

## ABSTRACT

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PITCH VARIABILITY, RATE OF SPEECH,  
AND CHILD LANGUAGE OUTCOMES

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Research regarding the influence of specific features typical of infant-directed speech (IDS) and their potential role in facilitating children's language development is still needed. Very little evidence links features of IDS to specific or general language outcomes. Surprisingly, given their pervasive description, the potential impacts of slowed speech rate and increased pitch variability of IDS on child language outcomes have not been examined. This study asks whether decreased speech rate and increased pitch variability in IDS among 42 mother-infant dyads at 7, 10/11, 18, and 24 months predicts language outcomes at two years. Decreased maternal speech rate at seven months related to increased child expressive language outcomes at two years. Contrary to hypotheses, children who were exposed to IDS characterized by decreased pitch variability at seven months had greater expressive language outcomes at two years than children who were exposed to IDS with increased pitch variability. Possible interpretations and clinical ramifications are discussed.

INFANT-DIRECTED SPEECH: MATERNAL PITCH VARIABILITY, RATE OF  
SPEECH, AND CHILD LANGUAGE OUTCOMES

By

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## Infant-Directed Speech

### Introduction

In most communities, the manner in which adults speak to infants and young children differs greatly from the typical form of language that adults use with one another in ordinary, conversational interaction. This simplified register used by both mothers and fathers, as well as other adults and even children (Fernald, Taeschner, Dunn, Papousek, Boysson-Bardies, & Fukui, 1989; Papousek, Papousek, & Haekel, 1987) across many languages (Fernald et al., 1989; Grieser & Kuhl, 1988; Kuhl et al., 1997) is often referred to as ‘motherese’, ‘parentese’, baby talk, or infant/child-directed speech (IDS/CDS). IDS differs from adult-directed speech (ADS) across many features, including semantics, syntax, and acoustic properties (Kuhl et al., 1997; Stern, Spieker, Barnett, & MacKain, 1983).

It is important to consider the purpose of this simplified register. Does IDS help infants in any way? Does it impact their eventual language acquisition? Several studies have examined the direct impact that IDS features have on language development. However, a larger number of studies have examined the impact that IDS features have on skills *indirectly* related to language acquisition, rather than the child’s language outcomes, *per se*. In the present study, we are particularly interested in looking at potential impacts of the acoustic features of IDS and how they relate directly to child language outcomes, something that has not been previously done. We are particularly interested in the acoustic features, because these features serve as the “delivery” system of speech input for all of the other important semantic and syntactic features of IDS.

Although this study is primarily concerned with acoustic features of IDS and their possible impact on child language development, the following section will briefly review how IDS differs from ADS on other levels of analysis and how these features may impact child language development, as well. Acoustic features (e.g., speech rate) are not completely separable from the other linguistic characteristics of IDS (e.g., shorter utterances); thus, it is wise to provide a general overview of the register before concentrating on its acoustic properties.

### *Simplification of IDS & its Impact on Child Language Outcomes*

In deciding if many of the widely studied features of IDS serve any specific purpose, researchers have largely agreed upon three key roles that IDS might play – to appeal to and maintain the focus of infants, convey positive emotion in the parent-child relationship, and assist with language development (Cooper, Abraham, Berman, & Staska, 1997; Grieser & Kuhl, 1988). With regard to the attentional and affective functions that IDS presumably promotes, Fernald and Kuhl (1987) found that when semantic and syntactic features of IDS were eliminated and only prosodic features were present, four-month-old infants showed preference for IDS of adults speaking to other four-month-old infants rather than adults speaking to other adults. Similar features are present in registers that are oftentimes used in communicative situations that do not require attention-getting motivation, such as speaking with children who are sick (Levin, Snow, & Lee, 1984) or speaking with foreigners (DePaulo & Coleman, 1986; Uther, Knoll & Burnham, 2007). However, because these three functions may co-occur, researchers have posited that different functions may be more important at different points in an infant's life – the attentional and affective functions may lead during early

infancy, while the linguistic function may become more significant later on (Fernald, 1992; Song, Demuth, & Morgan, 2010). The next section takes a closer look at the effects that individual features of IDS may have on language development.

### ***Impact of Semantic Simplification in IDS on Child Language Development***

Mothers' speech to infants is highly repetitive, characterized by a low type-token ratio (TTR) (Bernstein Ratner & Rooney, 2001; Broen, 1972; Phillips, 1973; Remick, 1976; Soderstrom, 2007). A low TTR signifies fewer unique or new words to total words in a given speech sample, while a high TTR signifies more unique or new words to total words. Therefore, speech to infants tends to include a more repetitive and restricted vocabulary.

Many researchers have found that it is the quantity of language input, rather than individual qualitative features, that impacts language development (Hart & Risley, 1995; Huttenlocher, Haight, Bryk, Seltzer, & Lyons, 1991; Rowe, 2012); more child-directed speech tends to predict larger child vocabulary scores. While quantity seems to be a widely agreed-upon indicator for child language development, recent research has found that the quality of this input may be just as important (Hurtado, Marchman, & Fernald, 2008; Rowe, 2012). Vocabulary diversity, as described by number of word types (Hurtado et al., 2008; Rowe, 2012), and vocabulary sophistication, as described by number of rare words (Rowe, 2012), of parental input both positively correlate with later child language development. Critically, the input that is most significant for future language development is the speech that is actually directed at the infants (Shneidman & Goldin-Meadow, 2012; Schneidman, Arroyo, Levin, & Goldin-Meadow, 2013; Weisleder & Fernald, 2013), rather than speech that is simply overheard.

Semantically, we know that quantity, diversity, and sophistication of maternal language input all impact child language development. While numerous studies have found that some semantic features of IDS may be linked directly to child language outcomes, none assessed the concurrent impact of acoustic features of IDS on language development. The acoustic features of IDS serve as the “delivery” system of speech input for all of these important semantic features, so it is essential to determine if these overlying features have any impact of their own; if so, they may further contribute to the benefits of IDS for child language development.

### ***Impact of Syntactic Simplification in IDS on Child Language Development***

Mothers’ speech to infants is quite repetitive. Complete, partial, and semantic repetitions can all be found in greater amounts in speech directed to younger children than speech directed to older children (Snow, 1972). Several studies have found that exact self-repetitions in both mothers and fathers occur more often than repetitions that are slight variations of original utterances (Papousek et al., 1987). In addition to exact-self repetitions, the frequency of word repetitions across utterances of different lengths (one- to three-word utterances) has been examined (Bernstein Ratner & Rooney, 2001). They found that in maternal two- and three-word utterances, 40% of the words were in common.

Several researchers have suggested ways in which repetition in IDS may support an infant’s abilities to learn language. It may help to gain and maintain the infants’ attention (Cooper & Aslin, 1990) or even to facilitate comprehension by making the speech more predictable (Fernald, 2000). When words, phrases, or sentences are repeated, an infant has more time to process and examine the speech signal (McRoberts,

McDonough, & Lakusta, 2009; Snow, 1972). More specifically, repetitions may help infants to determine and recognize elements in the speech, such as boundaries between grammatical units in an utterance (Snow, 1972).

Mothers' speech to infants is characterized by short utterances (Fernald & Simon, 1984; Snow, 1972; Soderstrom, 2007). Researchers have proposed that because smaller utterances in IDS tend to include fewer syntactic units, it is easier for infants to identify units in the speech input (Bernstein Ratner & Rooney, 2001; Snow, 1972). In 1979, Furrow et al. documented that shorter utterance length in mothers' IDS correlated positively with child language outcomes.

Researchers have examined several different measures of grammatical complexity in IDS. Maternal IDS tends to use a greater proportion of content words than function words, fewer verbs, verb forms, and modifiers (Phillips, 1973), and a shorter pre-verb length (Snow, 1972). Snow (1972) suggested that the smaller mean pre-verb length characteristic of IDS may make it easier for infants to match subject-verb relationships in sentences. Children's eventual use of certain verb forms has been correlated with IDS input frequency (Naigles & Hoff-Ginsberg, 2002; Newport, Gleitman, & Gleitman, 1977). For example, Naigles and Hoff-Ginsberg (2002) found that the more frequent a verb is in adult speech input, the more often it will appear in the child's speech. In addition, they found that use of a verb in a larger variety of syntactic environments increased the likelihood that the child would be able to use the same verb in several different syntactic environments.

In general, English-speaking mothers tend to produce nouns more often than verbs in short utterances (Goldfield, 1993). Nouns tend to be easier to learn than verbs

(Bornstein, 2005; Maguire, Hirsh-Pasek, & Golinkoff, 2006) for several reasons. For example, nouns have higher imageability than verbs (Golinkoff & Hirsh-Pasek, 2008); it is easier to picture the noun, 'bottle', than it might be to picture the verb 'look', a word that is perceptually more abstract. In addition, unlike nouns, verbs require arguments, making it the infant's responsibility to understand the syntactic relationships within utterances.

Newport et al. (1977) also found that the frequency of questions in mothers' speech to infants, which is generally elevated in IDS, is associated with the child's eventual grasp of the verbal auxiliary system. Yes/no questions front auxiliary verbs, potentially making them more salient to the child.

Thus, we know that many syntactic features of IDS appear to impact child language skills or outcomes. For example, repetitions may provide infants with more language processing time, shorter utterance length may ease child language processing demands, and a high frequency of questions in maternal speech may assist children with their eventual grasp of the verbal auxiliary system. Again, as noted earlier, none of these studies assessed the concurrent impact of acoustic features of IDS on language development.

