INDIVIDUAL VARIABILITY IN MATERNAL INFANT-DIRECTED SPEECH

A Thesis
Submitted to
the Department of Speech, Language, and Hearing Sciences
at the University of Missouri-Columbia

In Partial Fulfillment
of the Requirements for the Degree
Master of Health Sciences

by
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MAY 2023
The undersigned, appointed by the dean of the Graduate School, have examined the thesis entitled

INDIVIDUAL VARIABILITY IN MATERNAL INFANT-DIRECTED SPEECH

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and hereby certify that, in their opinion, it is worthy of acceptance.

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I would first like to thank my academic advisor Dr. Nicholas A. Smith of the School of Health Professions at the University of Missouri-Columbia for his consistent guidance, support, and encouragement throughout my master’s program. I would like to thank Dr. Elizabeth Kelley of the School of Health Professions at the University of Missouri-Columbia for providing valuable suggestions on my thesis. I would like to thank Dr. Ashley Groh of the Department of Psychological Sciences at the University of Missouri-Columbia for allowing me to use audio-video recordings of mother-child interactions that were collected in her lab for my thesis, and for providing helpful feedback on my thesis. Finally, I am grateful to the School of Health Professions at the University of Missouri-Columbia for providing me with the support and resources required to conduct my research.
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Abstract

Infant-directed speech (IDS) is a universal, distinctive way in which adults speak to infants. IDS is characterized by a higher and more variable voice pitch, slower rate of speech, shorter utterances, more repetition, longer pauses, and increased simplification. This study examined acoustical differences between IDS and adult-directed speech (ADS) in terms of mean and median pitch, and pitch variability during play interactions between 42 mother-infant dyads. Also, this study examined individual variability in the degree of pitch enhancement done by mothers in IDS as compared to their own ADS. Finally, this study investigated the potential relation between individual difference in maternal sensitivity and differences in maternal IDS. The results indicated significantly higher mean and median pitches, and a significantly more pitch variability in IDS as compared to ADS. Despite individual variability in the degree to which mothers enhanced their speech while interacting with infants, no significant correlation was found between maternal sensitivity and acoustic measures of IDS pitch.
Introduction

Adults change certain linguistic and prosodic aspects of their speech while interacting with infants (Garnica, 1977; Newport, Gleitman & Gleitman, 1977; Papousek, Papousek, & Bornstein, 1985). This way of speaking to infants is called infant-directed speech (IDS) and it is very different and distinct from adult-directed speech (ADS); ADS is used by adults to speak to other adults. IDS serves several functions. It may help in emotion regulation of the infant (Trainor, Austin & Desjardins, 2000), the maintenance of attention (e.g., Kaplan, Goldstein, Huckey, Owren & Cooper, 1995), and the formation of attachment relationships (e.g., Singh, Morgan & Best, 2002; Trainor et al., 2000). In this thesis, I am exploring the relationship between the pitch properties of maternal IDS and ADS, and how maternal IDS varies across mothers, particularly in relation to varying degrees maternal sensitivity. I begin by reviewing background literature on how caregivers modify their speech and interaction with infants, and how infants respond to these modifications. I then review findings and theoretical accounts related to the functions of these modifications and highlight the gaps in our understanding of infant-directed speech that motivate this project.

Infant-Directed Modifications

IDS (along with infant-directed singing) is characterized by many features: a slower speaking rate, longer pauses, higher pitch, greater pitch variability, shorter utterances, more repetition and simplification as compared to adult-directed speech (Fernald, 1989). Since adults communicate with infants for many reasons, IDS can take several forms, depending on the purpose of communication. For example, adults use different intonational contours for different functions such as attracting the infant’s
attention and giving the infant some comfort (Fernald, 1989, 1992; Katz et al., 1996). IDS is also used by adults to express emotions; different emotions (e.g., love, fear, surprise, etc.) are conveyed using distinct pitch and temporal contours in IDS (Trainor et al., 2000). IDS increases infant arousal (Dominey & Dodane, 2004; Werker & McLeod, 1989), assists in speech segmentation (Kemler Nelson, Hirsh-Pasek, Jusczyk & Cassidy, 1989; Thiessen, Hill & Saffran, 2005), and conveys affect (Bryant & Barrett, 2007; Burnham, Kitamura & Vollmer-Conna, 2002; Fernald, 1992).

The infant-directed quality of interaction extends beyond speech and vocalizations. Parents change their body movements in a wide variety of ways while interacting with infants. This set of modifications is termed “infant-directed action.” Brand and colleagues (2002) found that when mothers were asked to demonstrate the characteristics of objects to infants (as compared to adults), their actions demonstrated greater proximity to the infants, more enthusiasm, a larger range of motion, increased repetitiveness, more interactivity and turn-taking, increased simplification, and a larger amount of time spent looking at the infants’ faces. Also, mothers’ increased pitch range in IDS is combined with increased head movement while interacting with infants (Smith & Strader, 2014). As with IDS, infant-directed actions increase infant attention. This attention-grabbing quality of ID action helps the infant process relevant stimuli, reduce distractions, and provide an increased opportunity to take in information. Specifically, ID action’s characteristics such as increased proximity, more enthusiasm, a larger range of motion, and increased interactivity may facilitate the infant’s attention to the actor’s movements (Brand et al., 2002; see also Parrinello & Ruff, 1988). ID actions may indicate to the infant that the stimulus being presented to them is relevant to them (Csibra
which may facilitate their learning from it. ID action may also serve to highlight unit boundaries within a continuous flow of motion; for example, the increased repetitiveness in ID actions may be particularly helpful in segmenting units of action from the overall flow (Brand et al., 2002). So, there are several behavioral and acoustic modifications that adults adopt while interacting with infants; these modifications are beneficial to infants in a variety of ways that likely reflect sensitivity to the infant’s developmental needs on the part of the caregiver.

**Infants’ Responses to Infant-Directed Modifications**

As discussed in the section above, several studies have examined characteristics of IDS. Now let us look at infants’ responses to IDS. Infants have a preference for IDS over ADS as measured with a variety of experimental paradigms. Glenn and Cunningham (1983) showed that infants between the ages of 9 to 18 months have a preference for their own mother’s IDS as compared to her ADS. Also, using the two-choice head-turn procedure, Fernald (1985) reported that 4-month-olds preferred to listen to a woman’s IDS over her ADS. Initially, it was unclear whether infants preferred the lexical content or the prosody of IDS. However, when stimuli were passed through a low-pass filter at 400 Hz, removing all the lexical/phonetic information in the IDS, infants reliably chose to listen to IDS over ADS (Fernald, 1985). The acoustic modifications characteristic of IDS are also found in infant-directed singing. Mothers use an exaggerated prosody while singing to infants, and infants prefer to listen to infant-directed versions of songs over infant-absent versions (Trainor, 1996).

