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Shivani Patel April 9, 2015

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An abstract of
a thesis submitted to the Faculty of Emory College of Arts and Sciences
of Emory University in partial fulfillment
of the requirements of the degree of
Bachelor of Arts with Honors

Department of Linguistics

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Abstract

The Relationship Between Prosody and the Development of Conversational Turn-Taking In Infants at High and Low Risk of Autism Spectrum Disorder

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Prosody and social interaction are known to be two key elements of the developmental scaffold on which infants build language; however, there is little research exploring whether one element subserves the other or if they are inherently independent or interdependent. The goal of this study is to advance our understanding of early language development by investigating the influence of prosody on the timing of conversational turn-taking between infants at high and low risk of autism and their caregivers over the first fifteen months of life. We test the hypothesis that conversational turn-taking in infancy is stimulated by developmental changes in the intonation of caregiver infant-directed speech. Furthermore, we hypothesize that the derailment of synchronous conversational interactions in infants who go on to develop autism is a consequence of a receptive prosodic deficit present early in infancy. As part of an ongoing NIH Autism Center of Excellence program project, we collected day-long home recordings of 2 low-risk and 2 high-risk infants at 3, 6, 9, 12, and 15 months of age. We hand-coded each conversational interaction between primary caregiver and infant in the recordings. Final processing of the segments resulted in intonation contours derived from the original speech signal, event markers denoting the onset and offset of each utterance, and labels denoting the speaker of each utterance. Though the analysis did not find a statistically significant relationship between prosody and conversational interactions between risk groups across the first fifteen months of life, we fully expect that with greater power, the results will reach statistical significance. The present results do, however, establish a trajectory of conversational interactions expected in typical development and demonstrate a striking plateau in the high risk infants' interactions. Furthermore, the results

provide valuable information regarding the different ways in which caregivers of infants at high risk of autism may respond when their child is not demonstrating a typical progression towards spoken language. This information will be of great use in developing specifically targeted clinical interventions.

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Acknowledgements

I would like to express my deepest gratitude to Dr. Gordon Ramsay for the guidance and support he has provided in pursuit of this independent project. I am grateful for all of the members of the Spoken Communication Laboratory, who have helped shape the researcher I have become. I am so thankful to have had the opportunity to see our work develop and look forward to seeing what directions the Spoken Communication Laboratory will take in the future. I would also like to thank Dr. Lynne Nygaard and Dr. Philippe Rochat for serving on my Honors Thesis Committee. It was a great pleasure to present my work to you and to hear your insightful comments and suggestions. I would especially like to thank all of the families who participated in our study. This work would not have been possible without your dedicated involvement.

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The Relationship Between Prosody and the Development of Conversational Turn-Taking in Infants at High and Low Risk of Autism Spectrum Disorder

Introduction

Prosody, referring to the intonation, stress and rhythm of speech, and social interaction are known to be two key elements of the developmental scaffold on which infants build language. While there is a great deal of research investigating these topics independently, there is little research exploring whether one element subserves the other or if they are inherently independent or interdependent. One way to investigate the link between prosody and social interaction is to compare typical development to neurodevelopmental disorders in which there are known impairments related to these elements. Autism is a neurodevelopmental disorder characterized by core deficits in social communication and restricted interests or repetitive behaviors (American Psychiatric Association, 2013). Deficits in expressive and receptive prosody have been identified as core features of autism since the earliest descriptions of the disorder by Kanner and Asperger (Asperger & Frith, 1991; Kanner, 1943), but the nature of prosodic derailment in autism remains unclear (Baltaxe & Simmons, 1985; Dawson, 1989; McCann & Peppé, 2003; Paul, Augustyn, Klin, & Volkmar, 2005; Pronovost, Wakstein, & Wakstein, 1966; Schopler & Mesibov, 1992; Tager-Flusberg, 1981). Though autism is known to have a genetic basis (Folstein & Rutter, 1977) and seems to be present from birth, a reliable clinical diagnosis is not currently available until two years of age. The goal of this study is to advance our understanding of early language development by investigating the influence of prosody on the development of conversational turn-taking between infants at high and low risk of autism and their caregivers over the first fifteen months of life.

Prosodic function is typically divided into three areas—pragmatic, grammatical, and affective (McCann & Peppé, 2003). The pragmatic function includes using stress to denote contrastive words or using the appropriate intonation or inflection to indicate utterance type. Grammatical functions of prosody include using appropriate pause, stress and intonation to segment utterances. The affective function of prosody encompasses the use of factors such as intonation, loudness, and speech rate to express emotions or affective state. The majority of the literature on prosody in autism has focused on its pragmatic and affective functions, yet there have been no conclusive findings combining the expressive and receptive nature of the prosodic deficit in autism (McCann & Peppé, 2003). In adulthood, the prosodic deficit is an easily recognizable sign of disorder due to the unnatural tone of voice, lack of affective quality, atypical stress patterns, and poor loudness control. Even as individuals with autism spectrum disorder show improvement in other domains of language, prosodic development shows little change (Paul et al., 2005). The importance of expressive prosody for gaining social acceptance and the lack of conclusive research regarding the receptive nature of the prosodic deficit in autism calls for further research.

Information provided by prosody is often considered supplementary to vocal communication; however, it is vital in conveying extralinguistic information and is the most salient feature of vocal communication from the womb through infancy. Exposure to prosody begins prenatally in the womb, and infants use intonation to convey desires before they learn conventional phonetic forms of expression (Lehiste, 1970). Prosodic aspects of speech are highly prominent in both production and perception of language over the first two years of life (Crystal, 1979). Due to the low-pass filtering of sound into the womb, lower frequency characteristics of speech, such as prosody, are transmitted to the fetus much more clearly than higher frequency acoustic properties (Karmiloff & Karmiloff-Smith, 2009). The maternal voice is unique in that it is transmitted to the fetus with greater intensity than extra-uterine sounds and is accompanied by vibratory maternal body conduction (Querleu, Renard, Boutteville, & Crepin, 1989). For these reasons, preference for the maternal voice (Cooper & Aslin, 1990; Fernald, 1985) established in the womb plays a fundamental role in an infant's early development. For instance, within days after birth, infants demonstrate greater preference for stories read to the womb during the last trimester than for novel stories (DeCasper & Spence, 1986). Furthermore, infants discriminate their ambient language from another language when all linguistic properties excluding prosody are eliminated (Mehler et al., 1988).

When talking to infants, adults use a different speech register characterized by a wider fundamental frequency range, greater pitch modulation and increased duration (Ferguson, 1964; Fernald & Simon, 1984; Papoušek, Papoušek, & Haekel, 1987; Snow & Ferguson, 1979; Stern, Speiker, Barnett, & MacKain, 1983). This special speech register is referred to as infant-directed speech (IDS). As part of this register, mothers have been found to consistently exaggerate pitch at the end of their utterances (Fernald & Mazzie, 1991). Fernald and Kuhl (1987) conducted a series of experiments to determine if infants prefer auditory signals derived from the prosodic characteristics of IDS over those derived from traditional adult-directed speech. They found that infants demonstrated a stronger preference for the fundamental frequency patterns of infant-directed speech over those of adult-directed speech. However, infants did not demonstrate a similar preference for the amplitude or duration patterns of infant-directed speech. These results suggest that fundamental frequency is a highly salient feature of infant-directed speech. For these reasons, the present study examines the influence of caregiver fundamental frequency on the development of conversational turn-taking in infancy.

For purely physiological reasons, the fundamental frequency (f_0) of the voice decreases over the course of an utterance (Collier, 1975), naturally signaling major syntactic boundaries. Furthermore, speakers tend to produce a steeper f_0 when using highly modulated speech and a wider pitch range (Fernald & Simon, 1984; Grieser & Kuhl, 1988), as is the case in infant-directed speech. According to the "prosodic bootstrapping" hypothesis, pre-linguistic infants exploit these prosodic cues in order to identify phrase groups before they have developed an understanding of what speech is (Gleitman & Wanner, 1982). This suggests that prosody acts as an anchor for the infant's language development and therefore plays a key role in early language acquisition. Additionally, it is important to remember that the timing of bidirectional conversational interactions between infant and caregiver, not the unidirectional influences of the caregiver alone, strongly influences the growth and richness of an infant's language environment. Infant and caregiver provide "mutual stimulation and reinforcement," which lead to the development of a unique style of communication open to modification (H. Papoušek & Papoušek, 1975). The development and malleability of this infant-caregiver relationship further emphasizes the importance of social interaction on the development of communication.