### ***Impact of Acoustic Simplification in IDS on Child Language Outcomes***

Fundamental frequency has been extensively studied in IDS. Generally speaking, mothers tend to use a higher mean fundamental frequency when speaking with infants than when speaking with adults (Fernald & Simon, 1984; Garnica, 1977; McRoberts & Best, 1997; Remick 1976; Stern et al., 1983). This finding is present across most

languages (Fernald et al., 1989), even in tonal languages where pitch accent is important (Grieser & Kuhl, 1988).

We know that pitch range is often greater in IDS than ADS (Fernald et al., 1989; Yu, Khan, & Sundara, 2014); some studies have found that adults also use greater fundamental frequency variability when speaking to infants (Fernald et al., 1989; Jacobson, Boersma, Fields, & Olson, 1983). Fernald et al., (1989) found that intonation contours in IDS sometimes spanned across one to two octaves. They suggest that these exaggerated contours may serve an affective purpose for infants, such as gaining attention or encouraging a response from them.

Research has found that this characteristic prosodic range of IDS does not seem to impact word recognition skills in infants (Song et al., 2010), but that the elevated F0 does promote word learning in infants (Ma, Golinkoff, Houston, & Hirsh-Pasek, 2011). Ma et al. (2011) found that 21-month-old infants looked longer at words in an IDS condition with higher overall F0, but not in an ADS condition with lower overall F0. In another study where IDS was manipulated to include only specific statistical properties characteristic of IDS (e.g. F0, pitch contour), researchers found that IDS was easier for infants to segment than ADS (Thiessen, Hill, & Saffran, 2005). In addition, these large pitch contours have been found to improve infants' vowel discrimination skills (Trainor & Desjardins, 2002). Kaplan, Bachorowski, & Zarlengo-Strouse (1999) found that IDS of depressed mothers, which has less pitch modulation than speech of non-depressed mothers (Kaplan, Bachorowski, Smoski, & Zinser, 2001), does not support associative learning in infants, a skill that should be important in children's language development.

Several studies have found that speech rate is slower in IDS than ADS (Broen, 1972; Green, Nip, Wilson, Mefferd, & Yunusova, 2010; Lam & Kitamura, 2010), a finding that is present in both male and female IDS (Sachs, Brown, & Salerno, 1976). While some studies do not control for the longer between-utterance pauses that tend to occur in IDS when assessing speech rate (Sachs et al., 1976), other studies that have controlled for pauses by eliminating them from the calculation found similar results (Fernald & Simon, 1984). Because stressed syllables may be lengthened in content words in IDS (Morgan, 1986; Swanson, Leonard, & Gandour, 1992), this finding alone could explain why there is a decreased rate of speech in IDS. However, Bernstein Ratner (1985) found that stressed vowels in content words are not always lengthened in IDS versus ADS, suggesting that there may be another explanation for the decreased speech rate in IDS. Bernstein Ratner (1985) found that although speech rate was not slower in longer segments, mothers did slow their overall speech rate in shorter utterances.

Surprisingly, very little research has assessed the overall impact of decreased speech rate in IDS on child language outcomes. Although decreased speech rate has not been found to directly impact child language outcomes, it has been found to improve word recognition in infants (Song et al., 2010), a skill that is necessary for language acquisition. Using a preferential looking model, Song et al. (2010) found that infants looked longer at target rather than non-target words in IDS when stimuli were manipulated to only include the characteristic of decreased speech rate, but not when ADS was similarly manipulated.

Thus, from prior studies, we know that increased F0 promotes word learning in infants. Increased F0 and intonation contours characteristic of IDS improve infants'

vowel discrimination skills. Decreased pitch modulation appears to impair associative learning in infants. Finally, decreased speech rate may improve word recognition in infants in a laboratory situation. However, none of the studies directly relate acoustic features of IDS to child language outcomes.

Additionally, most studies assessing the influence of acoustic features of IDS on language development examine mothers' overall input across utterances, rather than within specifically selected utterances. This may pose a problem, because if utterances are not specially selected, the input being analyzed may include pauses, non-speech signals, more questions than statements, whispering or yelling, and many other elements that may impact acoustical analyses. Specifically, as discussed below, in order to accurately gauge maternal speech rate in IDS, it is important to control a number of variables.

### Summary & Hypotheses

Despite several hypotheses about the impacts of IDS on child language growth, research regarding the influence of specific features typical of IDS and their potential role in facilitating children's language development is still needed, because very little evidence links features of IDS directly to overall language outcomes.

In the present study, we are particularly interested in looking at the impact of two acoustic features of IDS over time and how they relate directly to child language outcomes, something that has not been previously explored. Therefore, we have the ability to expand upon the existing research by longitudinally assessing the direct effects of these specific acoustic features (IDS speech rate and pitch variability) on overall language outcomes of a large sample of infants.

The present study followed infants and their caregivers from seven months to twenty-four months to examine relationships between acoustic properties of IDS early in life and language outcomes later in life. Specifically, the effects of pitch variability (standard deviation of the fundamental frequency range) and rate of speech (in words per minute) within IDS utterances on children's later language acquisition were examined.

We had the following hypotheses:

- 1) Mothers will produce greater pitch variability and a slower rate of speech within utterances when using IDS at each age interval than when using ADS. Within the IDS conditions, these features will diminish as infants mature.

While it has been found that mothers produce a greater pitch variability and slower rate of speech in their speech to infants than in their speech to adults, we wanted to confirm this concept in this particular cohort to determine whether or not we were studying a typical population: mothers who speak more slowly to infants (IDS) than adults (ADS) and who speak with more pitch variability to infants (IDS) than adults (ADS).

As an exploratory measure, we were interested in determining whether or not these features of IDS diminish as infants mature. As previously discussed, some of these features may be used as attention-getting devices early on. Therefore, if the need for gaining infants' attention and the need for providing them with more processing time decreases over time, we may see a decline in the use of these two characteristic features.

- 2) Children of mothers who use greater pitch variability in IDS will have better language outcomes at two years of age.

Previous studies have found that pitch contours characteristic of IDS may improve infant segmentation and vowel discrimination skills. It has also been found that less pitch modulation may interfere with associative learning. Because these studies linked greater pitch variability to better language skills, we predicted that greater pitch variability would predict better child language outcomes.

- 3) Children of mothers who use a slower rate of speech in IDS will have better language outcomes at two years of age.

Researchers have found that decreased speech rate improves word recognition in infants, a skill that is necessary for language acquisition, but have not examined the direct impact of decreased speech rate on child language outcomes. We predicted that decreased speech rate would improve child language outcomes.

- 4) In this specific sample of mother-infant dyads, children of mothers who provide a greater amount of input (as measured by MLU-morphemes, types, tokens, and type-token ratio) will have better language outcomes at two years of age, indicating that the population under investigation is typical.

While this is a concept that has been extensively examined, we wanted to confirm previous findings in this specific cohort to confirm that we were studying a typical population of mothers and infants.

## Methods

### Participants

Participants were 42 mother-infant dyads who were part of a larger longitudinal study at the University of Maryland. All of the participating mothers and infants were native English-speakers. The infants were born within three weeks of their due dates. They were typically developing and had no previously diagnosed developmental disorders or delays or hearing loss. As part of the longitudinal study, each mother-infant dyad came to the University of Maryland for visits when the child was seven, ten, eleven, eighteen, and twenty-four months old. Infants were rewarded with a small prize for participation following each visit. The data for the present study were collected from each age range. However, data from the ten and eleven month visits were collapsed. Data were initially collected from fifty mother-infant dyads, because fifty mothers completed all of their visits and mother-child play sessions at each age. Some mothers were not able to attend every visit. These mother-infant dyads were excluded from the study. Data were then analyzed from forty-two mother- infant dyads, because eight of the mother-infant transcripts did not contain a sufficient number of eligible utterances for analysis. Utterance eligibility criteria will be described in a later section.

### IDS and ADS Samples

Once the participants arrived at the University of Maryland, they were guided to a sound-treated therapy room. The play session and interview were both conducted in this room. The mothers wore an Audio-Technica ATR-35S lavalier microphone. The experimenter utilized a Marantz PMD660 Professional Portable Digital Recorder set at a sample rate of 44.1 kHz to obtain the speech samples, which were recorded as

uncompressed WAV files. In addition, the play sessions were video-recorded with a flip camera. For the play session, the mother and infant were asked to choose from a variety of toys including play food, baby dolls, books, and stuffed animals. The mother was asked to play with her infant just as she would at home.

The mothers were told that the study was being conducted to examine their infants' play behavior. They were not aware that their speech was being examined; this was done to avoid any potential bias. To obtain the ADS sample, a student research assistant played with the child while the experimenter interviewed the mother regarding her infant's play behavior at home. The interview and play session both took about fifteen minutes. Following the last play session (twenty-four months) and the interview, participants were informed of the real purpose of the study and given an option to have their data excluded from the analysis. No participants chose to withdraw from the study.

### Transcription Methods

Play sessions and interviews were transcribed using the Computerized Language Analysis (CLAN) program (MacWhinney, n.d.).

### Outcome Measures

Following the twenty-four month session, language outcomes data were obtained by administration of several standardized language assessments. Measures included standardized tests for both expressive and receptive vocabulary. The *Peabody Picture Vocabulary Test 4* (PPVT-4) is a measure of receptive vocabulary for Standard American English, which assesses understanding of single words (Dunn & Dunn, 2007). Because the norms for the *PPVT-4* begin at two years, six months old, raw scores were utilized.