Infant perception can be tested, even at very young ages, using the visual fixation procedure. During this procedure, infants sit on an adult’s lap or in a highchair in front of
a screen on which visual stimuli are presented. The infant’s attention is first drawn to the screen (usually by a flashing red light on the screen) and then a picture is presented accompanied by an auditory stimulus. The auditory stimulus keeps playing as long as the infant maintains his/her gaze on the screen. Infants interest in the auditory stimulus being played is measured by the amount of time they choose to keep looking at the screen when a particular sound is playing. By comparing the amount of time infants spent looking at the screen to listen to an IDS stimulus to the amount of time they spent looking at the screen to listen to an ADS stimulus, experimenters can determine infant preference.

Cooper and Aslin (1990) used this procedure such that the auditory sequence kept playing for 5 minutes of looking time. Infants’ preference was determined by the mean looking time of infants (newborns and 4-week-olds) across IDS and ADS trials. So, infants are sensitive to modifications in prosody of IDS since very early on in life, and prefer to listen to it over ADS in both speech and singing (e.g., Cooper & Aslin, 1990; Fernald, 1985; Nakata & Trehub, 2004; Pegg, Werker & McLeod, 1992; Trainor, 1996).

Infants prefer ID over AD speech and songs even in the absence of pre- or postnatal exposure. Masataka (1999) used a modified version of the visual fixation-based auditory sequence preference procedure to test the preferences (for ID versus AD singing) in 2-day-old hearing infants of deaf parents. This study found that those infants preferred ID versions over AD versions of the songs in Japanese and English even when they had received no prenatal exposure to IDS from their mothers.

Infant preference for IDS is a widely replicated effect. This was recently confirmed by The ManyBabies Consortium (2020), a collaborative project that aimed to investigate whether infants prefer IDS over ADS, and whether their preference changes
according to age, native language, or research method. Sixty-nine labs from 16 different countries took part in this project by collecting data from 2,329 infants that were between the ages of 3-15 months. Three methods of assessment were used to examine infants’ interest: single-screen central fixation, eye-tracking, and the head-turn preference procedure. This project found that infants prefer IDS over ADS; infants’ preference for IDS increased significantly with age. Also, this preference significantly increased in children for whom the research stimuli matched their native language and dialect. This may be because infants slowly become more and more skilled in the phonology of their native language and start building vocabulary, so they may be listening to stimuli in their native language in a different way, viewing their language as not just “speech” or “register,” but as a language with meaning (Gervain & Mehler, 2010; Johnson, 2016). It is also possible that listening to a foreign language requires more attention, which made infants pay less attention to the differences between IDS and ADS. So, a particular infant’s preference for IDS may depend on how similar the presented IDS is to their experience with IDS in their native language. This preference for IDS over ADS was observed to be strongest in labs that used the head-turn procedure as compared to in labs that used central fixation and eye-tracking methods. This may be because when infants exert a larger amount of effort in tasks (i.e., turning their entire head in the head-turn procedure as opposed to just producing small eye movements in the other approaches), they are more engaged in the task, and this produces stronger effects. Also, only older infants (above the age of 6 months) can do head-turn. So, there may be an impact of the infant’s experience with his/her native language, that infant’s maturity, or both on this preference for IDS over ADS.
Functions of IDS

In the sections above, we looked at speech modifications done by adults while talking to babies, and at how infants prefer IDS. Now, let us examine some linguistic and non-linguistic functions of IDS.

Learning to use spoken language is a challenging achievement for infants. IDS may be providing children with the necessary support to develop speech and language (McMurray, 2016). The differences between IDS and ADS may be contributing to the improvement of several language-related domains such as phoneme category learning (Kuhl et al., 1997), word segmentation (Jusczyk, 1999; Thiessen et al., 2005), phrase segmentation (Hirsh-Pasek et al., 1987), and word learning (Ma et al., 2011). Acquiring phonemic categories and the structure of a particular language, however, are long-term goals that IDS helps infants achieve. What about the fundamental in-the-moment challenges of understanding a speech stream?

In order to understand verbal input, infants need to be able to accurately decode phonemes and words in it; IDS helps with this by making speech more intelligible to infants. The hyperarticulation hypothesis states that adults phonetically exaggerate important sound/lexical contrasts in their IDS, to help the infant learn (Kuhl et al., 1997; Lindblom, 1990). It was found that the vowel hyperarticulation during the production of IDS is significantly larger than that during the production of ADS (Burnham, Kitamura, Vollmer-Conna, 2002; Kuhl, Andruski, Chistovich, Chistovich, Ryskina, Stolyarova, Sundberg & Lacerda, 1997). Liu et al. (2003) found that the clarity of maternal IDS predicts speech discrimination in infants; so, IDS clarity may be facilitating infants’ linguistic development. However, vowel hyperarticulation is absent in IDS towards
infants whose auditory processing is impaired due to some sensory (Lam & Kitamura, 2010, 2012) or cognitive (Kalashnikova, Goswami & Burnham, 2016) disability. This suggests that IDS is used by parents as a didactic tool, and they only use hyperarticulation in IDS (albeit unconsciously) if the infant is going to benefit from it; parents do not use hyperarticulation if the infant has any impairments that may prevent him/her from benefitting from the hyperarticulation. There is also some evidence that IDS may actually have a reduced vowel space (a two-dimensional area formed by linking the first and second vowel formant frequency coordinates), and that IDS may be making speech categories less distinct (Benders, 2013; Englund, 2017; Englund & Behne, 2005; Cristià & Seidl, 2014; McMurray et al., 2013; Miyazawa et al., 2017).

Since very young infants are unable to understand linguistic messages through speech, the main function of IDS may be to convey non-aggression and positive emotions, and to facilitate the infant’s attention on the process of communication through speech prosody (Kuhl, 2000; Parise & Csibra, 2013). The prosody of IDS makes infants attentive to the linguistic input that is being presented; IDS helps facilitate early linguistic processing (Naoi, Minagawa-Kawai, Kobayashi, Takeuchi, Nakamura, Yamamoto, Kojima, 2012; Saito, Aoyama, Kondo, Fukumoto, Konishi, Nakamura, Kobayashi, Toshima, 2007; Zangl & Mills, 2007). Also, the positive affect often expressed through the prosody of IDS encourage infant preference for IDS (Cooper & Aslin, 1990; Trainor & Desjardins, 2002; Singh, Morgan & Best, 2002; Werker, Pegg & McLeod, 1994).

The “put-the-baby-down” hypothesis (Falk, 2009) suggests that IDS may have evolved to help mothers maintain some vocal contact with their infants if the infants are physically away from them. So, IDS may have evolved to comfort infants, help them fall
asleep, keep them attentive, and/or communicate to them that mother is nearby, if she has to put the infant down while doing tasks that require the use of both her hands. While producing IDS, parents use a shortened vocal tract, which is achieved by raising the larynx. When the larynx is raised, there is an increased tension in the vocal folds which leads to an increase in the pitch of the speaker’s voice (Hirai, Honda, Fujimoto & Shimada, 1994). A shortened vocal tract produces higher formant frequencies and a larger space between formants (Kalashnikova, Carignan & Burnham, 2017). In other words, hyper-acoustic vowels (i.e., a larger vowel triangle) and a higher pitch used in IDS by caregivers is primarily due to a shortened vocal tract created by raising the larynx (Kalashnikova, Carignan & Burnham, 2017). Across animal species, a shorter vocal tract is found in smaller animals, and many species raise their larynx while interacting with their young, since this behavior indicates friendliness and a lack of aggression (Morton, 1977). So, humans may be using IDS to appear smaller, friendlier, and less aggressive towards infants. The vocal tract length reduction associated with IDS leads to increased similarity in the acoustic qualities of maternal utterances and infant vocalizations. Infants prefer to listen to speech that is acoustically and linguistically resembling their own vocal productions as compared to speech that is directed towards other adults; this may be why infants prefer IDS over ADS. In summary, IDS appears to serve a number of linguistic and nonlinguistic functions.