Through the first two years of development, conversational asymmetries transform from caregiver-initiated interactions, to vocal clashes between caregiver and infant, to adult-like conversational turns (M. Papoušek, 1995). Caregivers need to be exquisitely sensitive to temporal contingencies in infant responses, just as infants need to be increasingly sensitive to contingent responses from surrounding caregivers. The resonant coupling between mother and child forms the basis for the natural process of social interaction that drives the infant along the path to spoken language. Feldman (2007) presents a timeline of synchrony ranging from the third trimester of pregnancy to the first year of life and onward. She describes the development of synchrony as a lead-lag dance in which the caregiver initially takes the lead. Soon after birth, the infant readily engages in social dyadic interactions with the caregiver. For example, Bloom (1975) found that adult stimulation caused an immediate increase in three-month-old infants' vocalizations, whereas a lack of adult input caused dramatic decreases in infant vocalization rate. This suggests that social stimulation among mother-infant dyads early in life has the power to elicit infant vocalizations. At around nine months of age, infants begin to develop joint attention skills and engage in triadic interactions. According to Feldman (2007) it is at this point in time that infant-caregiver interactions undergo an important reorganization in which the time lag to synchrony decreases. This lead-lag dance is continually refined until twelve months of age and beyond as each partner becomes more aware of the other's needs and desires.

Specific analyses of vocal interactions between mothers and infants have shown that mothers are most likely to vocalize within one second of an infant's vocalization and increasingly less likely to respond in the following seconds (Keller, Lohaus, Völker, Cappenberg, & Chasiotis, 1999; Van Egeren, Barratt, & Roach, 2001). By four to five months of age, infants develop an attunement to their mother's timing and relative contingency in interacting with them (Rochat, 2001). Maternal affective expression and contingency play a large role in an infant's socioemotional development (Cohn & Tronick, 1989). Numerous studies have shown that contingent interactions between caregiver and infant elicit both greater positive affect in the infant and modified responses shaped by the adult's input (Goldstein & Schwade, 2008; Rheingold, Gewirtz, & Ross, 1959; Trevarthen, 1979; Tronick, Als, & Adamson, 1979).

The goal of this study is to investigate the link between caregiver prosody and the development of conversational interactions between primary caregiver and infant. We aim to map out the developmental progression of mothers' infant-directed speech and changes in infant-caregiver interactions with respect to the infant's development. The interplay between f_0 in the acquisition of language and the development of conversational turn-taking has yet to be examined and may provide key insight into the development of social communication in infancy.

We test the hypothesis that conversational turn-taking in infancy is stimulated by developmental changes in the intonation of caregiver infant-directed speech. Furthermore, we hypothesize that the derailment of synchronous conversational interactions in infants who go on to develop autism is a consequence of a receptive prosodic deficit present early in infancy. By examining the emergence of features known to be deficient in autism, we hope to improve the prospect of early diagnosis and early intervention.

Method

The present study was conducted as part of an ongoing, prospective, longitudinal study funded by an NIH Autism Center of Excellence program project (NIH P50 MH100029), which includes studies investigating a) eye-tracking measures of social engagement [Project I], b) acoustic measures of spoken language development [Project II] and c) early treatment of infants at risk of ASD over the first two years of life [Project III]. The Home Recordings of Infant Speech study (Project II) aims to follow 230 infants at high risk of autism, 50 infants at risk of developmental delays due to low socioeconomic status, and 50 children at low risk of autism spectrum disorder or other developmental delays from birth to 36 months of age through the collection of daylong audio recordings made at monthly intervals. This study complements the ongoing research by utilizing a subset of the densely-sampled recordings of vocal behavior collected as part of Project II to investigate the influence of prosody on the development of conversational turn-taking in infants at risk of autism spectrum disorder. Notably, it is an original contribution to the existing project as investigating the relationship between prosody and conversational turn-taking was not part of the original program project proposal.

Participants

This study examined a subset of two infants at high risk of autism and two infants at low risk of autism from those enrolled in Project II. Inclusion criteria for participation in the study included living within a 30-mile radius of Atlanta, Georgia, enrolling in the study prior to 3 months of age, and having at least one older sibling with or without ASD. Infants with one or more older siblings diagnosed with an autism spectrum disorder were enrolled in the high-risk (HR-ASD) group, whereas infants with all typically developing older siblings, no documented pre- or perinatal complications, and no family history of ASD were enrolled in the low-risk (LR-TDx) group. Exclusion criteria for the study included gestational age below 34 weeks, major hearing or visual impairment determined during the neonatal period, non-febrile seizure disorders, or a known genetic syndrome. In order to avoid gender-biased results in our small sample, we included one male and one female in the LR-TDx and HR-ASD groups. However, in addition to the known gender difference in autism (4 males: 1 female), females with autism have been found to exhibit greater impairments in social communication, language, and adaptive function (Frazier, Georgiades, Bishop, & Hardan, 2014), which may lead to greater variability between participants in the HR-ASD group.

Diagnostic Assessments

As part of the initial intake interview, families who already had a child with autism who did not receive a diagnosis of ASD from the Marcus Autism Center were screened with a parent interview to verify the diagnosis of the older sibling. Families were only enrolled in the study if a reliable diagnosis of ASD was ascertained for the older sibling. We focus on four domains of function for diagnostic characterization: cognitive ability, adaptive function, communication and social affect, and autistic symptomatology. All infants were assessed using the *Mullen Scales of Early Learning* (Mullen, 1995) in order to determine their developmental level at 12, 24, and 36 months of age. This test provides standardized scores in five areas: Visual Reception, Receptive Language, Expressive Language, Fine Motor Skills, and Gross Motor Skills. To measure adaptive function, we administered the *Vineland Adaptive Behavior Scales-II*, a parent questionnaire assessing the infant's Communication, Daily Living Skills, Socialization, and Motor Skills (Sparrow, Cicchetti, & Balla, 2005), at 12, 24, and 36 months of age. In order to evaluate verbal and non-verbal communication and social-affective and symbolic abilities of infants from 6-24 months of age, clinicians administered the *Communication and Symbolic Behavior Scales* (CSBS) (Wetherby & Prizant, 2002). Like the other assessments, the CSBS was administered at 12, 24, and 36 months. In order to establish a diagnosis of autism, the *Autism Diagnostic Observation Schedule—Second Edition: Modules 1,2* (Lord, Luyster, Gotham, & Guthrie, 2012a) and *Toddler Module* (Lord, Luyster, Gotham, & Guthrie, 2012b) were administered. This assessment examines the child's behavior in terms of social communication, social relatedness, play and imagination, and restricted and/or repetitive behaviors. Every child determined to be at risk of autism at the 12-month visit was given the ADOS-T. Depending on the infant's language level at the 24- and 36-month visits, the clinician chose to administer the ADOS 1-2 or ADOS-T. All infants classified as having ASD or a developmental disorder at the 24-month visit, will be reevaluated when they reach 36 months of age in order to confirm their diagnosis. All assessments were conducted by trained clinicians at the Marcus Autism Center.

Both participants in the HR-ASD group received preliminary diagnoses of autism spectrum disorder at their 24-month visits. The LR-TDx participants showed no signs of autistic symptomatology and are assumed to be typically developing.

Data Collection

Audio recordings were collected monthly using LENA Digital Language Processors (DLP) (Xu, Yapanel, & Gray, 2009). Weighing only 70g, the DLP is a miniature battery-operated recorder that contains a signal processing unit capable of digitizing and storing up to 16 hours of audio data sampled at 16kHz with 16-bit resolution. It uses an omnidirectional microphone with a flat 20Hz-20kHz-frequency response and an internal clock that time-stamps every recording. Data from the DLP were downloaded to a computer via an integrated USB interface, resulting in a single audio file containing the entire recording.

During the process of obtaining consent for a child's participation in the study, we trained parents in the recording procedure and scheduled the initial recording target date. The subsequent recording dates were scheduled to occur on the same calendar date every month in order to rotate weekdays. The present study utilized recordings made at 3, 6, 9, 12, and 15 months of age as determined by gestational age.

One day prior to the scheduled recording date, a package containing detailed instructions for how to use the recorder, a charged DLP, a labeled return envelope, and clothing was sent to the family. On the day of the recording, parents dressed their child in the specially designed romper suit or T-shirt that we provided, as soon as they awoke. The DLP was then turned on and secured in the chest pocket on the clothing, thereby ensuring a constant 7-10cm distance between the microphone and the infant's mouth (Figure 1). This constant distance allows for enhanced recording quality. The recording process was entirely automatic and required no further intervention during the day. Before the child went to sleep at the end of the day, the parent removed and turned off the DLP, which they then returned to us using the labeled return envelope sent in the original package. Families were compensated $20 for each recording made.

Upon receiving the recorder, we transferred the recording from the DLP to a computer, checked for errors, and uploaded it to our data server.

Segmentation

Each daylong recording was segmented by hand for mother-infant interactions using Audacity® (Audacity Team, 2014). Conversational interactions were defined as a period in which the primary caregiver or infant responded to the initiating party within a 5 second period. A minimum of one non-cry vocalization was required by the other party. In total 230 hours were segmented, yielding a total of 2,043 episodes of infant-caregiver conversations. The short-term amplitude envelope and zero-crossing rate were calculated using Homunculus, a program developed by Dr. Gordon Ramsay, director of the Spoken Communication Laboratory at the Marcus Autism Center. We defined a minimum threshold in order to separate the speech segments from the background noise and silence segments. We then used fundamental frequency contour estimation based on harmonic analysis to extract the intonation contours. Next, we automatically placed event markers at the beginning and end of each utterance. We listened to each processed conversational interaction to label each contour with the appropriate speaker. Finally, using the event markers as utterance boundaries, we calculated the minimum, maximum, range, and mean fundamental frequency of each caregiver utterance. The end product resulted in intonation contours derived from the original speech signal, event markers denoting the onset and offset of each utterance, and labels denoting the speaker of each utterance (Figure 2). This segmentation enabled us to analyze the relationship between the fundamental frequency statistics and the development of conversational interactions between infant and caregiver. For the purposes of this analysis, we examined ten interactions per time point for each participant.