The *Expressive One Word Vocabulary Test* (EOWVT) is a measure of expressive vocabulary for Standard American English, which assesses use of single words (Martin & Brownell, 2010). Standardized scores were utilized for this measure. The mothers completed the *MacArthur Communicative Development Inventories* (MCDI) form. This parent report form asks mothers to check off the words that they believe their infants can understand (Fenson, Dale, Reznick, Thal, Bates, Pethick, & Reilly, 1993). Raw scores were utilized for this measure. In addition to these scores, because the play session at twenty-four months was transcribed in CLAN, clinical measures of interest, such as the child's mean length of utterance (MLU) in morphemes and number of word types, were also computed using the Kideval program to determine language outcomes (MacWhinney, n.d.).

#### *Data Selection Procedure*

In order to control for the influences of utterance length on speech rate, eligible utterances were considered to be those between four to eight words in length, as rate of speech appears to be affected by utterance length (Yuan, Liberman, & Cieri, 2006). For example, the longer an utterance, the shorter the average segment duration (Nakatani, O'Connor, & Aston, 1981). Conversely, when accounting for the effect of phrase-final lengthening, a shorter utterance will have a slower rate of speech than a longer utterance (Oller, 1973). One study looked at the impact of age, sex, and dialectal region on rate of speech – they found that the statistical significance of these factors was eliminated when utterance length was included. In other words, rate of speech is significantly impacted by utterance length (Quene, 2008).

All eligible utterances were statements; questions were excluded. It has been found that almost universally, questions are produced with higher pitch than their corresponding statements (Bolinger, 1989; Lindsey, 1985). In addition, it has been found in some languages that questions are associated with a faster speaking rate than statements (van Heuven & van Zanten, 2005).

Utterances were excluded if they exceeded ten seconds in duration, because they may contain long pauses or utterances from preceding or succeeding turns (Ko, 2012). Utterances that contained whispering or yelling and/or contained phonological fragments or unintelligible speech were excluded. If the acoustic signal of the utterance was disrupted by ambient noise, overlapping speech, or cries, then the utterance was excluded from acoustic analysis. Each transcript for all of the dyads included in this study met set criteria of fifteen utterances, but one, which had seven utterances.

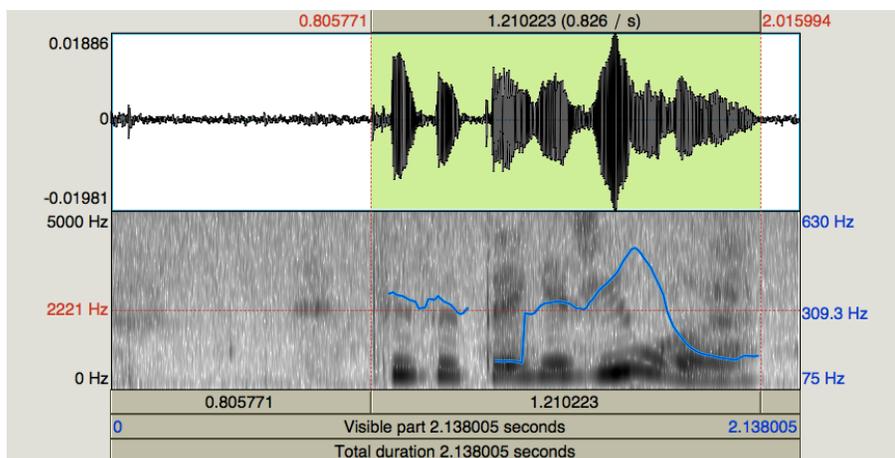
### Acoustic Analysis

Each utterance was acoustically analyzed using the program Praat (Boersma & Weenink, 2015). Once exported from CLAN for analysis, the utterances were further segmented to exclude any noise prior to or after the speech signal. Specifically, pitch variability (standard deviation of the fundamental frequency range) and rate of speech (in words per minute) within utterances were examined. These variables were assessed within utterances based on criteria discussed in the preceding section. Rate of speech and pitch range were calculated as follows:

### *Speech Rate*

Rate of speech was calculated in words per minute rather than syllables per second, because children between 7 and 24 months might not be as sensitive yet to the internal construction of a word (sounds, syllables) as they are to the whole word. It is also a more easily computed variable for potential clinical translation. Speaking rate for each utterance was calculated by first subtracting the time of speech onset from the time of speech offset. The audio was then played and the number of words for each utterance were counted and recorded. To calculate words per minute, the total number of words in the utterance was divided by the elapsed time of the utterance. This is a representation of the speaking rate as number of words per second. To convert to words per minute, the result was multiplied by sixty [# of words / (time at speech offset - time at speech onset) X 60]. Figure 1 displays a sample of an utterance that was extracted into Praat, in order to determine speech rate.

**Figure 1: Sample Utterance Extracted into Praat (Speech Rate Calculation)**



$$(6/1.210223) \times 60 = 297.465839 \text{ wpm}$$

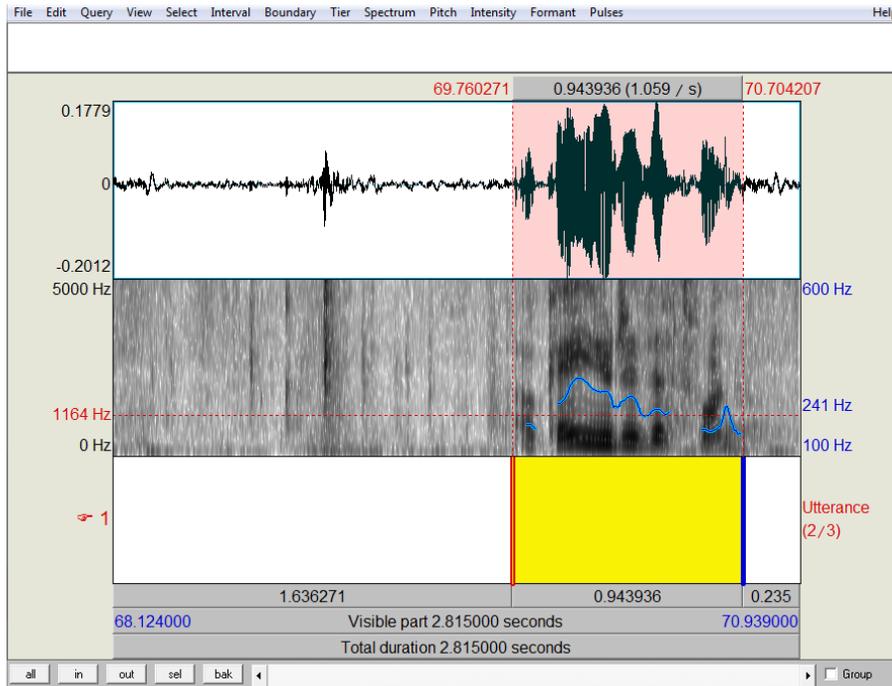
Although several recent studies (Hilton, Schuppert, & Gooskens, 2011; Ko, 2012) have used a Praat script that computes an automated measure of syllables necessary for

speech rate calculation (De Jong & Wempe, 2009), there are reasons to believe this may not be the most reliable measure when used alone. The script counts the number of intensity peaks in the speech signal that have voicing. Speech rate is then calculated by the number of syllables that are automatically counted, divided by the elapsed duration of the utterance (De Jong & Wempe, 2009). While it can speed computation minimally, it is less reliable than listener count of syllables and/or words (Hilton et al., 2011). Thus, this study used experimenter counts for words, particularly because the Praat script offers only a small time advantage over the more recent CLAN-Praat export utility.

### ***Pitch Variability***

The standard deviation of  $F_0$  was used as a measure of pitch variability. Praat provides a pitch contour curve for any selected utterance that is exported from CLAN. For this study, analysis parameters were pre-set to 100-600 Hz based on the expected pitch range of the speakers. For each utterance, a time domain was selected to exclude ambient noise, overlapping speech, or cries. The PitchTier function in Praat was utilized to get the standard deviation of the points within the specified time window. To run this function, each utterance was imported into Praat from CLAN and the appropriate selection was made from the sound file. The sound file's periodicity was then analyzed. Once analyzed, the standard deviation function was run. When the function ran, it excluded all undefined points. Figure 2 displays how an utterance was selected in Praat before being analyzed.

**Figure 2: Sample Utterance Extracted into Praat (Pitch Variability Calculation)**



### Reliability

To measure inter-rater reliability for the acoustical analyses, another research assistant analyzed a selection of the utterances. All utterances from four mother-infant dyads (transcripts at seven-, ten/eleven-, eighteen-, twenty-four-months, and ADS) were exported into Excel for a follow-up analysis (N = 300 utterances). This represented approximately ten percent of the total sample. Differences in speech rate and pitch variability measures between the two raters were expressed as absolute numbers. The mean difference between the first and second researcher's measurements for speech rate was 7.15 wpm. The mean difference between the first and second researcher's measurements for pitch variability was 1.209 Hz. Pearson correlations were also computed between each rater's values for speech rate and pitch variability. Pearson's  $r$  between the speech rate values was 0.998 and between the pitch variability values was

0.996. Both can be considered excellent values for inter-rater reliability for measures of speech rate and pitch variability. The first researcher's values were used in all statistical analyses.