**Uniformity and Variability in IDS**

The presence of these infant-directed modifications in so many cultures across the world indicates that infant-directed singing and speech are universal parental behaviors (Fernald et al., 1989; Grieser & Kuhl, 1988; Kitamura, Thanavishuth, Burnham &
Luksaneeyanawin, 2002). IDS is observed in several European, Asian, and African cultures (Ferguson, 1964, 1977; Fernald, 1992), and seen in urban centers all over the world, like Australia, Thailand, Syria, Germany, India, Russia, France, the Middle East, Mexico, etc. (Ferguson 1964, 1977; Fernald, 1992; Fernald et al., 1989; Kitamura, Thanavishuth, Burnham & Luksaneeyanawin, 2002). Also, Watson-Gegeo & Gegeo (1986) found that parents/caregivers in the Kwara’ae group (a Melanesian group of the Solomon Islands) changed their speech in a similar way to IDS when talking to children. Studies comparing gender differences in IDS and ADS showed that IDS used by both mothers and fathers had a higher pitch in IDS than ADS during play or natural discourse (Fernald et al., 1989; Jacobson, Boersma, Fields & Olson, 1983; Warren-Leubecker & Bohannon, 1984; Shute & Wheldall, 1999; Niwano & Sugai, 2003).

As reviewed above, infants pay attention to the prosodic characteristics of infant-directed speech and song and prefer listening to infant-directed versions over adult-directed versions in terms of both speech and song (e.g., Cooper & Aslin, 1990; Fernald, 1985; Nakata & Trehub, 2004; Pegg, Werker & McLeod, 1992; Trainor, 1996). Infants who have had no pre- or post-natal experience with IDS (i.e., hearing infants of deaf parents) still choose to listen to IDS over ADS (Masataka, 1999), and this preference increases with the infant’s age. Also, infants’ preference for IDS seems to be universal and not dependent on language. For instance, Werker, Pegg, & McLeod (1994) found that Cantonese and English infants listened to Cantonese IDS more attentively and affectively than Cantonese ADS. Clearly there has been plenty of evidence on the similarities between speakers of IDS and the universality of IDS, but not so much on how IDS varies across different people who use it or situations in which it is used.
Interactions between a mother and her infant are a combination of tactile, visual and vocal behaviors and facial expressions; IDS is a crucial part of this communication for preverbal infants when the prosodic aspects of IDS are more important than its linguistic content (Saint-Georges et al., 2013; Spinelli et al., 2017; Fernald, 1989; Stern, Spieler, Barnett & MacKain, 1983). A higher and more variable pitch is a hallmark characteristic IDS and is often seen with interactions between parents and their infants (Fernald & Simon, 1984; Fernald et al., 1989).

Pitch is closely related to the fundamental frequency, \( F_0 \), (measured in cycles per second, or Hertz). High-frequency sounds are perceived as high-pitched sounds, while low-frequency sounds are perceived as low-pitched. Voice pitch depends on several factors such as anatomy, cultural/social aspects of speech, etc. A high mean of \( F_0 \) and lots of \( F_0 \) variability indicate that the parent is expressing heightened positive/negative emotions (e.g., anger, happiness; Laukka, Juslin & Bresin, 2005). So, mothers may be using exaggerations in speech to communicate emotions, especially positive ones like happiness, to their infants (Fernald & Kuhl, 1987; Stern et al., 1982; Trainor, Austin & Desjardins, 2000; Kitamura & Burnham, 2003).

Prototypical IDS usually consists of an elevated pitch and increased pitch variation, and these two features of IDS keep the infant engaged and attentive during interactions involving IDS (Golinkoff, Can, Soderstrom & Hirsh-Pasek, 2015; Spinelli, Fasolo, & Mesman, 2017; Fernald & Simon, 1984). However, there are certain situations in which variability across different speakers of IDS can be seen. For instance, depression affects IDS in mothers. A decreased \( F_0 \) mean and variability, and a general absence of vocal emotional expression is found with depressed mothers, mothers who experienced...
an extremely controlled childhood as children, and mothers with a history of dismissing attachments (Kaplan, Bachorowski, Smoski & Zinser, 2001; Bettes, 1988; Poritt, Zinser, Bachorowski & Kaplan, 2014; Spinelli et al., 2016; Milligan, Atkinson, Trehub, Benoit & Poulton, 2003). Also, Lam-Cassettari and Kohlhoff (2020) found that non-depressed mothers used a more variable IDS pitch, produced responses more quickly, had more speech overlap, and used more positive affect in their voice as compared to depressed mothers. Non-depressed mothers also exhibited higher vocal energy during spontaneous play with infants as compared to depressed mothers (Lam-Cassettari & Kohlhoff, 2020). These authors asked naïve listeners to rate the prosody of IDS after passing it through a low-pass filter (to make the content unintelligible and to ensure that the segmental parts of speech samples do not influence listener ratings). The quality of affective intent for depressed mothers was rated as less arousing and exhibiting less positive emotional valence as compared to non-depressed mothers.

Mothers who are depressed take a longer time to respond to their infants’ vocalizations as compared to non-depressed mothers (Lam-Cassettari & Kohlhoff, 2020; Bettes, 1988; Smith, McDaniel, Ispa & McMurray, in press). That is, maternal responses following the end of infant vocalizations is slower with preschoolers when mothers are depressed (Breznitz & Sherman, 1987). The optimal interval between responses is less than a second in duration (e.g., Watson & Ramey, 1972), and pauses that are longer than 3 seconds signal periods of disengagement or “time-outs” (Stern & Gibbon, 1979). This indicates that interactions of children with depressed mothers, whose average response latency is nearly 2 seconds according to Bettes (1988), may be at a disadvantage in their
attempt to engage their mothers in conversation or play (Bateson, 1975; Bruner, 1983; Watson, 1972).

 Mothers who were depressed spoke less to their infants (i.e., produced fewer words) during play (Lam-Cassettari & Kohlhoff, 2020). This is an important result because the amount of communicative input children receive during childhood is linked to early language development (Ramírez-Esparza, García-Sierra & Kuhl, 2017; Ferjan Ramírez, Lytle & Kuhl, 2020; Goldstein, King & West, 2003; Goldstein & Schwade, 2008; Warlaumont & Finnegan, 2016). Sensitively timed turn-taking in conversation encourages infants to vocalize by engaging them in social interactions (Saint-Georges, Chetounani, Cassel, Apcella, Mahdhaoui, Muratori, et al., 2013; Spinelli, Fasolo & Mesman, 2017; Jaffe, Beebe & Feldstein, 2001; Trevarthan, 1998; Cohn & Tronick, 1988).

