount of speech occurring in the entire interaction (i.e., mothers and infants who vocalize more would be expected to have more simultaneous speech than those who vocalize sparingly), total duration of vocalizations was also included as a predictor in these analyses.

As can be seen in Table 2, both LR and HR mothers rarely interrupted infants ($M_{LR}$ = 4.33, SD = 5.05; $M_{HR}$ = 4.48, SD = 4.34), and Risk Status was not a significant predictor of this variable. We hypothesized that HR infants would interrupt their mothers more frequently than LR infants. However, while on average HR infants interrupted their mothers approximately 1 more time per 5-minute interaction than their LR counterparts ($M_{LR}$ = 5.22, SD = 4.44; $M_{HR}$ = 6.35, SD = 6.18), this difference was not significant.

The duration of an interruption after it is initiated is a dyadic variable that depends on both the interrupting and the interrupted speaker. When interruptions occurred, bouts of simultaneous speech tended to be quite short for both LR and HR dyads, lasting only 0.47 seconds (SD = 0.25) in interactions between LR mothers and infants and 0.46 (SD = 0.25) seconds for HR mothers and infants. Risk was not a significant predictor of this variable.

### 3.2.5 Coordination of switching pause duration

As previously discussed, prior research has revealed that mothers and infants tend to match the durations of their switching pauses, so that infants with relatively longer or shorter switching pauses have mothers with relatively longer or shorter switching pauses. Based on research suggesting various socio-communicative delays and differences in attention and engagement in HR infants, we predicted that HR infants and mothers would be less coordinated on this variable than their LR counterparts.

To assess the relationship between Risk Status and coordination of switching pause durations, a linear regression was carried out on the data, with average duration of mother switching pause as the dependent variable and average duration of infant switching pause and an infant switching pause-by-Risk Status interaction term as predictors. The first predictor (infant switching pause) assesses the relationship between infant and mother switching pause durations. The interaction term allows us to determine whether Risk Status has a moderating effect on the relationship between infant and mother switching pause duration, or, in other words, if the relationship between infant and mother switching pause duration differs for HR and LR dyads. Table 6 presents the results of this analysis.

**Table 6.** Moderating effect of Risk Status on switching pause coordination

| | DV: Caregiver SP Duration | | |
|---|---|---|---|
| *Variables* | *B* | *SE B* | $\beta$ |
| Infant SP Duration | $0.50^{*}$ | 0.20 | 0.58 |
| Risk * Infant SP Duration | -0.03 | 0.18 | -0.04 |
| Constant | 0.98 | 0.40 | |
| $R^2$ | $0.31^{**}$ | | |

*Note.* *B* = unstandardized regression coefficient; $\beta$ = standardized regression coefficient; $^{*}p <.05$, $^{**}p<.01$; SP = Switching Pause

Overall, the model is significant and explains 31% of the variance in mother switching pause ($R^2 = .31$, $F(2, 29) = 6.53$, $p < .01$). As expected, infant switching pause is a significant predictor of mother switching pause ($B = .50$, t (29) = 2.49, p <.05). However, contrary to our prediction, Risk Status did not moderate this relationship. Thus, within dyads, infants and mothers were similar to one another in the mean duration of their switching pauses, and Risk Status did not have a significant effect on this relationship.

### 3.3 THE EFFECT OF OUTCOME ON CHARACTERISTICS OF VOCAL INTERACTIONS

The second aim of this research was to assess the relationship between conversational state variables at 9 months and infant outcome classification at 36 months (No delay: ND; Language delay: LD). Means and standard deviations for each of the conversational state variables for LD and ND dyads are presented in Table 7. To assess differences between outcome groups in these variables, regression models were utilized to predict conversational state variables with Outcome. In cases where Risk Status was a significant predictor of the variable (i.e., infant non-linguistic vocalizations, mother switching pause CV; see above), Risk Status was also entered as a predictor to determine whether Outcome was a significant predictor above and beyond the effect of Risk. In addition, an Outcome-by-Gender interaction term was included in models for variables that differed significantly by Gender in preliminary analyses (i.e. frequency infant non-linguistic vocalizations, average duration infant intrapersonal pauses).

**Table 7.** Conversational state variables by Outcome

| | No Delay | | Delay | |
|---|---|---|---|---|
| | M | SD | M | SD |
| F Caregiver Voc | 69.76 | 24.69 | 67.00 | 17.25 |
| F Infant L | 25.10 | 20.40 | 23.73 | 17.15 |
| F Infant NL | 5.95 | 4.97 | 11.27 | 10.67 |
| M Caregiver IP | 2.93 | 1.84 | 2.92 | 1.44 |
| M Infant IP | 2.02 | 1.86 | 1.63 | 1.12 |
| M Caregiver SP | 2.33 | 1.50 | 1.94 | 1.44 |
| CV Caregiver SP | 1.33 | .36 | 1.33 | .31 |
| M Infant SP | 2.64 | 1.85 | 2.36 | 1.51 |
| CV Infant SP | 1.30 | .68 | 2.66 | 5.26 |
| F Caregiver Interrupt | 3.57 | 3.94 | 6.09 | 5.11 |
| F Infant Interrupt | 4.90 | 3.86 | 8.18 | 7.95 |
| Mean SS | .45 | .27 | .49 | .21 |

*Note.* F = Frequency; M = Mean; Voc = Voluntary Vocalization; L = Linguistic; NL = Non-Linguistic; IP = Intrapersonal Pause; SP = Switching Pause; CV = Coefficient of Variance.

### 3.3.1 Vocalizations.

As is evident in Table 7, mothers of ND infants and mothers of LD infants produced similar (and not significantly different) numbers of vocalizations in the 5-minute interaction ($M_{ND}$ = 69.76, SD = 24.69; $M_{LD}$ = 67.00, SD = 17.25).

With regard to infant vocalizations, our hypothesis was that LD infants would produce fewer linguistic and more non-linguistic vocalizations than ND infants. Contrary to this hypothesis, ND and LD infants were very similar in the frequency of linguistic vocalizations ($M_{ND}$ = 25.10, SD = 20.40; $M_{LD}$ = 23.73, SD = 17.15), and analyses confirmed that Outcome was not a significant predictor of this variable.

However, as hypothesized, LD infants produced more than twice as many non-linguistic vocalizations than ND infants ($M_{ND}$ = 5.95, SD = 4.97; $M_{LD}$ = 11.27, SD = 10.67). Due to the gender and Risk Status differences previously reported for this variable, our regression model included the main effect of Outcome, an Outcome-by-Gender interaction term, as well as Risk Status. Results of this model are presented in Table 8 and depicted in Figure 4. As is evident, Outcome was a significant predictor of the frequency of infant non-linguistic vocalizations ($B$ = 12. 87, t(28) = 4.39, p <.001), above and beyond the effect of Risk Status.