### Statistical Analysis

*Hypothesis One:* The first hypothesis of this study is that mothers will produce greater pitch variability and a slower rate of speech within utterances when using IDS at each age interval than when using ADS. In addition, within the IDS conditions, these features will diminish as infants mature. One-way ANOVAs (by child age) were computed for pitch variability and speech rate within utterances. Post-hoc Fisher's LSD Multiple-Comparison Tests were then used to detect significant differences among means.

*Hypothesis Two:* The third hypothesis of this study is that children of mothers who produce greater pitch variability within utterances will have greater language outcomes at two years of age. To determine the relationship between pitch variability within utterances and child language outcomes, Pearson correlations were used. As a *post-hoc* analysis, we decided to perform group analyses. We categorized the mothers at each stage by pitch variability within utterances using a median split to create 'high' and 'low' groups for pitch variability at each IDS stage. We then conducted a series of t-tests between the two groups at each age comparing all child language outcomes.

*Hypothesis Three:* The fourth hypothesis of this study is that children of mothers who produce a slower rate of speech within utterances will have greater language outcomes at two years of age. To determine the relationship between speech rate within utterances and child language outcomes, Pearson correlations were used. As a post-hoc

analysis, we decided to perform group analyses. We categorized the mothers at each stage by speech rate within utterances using a median split to create ‘high’ and ‘low’ groups for speech rate in IDS at each stage. We then conducted a series of t-tests between the two groups at each age against all child language outcomes.

*Hypothesis Four:* The last hypothesis of this study is that in this specific sample of mother-infant dyads, children of mothers who provide a greater amount of input (as measured by MLU-morphemes, types, and type-token ratio) will have greater language skills at two years of age. While this has been found in previous studies, we were interested to see if we would find similar results in our population, giving us a reason to believe that we were studying a typical group. To determine the relationship between variables related to the mother’s speech (MLU-morphemes, types, tokens, and type-token ratio) and child language outcomes, Pearson correlations were used.

## Results

### Hypothesis One – Comparison of IDS and ADS Acoustic Measures

Our first hypothesis predicted that mothers would produce greater pitch variability and a slower rate of speech within utterances when using IDS at each age interval than when using ADS and that within this IDS conditions, these features would diminish as infants matured. Separate one-way Analyses of Variances (ANOVAs) were computed to compare five groups (7-, 10/11-, 18-, 24-months, ADS) on the separate dependent variables (acoustic measures – speech rate and pitch variability). A Bonferroni adjustment was used for these measures. For each acoustic variable,  $p < .05$  was divided by four for each age interval, resulting in an alpha of  $p = .0125$ .

As a starting point for the pitch variability variable, we calculated pitch mean to verify that the IDS in this particular study was typical. For pitch mean, analysis revealed significant effects ( $F(4,209) = 38.64, p < .0125$ ). For the pitch variability variable, analysis revealed significant effects ( $F(4,209) = 25.86, p < .0125$ ). Results of a post-hoc Fisher's LSD Multiple-Comparison Test showed that pitch variability and pitch mean within utterances in ADS was significantly different from all other IDS conditions. As expected, pitch variability and pitch mean were greater in IDS than in ADS.

For the pitch variability variable, we predicted that pitch variability within utterances would decrease over time. A trend was present in the expected and appropriate direction. However, results of a post-hoc Fisher's LSD Multiple-Comparison Test showed that within the IDS conditions, the only significant difference was between the seven months and twenty-four months IDS registers. Pitch variability in IDS at seven months was significantly greater than at twenty-four months. This may suggest that most

mothers use quite melodic speech at each stage in infants' lives, with no major changes occurring across time. Based on our prediction that pitch variability would decrease over time, due to a mother's decrease in need to gain or maintain her infant's attention, it makes sense that pitch variability at the youngest age and pitch variability at the oldest age examined were significantly different.

For pitch mean, a similar trend was present in the expected and appropriate direction. However, results of a post-hoc Fisher's LSD Multiple-Comparison Test showed that within the IDS conditions, no significant differences were present among the groups. This shows that mothers do not necessarily adjust their overall pitch in any significant way over time as much as they might adjust their pitch variability. Perhaps mothers adjust their pitch variability more, because certain pitch contours may be used to satisfy certain needs, whereas overall pitch, decreased or increased, may not serve a specific purpose. For example, rising contours may help prompt an infant to attend to speech, but slowly falling contours may comfort a distraught infant (Katz, Cohn, & Moore, 1996).

Descriptive statistics for pitch variability and pitch mean within utterances across age intervals is shown in Tables 1-2.

**Table 1: Pitch Variability across Age Intervals**

	Mean	Standard Deviation	N
7 months	68.69	13.21	42
10/11 months	67.16	14.48	42
18 months	63.47	15.10	42
24 months	62.16	11.74	42
ADS	42.44	12.67	42

**Table 2: Pitch Mean across Age Intervals**

	Mean	Standard Deviation	N
7 months	252.78	24.55	42
10/11 months	248.77	25.53	42
18 months	243.70	23.16	42
24 months	243.48	22.34	42
ADS	198.66	18.73	42

We predicted that speech rate within utterances would be lower in IDS at each age interval than in ADS. This analysis revealed significant effects ( $F(4,209) = 5.37, p < .0125$ ). As expected, speech rate was slower in IDS than in ADS. Results of a *post-hoc* Fisher's LSD Multiple-Comparison Test showed that speech rate within utterances in ADS was significantly faster than the two earliest IDS conditions (seven months and ten/eleven months), but not the two later IDS conditions (eighteen and twenty-four months). This is not surprising, as we suspected that speech rate would increase as the children matured.

We predicted that speech rate within utterances would increase over time. Similar to pitch variability, a trend was present in the expected and appropriate direction. Results of a *post-hoc* Fisher's LSD Multiple-Comparison Test showed that within the IDS conditions, speech rate at seven months was significantly slower than speech rate at eighteen and twenty-four months (but not ten/eleven months) and speech rate at ten/eleven months was significantly slower than speech rate at eighteen and twenty-four months (but not seven months). Thus, speech rate at seven and ten/eleven months were more similar to one another and different from speech rate at eighteen and twenty-four months, which were more similar to one another. However, it is important to point out that the mean speech rate in IDS at twenty-four months was almost identical to the mean speech rate in ADS.

We predicted that speech rate would increase over time due to a mother’s decrease in need to provide the child listener with more processing time. Therefore, it makes sense that maternal speech rate at the youngest two ages and maternal speech rate at the oldest two ages examined were significantly different from each other.

Descriptive statistics for speech rate within utterances across age intervals are shown in Table 3.

**Table 3: Speech Rate across Age Intervals**

	Mean	Standard Deviation	N
7 months	240.26	33.37	42
10/11 months	244.21	34.59	42
18 months	261.62	34.72	42
24 months	266.42	39.79	42
ADS	266.31	33.02	42

*Hypothesis Two – Relationship between Pitch Variability in IDS and Child Language*

Outcomes

Our second hypothesis predicted that children of mothers who produce greater pitch variability within utterances would have greater language skills at two years of age. To determine the relationship between pitch variability within utterances and the three test scores obtained at twenty-four-months (EOWVT, PPVT, and MCDI), as well as a subset of child language production measures (MLU, types), Pearson correlations were used. A Bonferroni adjustment was used for these measures. For each age interval,  $p < .05$  was divided by five for each outcome measure, resulting in an alpha of  $p = .01$

The series of correlations that were conducted between pitch variability at each age interval and child language outcomes are shown in Table 4. Contrary to hypotheses, no significant correlations and no consistent trends emerged.

**Table 4: Relationship between Pitch Variability & Child Language Outcomes**

	PPVT Raw	MCDI Raw	EOWVT SS	MLU-Morphemes	Types
7 months	-0.0227 (0.8894)	-0.0547 (0.7309)	-0.0215 (0.8925)	-0.0335 (0.8331)	-0.0138 (0.9308)
10/11 months	-0.0153 (0.9256)	-0.0371 (0.8157)	-0.0096 (0.9518)	-0.0293 (0.8539)	-0.0017 (0.9914)
18 months	-0.0154 (0.9250)	-0.0329 (0.8363)	-0.0067 (0.9663)	-0.0250 (0.8751)	-0.0009 (0.9954)
24 months	-0.0134 (0.9346)	-0.0264 (0.8680)	-0.0033 (0.9833)	-0.0187 (0.9062)	0.0010 (0.9950)

Note. r (p)

As a *post-hoc* analysis, we performed group analyses. We categorized the mothers at each stage by pitch variability within utterances, using a median split – twenty-one mothers were in a ‘high’ group for this acoustic variable at each separate stage and twenty-one mothers were in a ‘low’ group. (Therefore, one mother who may have appeared in the ‘high’ group for pitch variability at seven months may not necessarily have appeared in the ‘high’ group for pitch variability at twenty-four months). A series of t-tests were conducted between the two groups at each age and for all child language outcomes. A Bonferroni adjustment was used for these measures, as well. For each age interval,  $p < .05$  was divided by five for each outcome measure, resulting in an alpha of  $p = .01$

Descriptive statistics for group differences among pitch variability and child language outcomes at each age interval are shown in Table 5. Similar to our previous correlational analyses, no significant findings between pitch variability in IDS at ten/eleven-, eighteen-, and twenty-four-months and child language outcomes were seen. However, contrary to our hypothesis, children who were exposed to IDS with *decreased* pitch variability at seven months had expressive language outcomes (MLU-morphemes)

that were significantly greater than the scores of children who were exposed to IDS with increased pitch variability ( $t(40) = -2.8, p < .01$ ).