Participant Group Matching

There are often various comorbidities associated with autism spectrum disorder. In order to ensure that our analysis could be attributed to the influence of caregiver prosody and not intellectual disability on part of the child, participants were matched for non-verbal cognitive ability (Table 1). Matching for non-verbal cognitive ability was based on the Visual Reception subtest of the *Mullen Scales of Early Learning* (Mullen, 1995), which specifically assesses an infant or child's non-verbal problem solving abilities. In order to compare verbal function among participants in both groups, we used scores from the Receptive Language subtest, which specifically assesses an infant or child's ability to understand language. As shown in Table 1, there were no significant differences between risk groups.

Results

Case Study

We preface our results with a qualitative description of the recordings because listening to the audio data provided great insight into the different social interaction styles between infants and their caregivers. The high risk infant-caregiver dyads exhibited two different interaction styles, whereas both low risk infant-caregiver dyads had very similar interaction styles. The audio recordings provide information that is not necessarily evident from the figures alone and allow for a clearer interpretation of the results.

LR-TDx dyads 1 and 2. Through listening to both low risk infant-caregiver dyads, we heard the expected natural progression of caregiver infant-directed speech. In the early months of the infants' lives, both caregivers used higher pitches and greater modulation; however, by the time the infants were 15 months of age, both caregivers talked to them just as they talked to the child's older sibling. This noticeable decline in caregiver infant-directed speech occurred at the same time as the increase in number of infant-caregiver conversational interactions. In typical development, caregivers alter the quality of their infant-directed speech in response to their child's progress in language acquisition and conversational turn-taking.

HR-ASD dyad 1. Through listening to the recordings, it was evident that the mother was talking to her daughter in the same way at 15 months as she did at 3 months. This supports what we saw in Figures 4-6, as the mother exhibited very little change in fundamental frequency from 3 to 15 months. Furthermore, it is clear in the recordings that the infant was not demonstrating great progression in her language development by 15 months of age. Combining what we heard in the recordings with the quantitative data in Figure 4, it becomes clearer that the infant is not increasingly engaging in conversational interactions with the caregiver. So, despite the caregiver's efforts to scaffold her infant's language development through the use of exaggerated pitch, the infant was not typically acquiring language.

HR-ASD dyad 2. In the second high risk infant-caregiver dyad, the mother started off with exaggerated infant-directed speech, but by 15 months, she had the same fundamental frequency as the mothers of the low-risk infants. However, as we see in Figure 4, high-risk infant 2 had approximately the same number of conversational interactions as high-risk infant 1, which were significantly fewer than the number of interactions the low risk infants were engaging in. By listening to HR-ASD dyad 2, we know that these changes in the mother's fundamental frequency were not reflective of her infant's language development, as her child sounds very different from both low risk infants. Through discussions with our clinicians, we learned that the child is receiving speech therapy through his pre-school program. Due to some improvements in the child's linguistic abilities after beginning therapy, the mother may have felt her child was doing better than he would have otherwise. For this reason, she may have stopped trying to scaffold his language with infant-directed speech, which would explain the decline in caregiver fundamental frequency.

Test of Main Hypotheses

Visual inspection of Figures 3 – 7 indicated clear patterns of differences in behavior across groups, similar to what we heard in the audio data alone. In order to quantify these patterns, we conducted two Repeated Measures Analysis of Variances (RM-ANOVA) with risk group (HR-ASD, LR-TDx) as the between-subjects factor with two levels (3 and 15 months of age) spanning developmental time. We expected significant differences across developmental time and risk group for number of conversational interactions, as well as fundamental frequency mean, range, and maximum.

RM-ANOVA to test for changes in the number of infant-caregiver conversational interactions found a significant different between risk groups ($F(1,2) = 10.5$, $p = 0.012$). However, there was no significant difference in the overall progression of conversational interactions from 3 to 15 months of age ($F(1,2) = 0.806$, $p = 0.396$).

RM-ANOVA for difference in mean fundamental frequency (Table 2) showed that the difference between the 3-month and 15-month time points was not statistically significant ($F(1, 2) = 7.50$, $p = .112$). Similarly, difference in mean fundamental frequency between risk groups was not statistically significant ($F(1, 2) = 8.87$, $p = .097$). Though the results do not indicate evidence of an interaction between developmental time and risk group, the analysis shows that the difference in mean fundamental frequency across time points was approaching significance in the LR-TDx group ($F(1, 2) = 115$, $p = .059$). Furthermore, RM-ANOVA for difference in f_0 range (Table 3) was not statistically significant across time ($F(1, 2) = .518$, $p = .547$) or risk group ($F(1, 2) = 2.93$, $p = .229$). However, there was a significant difference in f_0 range between subjects in the LR-TDx group (F(1, 2) = 168, p = 0.049). RM-ANOVA for f_0 maximum (Table 4) showed that there was no statistically significant difference across time (F(1, 2) = 1.72, p = .320), or risk group (F(1, 2) = 5.26, p = .149).

Pearson's test for correlation was used to test the hypothesis that an increase in the number of conversational interactions would be associated with decreased fundamental frequency of caregiver infant-directed speech (Figure 7). There was strong, negative correlation between caregiver fundamental frequency and number of conversational interactions in the low risk infant-caregiver dyads (r = -0.762, p = 0.239), indicating that a low fundamental frequency would predict a greater number of conversational interactions. There was a weak, positive correlation between caregiver fundamental frequency and number of conversational interactions in the high risk infant-caregiver dyads (r = 0.268, p = 0.732).

Because analyses did not yield statistically significant results, we fail to reject the null hypothesis that caregiver prosody does not influence the development of conversational turn-taking in infancy. However, we suspect the lack of significance is due to insufficient power. We fully expect that the results will be statistically significant when we add more participants because the audio data wholly support our hypotheses.

Discussion

The present study investigated the influence of caregiver prosody and the development of conversational turn-taking in infants at high and low risk of autism spectrum disorder. The study suggests that the prosody of caregivers of infants at high risk of autism differs from caregivers of infants at low risk of autism from as early as 3 months of age. Mothers of LR-TDx infants had similar mean fundamental frequencies, as well as f_0 maxima and range. Conversely, mothers of HR-ASD infants had greater mean values, maxima, and ranges of fundamental frequency than the mothers of LR-TDx infants. The greater fundamental frequency range and greater maximum fundamental frequency in the caregivers of HR-ASD participants demonstrate that these caregivers raise their pitch and modulate their voices more than the caregivers of LR-TDx infants in an attempt to motivate their unresponsive children to engage in the interaction.

Furthermore, the developmental trajectory of the mothers of LR-TDx infants was found to be nearly parallel in each participant, whereas there was greater variability in the developmental trajectories of HR-ASD caregiver fundamental frequencies. For instance, Figure 4 demonstrates that one of the HR-ASD mothers initially had a higher mean f_0 but later shifted to a trajectory similar to that of the LR-TDx caregivers around 12 and 15 months of age. However, the same figure shows that the caregiver of the second HR-ASD participant exhibited very little change in mean fundamental frequency between the 3 and 15-month time points. Thus, we see two distinct developmental progressions of caregiver prosody from 3 to 15 months of age.

However, Figure 3 shows a similar pattern in both of HR-ASD participants in terms of the number of conversation interactions they participated in. The results establish a notable increase in the number of conversational interactions in the LR-TDx group around 12 months of age, but a plateau in the HR-ASD infants number of conversational interactions. Social interaction, as expressed by the number of conversational interactions, has been throttled in both HR-ASD infants. Because the changes in the prosody of caregiver infant-directed speech are occurring along the same time frame as the changes in conversational interactions, the results suggests that there is likely a strong connection between prosody and social interaction. Based on the highly similar progression of caregiver prosody in the LR-TDx group, we posit that caregiver prosody is a valuable indicator of a child's language learning stage. Typical development is robust against minor differences between caregivers and infants, ensuring that all children ultimately achieve a similar level of linguistic ability; however, the disruption of these mechanisms in autism leads to variable outcomes. This also results in different strategies among caregivers as they try to drive their infant further along the path to spoken language.