**Table 8.** Frequency infant non-linguistic vocalizations and Outcome

| | DV: Caregiver SP Duration | | |
|---|---|---|---|
| *Variables* | *B* | *SE B* | *βeta* |
| Outcome | 12.87*** | 2.93 | 0.81 |
| Gender*Outcome | -16.37*** | 3.34 | -0.84 |
| Risk | 3.22 | 2.43 | 0.19 |
| Constant | 4.11 | 1.84 | |
| $R^2$ | 0.54 | | |

*Note.* *B* = unstandardized regression coefficient; *β* = standardized regression coefficient; ***p<.001

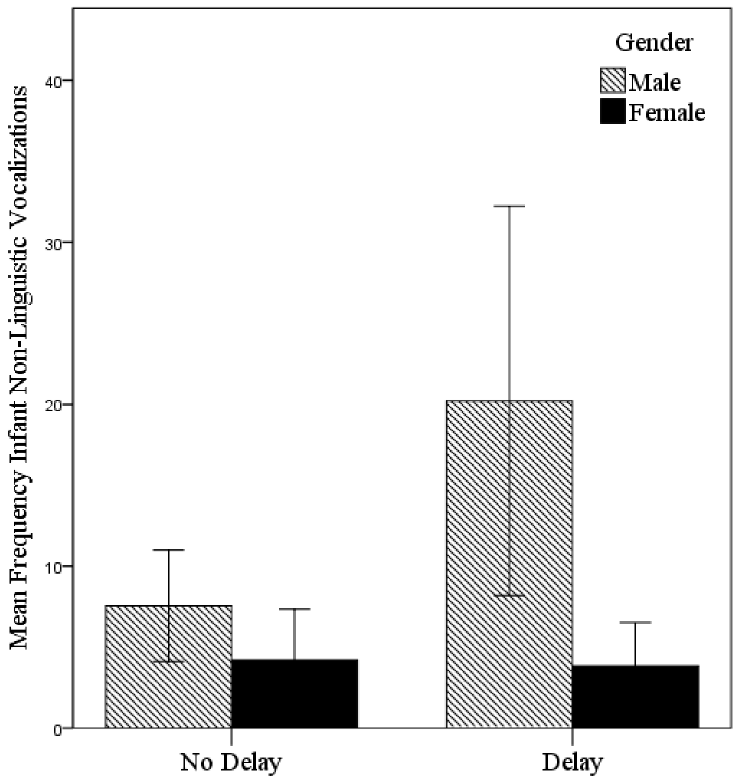



**Figure 4.** Frequency infant non-linguistic vocalizations, Outcome-by-Gender interaction

There was also a significant Outcome-by-Gender interaction ($B$ = -16.37, t(28) = -4.91, p <.001), such that LD males produced a notably higher frequency of non-linguistic vocalizations (M = 20.20; SD = 17.54) relative to all other infants (Female $M_{ND}$ = 4.20, SD = 4.39; Male $M_{ND}$ = 7.55, SD = 5.13; Female $M_{LD}$ = 3.83, SD = 2.56). Inspection of the data reveals that this difference was robust across individual infants: 4 out of 5 of the LD males-- but none of the LD females and only 3 of 21 ND infants (2 male, 1 female) -- produced more than 10 non-linguistic vocalizations. As can be seen in Table 8, with Outcome included in the model, Risk Status was no longer a significant predictor of frequency of infant non-linguistic vocalizations, indicating that the relationship between Risk Status and this variable is likely driven by those HR infants who go on to have a language delay.

### 3.3.2 Intrapersonal pauses.

As can be seen in Table 7, mothers with ND and LD infants were comparable in the durations of their intrapersonal pauses ($M_{ND}$ = 2.93, SD = 1.84; $M_{LD}$ = 2.92, SD = 1.44), and analyses confirmed that there was not a significant difference between Outcome groups for this variable. While ND infants left somewhat longer pauses (M = 2.02, SD = 1.86) between two of their own vocalizations than their LD counterparts (M = 1.63, SD = 1.12), these differences were also not significant.

### 3.3.3 Switching pauses.

Mothers of LD infants had slightly shorter (M = 1.94, SD = 1.44) switching pause durations than mothers of ND infants (M = 2.33, SD = 1.50; see Table 7), but this difference was not significant. The switching pause CVs of mothers with ND and LD infants were virtually identical ($M_{NS}$ = 1.33, SD = .36; $M_{LD}$ = 1.33, SD = .31), and Outcome was not a significant predictor of this variable accounting for the effect of Risk Status (note that Risk Status was included in this analysis as it was a significant predictor of this variable).

Similarly, ND and LD infants had comparable average durations of switching pauses ($M_{ND}$ = 2.64, SD = 1.85; $M_{LD}$ = 2.36, SD = 1.51). Owing to the significant gender difference in this variable, an Outcome-by-Gender interaction term was included in the regression model. However, neither the main effect of Outcome nor the interaction term was a significant predictor. The mean switching pause CV for ND infants was quite a bit smaller (M = 1.30, SD = .68) than that for LD infants (M = 2.66, SD = 5.26), but the difference did not reach significance, likely due to the substantial variability among LD infants.

### 3.3.4 Interruptions.

Mothers of LD infants interrupted their infants almost twice as often as mothers of ND infants ($M_{ND}$ = 3.57, SD = 3.94; $M_{LD}$ = 6.09, SD = 5.11). Table 9 displays the results of the regression model predicting frequency of mother interruptions with outcome. Note that, as in the analyses above, total duration of vocalizations was included in the model to partial out the potential effects of the overall amount of speech produced on the frequency of interruptions. The difference between mothers of ND and LD infants in frequency of interruptions, after accounting for total speech, was only marginally significant (*B* = 2.11., t(29) = 1.70, p <.10); this is shown in Figure 5 (note that the data in this figure do not control for differences in total speech). As is evident, the marginally significant difference is likely related to substantial variability in the frequency of mother interruptions.