 Mothers who are more/clinically depressed are less sensitive (i.e., display lower maternal sensitivity) to their infants’ cues as compared to mothers who are less depressed (Bernard, Nissim, Vaccaro, Harris & Lindheim, 2018).

**Maternal Sensitivity**

 Maternal sensitivity is a broad construct consisting of several interrelated attributes of caregiving, such as affect, timing, flexibility, awareness of the infant’s cues, acceptance, conflict mediation/negotiation, and appropriate responsiveness (van Doesum et al., 2007). In other words, maternal sensitivity is a mother’s ability to accurately recognize and interpret her infant’s communication and then respond in a prompt and suitable way (Ainsworth, Bell & Stayton, 1971, 1972, 1974). It is a crucial measure of the quality of the interactions between mothers and infants and it also affects the infant’s
behavior and development (Crittenden & Bonvillian, 1984). Maternal sensitivity to infant feedback helps in the development of secure infant-mother attachments (Bowlby, 1969). Mothers who are highly responsive to infant cues when the infant is a year old develop more secure relationships with their children as compared to mothers who are less responsive (Ainsworth, 1979, 1982; Ainsworth, Blehar, Waters & Wall, 1978). A sensitive mother also provides appropriate contingent and timely vocal cues and acknowledgements of the child’s interests, endeavors, achievements, and affect. Even though she keeps the child busy with and interested in a particular toy/activity, she also allows the child to disengage at times to recompose/reorganize their behavior. A sensitive mother assists the child in regulating arousal and affect. She watches the child and takes an interest in the child’s activities to provide comments or embellishments when the child is no longer interested in that particular activity/toy.

Infants can express and manage their emotions better if their mothers understand and respond appropriately to infant cues (Ainsworth, Blehar, Waters & Wall, 1978; Crockenberg & Leerkes, 2003; Leerkes, Blankson & O’Brien, 2009). However, maternal insensitivity (intrusiveness or hostility towards the infant by the mother) increases unregulated negative affect expressed by the infant and has been linked to behavioral and/or emotional problems in the infant since they are afraid of their mother’s hostility (Eisenberg, Taylor, Widaman & Spinrad, 2015; Kogan & Carter, 1996; Little & Carter, 2005; Papoušek, 2007). Other insensitive behaviors by the mother (rejection, dismissal and ignoring of negative emotions) may cause the infant to reduce negative affect expression, since they do not expect the mother to respond in any way (Field, 1994; Papoušek, 2007; Tronick, 1989; Weinberg & Tronick, 1998).
Maternal Sensitivity and IDS

As discussed above, mothers make modifications to their speech while talking to infants, and these modifications are preferred by and helpful for the linguistic development of infants. This modified speech is IDS. Sensitive mothers can precisely recognize and understand their infant’s cues and respond promptly and appropriately. Why might these two seemingly distinct concepts, i.e., maternal IDS and maternal sensitivity, be related to each other?

First, highly sensitive mothers may be using more exaggerated IDS because they are more in-sync with their infant’s emotions and affect; highly sensitive mothers may be using exaggerated IDS also to continue having a positive interaction with their infants. Spinelli and Mesman (2018) examined maternal sensitivity and maternal IDS prosody in relation to how well the infant is able to regulate negative affect within the Still-Face Paradigm (SFP). The SFP is a simulation and exaggeration of an interruption in parent-child interaction to understand the actions of the parent and the child that indicate the mutual organization of emotions in social interactions (Adamson & Frick, 2003; Tronick & Gianino, 1986; Tronick, Ricks, & Cohn, 1982). The SFP is divided into three distinct phases: the baseline episode, the still-face episode, and the reunion episode. During the baseline episode, the parent is first asked to engage in face-to-face dyadic interaction with the infant for a few minutes. Then, during the still-face episode, the parent abruptly discontinues this interaction and keeps looking at the infant with an expressionless and unresponsive face. After 1-3 minutes, the parent restarts dyadic interaction with the infant (the reunion episode). The quantity and quality of negative affect expressed by the infant reflect the infant’s ability to communicate and regulate negative arousal in the parent-
child interaction (Cohn, 2003). The dyad’s capacity to repair the disruption of the dyadic interaction is an important measure of the quality of that interaction (Kogan & Carter, 1996). Spinelli and Mesman (2018) found that neither IDS prosody nor maternal sensitivity (during the baseline episode of SFP) alone were directly related to the infant’s negative affect during the SFP. However, when maternal sensitivity was accompanied by more modulated, prototypical IDS, the infant displayed an increased ability of regulating negative affect during the stressful SFP episode. In other words, mothers’ production of more prototypical IDS along with more sensitive responses to infant cues may show a more comprehensive understanding of the infant’s emotional needs and affective expressions than either maternal IDS prosody or maternal sensitivity alone. Mothers’ sensitive response to infant distress has increased effectiveness when this response is paired with higher levels of IDS prosody, which may be soothing and regulating for the infant (Spinelli & Mesman, 2018). IDS can regulate infant affect effectively if it is used in a way that fits the infant’s cues. In such conditions, prototypical IDS may be used to express positive emotions as well as to re-establish regular interaction after mismatched moments and after the infant experiences distress (Fernald, 1989; Stern et al., 1982). So, it is possible that more sensitive mothers may be unconsciously (but measurably) using a more exaggerated IDS prosody because they are more attuned to their infant’s specific emotional needs and affective expressions, and because those highly sensitive mothers use this exaggerated IDS to convey positive emotions and continue a positive match during mother-child interactions.

Secondly, mothers change the physical length of their vocal tract while interacting with infants; when mothers produce IDS, they reduce the length of their vocal tract,
which results in increased acoustic similarity between maternal utterances and infant vocalizations (Kalashnikova, Carignan & Burnham, 2017). Mothers’ unconscious attempts through their voice at approximating infants’ utterances during mother-child contingent interactions can indicate maternal sensitivity to the infants’ cues; maternal sensitivity that develops early in the infant’s life facilitates the infant’s linguistic, social, cognitive, and communicative development (Papousek, 2007).

Finally, IDS is influenced by maternal sensitivity to real-time feedback from the infant. In a study by Smith and Trainor (2008), mothers were asked to use words or song to interact with their infants through a microphone. The mothers could watch those infants in real time on silent video, and the mothers were asked to make the infants happy. In the high-positive condition, a mother would receive positive reactions from her infant when her voice pitch rose above a baseline. In the low-positive condition, a mother would receive positive feedback from her infant if her voice pitch fell below that baseline, and her IDS sounded lower-pitched and less like typical IDS. The results of this study showed that maternal IDS was higher in pitch in the high-positive condition than in the low-positive condition, implying that maternal IDS is impacted on by infant feedback. In other words, mothers sensitively respond to their children’s cues by making changes to the pitch of their IDS.