Clinical Implications

As a whole, the results provide evidence that there are noticeable differences in caregiver prosody between mothers of infants at high and low risk of autism spectrum disorder. We have documented the pattern of prosody and social interaction in LR-TDx infants and have established that both develop along the same time scale. Our results lucidly illustrate two different ways in which parents may react when their child is not exhibiting a typical progression towards spoken language. One caregiver of an HR-ASD participant hyper-articulated her infant-directed speech and demonstrated very little change in prosody as her infant aged from 3 to 15 months, while the caregiver of the second HR-ASD infant started off like the first caregiver but then seemed to give up as the infant aged to 15 months. Both of these strategies differ from the path found in the LR-TDx group and indicate that prosodic patterns from the first months of life can inform us about the different relationships between caregiver and infant. We can use this dyad-specific information to formulate intervention strategies specific to the interaction style of the pair. This work has the potential to be especially influential in changing the lives of children with autism through education of parents and teachers on the importance of stimulating child-adapted conversations early in infancy.

Future Directions

The present study investigated the developmental progression of caregiver infant-directed speech and conversational turn-taking between mother-infant dyads over the span of 15 months. The results presented represent only a small fraction of the utterances coded, so in order to obtain a clearer picture of the developmental trajectories, we aim to expand the analysis to the entire corpus. In future work, we aim to complete an in-depth study of the influence of prosodic bootstrapping on the development of conversational turn-taking by examining these relations on a moment-to-moment basis within each conversational interaction. The proposed study (Appendix A) has been awarded funding through a National Science Foundation Graduate Research Fellowship Program grant, and the author intends to pursue this study as part of her doctoral work.

Conclusions

This study established that there is a steady increase in conversational interactions across the first year of life in typical development. We showed that there is no such increase in conversational interactions in infants who go on to receive a diagnosis of autism spectrum disorder. Furthermore, we demonstrated a systematic decline in mean, maximum, and range of fundamental frequency in caregiver prosody across a typically developing infant's first year of life. Caregivers of the HR-ASD participants, both of whom received diagnoses of autism, exhibited heterogeneous prosodic patterns across the same time frame. This study demonstrated that prosodic changes in caregiver-infant directed speech occur along the same developmental time frame as progressions in conversational interactions, reflecting the possible mutual influence between prosody and social interaction.

References

American Psychiatric Association. (2013). *Diagnostic and Statistical Manual 5*.

Asperger, H., & Frith, U. (Trans). (1991). "Autistic psychopathy" in childhood. In U. Frith (Ed.), *Autism and Asperger syndrome* (pp. 37–92). New York: Cambridge University Press.

Audacity Team. (2014). Audacity®. Retrieved from http://audacity.sourceforge.net/

Baltaxe, C. A. M., & Simmons, J. Q. I. (1985). Prosodic development in normal and autistic children. In *Communication problems in autism* (pp. 95–125). New York, NY: Springer.

Bloom, K. (1975). Social elicitation of infant vocal behavior. *Journal of Experimental Child Psychology*, *20*(1), 51–58.

Cohn, J. F., & Tronick, E. (1989). Specificity of infants' response to mothers' affective behavior. *Journal of the American Academy of Child and Adolescent Psychiatry*, *28*(2), 242–248.

Collier, R. (1975). Physiological correlates of intonation patterns. *The Journal of the Acoustical Society of America*, *58*, 249–255.

Cooper, R. P., & Aslin, R. N. (1990). Preference for infant-directed speech in the first month after birth. *Child Development*, *61*(5), 1584–1595.

Crystal, D. (1979). Prosodic development. *Language Acquisition*, 33–48.

Dawson, G. (1989). *Autism: Nature, diagnosis, and treatment*. Guilford, CT: Guilford Press.

DeCasper, A. J., & Spence, M. J. (1986). Prenatal maternal speech influences newborns' perception of speech sounds. *Infant Behavior and Development*, *9*(2), 133–150.

Feldman, R. (2007). Parent-infant synchrony and the construction of shared timing; physiological precursors, developmental outcomes, and risk conditions. *Journal of Child Psychology and Psychiatry and Allied Disciplines*, *48*, 329–354.

Ferguson, C. A. (1964). Baby talk in six languages. *American Anthropologist*, (1956), 103–114.

Fernald, A. (1985). Four-month-old infants prefer to listen to motherese. *Infant Behavior and Development*, *8*, 181–195.

Fernald, A., & Kuhl, P. (1987). Acoustic determinants of infant preference for motherese speech. *Infant Behavior and Development*, *10*, 279–293.

Fernald, A., & Mazzie, C. (1991). Prosody and focus in speech to infants and adults. *Developmental Psychology*, *27*(2), 209–221.

Fernald, A., & Simon, T. (1984). Expanded intonation contours in mothers' speech to newborns. *Developmental Psychology*, *20*(1), 104–113.

Folstein, S., & Rutter, M. (1977). Genetic influences and infantile autism. *Nature*, *265*, 726–728.

Frazier, T. W., Georgiades, S., Bishop, S. L., & Hardan, A. Y. (2014). Behavioral and cognitive characteristics of females and males with autism in the simons simplex collection. *Journal of the American Academy of Child and Adolescent Psychiatry*, *53*(3), 329–340.

Gleitman, L. R., & Wanner, E. (1982). Language acquisition: The state of the art. In E. Wanner & L. R. Gleitman (Eds.), *Language Acquisition: The State of the Art* (Vol. 6, pp. 3–48). Cambridge University Press.

Goldstein, M. H., & Schwade, J. a. (2008). Social feedback to infants' babbling facilitates rapid phonological learning. *Psychological Science*, *19*(5), 515–523.

Grieser, D. L., & Kuhl, P. K. (1988). Maternal speech to infants in a tonal language: Support for universal prosodic features in motherese. *Developmental Psychology*, *24*, 14–20.

Kanner, L. (1943). Autistic disturbances of affective contact. *Nervous Child*, *2*(3), 217–250.

Karmiloff, K., & Karmiloff-Smith, A. (2009). *Pathways to language: From fetus to adolescent*. Cambridge, MA: Harvard University Press.

Keller, H., Lohaus, A., Völker, S., Cappenberg, M., & Chasiotis, A. (1999). Temporal contingency as an independent component of parenting behavior. *Child Development*, *70*(2), 474–485.

Lehiste, I. (1970). *Suprasegmentals*. Cambridge, MA: MIT Press.

Lewis, M. M. (1936). *Infant Speech*. Kegan Paul, Trench & Trubner.

Lord, C., Luyster, R. J., Gotham, K., & Guthrie, W. (2012a). *The Autism Diagnostic Observation Schedule, Second Edition (ADOS-2), Manual (Part I): Modules 1-4*. *The Autism Diagnostic Observation Schedule, Second Edition (ADOS-2)*. Torrance, CA: Western Psychological Services.

Lord, C., Luyster, R. J., Gotham, K., & Guthrie, W. (2012b). *The Autism Diagnostic Observation Schedule, Second Edition (ADOS-2), Manual (Part II): Toddler Module*. Torrance, CA: Western Psychological Services.

McCann, J., & Peppé, S. (2003). Prosody in autism spectrum disorders: a critical review. *International Journal of Language & Communication Disorders*, *38*, 325–350.

Mehler, J., Jusczyk, P., Lambertz, G., Halsted, N., Bertoncini, J., & Amiel-Tison, C. (1988). A precursor of language acquisition in young infants. *Cognition*, *29*, 143–178.

Mullen, E. M. (1995). *Mullen Scales of Early Learning*. Circle Pines, MN: American Guidance Service.

Papoušek, H., & Papoušek, M. (1975). Cognitive aspects of preverbal social interaction between human infants and adults. In *Ciba Foundation Symposium 33-Parent-Infant Interaction* (pp. 241–269).

Papoušek, M. (1995). Origins of reciprocity and mutuality in prelinguistic parent-infant "dialogues." In *Mutualities in dialogue* (pp. 58–81).

Papoušek, M., Papoušek, H., & Haekel, M. (1987). Didactic adjustments in fathers' and mothers' speech to their 3-month-old infants. *Journal of Psycholinguistic Research*, *16*(5), 491–516.

Paul, R., Augustyn, A., Klin, A., & Volkmar, F. R. (2005). Perception and production of prosody by speakers with autism spectrum disorders. *Journal of Autism and Developmental Disorders*, *35*(2), 205–220.

Pronovost, W., Wakstein, M. P., & Wakstein, D. J. (1966). A longitudinal study of the speech behavior and language comprehension of fourteen children diagnosed atypical or autistic. *Exceptional Children*, *33*(1), 19–26.

Querleu, D., Renard, X., Boutteville, C., & Crepin, G. (1989). Hearing by the human fetus? *Seminars in Perinatology*, *13*(5), 409–20.

Rheingold, H. L., Gewirtz, J. L., & Ross, H. W. (1959). Social conditioning of vocalizations in the infant. *Journal of Comparative and Physiological Psychology*, *52*(1), 68–73.

Rochat, P. (2001). *The Infant's World*. Harvard University Press.

Schopler, E., & Mesibov, G. B. (Eds.). (1992). *High-Functioning Individuals with Autism*. Boston, MA: Springer.

Snow, C. E., & Ferguson, C. A. (1979). Talking to children: Language input and acquisition. *Language*, *55*(2), 449–454.

Sparrow, S. S., Cicchetti, D. V., & Balla, D. A. (2005). *Vineland Adaptive Behavior Scales, Survey Form* (2nd ed.). San Antonio, TX: Pearson.