In regard to the non-significant findings, we might argue that these mothers were always quite variable when they spoke to their infants, thus creating a ceiling effect that obscured any significant relationship. Alternatively, because the utterances we analyzed were controlled based on specific inclusion parameters that were meant to eliminate any elements that might affect the acoustical analyses (i.e., non-speech signals, pauses), the true pitch variability of the mothers' overall input across utterances was not well represented. The pitch variability assessed was not a snapshot of the mothers' entire speech input, but analyses within specifically selected utterances. Additionally, we might predict that if pitch variability of the mothers' overall speech input over a total sample was compared to child language outcomes, rather than within individual utterances, results may have been different. For example, in one utterance, a mother may be speaking with a very high pitch, but in the following utterance, she may significantly drop her pitch. Thus, if these utterances are analyzed together, greater pitch variability would be apparent. However, if the utterances are examined separately, as we did in our study, there would not be as much pitch variability.

**Table 5: Group Differences among Pitch Variability & Child Language Outcomes (at each age interval)**

	7 mo.	10/11 mo.	18 mo.	24 mo.
Types	-1.5195 (0.1365)	-0.4972 (0.6217)	-0.1878 (0.8520)	0.1685 (0.8670)
MLU-Morphemes	<b>-2.7713</b> <b>(0.0084)*</b>	-0.2272 (0.8213)	1.7721 (0.0839)	-0.1298 (0.8974)
EOWVT Standard Score	0.0421 (0.9666)	-0.0421 (0.9666)	0.6780 (0.5017)	0.7639 (0.4494)
MCDI Raw Score	-1.4383 (0.1581)	0.7721 (0.4446)	1.5126 (0.1383)	1.0480 (0.3009)
PPVT Raw Score	0.0113 (0.9911)	0.5967 (0.5542)	2.0488 (0.0474)	0.7585 (0.4528)

Note. t (p)

\* = significant at .01 level

*Hypothesis Three – Relationship between Speech Rate in IDS and Child Language*

*Outcomes*

Our third hypothesis predicted that children of mothers who produce a slower rate of speech within utterances would have greater language skills at two years of age. To determine the relationship between speech rate within utterances and the three test scores obtained at twenty-four-months (EOWVT, PPVT, and MCDI), as well as a subset of child language production measures (MLU, types), Pearson correlations were used. A Bonferroni adjustment was used for these measures. For each age interval,  $p < .05$  was divided by five for each outcome measure, resulting in an alpha of  $p = .01$ . The series of correlations that were conducted between speech rate at each age interval and the child language outcomes are shown in Table 6.

There was a significant correlation between speech rate within utterances of IDS at seven months old and child MCDI raw scores at two years of age. The slower the mother spoke to her infant at seven months of age, the greater the child's language scores were at two years of age based on parent-completed reports ( $r = -.4390, p = .0036$ ). There

were no significant correlations between speech rate of IDS at any other age and child language outcomes.

Because only one correlation reached significance, it is important to keep in mind how the stimuli were chosen. Because only utterances between four to eight words in length were analyzed, the speech rate measures obtained may not be representative of the mothers' overall speech input. Since utterance length may affect speech rate, excluding utterances of a wide range of lengths may not represent the speech rate of the overall input. In fact, the MLU in words of all of the mothers' utterances during the play sessions at each age are lower than the range of utterances we chose to analyze (7 months: 3.95 words, 10/11 months: 3.75 words, 18 months: 3.64 words, 24 months: 3.98 words). Additionally, the MLU in words of the mothers' utterances at each age that we actually analyzed is consistently at the lower end of the range that we chose (7 months: 5.28 words, 10/11 months: 5.40 words, 18 months: 5.29 words, 24 months: 5.38 words). This further suggests that the utterances we chose to analyze may not be truly representative of the mothers' overall speech input.

Only one significant correlation emerged, correlating speech rate within utterances to the child's language level on the MCDI, but not other language tests. The MCDI differs from both the PPVT and the EOWVT, because it is a parental inventory that allows parents to report their child's expressive language ability on a scale that includes over 500 items. The PPVT and EOWVT are child-directed tests that require children to look at a set number of items and respond. At two years of age, this may not be an easy task for all children, as it requires significant attention and self-regulation. Additionally, the range of appropriate items for this age is quite restricted. The difference

that distinguishes the most expressive child from the least expressive on the EOWVT may be as few as twenty items. The MCDI offers opportunity for much greater variability in scores and allows more fine-grained analyses of outcomes.

**Table 6: Relationship between Speech Rate (wpm) & Child Language Outcomes**

	PPVT Raw	MCDI Raw	EOWVT SS	MLU-Morphemes	Types
7 months	-0.2088 (0.1960)	<b>-0.4390</b> <b>(0.0036)*</b>	-0.2177 (0.1661)	-0.2212 (0.1592)	-0.0864 (0.5863)
10/11 months	-0.0216 (0.8947)	-0.0486 (0.7599)	-0.0112 (0.9438)	-0.0381 (0.8106)	0.0047 (0.9763)
18 months	-0.0237 (0.8844)	-0.0417 (0.7930)	-0.0100 (0.9497)	-0.0325 (0.8382)	0.0014 (0.9929)
24 months	-0.0159 (0.9223)	-0.0321 (0.8400)	-0.0049 (0.9753)	-0.0220 (0.8902)	0.0000 (0.9998)

Note. r (p)

\* = significant at .01 level

We performed group analyses for speech rate, as well. We categorized the mothers at each stage by speech rate within utterances, using a median split – twenty-one mothers were in a ‘high’ group for speech rate at each separate stage and twenty-one mothers were in a ‘low’ group. A series of t-tests were conducted between the two groups at each age and all child language outcomes. A Bonferroni adjustment was used for these measures, as well. For each age interval,  $p < .05$  was divided by five for each outcome measure, resulting in an alpha of  $p = .01$ .

Descriptive statistics for group differences among speech rate and child language outcomes at each age interval are shown in Table 7. Speech rate within utterances of IDS at seven months old impacted child MCDI raw scores at two years of age. Children whose mothers spoke the most slowly at seven months of age had superior MCDI scores ( $t(40) = -3.3, p < .01$ ). No other comparisons reached significance.

Speech rate at seven months predicted child language outcomes, both by correlation and group analyses. It is important to consider what is so significant about this acoustic variable and this age. By seven months of age, infants may be beginning to focus more on the content of the speech they hear. By this age, pitch variation may provide less benefit than speech rate. Speech rate is part of the ‘delivery’ system for the overall input; by decreasing speech rate, mothers provide infants with more time to process the content that they are hearing. Why rate is important at the earliest point, but not the later ages, is unclear. It should help all listeners. Further exploration of this question is warranted.

**Table 7: Group Differences among Speech Rate & Child Language Outcomes (at each age interval)**

	7 mo.	10/11 mo.	18 mo.	24 mo.
Types	-0.8004 (0.4282)	0.5070 (0.6150)	0.1300 (0.8972)	-0.3422 (0.7340)
MLU-Morphemes	-1.5551 (0.1278)	-0.7653 (0.4486)	-1.5540 (0.1281)	-0.3940 (0.6957)
EOWVT Standard Score	-1.4480 (0.1554)	0.3375 (0.7375)	-0.8936 (0.3769)	-1.1123 (0.2727)
MCDI Raw Score	<b>-3.0329</b> <b>(0.0042)*</b>	-0.1715 (0.8647)	-1.4921 (0.1435)	-0.6777 (0.5019)
PPVT Raw Score	-2.2691 (0.0290)	-0.9768 (0.3349)	-0.8441 (0.4039)	-0.6815 (0.4997)

Note. t (p)

\* = significant at .01 level

While we found that speech rate within utterances at seven months relates to and impacts children’s expressive language outcomes at two years, it is important to consider what in those utterances is so important for children. Therefore, we chose to determine through post-hoc analysis if the MLU in words in these specific utterances (rather than across the entire play session sample) also related to children’s expressive language outcomes. To determine the relationship between MLU-words within utterances analyzed and the three test scores obtained at twenty-four months (EOWVT, PPVT, and MCDI), as well as a subset of child language production measures (MLU, types), Pearson

correlations were used. A Bonferroni adjustment was used for these measures. For each age interval,  $p < .05$  was divided by five for each outcome measure, resulting in an alpha of  $p = .01$ . Results are shown in Table 8. No correlations reached significance, although the majority of correlations were in the expected direction and in one case, at seven months, would have reached significance without correction. Why these particular utterances did not show the same relationship with outcomes as the total sample did is unclear, although it is possible that the effects of rate and maternal MLU, since both correlate positively with outcomes, are cumulative. Additional statistical analyses may be able to further elucidate this relationship. Further exploration into what, specifically, in the content of the slower utterances benefits child language outcomes would allow us to determine the mechanism by which slower speech predicts better language outcomes.