**Table 9.** Frequency caregiver interruptions and Outcome

| | DV: Frequency Caregiver Interruptions | | |
|---|---|---|---|
| *Variables* | *B* | *SE B* | *β* |
| Outcome | 2.11° | 1.24 | 0.23 |
| Total Vocalizations | 0.07 | 0.02 | 0.64 |
| Constant | -4.36 | 1.81 | |
| $R^2$ | 0.48*** | | |

*Note.* *B* = unstandardized regression coefficient; *β* = standardized regression coefficient; °p <.10, ***p<.001

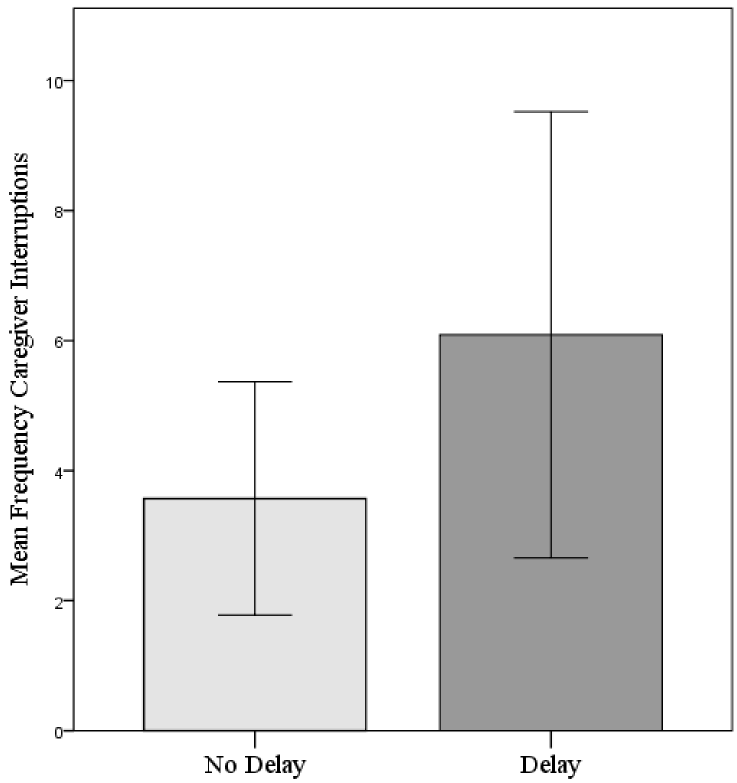


**Figure 5. Frequency caregiver interruptions by Outcome**

With regard to infant interruptions, we predicted that LD infants would interrupt their mothers more frequently than ND infants over the course of the interaction. Consistent with this hypothesis, ND infants vocalized when their mothers were speaking 4.9 times (SD = 3.86) on average, while LD infants vocalized when their mothers were speaking 8.18 times (SD = 7.95) on average. Results from the regression model predicting frequency of infant interruptions with Outcome (controlling for total speech) are presented in Table 10 and Figure 6. Outcome was a significant predictor of frequency of infant interruptions ($B$ = 2.65, t(29) = 2.10, p < .05). Again, however, it should be noted that the substantial variability makes the group difference in this variable somewhat difficult to interpret. Furthermore, inspection of the data suggests that the difference between the groups may be skewed by a single LD infant who vocalized when his mother was vocalizing 28 times, almost twice as often as the infant with the next highest frequency (15).

**Table 10.** Frequency infant interruptions and Outcome

| | DV: Frequency Infant Interruptions | | |
|---|---|---|---|
| *Variables* | *B* | *SE B* | *β* |
| Outcome | 2.65* | 1.26 | 0.22 |
| Total Vocalizations | 0.12 | 0.02 | -0.77 |
| Constant | -7.33 | 1.84 | |
| $R^2$ | 0.67*** | | |

*Note. B* = unstandardized regression coefficient; *β* = standardized regression coefficient; *p <.05, ***p<.001

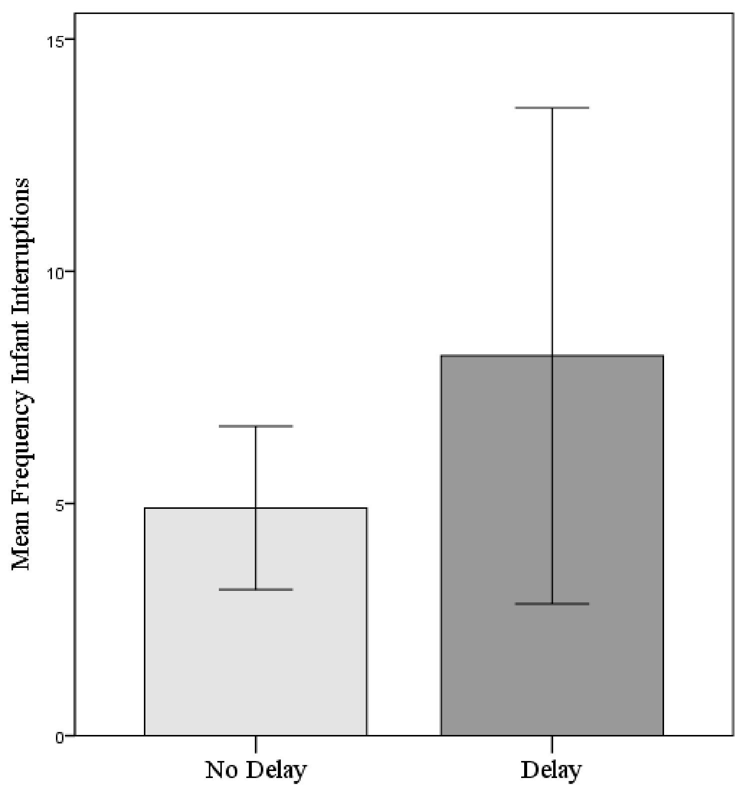



**Figure 6.** Frequency infant interruptions by Outcome

When interruptions occurred, dyads with ND and LD infants had similar durations of simultaneous speech ($M_{ND}$ = 0.45, SD = 0.27; $M_{LD}$ = 0.49, SD = 0.21). Analyses confirmed that there was no difference between groups on this variable.

### 3.3.5 Coordination of switching pause duration.

We predicted that Outcome would moderate the relationship between mother and infant switching pause duration, such that LD dyads would be less coordinated than ND dyads. To assess this moderation effect, a regression model was estimated predicting average duration of mother switching pause with average duration of infant switching pause and an infant switching pause-by-Outcome interaction term. Results are presented in Table 11.

**Table 11.** Moderating effect of Outcome on switching pause coordination

| | DV: Caregiver SP Duration | | |
|---|---|---|---|
| *Variables* | *B* | *SE B* | $\beta$ |
| Infant SP Duration | $0.53^{***}$ | 0.13 | 0.63 |
| Outcome * Infant SP Duration | $-0.30^{\circ}$ | 0.15 | -0.29 |
| Constant | 1.08 | 0.38 | |
| $R^2$ | $0.39^{***}$ | | |

*Note. B* = unstandardized regression coefficient; $\beta$ = standardized regression coefficient; °p <.10, ***p<.001; SP = switching pause.