Stern, D. N., Speiker, S., Barnett, R. K., & MacKain, K. (1983). The prosody of maternal speech: infant age and context related changes. *Journal of Child Language*, *10*, 1–15.

Tager-Flusberg, H. (1981). On the nature of linguistic functioning in early infantile autism. *Journal of Autism and Developmental Disorders*, *11*(1), 45–56.

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

Tronick, E., Als, H., & Adamson, L. B. (1979). Structure of early face-to-face communicative interactions. In M. Bullowa (Ed.), *Before speech: The beginning of interpersonal communication* (pp. 349–372). Cambridge, MA: Cambridge University Press.

Van Egeren, L. A., Barratt, M. S., & Roach, M. A. (2001). Mother-infant responsiveness: Timing, mutual regulation, and interactional context. *Developmental Psychology*, *37*, 684–697.

Wetherby, A., & Prizant, B. (2002). *Communication and Symbolic Behavior Scales - Developmental Profile*. Baltimore, MD: Paul H. Brookes.

Xu, D., Yapanel, U., & Gray, S. (2009). Reliability of the LENA language environment analysis system in young children's natural home environment. In *LENA technical reports*. LENA Foundation.

Tables and Figures

Table 1: Matching of Participant Groups

	HR-ASD		**LR-TDx**		
	Mean	SD	Mean	SD	P
Non-Verbal Function	15.50	0.71	16.00	0.00	0.423
Verbal Function	10.00	4.24	10.00	0.00	0.698
Age (months)	12.32	0.13	12.48	0.61	0.744
N (M:F)	2 (1:1)		2 (1:1)		

Table 2: Repeated Measures ANOVA: Mean Fundamental Frequency

LR-TDx:

	SS	df	MS	F	p
Developmental Time	2.047E+03	1	2.047E+03	114.7523	0.0593
Subjects	3.401E+02	1	3.401E+02	19.0626	0.1433
Error	1.784E+01	1	1.784E+01		
Total	2.405E+03	3			

HR-ASD:

	SS	df	MS	F	p
Developmental Time	2.088E+03	1	2.088E+03	1.9238	0.3977
Subjects	4.311E+02	1	4.311E+02	0.3972	0.6420
Error	1.085E+03	1	1.085E+03		
Total	3.605E+03	3			

LR-TDx vs. HR-ASD:

	SS	df	MS	F	p
Developmental Time	4.135E+03	1	4.135E+03	7.4962	0.1115
Risk Group	3.422E+03	1	3.422E+03	8.8732	0.0966
Interaction	1.021E-01	1	1.021E-01	0.0002	0.9904
Subjects (matching)	7.712E+02	2	3.856E+02	0.6990	0.5886
Error	1.103E+03	2	5.516E+02		
Total	9.431E+03	7			

Table 3: Repeated Measures ANOVA: Fundamental Frequency Range

LR-TDx:

	SS	df	MS	F	p
Developmental Time	6.795E+01	1	6.795E+01	26.3437	0.1225
Subjects	4.331E+02	1	4.331E+02	167.9072	0.0490
Error	2.579E+00	1	2.579E+00		
Total	5.036E+02	3			

HR-ASD:

	SS	df	MS	F	p
Developmental Time	5.851E+02	1	5.851E+02	0.2884	0.6863
Subjects	1.616E+03	1	1.616E+03	0.7962	0.5362
Error	2.029E+03	1	2.029E+03		
Total	4.230E+03	3			

LR-TDx vs. HR-ASD:

	SS	df	MS	F	p
Developmental Time	5.259E+02	1	5.259E+02	0.5177	0.5465
Risk Group	3.001E+03	1	3.001E+03	2.9299	0.2291
Interaction	1.271E+02	1	1.271E+02	0.1252	0.7573
Subjects (matching)	2.049E+03	2	1.024E+03	1.0083	0.4979
Error	2.032E+03	2	1.016E+03		
Total	7.735E+03	7			

Table 4: Repeated Measures ANOVA: Fundamental Frequency Maximum

LR-TDx:

	SS	df	MS	F	p
Developmental Time	8.079E+02	1	8.079E+02	39.7279	0.1002
Subjects	2.391E+02	1	2.391E+02	11.7586	0.1806
Error	2.034E+01	1	2.034E+01		
Total	1.067E+03	3			

HR-ASD:

	SS	df	MS	F	p
Developmental Time	1.307E+03	1	1.307E+03	0.544	0.5954
Subjects	8.965E+02	1	8.965E+02	0.3733	0.6509
Error	2.402E+03	1	2.402E+03		
Total	4.605E+03	3			

LR-TDx vs. HR-ASD:

	SS	df	MS	F	p
Developmental Time	2.085E+03	1	2.085E+03	1.7214	0.3199
Risk Group	2.985E+03	1	2.985E+03	5.2578	0.1489
Interaction	2.981E+01	1	2.981E+01	0.0246	0.8897
Subjects (matching)	1.136E+03	2	5.678E+02	0.4688	0.6808
Error	2.422E+03	2	1.211E+03		
Total	8.658E+03	7			

Figure 1. LENA recorder and romper suit. The caregiver turns the recorder on and inserts it into the chest pocket on the romper for the entirety of the recording day.

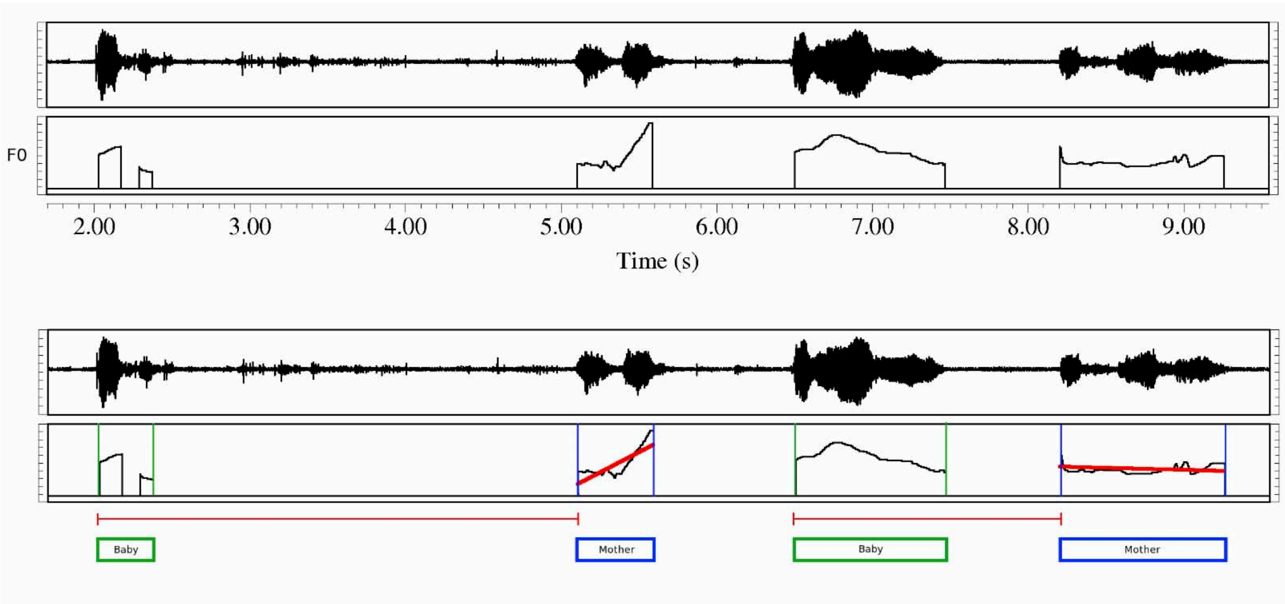

Figure 2. Final output of a single processed conversational interaction. This figure illustrates the intonation contours, event markers, and speaker labels obtained after complete processing of an individual hand-coded segment.