In conclusion, adaptations that mothers make to their voice while interacting with infants seem to be related to maternal sensitivity. Consequently, acoustic features of IDS may also be related to maternal sensitivity. However, this relation between acoustic features of IDS and maternal sensitivity has not been examined directly, which is the gap in literature my study is aiming to fill.
Current Study

One of the main goals of this thesis is to explore the relation between acoustic features of IDS and maternal sensitivity. Given then IDS is characterized by higher mean pitch and greater pitch variability than ADS, I hypothesize that these IDS-related acoustical changes would be demonstrated to greater degree in mothers with higher levels of maternal sensitivity. Specifically, I hypothesize that mothers who are less sensitive to their infants’ cues would have a lower mean pitch and pitch variability for IDS than mothers who are more/highly sensitive. Another goal of this thesis is to examine individual variability in maternal IDS to determine how IDS varies in comparison to ADS across different mothers. Since there seem to be plenty of individual differences (these can be observed in everyday life) among people regarding infant-directed and adult-directed behavior in general, I hypothesize that there is a lot of individual variability in the IDS and ADS used by different mothers.

Method

Participants

Audio-video recordings of mother-infant interaction from 42 dyads (18 male infants; 24 female infants) were examined in this study. These infants were between 5-7 months of age; the majority of infants being 6 months old. This sample comprises a subset of dyads that were originally recruited as part of a larger study (n = 142) on adult attachment representations examined during parent-child interactions (Xu & Groh, 2021). The subset of dyads selected for acoustical analysis in this study were prioritized on the basis of having a broad range of sensitivity scores. The mothers were recruited via University of Missouri university newsletters, the University Hospital, and through yearly
community events. All the mothers in the sample for this thesis were of European origin and native speakers of English. The mothers’ education levels ranged from high school graduation to advanced degree.

**Procedure**

The mother-infant dyads were originally observed at the Family and Child Development Lab at the University of Missouri. The observation room was set up similarly to a living room and there was a blanket on the floor. Mother-child interactions were video-recorded and coded offline for parenting behaviors. Mothers were instructed to play with their infants as they normally would at home, without using any pacifiers or toys for approximately five minutes. Then, the mothers were asked to play with their infants using three different toys (one toy at a time) placed in three separate boxes. Audio recordings of these interactions were used to collect infant-directed speech samples for this thesis.

In this thesis, I primarily focus on acoustic features of mother-infant interactions and the interactions between mothers and other adults. I will only briefly describe details of the method used by Xu and Groh (2021) for collecting recordings of mothers’ interactions with other adults. Mothers’ attachment representations were assessed in the Family and Child Development Lab using the Attachment Script Assessment (ASA; Waters & Rodrigues-Doolabh, 2004). Repeated experiences are represented through cognitive scripts (Bretherton, 1987, 1990; Nelson, 1986; Schank, 1982, 1999); this forms the basis of the ASA. This assessment uses the word-prompt method to examine a person’s access to and awareness of a secure base script; this base script may be supplied by that person’s individual history of secure base support early in life (Waters & Waters,
During this assessment, mothers were given 6 cards (counterbalanced in order), each containing a story title and 12 words; these words provided them with a general outline to build the story. They were asked to come up with the best possible story they could. They were told that each story should be approximately a page’s length if written down, and that the mothers should include as much detail in the story as they could. The mothers were told that, while telling a story, they could change the order of the words or the words themselves, if required. Three of these six stories were about relationships between children (“Baby’s Morning”, “Doctor’s Office”, and “Trip to the Park”). Three of those stories were about relationships of adults (“Camping Trip”, “The Accident”, “Shopping”). Audio recordings of these monologues were used to collect adult-directed speech samples for this thesis.

In previous studies, interactions between mothers and their infants and those between mothers and other adults were recorded using similar procedures as those described in this thesis. For instance, Kondaurova and colleagues (2013) asked mothers to play with their children (using quiet toys) on a blanket on the floor or a chair. The mothers were asked to speak to their children as they normally would at home, and these interactions were recorded and used for collecting IDS samples. In the adult-directed condition, an adult researcher conducted a semi-structured interview with the mothers, this interaction was recorded and used for collecting ADS samples. ADS and IDS sessions were approximately 4-5 minutes long.

**Acoustical Analysis of Mothers’ IDS**

I extracted audio tracks from video recordings of mother-child interactions and saved those audio (.wav) files using Adobe Audition. I then analyzed those audio
recordings using Praat (Boersma, 2001). Segments of each audio file containing productions of IDS or ADS were manually marked by a human coder (the author) in the Praat TextGrids and split into separate audio files. Some such segments were excluded because of background noise, if the mother was talking to one of the researchers in the room, or if the infant was crying/babbling/making any other noise when the mother talked. In previous studies, recordings with background noise were not included in analyses. For instance, Kondaurova and colleagues (2013) excluded any utterances that were accompanied by background noise, infant noises (e.g., infant crying, hiccupping, vocalizing), maternal utterances produced using vocal fry, mothers’ whispers, and noises due to non-speech actions (e.g., laughing, kissing).

The changing pitch contour over time from each of these smaller audio files was derived using the autocorrelation method in Praat (Boersma, 1993). The pitch floor setting on Praat for gathering this pitch data was at 150Hz, and the pitch ceiling was at 1,100 Hz, providing pitch samples at a rate of 167 samples/second. These pitch tracking parameters were set to provide accurate measures of maternal voice pitch while eliminating background noise (e.g., the noise of the air conditioning in the room where the observations were created). All the pitch data (i.e., mean pitch, median pitch, standard deviation (SD) of pitch, interquartile range (IQR) of pitch, difference between IDS and ADS in octaves) was compiled into a single file for each mother. All the statistical analyses of pitch and sensitivity (explained in more detail below) were done using R.

**Maternal Sensitivity Measures**

Parenting behavior was assessed by the Family and Child Development Lab using 5-point scales adapted from those developed for the NICHD Study of Early Child Care
and Youth Development (Frosch & Owen, 2016). These 5-point scales assessed maternal sensitivity to distress and non-distress among other measures. Sensitivity to distress examined the promptness and appropriateness of maternal response to infant cues of distress. Lower scores (i.e., 1-2.9) on this scale indicated that the mother was “very insensitive and unresponsive to her infant’s distress, and higher scores (i.e., 3-5) on this scale indicated that the mother was “exceptionally sensitive and responsive to her infant’s distress. Sensitivity to non-distress examines the mother’s observation and response to her infant’s social gestures, expressions, and other cues. Lower scores on this scale indicate that interactions between the mother and the infant are “characteristically ill-timed or inappropriate” while higher scores indicate that the mother is “exceptionally sensitive and responsive” to her infant’s non-distress cues.

I calculated the mean sensitivity rating of each mother to her infant’s distress and non-distress. This mean sensitivity was used in all the analyses in this thesis. If the infant did not show any signs of distress during the session, this type of sensitivity could not be judged. In these situations, the average sensitivity of the mother was rated the same as her sensitivity to the infant’s non-distressed behavior. Mothers’ sensitivity was rated across toy play and free play; these two contexts were not separated. The subsample of mothers analyzed for this thesis consisted of mothers with a wider range of average sensitivity scores. Correlations between different acoustic measures (e.g., pitch, inter-quartile range, median, etc.) and sensitivity were also calculated to examine the degree of coordination in those acoustic measures and sensitivity.