**Table 8: Relationship between MLU-Words & Child Language Outcomes**

	7 mo.	10/11 mo.	18 mo.	24 mo.
Types	0.3300 (0.0328)	0.0131 (0.9345)	-0.2915 (0.0611)	-0.1414 (0.3718)
MLU-Morphemes	0.2438 (0.1197)	0.0198 (0.9010)	-0.1167 (0.4617)	-0.2325 (0.1384)
EOWVT Standard Score	0.1351 (0.3935)	0.0160 (0.9198)	-0.1327 (0.4022)	0.0360 (0.8210)
MCDI Raw Score	0.2651 (0.0897)	-0.0145 (0.9276)	-0.0690 (0.6642)	0.0004 (0.9978)
PPVT Raw Score	0.2486 (0.1219)	0.1696 (0.2954)	-0.1106 (0.4968)	-0.1228 (0.4504)

Note.  $r(p)$

*Hypothesis Four – Relationship between Amount of Maternal Input and Child Language Outcomes*

Our final hypothesis predicted that in this specific sample of mother-infant dyads, children of mothers who provide a greater amount of input (as measured by MLU-morphemes, types, tokens, and type-token ratio) would have better language skills at two

years of age, similar to other populations that have been previously studied. This was done to determine that the population we were studying is typical.

Correlations that were conducted between each maternal input variable and each child language variable at each age are shown in Tables 9-12. A Bonferroni adjustment was used for these measures. For each age interval,  $p < .05$  was divided by four for each maternal input measure, resulting in an alpha of  $p = .0125$ .

Each maternal input measure was examined as a separate hypothesis, because the ways in which each maternal input measure potentially relate to the different child language outcomes differ. For example, the number of different words that a child hears (TTR) might affect a child's eventual vocabulary, whereas MLU-morphemes might affect a child's eventual grammatical development, including morphology (word forms) and syntax (sentence structure) skills.

**Table 9: Relationship between Amount of Maternal Input (at 7 mos) & Child Language Measures**

		Child Language Outcomes				
		PPVT Raw	MCDI Raw	EOWVT SS	MLU- Morphemes	Types
Maternal Input Variables	MLU- Morphemes	.2643 (.0993)	<b>.4041</b> <b>(.0079)*</b>	.2172 (.1671)	.2962 (.0568)	.1877 (.2339)
	Types	.3109 (.0509)	.3027 (.0514)	.1394 (.3786)	.3005 (.0532)	.1951 (.2156)
	Tokens	.2456 (.1266)	.2677 (.0865)	.1664 (.2923)	.3016 (.0523)	.2288 (.1450)
	Type-Token Ratio	-.1829 (.2586)	.2526 (.1066)	-.2486 (.1123)	-.2083 (.1856)	-.2333 (.1370)

Note. r (p)

\* = significant at .01 level

**Table 10: Relationship between Amount of Maternal Input (at 10/11 mos) & Child Language Measures**

		Child Language Outcomes				
		PPVT Raw	MCDI Raw	EOWVT SS	MLU- Morphemes	Types
Maternal Input Variables	MLU- Morphemes	.1951 (.2276)	.0108 (.9461)	-.1164 (.4627)	.0622 (.6957)	-.1549 (.3273)
	Types	.3106 (.0511)	.3038 (.0505)	.1593 (.3137)	.3269 (.0346)	.2499 (.1105)
	Tokens	.2719 (.0897)	.1400 (.3765)	.1396 (.3779)	.1399 (.3770)	.1115 (.4821)
	Type-Token Ratio	-.2309 (.1516)	-.0324 (.8384)	-.2173 (.1669)	.0610 (.7013)	-.0300 (.8505)

Note. r (p)

**Table 11: Relationship between Amount of Maternal Input (at 18 mos) & Child Language Measures**

		Child Language Outcomes				
		PPVT Raw	MCDI Raw	EOWVT SS	MLU- Morphemes	Types
Maternal Input Variables	MLU- Morphemes	.0636 (.6968)	-.0545 (.7317)	-.1494 (.3451)	-.0174 (.9128)	-.0379 (.8118)
	Types	<b>.4599</b> <b>(.0028)*</b>	<b>.3943</b> <b>(.0098)*</b>	.2901 (.0624)	.2944 (.0584)	-.1787 (.2574)
	Tokens	<b>.4435</b> <b>(.0041)*</b>	<b>.4177</b> <b>(.0059)*</b>	.3079 (.0473)	.3234 (.0367)	.1418 (.3705)
	Type-Token Ratio	-.2538 (.1140)	-.3429 (.0262)	-.2723 (.0810)	-.2252 (.1516)	-.0805 (.6122)

Note. r (p)

\* = significant at .01 level

**Table 12: Relationship between Amount of Maternal Input (at 24 mos) & Child Language Measures**

		Child Language Outcomes				
		PPVT Raw	MCDI Raw	EOWVT SS	MLU- Morphemes	Types
Maternal Input Variables	MLU- Morphemes	.1017 (.5322)	.2956 (.0573)	.0707 (.6564)	.3766 (.0140)	.0896 (.5727)
	Types	.3423 (.0306)	.2141 (.1734)	.1998 (.2045)	.2564 (.1012)	.2124 (.1769)
	Tokens	.1886 (.2439)	.1212 (.4446)	.0065 (.9676)	.1621 (.3051)	.0772 (.6272)
	Type-Token Ratio	.0122 (.9406)	-.0093 (.9533)	.1771 (.2618)	-.0052 (.9737)	.0197 (.9014)

Note. r (p)

There was a significant effect of MLU-morphemes (for the entire play session sample) in maternal input at seven months on 24-month MCDI scores ( $r = .4041, p = .0079$ ), types in maternal input at eighteen months on 24-month PPVT scores ( $r = .4599, p = .0028$ ) and MCDI scores ( $r = .3943, p = .0098$ ), and tokens in maternal input at eighteen months on PPVT scores ( $r = .4435, p = .0041$ ) and MCDI scores ( $r = .4177, p = .0059$ ).

Although expected trends were observed (increased maternal input relates to increased child language outcomes), only five correlations reached statistical significance. Because these correlations were quite scattered across age intervals and input measures, it is important to consider why this may have occurred. The particular population we studied included a very homogenous middle-class group of mothers and children who generally scored within the typical range at age two. Therefore, there may not be as much variability across maternal language input measures and or child language outcomes as might be found in a more diverse sample, obscuring stronger relationships between input measures and child language outcomes.

Despite the lack of overall significance in these findings, the appropriate observable trends still suggest that this population is typical, because they show that as amount of maternal input increased, child language outcomes improve, a finding that has been previously documented in other typical populations.

## Discussion

The purpose of the present study was to examine the impact of acoustic properties of IDS on child language outcomes. Our parent-child sample appeared representative of those studied by other groups; we confirmed previous descriptions of differences in speech rate and pitch variability between IDS and ADS in our cohort. In addition, we confirmed previous findings that increased amount of maternal input relates to improved child language outcomes across a number of analyses. Thus, we feel able to generalize any significant findings found to other typical populations.

In examining our primary questions, we found that there was a significant relationship between decreased speech rate of maternal IDS at seven months of age and child language development, but that increased pitch variability in IDS did not facilitate child language development; in fact, one significant finding emerged to suggest just the opposite, that pitch variability might adversely impact outcomes. Both results are consistent with Song et al.'s (2010) suggestion that linguistically-relevant acoustic properties of IDS (such as speech rate) might be more relevant for language development than non-linguistically relevant acoustic properties (such as pitch). Surprisingly, no previous studies have examined this relationship. Song et al. (2010) examined the impact of decreased speech rate on task performance in infants who were nineteen-months old. However, based on findings from our exploratory measure regarding the change in speech rate across time within the IDS conditions, the earliest two age intervals (seven and ten/eleven months) were characterized by significantly slower maternal speech rate than the later two age intervals (eighteen and twenty-four months). Therefore, it may be more important to look at the impact that slowed speech rate might have at even earlier

ages. Our results suggest that adjusting speech input rate as early as seven months may be predictive of language outcomes at two years of age.

This finding makes contributions to other areas of research in language development. Previous literature has identified positive impacts that semantic and syntactic properties of IDS have on language development. With our current finding, we can add to the existing literature by proposing the idea that superimposing an acoustic property, such as decreased speech rate, on the already important and impactful semantic and syntactic features of IDS, may provide infants learning language with an even greater benefit.

Although we found a significant relationship between decreased speech rate and child language outcomes, it is possible that there are other factors in our study that may have influenced these results, such as our inclusion criteria. Thus, we cannot necessarily confirm a definite relationship between decreased speech rate and child language outcomes. This potential shortcoming will be discussed in a following section.

Previous research found that, in speech that was manipulated to include either pitch contours characteristic of IDS or ADS, the IDS was easier for infants between the ages of six and a half to seven and half months to segment than ADS (Thiessen, Hill, & Saffran, 2005). In addition, these large pitch contours have been found to improve vowel discrimination skills in infants between six and seven months of age (Trainor & Desjardins, 2002). No significant positive correlations between increased pitch variability in IDS and child language outcomes emerged in the present study. One explanation for this finding is that we found that, across the IDS conditions, pitch variability was only significantly different between the seven and twenty-four month age intervals. Therefore,

if most mothers use quite melodic speech prosody across all age intervals, then significant relationships between the variable at different stages and child language outcomes will not appear due to a ceiling effect.

It is interesting that one acoustic variable (speech rate) significantly related to child language outcomes (MCDI), but the other (pitch variability) did not. However, there are plausible explanations for these results. Decreased speech rate is a linguistically relevant acoustic property – it may provide infants with more time to process the content that they hear. Pitch variability in English, though, may be less linguistically relevant. Changes in pitch in English, a non-tonal language, do not change the meaning of words. Instead, their function in IDS at early stages in infants' lives may be to serve specific behavioral and affective purposes, such as gaining infants' attention or soothing them when they are upset. Therefore, by the age of seven months, gaining an infant's attention by use of exaggerated intonation contour may not be as important to their communicative development as the use of slower rate of speech, which provides an infant with more time to learn.