As expected, infant switching pause duration was significantly related to mother switching pause duration (*B* = .53, t(29) = 4.19, p <.001). In addition, consistent with our hypothesis, there was a marginally significant moderating effect of Outcome on the relationship between infant and mother switching pause duration ($B$ = -.30, $t(29) = -1.95$, $p = .06$).

To identify the locus of this effect, Pearson correlations were computed for average duration of mother switching pauses and average duration of infant switching pauses separately for ND and LD infants. Figure 7 displays scatterplots of the correlations between mother and infant switching pause durations for ND and LD dyads respectively. As is apparent in the figure, ND dyads showed a strong positive correlation ($r = .821$, $p < .001$) between mother switching pause duration and infant switching pause duration, while the corresponding correlation for the LD group was weakly negative and not significant ($r = -.121$, n.s.).

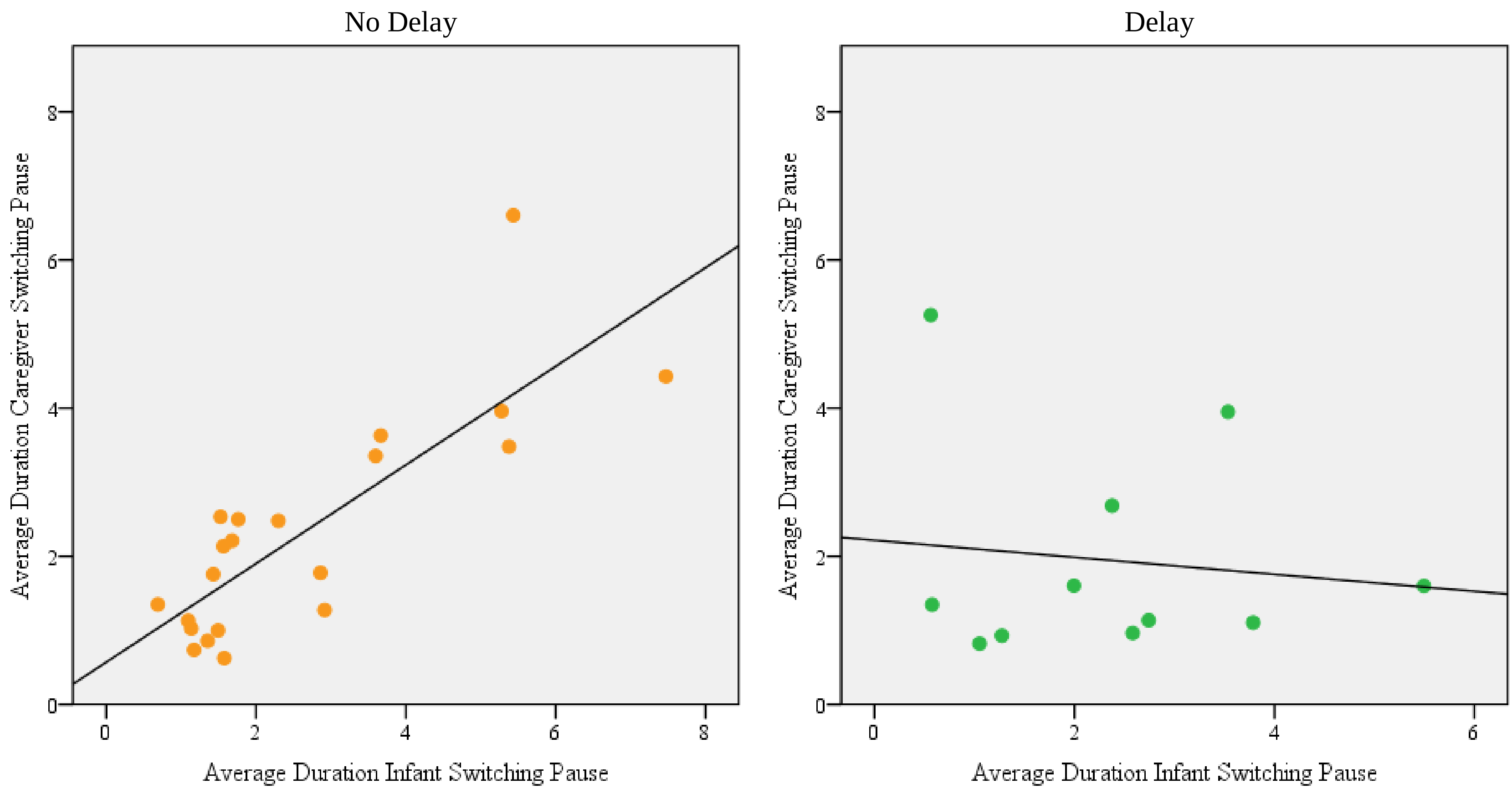



**Figure 7.** Moderating effect of Outcome on switching pause coordination

## 3.4 RELATIONSHIP BETWEEN INDIVIDUAL DIFFERENCES IN CHRARACTERISTICS OF VOCAL INTERACTIONS AT 9-MONTHS AND INDIVIDUAL DIFFERENCES IN LANGUAGE DEVELOPMENT AND ASD SYMPTOM SEVERITY IN TODDLERHOOD AMONG HR INFANTS

Analyses for the final aim were designed to examine whether and how the conversational state variables that were found to be related to Outcome (i.e., frequency of infant non-linguistic vocalizations, frequency of mother interruptions, frequency of infant interruptions, and coordination of switching pause durations) predict to a continuous measure of language in toddlerhood (henceforth referred to as "language composite") and to ASD severity scores at 36 months. Note that, as previously discussed, 24- and 36-month data were only available for HR infants, and thus the analyses reported below were limited to this group.

In order to explore the predictive utility of the conversational state variables listed above, separate regression models were estimated predicting language composite and ASD severity scores respectively with each variable of interest.

### 3.4.1 Infant non-linguistic vocalizations.

Frequency of infant non-linguistic vocalizations was not a significant predictor of either language composite or ASD severity score (Language: $B$ = .01, t(21) = .23, p = .82; ADOS: $B$ = -.01, t(18) = - .21, p = .84). Thus, while frequency of non-linguistic vocalizations is related to

LD vs. ND status at 36 months, it was not systematically related to language in toddlerhood, nor was it related to ASD symptom severity.