**Results**

The primary goal of this analysis was to determine whether mothers’ IDS was
higher and more variable in pitch that their ADS, and to examine the individual
variability of IDS and ADS across mothers. Each mother’s pitch was analyzed during her
production of IDS and ADS to obtain measures of mean and median pitch (i.e., how high
in Hz mothers spoke on average in IDS and ADS), as well as measures the mother’s pitch
range and variability (characterized here in terms of standard deviation and inter-quartile
range). A central goal of this project was to examine the degree to which maternal IDS
pitch measures are related to maternal sensitivity during infant distress and non-distress –
whether high-sensitivity mothers use more exaggerated or enhanced IDS than low-
sensitivity mothers.

**Analysis of Voice Pitch**

For each mother, voice pitch samples estimated her changing pitch over periods
of time in the recording when she was addressing her infant (IDS) and periods of time
when she was addressing an adult (ADS). The goal of this analysis was to contrast
measures of central tendency (mean pitch, median pitch) and variability (SD and
interquartile range) for IDS and ADS, both at the level of individual mothers and for the
group as whole. This analysis, therefore, set out to confirm that this group of mothers
engaged in IDS that is similar to that shown in previous studies (i.e., IDS has higher
mean pitch and expanded pitch range), as well as to provide measures of individual
differences in the degree of IDS-related pitch enhancement.

**Comparison of Maternal IDS and ADS**

Using R (R Core Team, 2021), the mean IDS and ADS pitch of each individual
mother was calculated individually for each mother. After this, a mean IDS and ADS
pitch value of the whole group of mothers was calculated. To investigate whether
mothers had a higher pitch in IDS than in ADS, a t-test was conducted on the group means for the IDS and ADS pitches of all the mothers. Mothers’ group IDS pitch mean ($M = 268$ Hz; $SD = 77$ Hz) was significantly higher than their ADS ($M = 217$ Hz; $SD = 70$ Hz; $t(41) = -11.65; p < .01$). A similar procedure was used to calculate the group average median pitch for the IDS condition and the ADS condition. The mean is influenced by outliers, but the median is less so. Therefore, the median pitches of both the IDS and ADS groups were calculated and compared. The group IDS median pitch (250 Hz) was significantly higher, $t(41) = -15.95; p < .01$), than the group ADS median pitch (198 Hz).

**Table 1**

*Pitch characteristics in IDS and ADS*

<table>
<thead>
<tr>
<th>Acoustic measure</th>
<th>IDS condition (Hz)</th>
<th>ADS condition (Hz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>268</td>
<td>217</td>
</tr>
<tr>
<td>Median</td>
<td>250</td>
<td>198</td>
</tr>
<tr>
<td>SD</td>
<td>77</td>
<td>70</td>
</tr>
<tr>
<td>IQR</td>
<td>80</td>
<td>40</td>
</tr>
</tbody>
</table>

The outliers in the data were trimmed by 1% each at the top and bottom ends to eliminate extreme values in the data. A trimmed mean reduces the influence of outliers on measures of a set of data by excluding a certain percentage of observations from the upper and lower end of that dataset. Trimmed means are used to provide a more accurate and reliable statistical mean by lessening the influence of extreme values on the mean. Pitch variability in maternal IDS and ADS was also compared to determine if mothers used a more variable pitch while talking with infants as compared to with adults. IDS was considered whenever the mother talked to the infant. First, the standard deviation (SD),
and then inter-quartile range (IQR; a measure more robust to outliers) of each mother’s pitch values were derived from the IDS and ADS recordings. IQR is used to assess the spread of the data around the median; it is the difference between the 25th and 75th percentiles of a set of values. The results of a paired-samples t-test on these values indicate that the group IDS IQR was significantly higher, $t(41) = -9.33; p < .01$, than the group ADS IQR. The pitch range of mothers’ IDS was twice as wide in their IDS (IQR = 80 Hz) than that in their ADS (IQR = 40 Hz). The group IDS SD was also higher than the group ADS SD, $t(41) = -1.70; p = .10$, but not significantly so. The group IDS SD was 77 Hz and the group ADS SD was 70 Hz. This discrepancy between the difference in IQR and the difference in SD can be explained by the way these two measures work. As mentioned above, IQR is looking at the spread in the middle of the distribution of IDS pitch values and is not affected by outliers. The SD is looking at the average distance of each value from the mean IDS pitch value. SD is affected by outliers. In this case, the outliers seem to have pulled the values of SD for IDS and ADS higher up as compared to their IQR values. The results of the acoustic characteristics of maternal IDS and ADS are summarized in Table 1.

When describing the degree of IDS enhancement for individual mothers it is important to account for baseline differences in mother’s voice pitch which vary across individuals: some mothers have higher or lower pitched voices in general. Therefore, it is useful to calculate individual difference scores in IDS as compared to ADS. This can be done in Hertz units, but octaves above the ADS baseline are useful because they reflect the scaling of frequency by the auditory system. These octaves were calculated using the formula $\log_2(\text{IDS mean pitch}/\text{ADS mean pitch})$. So, each mother’s IDS mean pitch was
calculated in octaves above her ADS pitch to control for baseline differences in ADS pitch across all the mothers. A value of 0 octaves indicates that there is no difference in pitch between that mother’s ADS and IDS pitches. Octave values greater than 0, indicate that that mother’s IDS was higher in pitch as compared to her own ADS. Octave values < 0 indicate that that mother’s IDS was lower in pitch as compared to her own ADS.

On average, mothers’ IDS was 0.3 octaves above her ADS, but considerable individual variability was observed, with the amount of IDS enhancement ranging between -0.12 octaves to 0.59 octaves. Negative values indicate an atypical lowering of pitch in IDS by some mothers.

The analyses above confirm the well-established finding that mothers use a higher mean pitch and expanded pitch range when producing IDS as compared to when producing ADS. Next, we examined individual differences in IDS-related pitch enhancement. Do all mothers produce IDS in a similar way, or does individual variability exist, with some mothers having a much higher pitch and expanded pitch range than others? How do these individual differences relate to other measures of maternal behavior? Do more sensitive mothers enhance their IDS more than less sensitive mothers?