In our post-hoc analysis, once we ranked our cohort based on the pitch variability they heard, a significant group difference emerged at seven months of age, but it was in the opposite direction that had been predicted. This unexpected finding may relate to the way we analyzed our utterances, which may have given us measures that do not truly represent the variability across the mothers' overall input, and are confined to variability within individual utterances. Another possible, yet weaker, explanation may relate to the idea that perhaps infants at seven months who hear speech with increased pitch variability are not benefitting from the linguistic content of utterances used to gain and

maintain their attention. Alternatively, mothers who produce prosodically more variable utterances are doing so to guide or focus the attention of children who are not paying attention during the task at hand or present with difficult behaviors, who may already not be as receptive to the content of their mothers' input.

Our findings suggest that at seven months of age, adjusting a linguistically relevant acoustic variable in maternal input, such as speech rate, may be advantageous for infants. At an early age (seven months) when content is beginning to become more important and other factors are not greatly interrupting the processing of maternal input, infants may benefit from acoustic properties that assist in providing them with more time to process the content they hear. As they mature, this acoustic property may become less essential, because as their language skills improve, they may not need as much processing time for speech input. However, it would seem as though listeners at any age should benefit from slower presentation of information, so the failure to find this relationship at older child ages merits further consideration.

### Limitations

In interpreting findings of this study, it is important to consider the sample size. Due to our inclusion criteria, several mother-infant dyads were eliminated. Having additional data would allow us to more confidently validate the trends that were observed. Additionally, it is possible that a larger sample size would have provided more power to our analyses.

The recorded play sessions that were analyzed in this study were conducted in a laboratory setting. While the sound-treated therapy room helped to increase experimental control, the interactions did not take place in a natural setting. Although the mothers were

not aware that their input was going to be analyzed, this may impact the ecological validity of the study.

Another limitation was that the mothers' speech (at each stage) and the children's language outcomes were only assessed at a single moment in time. Although the mothers' input was examined longitudinally, at each specific stage, it was only assessed once. If the mothers, on the day of their session, were not having a day that was very typical for them (perhaps in regard to their mood), this could have affected the way they spoke to and with their children. If the children were having an atypical day on the day of their language testing, this could have also affected their outcomes.

Finally, to examine acoustic variables within the mothers' speech, we extracted specific utterances from the overall play session to analyze. Then, these variables were analyzed *within* utterances rather than *across* utterances. While this allowed us to ensure we were matching the stimuli on variables known to influence both rate and prosody, it did not allow us to capture the overall pitch variability across the mothers' speech. For example, a mother may have great pitch variability *across* two utterances (using a high pitch in one turn then quickly adjusting to a lower pitch in the next, as we often saw when mothers interacted with the toys in the session), but when these utterances are divided and assessed separately, pitch variability is obscured. Perhaps a different profile related to pitch variability and child language skills would have emerged if data were not controlled the way that they were.

In addition to potentially impacting the pitch variability variable, extracting specific utterances may also impact the speech rate variable. Adults tend to use longer pauses between utterances when speaking to infants than when speaking to adults (Broen,

1972; Fernald & Simon, 1984; Fernald et al., 1989). By eliminating these characteristic pauses rather than including them, which was done in this study, the impact of speech rate on child language outcomes that we observed may have been different, because previous research has highlighted the potential benefits of IDS with pauses at clausal boundaries (Kemler Nelson, Hirsh-Pasek, Jusczyk, & Cassidy, 1989).

### Directions for Future Research

To account for the limitations mentioned above, future research should assess mother-infant dyad interactions in a natural setting to improve its ecological validity and use a larger sample size to increase statistical power.

Another possibility for future research is to examine these same relationships, but rather than assessing the pitch variability within utterances of IDS, examine the variability across utterances. As previously discussed, controlling for length of utterances may have also impacted the speech rate measures that we obtained. Therefore, it would be helpful for future research to analyze speech rate in utterances with a wider range of utterance lengths, in order to get a true representation of the mothers' overall speech rate.

A final consideration would be to examine these acoustic variables at an even earlier age. It would be interesting to assess the relationship between these acoustic variables of IDS when an infant is just a few weeks or months old and the children's eventual language skills at two years of age. If infants are more focused on the content of input by seven months of age, then acoustic variables, specifically pitch variability, may be more important to them at an earlier age. If this is the case, then researchers may be

able to support the idea that adjusting acoustic variables very early on, such as pitch variability, may be helpful for infants' eventual language development.

In addition to assessing the IDS at an earlier age, it would be interesting to assess the children's language outcomes at a later age to determine if any relationships persist over time. If found to be true, then researchers may suggest that adjusting certain acoustic variables of IDS may have long-term effects on language development.

As previously discussed, there are several other acoustic, semantic, and syntactic features of IDS that may impact language outcomes in some way. By superimposing a decreased rate of speech on this entire package or signal of features, it is possible that infants may gain an additional benefit. If this is the case, rather than speech rate being independent of these other IDS characteristics, they may be considered a type of "delivery" system or packaging for all of these other important features of IDS. An important consideration, then, is for future research to consider and account for speech rate of IDS together with other acoustic, grammatical, and lexical features, rather than by itself, in examining how differences in IDS registers might impact child language outcomes.

### *Clinical Implications*

Our results suggest that speech rate at seven months may impact language learning. This finding may provide useful information in counseling parents of infants, caretakers in child care centers, and other similar populations. Caregivers and parents may utilize this information in adjusting their speech to young infants. It may be beneficial to encourage parents or caregivers to decrease their speech rate when speaking

to their infants at an early age, as it may provide infants with more time to process the speech input to gain maximum benefit from it in the process of language learning.

## References

- Bernstein Ratner, N. (1985). Dissociations between vowel durations and formant frequencies. *Journal of Speech and Hearing Research*, 255–264.
- Bernstein Ratner, N., & Rooney, B. (2001). How accessible is the lexicon in motherese? In J. Weissenborn, & B. Hohle (Eds.), *Approaches to Bootstrapping: Phonological, lexical, syntactic, and neurophysiological aspects of early language acquisition* (pp. 71–78). Amsterdam/Philadelphia: John Benjamins Publishing Company.
- Boersma, Paul & Weenink, David (2015). Praat: doing phonetics by computer [Computer program]. Version 5.4.08, retrieved 14 April 2015 from <http://www.praat.org>
- Bolinger, D. (1989). *Intonation and its uses*. Palo Alto: Stanford University Press.
- Bornstein, M.H. (2005) Expressive vocabulary in language learners from two ecological settings in three language communities. *Infancy*, 7, 299–316.
- Broen, P.A. (1972). The verbal environment of the language-learning child. *Monograph of American Speech and Hearing Association* no. 17, December.
- Cooper, R. P., & Aslin, R. N. (1990). Preference for infant-directed speech in the first month after birth. *Child Development*, 1584–1595.
- Cooper, R. P., Abraham, J., Berman, S., & Staska, M. (1997). The development of infants' preference for motherese. *Infant Behavior and Development*, 477–488.
- De Jong, N. H., & Wempe, T. (2009). Praat script to detect syllable nuclei and measure speech rate automatically. *Behavior Research Methods*, 385–390.
- DePaulo, B.M., & Coleman, L.M. (1986). Talking to children, foreigners, and retarded adults. *Journal of Personality and Social Psychology*, 51, 945–959.
- Dunn, L. M., & Dunn, D. M. (2007). Peabody Picture Vocabulary Test: Fourth Edition. Minneapolis, Minnesota: Pearson Assessments.
- Fenson, L., Dale, P. S., Reznick, S. J., Thal, D., Bates, E., Pethick, S., & Reilly, J. S. (1993). The MacArthur Communicative Development Inventories. Baltimore, Maryland: Paul H. Brookes Publishing Co., Inc.
- Fernald, A. (1992). Human maternal vocalizations to infants as biologically relevant signals. In J. Barkow, L. Cosmides, & J. Tooby (Eds.), *The adapted mind: Evolutionary psychology and the generation of culture*. (pp. 391–428). New York: Oxford University Press.