### 3.4.2 Interruptions.

Frequency of mother interruptions was not a significant predictor of either language composite or ASD severity score (Language: $B$ = -.06, t(20) = -1.17, p = .25; ADOS: $B$ = -.01, t(18) = - .81, p = .43). Frequency of infant interruptions was also not a significant predictor of either language outcome or ASD severity score (Language: $B$ = -.05, t(20) = -.81, p = .43; ADOS: $B$ = .13, t(18) = 1.053, p = .31). While there were group-level differences between ND and LD dyads in frequency of interruptions, there was no systematic relationship between these variables and standardized language scores or ASD symptom severity.

### 3.4.3 Coordination of switching pause duration.

In order to create a single variable as a proxy for switching pause coordination to use in the regression models, I calculated the absolute value of the difference between infant and mother switching pause durations. The average durations of mother and infant switching pauses were also included in the models to ensure that larger difference scores were not simply indicative of longer switching pauses.

Tables 12 and 13 display the results for these two regression models. Switching pause difference score was a significant predictor of both the language composite ($B$ = -.50, t(19) = -4.060, p = .001) and ASD severity score ($B$ = 1.04, t(16) = 2.98, p = .01). For every 1s increase in the difference in switching pause duration between mothers and infants, there was a .50 unit decrease in language composite in toddlerhood and a 1.04 unit increase in ASD severity score. However, this latter finding should be interpreted cautiously given the large number of HR infants with ASD severity scores of 0. Figures 8 and 9 display the relationship between the switching pause difference score and language composite and ASD severity score respectively. As can be seen, infants who were more similar to their mothers (i.e. had a smaller difference score) in the mean duration of their switching pauses had higher language composite scores and lower ASD symptom severity in toddlerhood. Inspection of the data reveals that all 3 infants who went on to receive a diagnosis of ASD came from dyads who fell above the 75th percentile on this variable, meaning that the difference between mother and infant switching pause duration for dyads with an infant later diagnosed with ASD was larger than that of 75% of the HR dyads.

**Table 12.** Switching pause difference predicting Language Composite

| | DV: Caregiver SP Duration | | |
|---|---|---|---|
| *Variables* | *B* | *SE B* | *β* |
| SP Difference | $-.50^{**}$ | .28 | -.75 |
| Caregiver SP | .16 | .10 | .29 |
| Infant SP | .04 | .09 | .08 |
| Constant | .20 | .28 | |
| $R^2$ | $.48^{**}$ | | |

*Note. B* = unstandardized regression coefficient; *β* = standardized regression coefficient; °p <.10, ***p<.001; SP = switching pause.

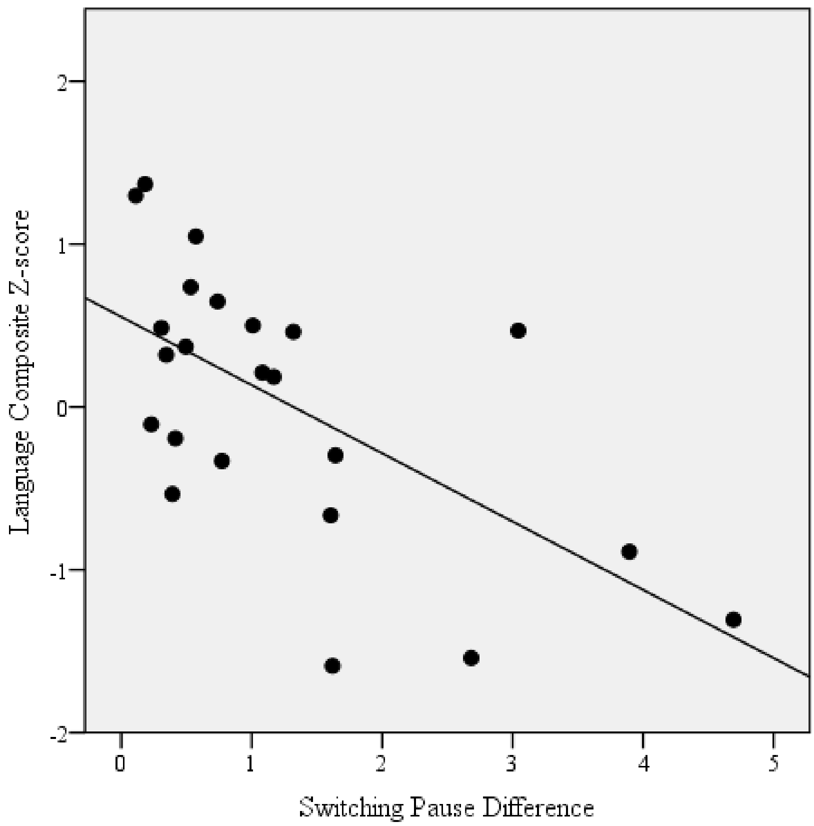



**Figure 8.** Switching pause difference and language composite

**Table 13.** Switching pause difference predicting ADOS Severity Score

| | DV: Caregiver SP Duration | | |
|---|---|---|---|
| *Variables* | *B* | *SE B* | *β* |
| SP Difference | 1.04** | .35 | -.75 |
| Caregiver SP | -.44 | .28 | .29 |
| Infant SP | -.09 | .25 | .08 |
| Constant | 2.50 | .70 | |
| $R^2$ | .37° | | |

*Note. B* = unstandardized regression coefficient; *β* = standardized regression coefficient; °p <.10, ***p<.001; SP = switching pause.