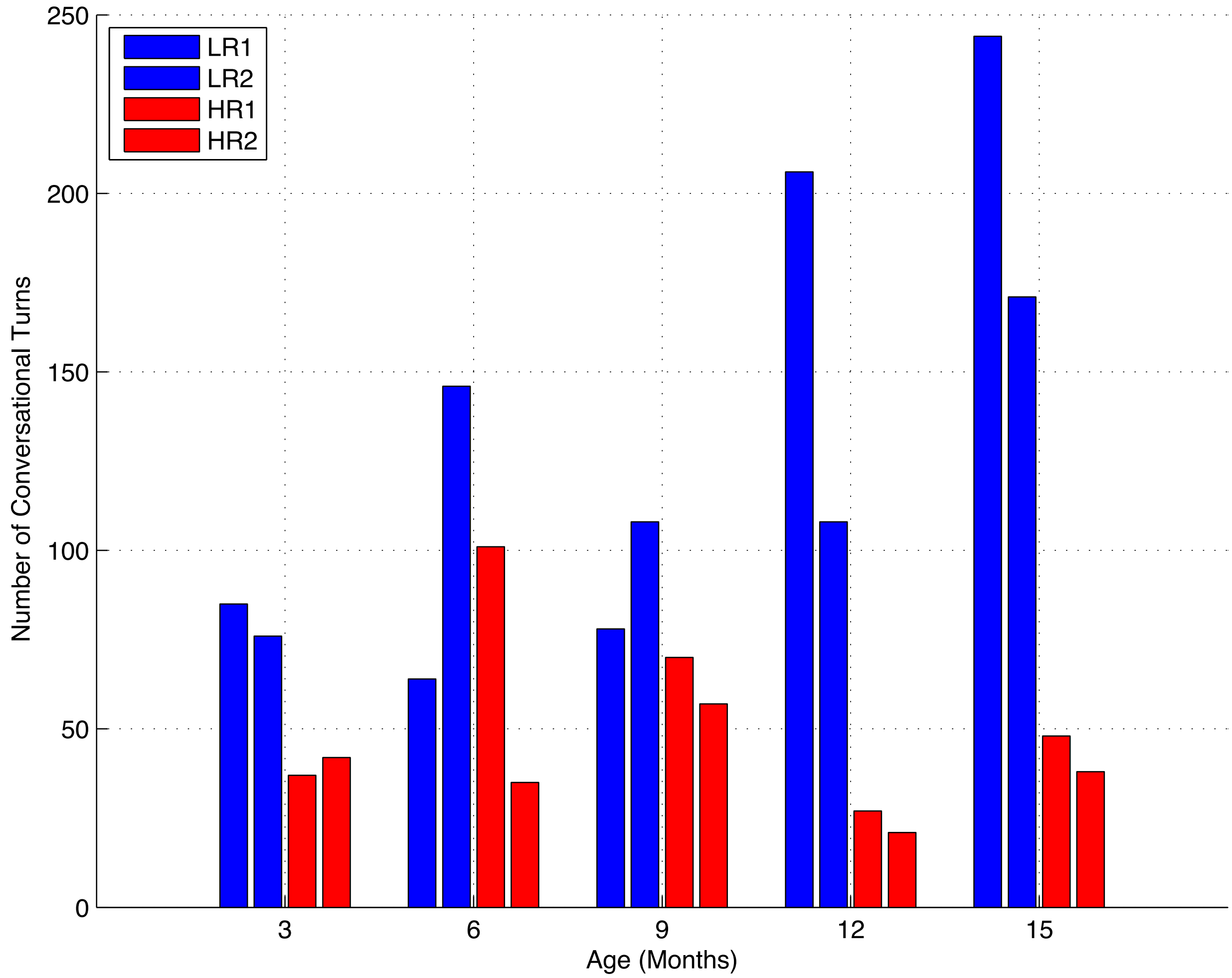

Figure 3: Number of caregiver-infant conversational interactions from 3 to 15 months. This figure of caregiver-infant conversational interactions illustrates the developmental progressions in social interaction in the HR-ASD versus LR-TDx infants from birth until 15 months of age.

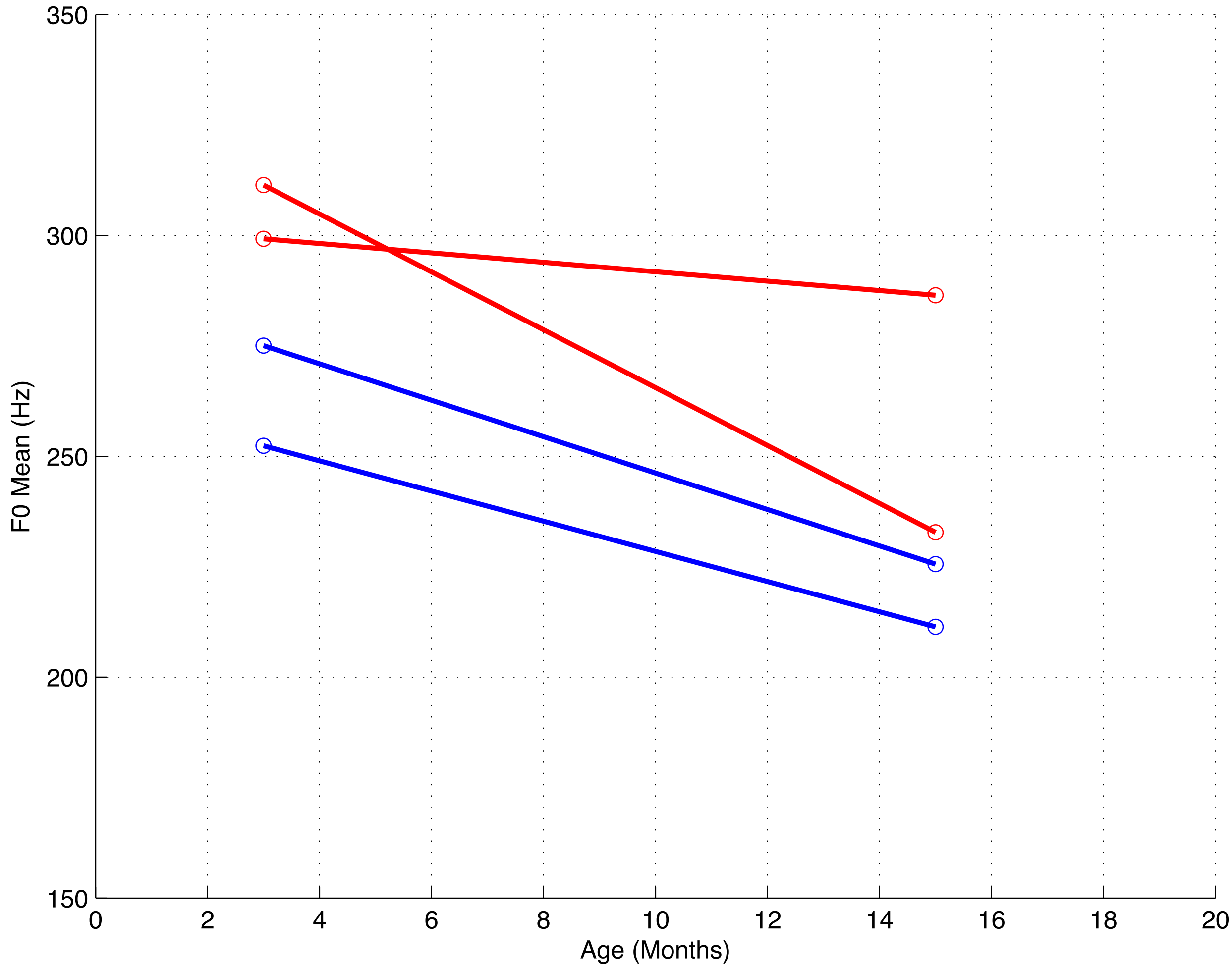

Figure 4: Caregiver mean fundamental frequency trajectories from 3 to 15 months (LR-TDx: blue; HR-ASD: red). This figure demonstrates overall greater mean fundamental frequency in HR-ASD caregivers, as well as greater variability in mean fundamental frequency within the HR-ASD group than the LR-TDx group. The LR-TDx caregivers exhibit a systematic decline in mean fundamental frequency across the first 15 months of life, reflecting changes in infant-directed speech.