**Individual Variability in Maternal IDS and ADS**

Voice pitch sample distributions (in Hz) that were compiled (in the form of box plots) for IDS and ADS show that there is notable individual variability in the degree of pitch enhancement (i.e., an increase in the median pitch of voice as well as an increase in pitch variability) in IDS relative to ADS (see Figure 1). This means that all the mothers do not enhance their IDS to the same extent. The box plots show the minimum pitch,
pitch in the first quartile, median pitch, pitch in the third quartile, and the maximum pitch. As can be seen in Figure 1, most mothers (39/42 or 93%) showed the group effect reported above. However, considerable individual variability was observed. Some mothers (e.g., 1118) showed a large increase in their median pitch and pitch variability when talking to their infants as compared to when talking to adults. Others (e.g., 1017) showed little/no enhancement in their IDS as compared to their ADS. Pitch enhancement is measured through an increase in the mean and median pitch, and through an increase in pitch variability. One way in which pitch variability can be calculated is by using the interquartile range. As mentioned above, the interquartile range is the difference between the first and third quartiles of a set of data, and the IQR is less affected by outliers. In Figure 1, the IQR is represented by the difference in the upper and lower boundaries of each box plot. A large difference in the upper and lower boundaries of a particular box represents large pitch variability used by that mother in that condition (i.e., while using either IDS or ADS). For instance, Mother 1107 uses a much larger pitch variability while talking to her infant as compared to while talking to another adult; this is represented by the much larger difference in the upper and lower bounds of her IDS box plot as compared to the difference in the upper and lower bounds of her ADS box plot.
Figure 1

Box plots showing the distribution of pitch sample values (in Hz) for individual mothers for IDS and ADS

Note. Individual mothers’ (by subject ID) ADS and IDS box plots are shown in each panel. It is expected for the IDS box plots (as compared to the ADS box plots) to be wider (i.e., have a larger IQR) and have a higher median for each of the mothers, although exceptions to this are observed in the figure (e.g., 1016).

Maternal Sensitivity and IDS Features

In Figure 2, IDS-related octave differences are plotted as a function of maternal sensitivity, where each point represents the value of the difference between a particular mother’s IDS and ADS pitches in octaves. Contrary to expectations, it was found that there was a non-significant correlation between sensitivity and the number of octaves by
which IDS is higher in pitch than ADS, $r(40) = -.16, p = .32$ (see Figure 2). That is, highly sensitive mothers did not raise their IDS more than less sensitive mothers.

**Figure 2**
*Octave difference in IDS and ADS as a function of maternal sensitivity scores*

![Octave difference in IDS and ADS as a function of maternal sensitivity scores](image)

*Note.* Values above horizontal line at 0 represent mothers with higher IDS than ADS.

Correlations between different acoustic measures and maternal sensitivity were calculated to test whether mothers that were higher in sensitivity had IDS that was different in some way than mothers with low sensitivity. A non-significant correlation was observed between IDS mean pitch and maternal sensitivity, $r(40) = -.20; p = .21$ (see Figure 3, Table 2). There was also a nonsignificant correlation between IDS median pitch
and maternal sensitivity, \( r(40) = -0.21; p = 0.18 \) (see Figure 4, Table 2). These results indicate that as maternal sensitivity increases, the pitch of maternal IDS decreases slightly, although the results were nonsignificant. Highly sensitive mothers tended to have a slightly lower IDS pitch as compared to low sensitivity mothers. This result is surprising and does not support the study’s hypothesis that highly sensitive mothers would have a higher IDS pitch as compared to low sensitivity mothers.

Figure 3

*Mothers’ mean IDS pitch (Hz) as a function of maternal sensitivity scores*
There was a non-significant correlation between maternal IDS SD and maternal sensitivity: $r(40) = -0.05; p = 0.77$ (see Figure 5, Table 2). There is also a non-significant correlation between maternal IDS IQR and maternal sensitivity: $r(40) = 0.00; p = 0.98$ (see Figure 6, Table 2). There doesn’t seem to be any significant relation between maternal sensitivity and IDS pitch variability. This is another surprising result and goes against this study’s hypothesis that highly sensitive mothers would have a more variable IDS pitch variability as compared to low sensitivity mothers.
Table 2

*Correlations between maternal sensitivity and acoustical measures of maternal IDS*

<table>
<thead>
<tr>
<th>Maternal Sensitivity</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Octaves (IDS - ADS)</td>
<td>-0.13</td>
</tr>
<tr>
<td>IDS mean pitch</td>
<td>-0.20</td>
</tr>
<tr>
<td>IDS median pitch</td>
<td>-0.21</td>
</tr>
<tr>
<td>IDS SD</td>
<td>-0.05</td>
</tr>
<tr>
<td>IDS IQR</td>
<td>-0.00</td>
</tr>
</tbody>
</table>

Figure 5

*SD in mothers’ pitch (Hz) as a function of maternal sensitivity scores*
Discussion

The present study examined acoustical differences between maternal IDS and ADS (in terms of different acoustic measures such as mean pitch, standard deviation in pitch, inter-quartile ranges of pitch). The primary purpose of this was to examine individual variability in mothers’ IDS. This study also investigated the relationship between these acoustic measures of IDS and measures of maternal sensitivity.
It was found in this study that mothers’ pitch was significantly higher in the IDS condition as compared to ADS condition. This confirms and replicates previous research. For instance, Garnica (1977) found that mothers use a higher pitch and more pitch variability in their IDS while interacting with 2-year-olds as compared to 5-year-olds. Maternal mean IDS pitch in this thesis was close in value to maternal mean IDS pitch found in previous studies (e.g., Kondaurova et al., 2013; Fernald et al., 1989; McRoberts & Best, 1997; Kondaurova & Bergeson, 2011). In this study, mothers mean pitch increased from 217 Hz in the ADS condition to 268 Hz in the IDS condition – an increase of 0.3 octaves. For the purposes of comparison, I calculated the average IDS-ADS pitch difference across several studies also examining speech in English-speaking American mother-infant dyads. Across these studies (i.e., Kondaurova et al., 2013; Fernald et al., 1989; McRoberts & Best, 1997; Kondaurova & Bergeson, 2011), mothers’ pitch increased from an average of 195 Hz in ADS, to 282 Hz in IDS – an increase of 0.53 octaves. This smaller difference of 0.3 octaves between maternal IDS and ADS in this study appears to be due to the higher mean ADS value (as compared to mean ADS in previous studies). A possible reason for mothers using a higher pitched ADS in this thesis’ sample may be that the mothers were nervous during the recording. Another possibility is that these particular mothers may have happened to use a higher ADS pitch at the time the recording was done (since these mothers were telling parent-infant relevant stories to other adults and not simply communicating with other adults) and that this pitch may not be indicative/reflective of their overall ADS pitch. In some previous studies, experimenters used a semi-structured short interview to elicit ADS from mothers (e.g., Kondaurova & Bergeson, 2011). Some studies used role-playing situations (e.g.,
adults expressing approval to other adults, adults answering a phone call by starting a conversation with another adult, etc.) to elicit ADS from mothers (e.g., Fernald et al., 1989).