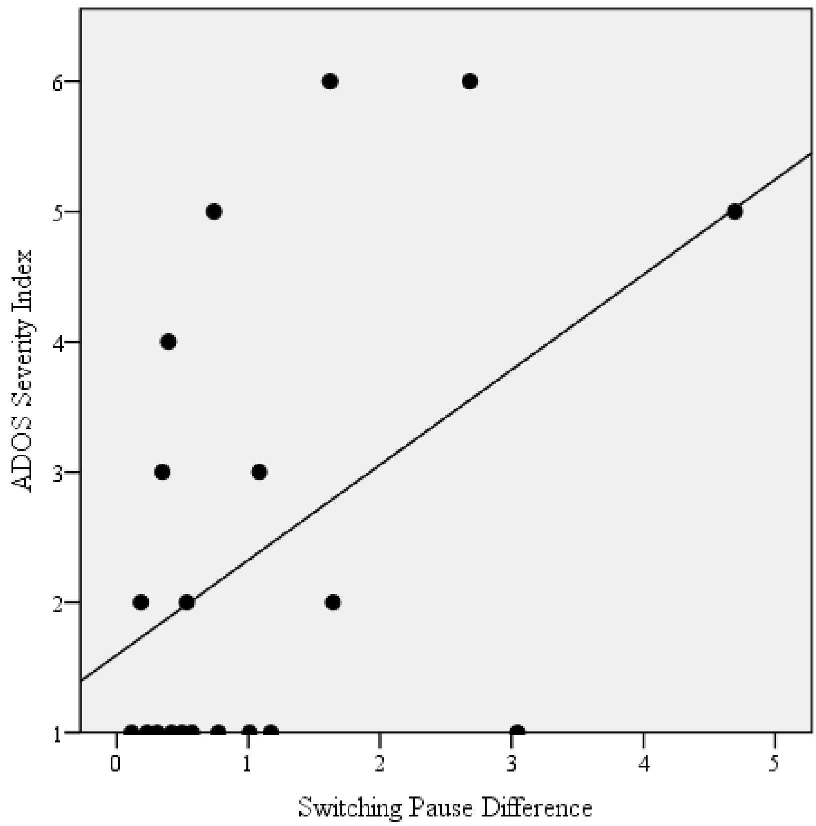



**Figure 9.** Switching pause difference and ADOS severity

## 4.0 DISCUSSION

This research was designed to examine how genetic risk for ASD influenced vocal characteristics of mother-infant interaction, and how these characteristics related to the emergence of language delay among a subset of infants. It also explored the relationship between these characteristics and individual differences in language development and ASD symptom severity in toddlerhood. There were three main sets of findings. First, Risk status was directly related to only one conversational state variable—mother switching pause variability—and interacted with Gender to predict infant switching pause duration. Second, several conversational state variables, including frequency of non-linguistic vocalizations and frequency of interruptions, were related to language delay in toddlerhood. Finally, coordination of switching pause durations appeared to be a particularly important aspect of vocal interaction, both as a possible marker of language delay at age 3 and as a predictor of individual differences in language development and ASD symptom severity among HR infants in toddlerhood. These three main sets of results will be discussed in turn.

### 4.1 RISK STATUS AND VOCAL INTERACTIONS

Based on research indicating various socio-communicative delays in HR infants (e.g. Toth et al., 2007; Yirmiya et al., 2006), we predicted differences in several characteristics of vocal interactions based on infant Risk Status. However, our results indicated that Risk Status was directly related to characteristics of mother-infant vocal interactions in only one instance: HR mothers had greater variability of switching pauses than LR mothers. Although Risk Status was not a direct predictor of any infant conversational state variables, there was a Risk-by-Gender interaction for the duration of infant switching pauses, with female HR infants exhibiting longer durations of switching pauses than male HR infants. This difference was greater than that between LR male and female infants.

In line with our prediction, mothers of HR infants had more variable switching pause durations than mothers of LR infants. It is important to note that this result was not driven by mothers of infants who went on to have language delays. One of the most parsimonious explanations for this finding comes from literature on response styles in depressed mothers. As mentioned previously, research has shown that mothers with higher levels of depressive symptoms tend to have longer and more variable switching pauses than mothers with low levels of depressive symptoms (Bettes, 1988; Zlochower & Cohn, 1996). By definition, the mothers in the HR group all have a child with ASD, and caregivers of children with ASD have higher levels of stress and higher levels of depressive symptoms on average than mothers of TD children (Abbeduto et al., 2004; Baker-Ericzen, Brookman-Frazee, & Stahmer, 2005). Although we do not have data on stress and depressive symptoms in the current group of mothers that can address this issue, increased symptoms of mood disorders in this population may have contributed to this difference in response style

In addition, owing to their experiences with a child with ASD, mothers of HR infants may have different expectations about and experiences with infant development, which could affect their interaction styles. The literature suggests that the interaction styles of children with

ASD may be quite different from TD children (Feldstein, Konstantareas, Oxman, & Webster, 1982; Zwaigenbaum et al., 2005), and the experience that mothers have had interacting with their older affected children may have influenced their interaction styles with later-born children.

It is important to note, however, that this research focused on only one aspect of an interaction: vocal exchanges. Although Risk Status was not found to be directly related to any aspect of infant *vocal* behavior in this study, it is possible that there are differences in other infant behaviors (e.g., visual attention, quality of infant vocalizations) that may influence caregiver response timing. Mother-infant interactions are complex, dynamic, multimodal events, and caregiver vocal behavior is likely affected by many aspects of infant behavior.

As mentioned previously, Risk Status did not directly predict any of the conversational state variables for infants. However, there was a Risk-by-Gender interaction in the average duration of infant switching pauses. Specifically, female infants had longer switching pauses than male infants, and this difference was even more pronounced among HR infants. This finding was unexpected and has no precedent in the existing literature. It should therefore be interpreted with caution until it has been replicated with a larger sample size.

## 4.2 LANGUAGE DELAY AND VOCAL INTERACTIONS

We hypothesized that LD infants would produce fewer linguistic and more non-linguistic vocalizations than ND infants, and that LD infants would be more likely to interrupt their mothers. Consistent with this prediction, three conversation state variables were related to future language delay: frequency of infant non-linguistic vocalizations, frequency of mother interruptions, and frequency of infant interruptions.

For non-linguistic vocalizations, the data revealed a robust Outcome-by-Gender interaction: LD male infants produced far more non-linguistic vocalizations in interactions with their mothers at 9 months than any other subgroup of infants. The finding that HR infants, and in particular those HR infants with subsequent language delay, produced more non-linguistic vocalizations is consistent with research by Paul et al. (2012). They reported that HR infants produced more "non-speech" vocalizations (using very similar criteria to the current study's "non-linguistic" category) than their LR counterparts, but they did not examine the effect of Gender or later language delay on the production of non-speech vocalizations in infancy. The findings of the current study add to the literature, suggesting that at least among male infants, frequency of non-linguistic vocalizations may be an early marker of language delay.

We also found a relationship between later language delay and the frequency of both mother and infant interruptions, such that dyads with LD infants had more interruptions on average than dyads with ND infants. While this relationship was not strong and needs to be replicated with a larger sample, it is consistent with research suggesting that HR infants are less "synchronous" with their mothers than LR infants (Yirmiya et al. 2006). That study reported that HR infants were less likely to match their mothers' state of engagement than LR infants. If LD infants are less likely to be jointly engaged with their mothers, the timing of their vocalizations may be less influenced by the timing of their mothers' vocalizations. Similarly, mothers of LD infants may use interruptions as a way of drawing disengaged infants back into the interaction. Examination of other infant behavior during interactions (e.g., directedness of infants' visual attention during vocalizations) may help to clarify whether engagement is affecting the frequency of interruptions in LD dyads.