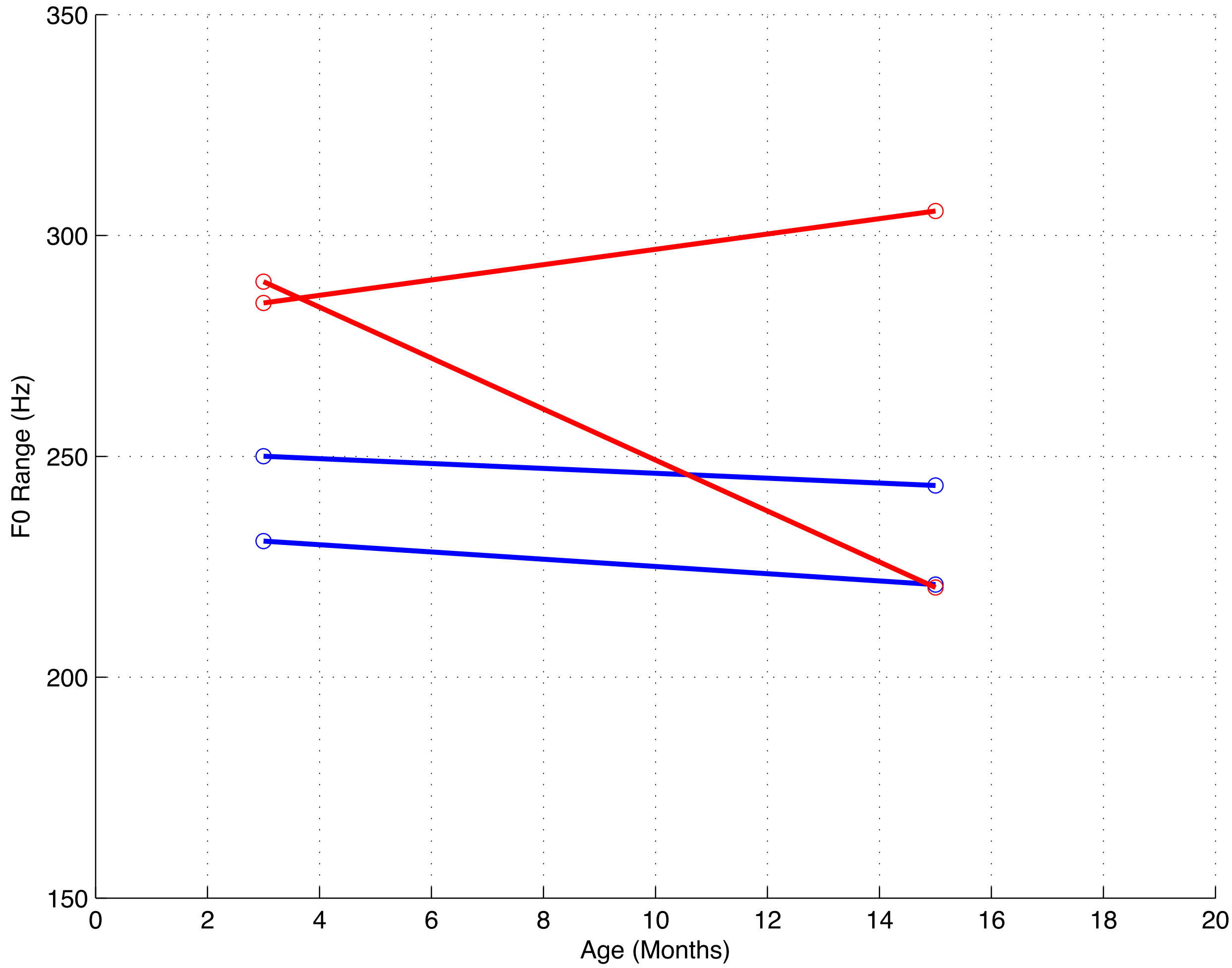

Figure 5: Caregiver fundamental frequency range trajectories from 3 to 15 months. This figure demonstrates that both caregivers of HR-ASD participants initially had comparable fundamental frequency ranges, which were greater than those found in the LR-TDx caregivers. Ultimately, however, one of the HR-ASD caregivers had a fundamental frequency range similar to the LR-TDx caregivers, whereas the other HR-ASD caregiver demonstrated little change in fundamental frequency range.

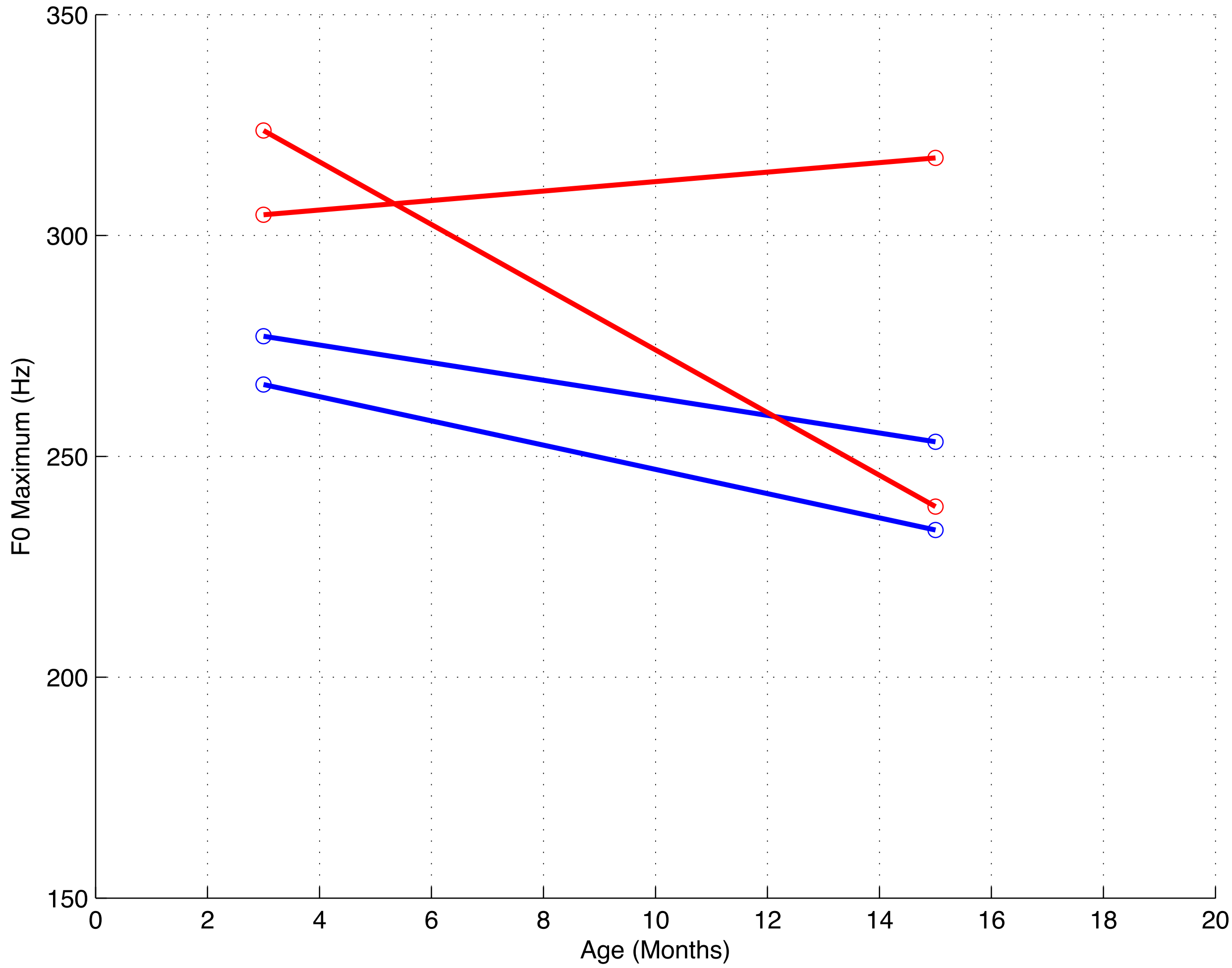

Figure 6: Caregiver fundamental frequency maximum trajectories from 3 to 15 months. This figure demonstrates that caregivers of HR-ASD infants began with greater fundamental frequencies compared to the LR-TDx caregivers. The LR-TDx caregivers systematically decrease their peak fundamental frequency across the first 15 months of life. One of the HR-ASD caregivers ultimately had a maximum fundamental frequency within the range of the LR-TDx caregivers. The second HR-ASD caregiver had a similar maximum fundamental frequency throughout the course of the developmental time period examined.