- Fernald, A. (2000). Speech to infants as hyperspeech: Knowledge-driven processes in early word recognition. *Phonetica*, 57, 242–254.
- Fernald, A., & Kuhl, P. (1987). Acoustic determinants of infant preference for motherese speech. *Infant Behavior and Development*, 279–293.
- Fernald, A., & Simon, T. (1984). Expanded intonation contours in mothers' speech to newborns. *Developmental Psychology*, 104–113.
- Fernald, A., Taeschner, T., Dunn, J., Papousek, M., Boysson-Bardies, B. de, & Fukui, I. (1989). A cross-language study of prosodic modifications in mothers' and fathers' speech to preverbal infants. *Journal of Child Language*, 16, 477–501.
- Furrow, D., Nelson, K., & Benedict, H. (1979). Mothers' speech to children and syntactic development: Some simple relationships. *Journal of Child Language*, 6, 423–442.
- Garnica, O. K. (1977). Some prosodic and paralinguistic features. In C. E. Snow, & C. A. Ferguson (Eds.), *Talking to children: Language input & acquisition* (pp. 63–88). Middle Park: Cambridge University Press.
- Goldfield, B. (1993). Noun bias in maternal speech to one-year-olds. *Journal of Child Language*, 20, 85–99.
- Golinkoff, R.M., & Hirsh-Pasek, K. (2008) How toddlers begin to learn verbs. *Trends in Cognitive Sciences*, 12, 397–403.
- Green J.R., Nip I.S.B., Wilson E.M., Mefferd A.S., & Yunusova, Y. (2010). Lip movement exaggerations during infant-directed speech. *Journal of Speech, Language and Hearing Research*, 53, 1529–1542.
- Grieser, D. L., & Kuhl, P. K. (1988). Maternal speech to infants in a tonal language: Support for universal prosodic feature in motherese. *Developmental Psychology*, 24, 14–20.
- Hart B., & Risley, T.R. (1995). *Meaningful differences in the everyday experience of young American children*. Baltimore: Paul H. Brookes Publishing Co.
- Hilton, N. H., Schuppert, A., & Gooskens, C. (2011). Syllable reduction and articulation rates in Danish, Norwegian, and Swedish. *Nordic Journal of Linguistics*, 215–237.
- Hoff, E., & Naigles, L. (2002). How children use input in acquiring a lexicon. *Child Development*, 73, 418–433.

- Hurtado, N., Marchman, V. A., & Fernald, A. (2008). Does input influence uptake? Links between maternal talk, processing speed and vocabulary size in Spanish-learning children. *Developmental Science, 11*, 31–39.
- Huttenlocher J., Haight W., Bryk A., Seltzer M., & Lyons T. (1991). Early vocabulary growth: Relation to language input and gender. *Developmental Psychology, 27*, 236–348.
- Jacobson J. L., Boersma D. C., Fields R. B., & Olson K. L. (1983). Paralinguistic features of adult speech to infants and small children. *Child Development, 54*, 436–442.
- Kaplan, P.S., Bachorowski, J.-A., Smoski, M.J., & Zinser, M. (2001) Role of clinical diagnosis and medication use in effects of maternal depression on infant-directed speech. *Infancy, 2*, 537–548.
- Kaplan, P.S., Bachorowski, J.-A., & Zarlengo-Strouse, P. (1999). Child-directed speech produced by mothers with symptoms of depression fails to promote associative learning in four-month old infants. *Child Development, 70*, 560–570.
- Katz, G. S., Cohn, J. F., & Moore, C. A. (1996). A combination of vocal fo dynamic and summary features discriminates between three pragmatic categories of infant-directed speech. *Child Development, 205–217*.
- Kemler Nelson, D. G., Hirsh-Pasek, K., Jusczyk, P. W., & Cassidy, K. W. (1989). How the prosodic cues in motherese might assist language learning. *Journal of Child Language, 55–68*.
- Ko, E.S. (2012). Nonlinear development of speaking rate in child-directed speech. *Lingua, 841–857*.
- Kuhl, P.K., Andruski, J.E., Chistovich, I.A., Chistovich, L.A., Kozhevnikova, E.V., Ryskina, V. L., . . . Lacerda, F. (1997). Cross-language analysis of phonetic units in language addressed to infants. *Science, 227*, 684–686.
- Lam, C., & Kitamura, C. (2010). Maternal interactions with a hearing and hearing-impaired twin: Similarities and differences in speech input, interaction quality, and word production. *Journal of Speech Language and Hearing Research, 53*, 543–555.
- Levin, H., Snow, C., & Lee, K. (1984). Nurturant talk to children. *Language and Speech, 147–162*.
- Lindsey, G. A. (1985). Intonation and interrogation: tonal structure and the expression of a pragmatic function in English and other languages (Ph.D. Thesis). Los Angeles, California: University of California.

- Ma, W., Golinkoff, R. M., Houston, D. M., & Hirsh-Pasek, K. (2011). Word learning in infant- and adult-directed speech. *Language Learning and Development*, 185–201.
- MacWhinney, B. (n.d.). Computerized Language Analysis. Pittsburgh, Pennsylvania: Carnegie Mellon University.
- Maguire M.J., Hirsh-Pasek K., & Golinkoff, R.M. (2006). A unified theory of word learning: Putting verb acquisition in context. In K. Hirsh-Pasek & R.M. Golinkoff RM (Eds.), *Action meets word: How children learn verbs* (pp. 364-391). New York: Oxford University Press.
- Martin, N. A., & Brownell, R. (2010). Expressive One-Word Picture Vocabulary Test: Fourth Edition. Novato, California: ATP Assessments.
- McRoberts, G. W., & Best, C. T. (1997). Accommodation in mean f0 during mother-infant and father-infant vocal interactions: A longitudinal case study. *Journal of Child Language*, 24, 719–736.
- McRoberts, G.W., McDonough, C., & Lakusta, L. (2009). The role of verbal repetition in the development of infant speech preferences from 4- to 14-months of age. *Infancy*, 14, 162–194.
- Morgan, J.L. (1986). *From simple input to complex grammar*. Cambridge, MA: MIT Press.
- Nakatani, L. H., O'Connor, K. D., & Aston C. H. (1981) Prosodic aspects of American English speech rhythm. *Phonetica*, 38, 84–106.
- Newport, E. L., Gleitman, H., & Gleitman, L. R. (1977). Mother, I'd rather do it myself: Some effects and non-effects of maternal speech style. In C. E. Snow & C. A. Ferguson (Eds.), *Talking to children: Language input & acquisition* (pp. 109–149). Middle Park: Cambridge University Press.
- Oller, D. (1973). The effect of position in utterance on speech segment duration in English. *The Journal of the Acoustical Society of America*, 1235–1247.
- Papousek, M., Papousek, H., & Haekel, M. (1987). Didactic adjustments in fathers' and mothers' speech to their 3-month-old infants. *Journal of Psycholinguistic Research*, 16, 491–516.
- Phillips, J. R. (1973). Syntax and vocabulary of mothers' speech to young children: Age and sex comparisons. *Child Development*, 182–185.

- Quene, H. (2008). Multilevel modeling of between-speaker and within-speaker variation in spontaneous speech tempo. *The Journal of the Acoustical Society of America*, *123*, 1104–1113.
- Remick, H. (1976). Maternal speech to children during language acquisition. In W. von Raffler-Engel & Y. Lebrun (Eds.), *Baby talk and infant speech* (pp. 223–233). Lisse, Netherlands: Swets & Zeitlinger.
- Rowe, M. L. (2012). A longitudinal investigation of the role of quantity and quality of child-directed speech in vocabulary development. *Child Development*, *83*, 1762–1774.
- Sachs, J., Brown, R., & Salerno, R. A. (1976). Adults' speech to children. In W. von Raffler-Engel & Y. Lebrun (Eds.), *Baby talk and infant speech* (pp. 240–245). Lisse, Netherlands: Swets & Zeitlinger.
- Shneidman, L. A., & Goldin-Meadow, S. (2012). Language input and acquisition in a Mayan village: How important is directed speech? *Developmental Science*, *15*, 659–673.
- Shneidman, L. A., Arroyo, M. E., Levine, S., & Goldin-Meadow, S. (2013). What counts as effective input for word learning? *Journal of Child Language*, *40*, 672–686.
- Snow, C.E. (1977). Mothers' speech research: From input to interaction. In C.E. Snow & C.A. Ferguson (Eds.), *Talking to children: Language input and acquisition* (pp. 31–49). London: Cambridge University Press.
- Soderstrom, M. (2007). Beyond babytalk: Re-evaluating the nature and content of speech input to preverbal infants. *Developmental Review* *27*, 501–532.
- Song, J. Y., Demuth, K., & Morgan, J. (2010). Effects of the acoustic properties of infant-directed speech on infant word recognition. *Journal of Acoustical Society of America*, 389–400.
- Stern, D. N., Spieker, S., Barnett, R., & MacKain, K. (1983). The Prosody of maternal speech: Infant age and context related changes. *Journal of Child Language*, 1–15.
- Swanson, L.A., Leonard, L.B., & Gandour, J. (1992). Vowel duration in mothers' speech to young children. *Journal of Speech and Hearing Research*, *35*, 617–630.
- Thiessen, E. D., Hill, E. A., & Saffran, J. R. (2005). Infant-directed speech facilitates word segmentation. *Infancy*, 53–71.
- Trainor, L. J., & Desjardins, R. N. (2002). Pitch characteristics of infant-directed speech affect infants' ability to discriminate vowels. *Psychonomic Bulletin and Review*, *9*, 335–340.

- Uther, M., Knoll, M.A., & Burnham, D. (2007). Do you speak E-NG-LI-SH? A comparison of foreigner- and infant-directed speech. *Speech Communication, 49*, 27.
- van Heuven, V. J., & van Zanten, E. (2005). Speech rate as a secondary prosodic characteristic of polarity questions in three languages. *Speech Communication, 47*, 87–99.
- Weisleder, A., & Fernald, A. (2013). Talking to children matters: Early language experience strengthens processing and builds vocabulary. *Psychological Science, 24*, 2143–2152.
- Yu, K.M., Khan, S.D., & Sundara, M. (2014). Intonational phonology in Bengali and English infant-directed speech. *Proceedings of Speech Prosody, 7*.
- Yuan, J., Liberman, M., & Cieri, C. (2006). Towards an integrated understanding of speaking rate in conversation. *Proceedings of Interspeech, 7*, 541–544.