Another possible explanation for this finding is related to the frequency of non-linguistic vocalizations produced by LD infants. While we did not code whether or not simultaneous speech included linguistic or non-linguistic vocalizations, it is possible that mothers are more likely to interrupt infants' non-linguistic vocalizations, and that infants are more likely to vocalize with non-linguistic vocalizations while their mothers are vocalizing. Again, examination of additional infant behaviors, in this case the quality of infant vocalizations during simultaneous speech, may help clarify the implications of this finding.

## 4.3 COORDINATION OF SWITCHING PAUSE DURATIONS

Coordination of switching pause durations is apparent in typical development by 9 months of age and is seen consistently in interactions between adults (Crown et al., 2002; Jaffe et al., 2001; Jasnow & Feldstein, 1986). Based on literature suggesting differences between HR and LR infants in several aspects of social communication, attention, and interaction style (e.g. Droucker, Curtin, & Vouloumanos, 2013; Goldberg et al., 2005; Yirmiya et al., 2006), we hypothesized that Risk Status and Outcome would moderate the relationship between mother and infant switching pause durations. Only Outcome was revealed to have a moderating effect. Specifically, LD infants were less likely to have durations of switching pauses similar to those of their mothers than were ND infants.

In addition, the difference in average duration of infant and mother switching pause was predictive of language development at 24 and 36 months and ADOS symptom severity at 36 months. Moreover, inspection of the data revealed that dyads with infants later diagnosed with ASD had relatively large differences between mother and infant switching pause duration, even compared to other HR infants. These findings suggest that switching pause coordination is important, not only as a possible early marker of language delay, but also as a potential predictor of language development. While the relationship between switching pause coordination and ASD symptom severity is somewhat more tenuous due to the large number of HR infants with ASD severity scores of 0, the data do indicate that this variable is the most likely candidate for a marker that is predictive of ASD specifically.

Coordination of switching pause durations between mothers and infants is likely a phenomenon that develops over time, through repeated experiences interacting together. While the current study cannot speak to the mechanisms underlying this lack of coordination, results indicate that these mother-LD infant dyads are not successfully adjusting the timing of their vocalizations to match with conversational partners in an interaction. A lack of coordination could reflect a number of possible delays or differences, including disparities in engagement, delays in vocal control, difficulty detecting contingencies, and/or differences in the predictability of either of both partners.

In addition to being a potential marker of atypicality, lack of coordination may also have cascading effects for future learning. The predictive utility of this variable for language development and ASD symptom severity is consistent with this theory. One possibility is that coordinating switching pause durations makes responses in vocal interactions more predictable, and may consequently provide more frequent or higher quality learning experiences for infants. It is also likely that lack of coordination in this domain coincides with a lack of coordination in other domains as well, and it is in the context of this broader asynchrony that delays emerge.

## 4.4 GENERAL CONCLUSIONS

The results reported here suggest two general conclusions and a variety of areas for future research. First, this research suggests that studying HR infants who go on to have language delays reveals important differences that are not apparent when only Risk Status is considered. Previous research on HR infants has revealed a variety of on-average differences between this population and LR infants over the first years of life (e.g. Cassel et al., 2007; Goldberg et al., 2005; Toth et al., 2007); however, it may be that these on-average discrepancies are driven by a subset of LD infants. Very little research to date has looked specifically at this subgroup of infants, but the wide heterogeneity among HR infants in developmental trajectories suggests that creating subgroups in this way may give researchers a more nuanced understanding of delay in this population. The findings reported here support this notion: a majority of differences in vocal interactions were revealed when analyses focused on Outcome rather than Risk Status.

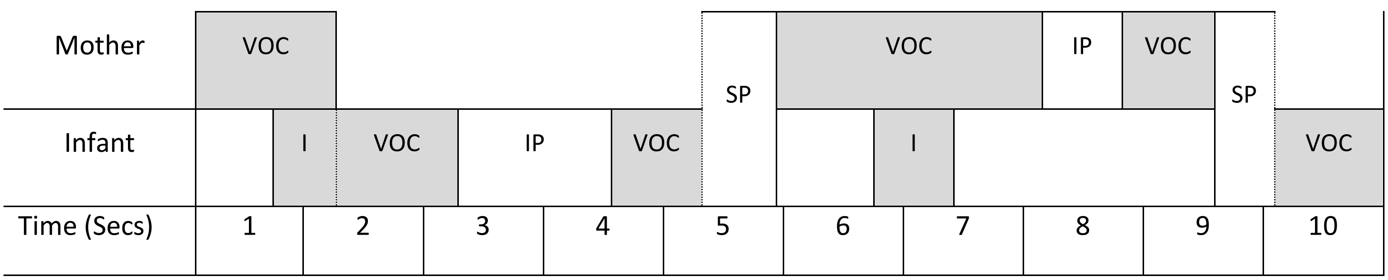
Second, these data emphasize the importance of understanding infant development in the context of social interaction. While much of the previous research seeking to identify early markers of delay in HR infants has focused on individual characteristics of the child, the current study attempted to describe infant behavior and development in a dyadic interaction. The results call attention to the importance of studying development in this way, as it was analyses of the *coordination* of vocal behavior that revealed subtle early differences between infants who went on to have delays and those who did not, and *only* coordination of behavior predicted the course of development.

Coordinating vocal behavior with a partner both facilitates and requires the development of a complex mix of selective attention, sophisticated vocal production, and social engagement. A disruption or delay in any of these areas could have significant effects on interactions between caregivers and infants, and on later development. The findings presented here suggest that characteristics of mother-infant interactions not only have the potential to reveal early markers of delay, but could also be viewed in a developmental context as potential contributors to delay. An interactionist perspective on development suggests that infants learn through a dyadic process that involves both their own behavior and the input they receive from adults around them. A disruption in this dyadic process could therefore have cascading effects in multiple modalities.

In the future, we hope to replicate this study with a larger sample of infants, and, in particular, to include more infants who go on to an ASD diagnosis. We are also interested in taking a broader approach to studying behavior in mother-infant interaction, including visual attention, affective states, infant vocalization quality, and quality of maternal responses. Having more information about these fundamental interactions may further our understanding of the differences described here and provide greater insight into how delays emerge over time.