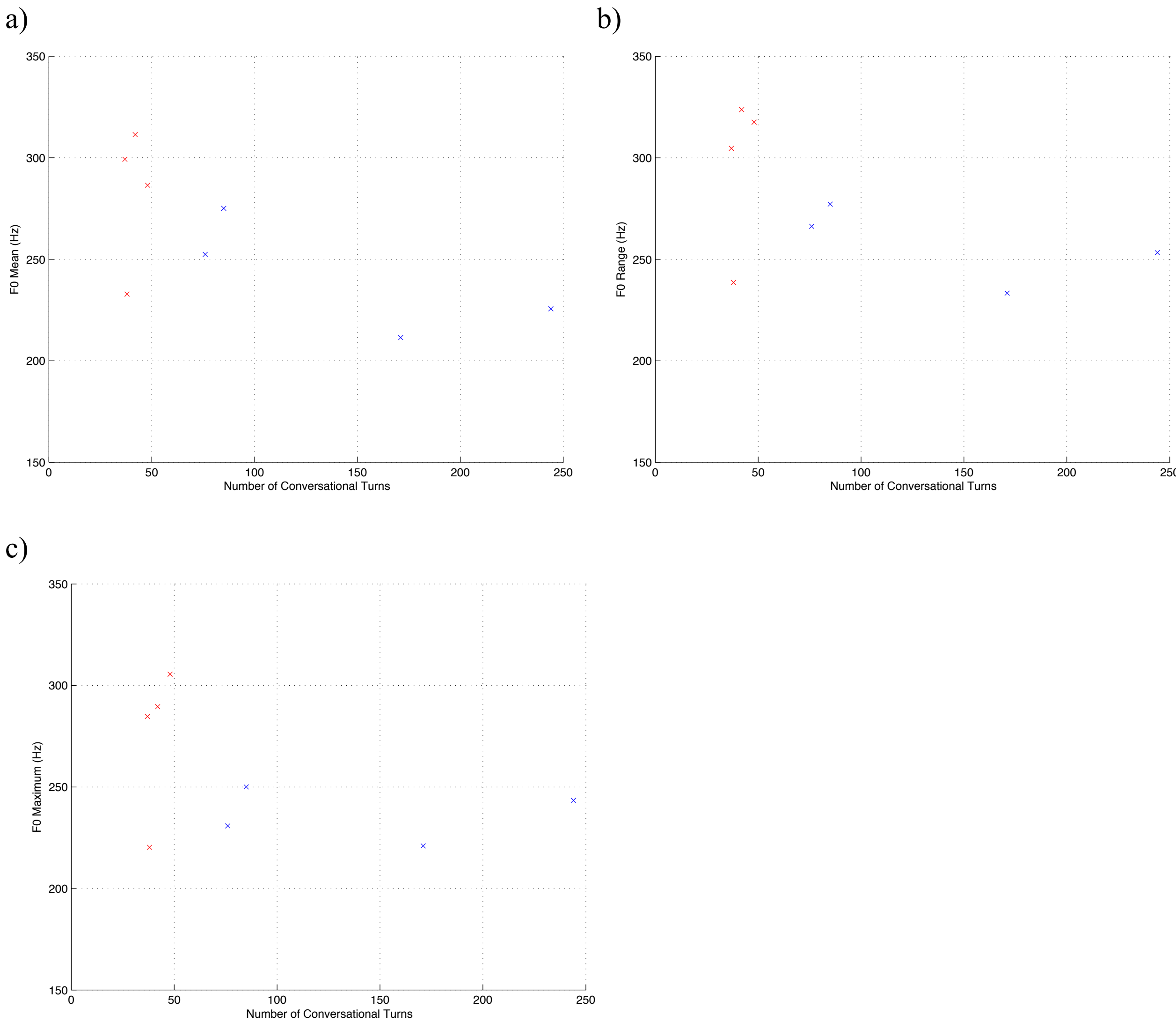

Figure 7: Correlation of Number of Conversational Interactions and a) f_0 Mean, b) f_0 Range, and c) f_0 Maximum. This figure demonstrates a strong, negative correlation between mean, range and maximum fundamental frequency and number of conversational interactions in the LR-TDx infant-caregiver dyads and a weak, positive correlation in the HR-ASD infant-caregiver dyads.

Appendix A

NSF GRFP Proposal

The present study serves as a pilot to a larger study, which has received funding through the National Science Foundation Graduate Research Fellowship Program. The author will pursue this work during her doctoral training in the Communication Sciences and Disorders Program at Northwestern University.

Title: The Influence of Prosody on the Development of Conversational Turns in Infancy

Keywords: prosody, conversational turn-taking, language acquisition, infancy

Prosody, referring to the intonation, stress and rhythm of speech, and social interaction are known to be two key elements of the developmental scaffold on which infants build language, but there is little research exploring whether one element subserves the other or if they are inherently independent or interdependent. The goal of this study is to advance our understanding of early language development by investigating the influence of prosody on the timing of conversational turn-taking between infants and their caregivers over the first two years of life.

Preference for the intonation of the maternal voice is established in the womb, and infants are sensitive to pitch change, rhythm and duration by 2 months [1]. For purely physiological reasons, the fundamental frequency (f_0) of the voice decreases over the course of an utterance, naturally signaling major syntactic boundaries. Caregivers exaggerate this effect in infant-directed speech by using highly modulated intonation and a wider-pitch range. According to the "prosodic bootstrapping" hypothesis [2], pre-linguistic infants exploit these prosodic cues to identify phrase groups, suggesting that this may constitute a key mechanism for early language acquisition.

Through the first two years of development, conversational asymmetries transform from caregiver-initiated interactions, to vocal clashes between caregiver and infant, to adult-like conversational turns [3]. Caregivers need to be exquisitely sensitive to temporal contingencies in infant responses, just as infants need to be increasingly sensitive to contingent responses from surrounding caregivers; the resonant coupling between mother and child forms the basis for the natural process of social interaction that drives the infant along the path to spoken language.

Both prosody and conversational turn-taking show developmental progressions that co-evolve throughout the course of the child's first few years of life, suggesting causal relationships, but the relative timescales of these two mechanisms and their potential interdependency have never been traced back to birth. By mapping out early vocal development in a large cohort of infants over the first two years of life, we aim to test the central hypothesis that f_0 declination in caregiver speech influences the emergence of conversational turn-taking in infancy:

Aim 1: Identify developmental changes in the prosody of caregiver infant-directed speech and conversational turn-taking between infant and caregiver.

We aim to map out the longitudinal progression of infant-directed speech and changes in infant-caregiver interactions with respect to the infant's development. We test the hypothesis that both caregiver prosody and infant-caregiver conversational interactions exhibit developmental changes over the course of the first two years of the infant's life.

Aim 2: Predict the acquisition of turn-taking in infancy from caregiver prosody.

Our second aim is to investigate the link between caregiver prosody and the timing of contingent interactions between the primary caregiver and infant. We test the hypothesis that conversational turn-taking in infancy is stimulated by developmental changes in the intonation of caregiver infant-directed speech.

Methodology: Capitalizing on recruitment for an ongoing, large-scale, longitudinal study funded as part of an NIH Autism Center of Excellence program project (NIH MH100029), we will be able to retrospectively follow 50 typically developing infants from birth. Using LENA Digital Language Processors [4] worn by each child, we have already collected day-long audio recordings of the home environment at monthly intervals from 3 months to 24 months of age, amounting to approximately 9,000 hours of data. In the present study, we will identify all conversational interactions between infant and caregiver within each recording. We will automatically label the onset and offset of each vocalization, and calculate standard indices of temporal contingency [5] based on the timing of the onset of infant responses relative to the onset and offset of maternal vocalizations. We will also extract f_0 contours through inverse-filtering, using spline fitting to determine the mean value and slope of each contour (Figure 1). We will test for significant differences in caregiver f_0 mean and slope across time points using a 1-way MANOVA with age as a factor to determine whether there is a developmental progression in infant-directed prosody (Aim 1). We will also test for significant changes in infant-caregiver interactions across time points from our contingency indices, using a 1-way MANOVA (Aim 1). We will determine whether caregiver prosody influences infant-caregiver interaction by repeating this analysis using a 1-way MANCOVA, including the caregiver f_0 mean and slope as covariates (Aim 2). We predict main effects of age in both analyses and will use post-hoc tests to identify significant points of developmental change (Aims 1-2).

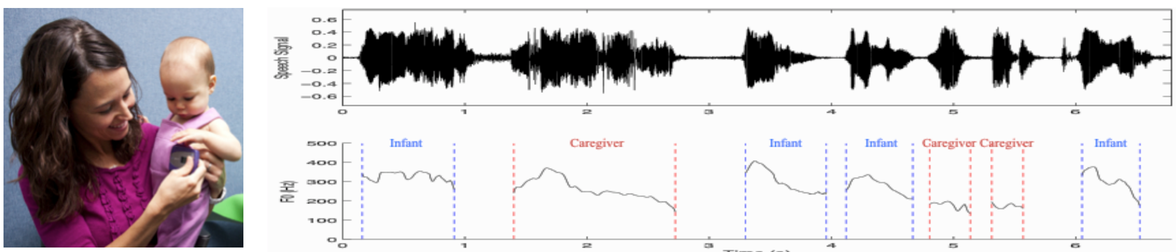

Figure 1: Automated analysis of intonation and timing of interactions between infant and caregiver.

Intellectual Merit: The present study seeks to elucidate the controversy surrounding the "prosodic bootstrapping" hypothesis, thereby advancing the fields of linguistics and psychology. This research is transformational in using "big data" in the field of language acquisition to establish a large, normative sample for language acquisition in the first two years of life. The study is innovative because it determines whether the prosody of infant-directed speech predicts the emergence of conversational turn-taking, thereby identifying a critical scaffold from which social communication may emerge early in infancy.

Broader Impacts: This study of typical development has broader impact in guiding clinical interventions for early language delays and social communication disorders. Due to the social and prosodic deficits characteristic of autism, this work will be especially influential in changing the lives of children with autism through education of parents and teachers on the importance of stimulating conversations early in infancy. Taking advantage of socioeconomic differences in our cohort, we will be able to identify disparities across minority groups, thereby representing populations traditionally neglected in the literature and identifying population-specific trends relevant to community health initiatives. As a co-organizer of the annual Emory workshop on Early Vocal Behavior, I will work to bring together researchers across disciplines from basic science and clinical practice, in order to disseminate these findings to the broader community.

References

[1] Saffran, J. R., Werker, J. F., & Werner, L. A. (2006). The infant's auditory world: Hearing, speech, and the beginnings of language. *Handbk of Child Psychol*. **[2]** Gleitman, L. R., & Wanner, E. (Eds.). (1982). *Language Acquisition: The state of the art*. Cambridge University Press. **[3]** Papoušek, M. (1995). Origins of reciprocity and mutuality in prelinguistic parent-infant 'dialogues'. In I. Marková, C. Graumann, & K. Foppa (Eds.), *Mutualities in Dialogue* (pp. 58-81). **[4]** Xu, D., Yapanel, U., & Gray, S. (2009). Reliability of the LENA language environment analysis system in young children's natural home environment. *LENA Foundation Technical Report.* **[5]** Keller, H., Lohaus, A., Volker, S., Cappenberg, M., Chasiotis, A. (1999). Temporal contingency as an independent component of parenting behavior. *Child Development*, *70*(2), 474-485.