## APPENDIX A

## VISUAL REPRESENTATION OF CONVERSATIONAL STATES




Shaded areas are periods of sound. VOC = Vocalization; I = Interruption; IP = Intrapersonal Pause; SP= Switching Pause

**Figure 10. Visual representation of conversational states**

# APPENDIX B

## CONVERSATIONAL STATE VARIABLE BY DIAGNOSIS

**Table 14.** Conversational state variables by Diagnosis

| | LR-ND | HR-ND | HR-LD | ASD1 | ASD2 | ASD3 |
|---|---|---|---|---|---|---|
| F Caregiver Voc | 75.00 | 65.83 | 68.88 | 39.00 | 70.00 | 77.00 |
| F Infant L | 25.89 | 24.50 | 27.75 | 8.00 | 23.00 | 8.00 |
| F Infant NL | 4.11 | 7.33 | 13.50 | 2.00 | 6.00 | 8.00 |
| M Caregiver IP | 2.95 | 2.92 | 2.59 | 6.53 | 2.18 | 2.66 |
| M Infant IP | 2.04 | 2.01 | 1.43 | 3.36 | 3.08 | .00 |
| M Caregiver SP | 1.90 | 2.65 | 1.76 | 5.26 | 1.10 | .96 |
| CV Caregiver SP | 1.13 | 1.48 | 1.26 | 1.95 | 1.37 | 1.18 |
| M Infant SP | 2.23 | 2.94 | 2.38 | .56 | 3.79 | 2.58 |
| CV Infant SP | 1.10 | 1.45 | 1.28 | 18.20 | .40 | .44 |
| F Caregiver Interrupt | 4.33 | 3.00 | 7.25 | 1.00 | 6.00 | 2.00 |
| F Infant Interrupt | 5.22 | 4.67 | 9.63 | 2.00 | 4.00 | 7.00 |
| Mean Interrupt | .47 | .43 | .49 | .40 | .59 | .41 |

*Note.* F = Frequency; M = Mean; Voc = Voluntary Vocalization; L = Linguistic; NL = Non-Linguistic; IP = Intrapersonal Pause; SP = Switching Pause; CV = Coefficient of Variance.

## APPENDIX C

## CODING MANUAL

- **Infant Vocalization**
  - Vocalization- Voluntary: An infant Vocalization is any sound produced by the infant. This includes all babbles, vocalizations, fusses, and vegetative sounds.
    - For a vocalization to end, the speaker must either stop vocalizing for at least ½ of a second or *take a breath*. Some speakers pause in between their vocalizations without taking a breath in between. In these instances, if the pause is less than ½ second, code all sounds produced as a single vocalization.
    - Vocalizations *can* occur in whisper form. These vocalizations should be coded. Do not confused deep breaths with whispers. Deep breaths are not coded.
    - Voluntary Vocalizations are coded as either linguistic or non-linguistic:
      - Linguistic vocalizations are any sound produced by the infant that is of a vocal quality. This includes immature sounds as well as babbles, fusses, and squeals.
      - Non-linguistic vocalizations are sounds produced by the infant that either do not involve the vocal chords for production (e.g. raspberries, kisses, clucks, laughs/chuckles) or are no longer under control (e.g. full blown cries).
  - Involuntary: Burp, Hiccup, Cough, Sneeze etc. (same as adults make)
- **Caregiver Vocalization**
  - Vocalization: Any voluntary sound produced by the caregiver.
    - For a vocalization to end, the caregiver must either stop vocalizing for at least at least ½ of a second or *take a breath*.
    - Voluntary Vocalizations are coded as either linguistic or non-linguistic:

            - Linguistic vocalizations are any sound produced by the caregiver that is of a vocal quality. This can include singing, talking, and nonsense words.
            - Non-linguistic vocalizations are sounds produced by the caregiver that do not involve the vocal chords for production (e.g. raspberries, kisses, clucks, laughs/chuckles, non-vocal animal noises).
        - Involuntary: Burp, Hiccup, Cough, Sneeze.
- **Switching Pause**
    - A switching pause is coded as the time between when one speaker stops speaking and the other speaker begins speaking. It is attributed to the individual who breaks the pause.
- **Intrapersonal Pause**
    - An intrapersonal pause is coded as the time between when one speaker stops speaking and the same speaker begins speaking again. It is attributed to the speaker who speaks before and after the pause.
- **Interruptions**
    - Interruptions are coded when both speakers are vocalizing at the same time.
    - Interruptions are attributed to the interrupting speaker.

# APPENDIX D

# MEANS, STANDARD DEVIATIONS, AND INTERCORRELATIONS OF ALL CONVERSATIONAL STATE VARIABLES

**Table 15.** Means, standard deviations, and intercorrelations of all conversational state variables

| | M | SD | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. F Caregiver Voc | 68.81 | 22.16 | -- | | | | | | | | | | |
| 2. F Infant L | 24.63 | 19.07 | -.024 | -- | | | | | | | | | |
| 3. F Infant NL | 7.78 | 7.70 | .256 | .322 | -- | | | | | | | | |
| 4. M Caregiver IP | 2.93 | 1.69 | -.771** | -.336 | -.359* | -- | | | | | | | |
| 5. M Infant IP | 1.89 | 1.631 | -.543** | -.246 | -.226 | .492** | -- | | | | | | |
| 6. M Caregiver SP | 2.19 | 1.47 | -.674** | -.359* | -.356* | .638** | .546** | -- | | | | | |
| 7. M Infant SP | 2.54 | 1.72 | -.531** | -.448* | -.354* | .492** | .573** | .557** | -- | | | | |
| 8. CV Caregiver SP | 1.33 | 0.34 | -.241 | .079 | .068 | .260 | .142 | .073 | -.017 | -- | | | |
| 9. CV Infant SP | 1.77 | 3.11 | -.241 | -.102 | -.069 | .355* | .139 | .384* | -.300 | .447* | -- | | |
| 10. F Caregiver Interrupt | 4.44 | 4.46 | .452** | .377* | .665** | -.448* | -.212 | -.464** | -.435* | .130 | -.065 | -- | |
| 11. F Infant Interrupt | 6.03 | 5.70 | .369* | .571** | .795** | -.449** | -.304 | -.510** | -.493** | .029 | -.094 | .706** | -- |
| 12. Mean Interrupt | 0.49 | 0.22 | .177 | .064 | .250 | -.236 | -.067 | -.155 | -.046 | .125 | -.046 | .467** | .211 |

*Note*. ** < 0.01 level; *p<.05.; F = Frequency; M = Mean; Voc = Voluntary Vocalization; L = Linguistic; NL = Non-Linguistic; IP = Intrapersonal Pause; SP = Switching Pause; CV = Coefficient of Variance.

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