The results of this thesis indicated that mothers used a significantly more variable pitch, when quantified in terms of IQR, in the IDS condition as compared to the ADS condition. This result corroborates the findings of several previous studies. For instance, Stern et al. (1983) discovered that maternal IDS pitch variability is highest when the mothers are talking to 4-month-olds as compared to newborns, 12-, and 24-month-olds. However, the standard deviation values of IDS and ADS was very similar. The standard deviations of the pitches of maternal IDS and ADS in this thesis were much higher in value (IDS: 77 Hz vs ADS: 70 Hz) than those in previous studies (IDS: 45 Hz vs. ADS: 18 Hz; Kondaurova et al., 2013; Fernald et al., 1989; McRoberts & Best, 1997; Konduarova & Bergeson, 2011). This increased variability in terms of standard deviation observed in this thesis may be due to a variety of reasons. For instance, this particular set of mothers may have had a higher-than-average variation in their IDS and ADS. Also, previous research has shown that when mothers produced spontaneous speech, there was more pitch variability between IDS and ADS as compared to the speech mothers used while reading to their infants (Cox et al., 2022). Therefore, it is possible that the IDS from the recordings used for this thesis could have varied in pitch across tasks (i.e., during free play, toy play, and book reading). An in-depth analysis of the pitch variability used by mothers in different tasks may better explain the variation in standard deviation observed in this thesis.
Several characteristics of IDS, including a higher pitch (Fernald et al., 1989) and a wider pitch range (e.g., Garnica, 1977; Stern et al., 1983; Fernald & Simon, 1984; Fernald et al., 1989), are shared across different languages such as French, German, Italian, English (Fernald et al., 1989), Japanese (Fernald et al., 1989; Werker et al., 2007), Mandarin (Liu et al., 2007) and Thai (Kitamura et al., 2002). So, it is quite clear that IDS modifications are commonplace. However, do all mothers make these speech modifications while talking to their infants? Also, do all mothers modify their speech to the same extent? Very little research has examined the degree to which different mothers vary their IDS in comparison to their ADS. One of the major goals of this study was to examine and compare the IDS and ADS of different mothers. Specifically, we examined the degree of enhancement, by looking at the increase in mean and median pitch and the increase in pitch variability in maternal IDS relative to maternal ADS. The results showed that there is considerable individual variability across mothers in terms of median pitch and pitch variability in IDS and ADS (see Figure 1). As seen in this figure, some mothers (e.g., 1107) showed increased variability and a much higher median pitch while using IDS than ADS. Some other mothers (e.g., 1001) showed a very small increase in variability and median pitch while interacting with infants as opposed to with other adults. Others still actually spoke to infants with a decreased pitch variability and median pitch than to other adults – a pattern that runs counter to typical IDS. These results suggest that IDS modifications can and do vary quite a bit across mothers.

**Influences on IDS across Different Groups**

Just as there are individual factors that make IDS vary across different mothers, there are also some influences on IDS that make it vary across different groups of people.
Let us now consider some of these group influences on IDS. Although there is little evidence about individual differences in IDS usage, there is considerable evidence on group variability in IDS. For instance, Benders, StGeorge and Fletcher (2021) found that both fathers and mothers used a higher and more variable pitch while using IDS as compared to ADS. Benders, StGeorge and Fletcher (2021) also found that fathers used a more variable pitch range within utterances as compared to mothers. This contrasts with previous research claiming that fathers did not vary their pitch at all while using IDS (Sheehan, 2008; Broesch & Bryant, 2018; Gergely et al., 2017; Jacobson et al., 1983; Van de Weijer, 1997), that fathers did not vary their pitch as much as mothers did (Fernald et al., 1989; Papoušek et al., 1987), or that fathers used a similarly-varied pitch range as compared to mothers (Weirich & Simpson, 2019; Weirich et al., 2019). Benders, StGeorge & Fletcher (2021) found that both mothers and fathers expanded their pitch range across utterances.

As between parents/caregivers, there are some similarities and differences across the IDS used by different populations, cultures, and languages. For instance, Fernald et al. (1989) found less pitch variability in Japanese IDS as compared to the IDS of Germanic languages. More recently, Broesch & Bryant (2015) found that Fijian, Kenyan, and North American mothers used a higher and more variable IDS pitch (with no significant differences in average IDS pitch across the cultures) and a lower speech rate while using IDS. In a large-scale, international study done by Hilton et al. (2022), more than 1,600 recordings of infant-directed and adult-directed speech and song were obtained from 410 individuals in 21 urban, rural, and small communities. These recordings were played to over 51,000 people from 187 different countries. The results of
this study indicated that naive listeners could reliably differentiate between infant-directed vocalizations and adult-directed vocalizations of unfamiliar linguistic, cultural, and geographic origins. This study also found that there are some acoustic and perceptual patterns in infant-directed speech that are influenced by culture. This study also found that, across cultures, infant-directed speech is more intense and variable (e.g., consisting of higher pitch variability and increased intensity) and infant-directed song was more soothing (e.g., ID song had decreased pitch variability and intensity) when both of these were addressed to a “fussy infant.” These results indicate that infant-directed vocal communication (including ID speech) is influenced by the infant’s mood.

Infant age and other factors (e.g., hearing ability) have an impact on IDS. While IDS consistently has a higher pitch as compared to ADS, IDS pitch varies as a function of infant age. Pitch continues to increase over infant age until the infant is around a year old, and then pitch decreases when the infant is between 16 to 30 months of age (Kitamura, Thanavishuth, Burnham, & Luksaneevanawin, 2002; Remick, 1976; Stern, Spieker, Bernet, & MacKain, 1983).

Along with a heightened pitch, IDS is also characterized by more positive vocal affect (than ADS), which conveys positive emotion and helps maintain the emotional state of infants during early caregiver-child interactions (Kitamura & Burnham, 2003; Singh, Morgan & Best, 2002; Papoušek, Bornstein, Nuzzo, Papoušek & Symmes, 1990). The nature of positive affect in maternal IDS changes as a function of infant age. Maternal IDS is more comforting to infants at 3 months, more approving at 6 months, and more directive at 9 months. Positive affect in IDS is also influenced by infant hearing abilities and age; mothers modulate the affective qualities of their IDS according to their
infant’s hearing experience and the directive qualities of their IDS according to the infant’s chronological age (Kondaurova, Bergeson, Xu & Kitamura, 2015).

Another component of IDS is vowel hyperarticulation. The area of the triangle in a plot of the first and second formants of the vowels /i/ (“ee”), /u/ (“oo”), and /a/ (“aa”) is significantly larger in IDS as compared to that in ADS (Burnham et al., 2002; Kalashnikova et al., 2017; Kuhl et al., 1997; Uther, Knoll & Burnham, 2007). This expanded vowel triangle makes speech more intelligible to infants (Bradlow, Torretta & Pisoni, 1996). However, caregivers do not use vowel articulation with infants that have impaired hearing abilities due to cognition-related (genetic risk for dyslexia; Kalashnikova et al., 2018) or sensory-related disorders (hearing loss; Lam & Kitamura, 2010).

Finally, maternal IDS is also influenced by maternal depression. As discussed previously, depressed mothers have lower IDS mean pitch and variability, convey a lower amount of emotional expression and positive affect through IDS (Kaplan, Bachorowski, Smoski & Zinser, 2001; Bettes, 1988; Poritt, Zinser, Bachorowski & Kaplan, 2014; Spinelli et al., 2016; Milligan, Atkinson, Trehub, Benoit & Poulton, 2003; Lam-Cassettari & Kohlhoff 2020). So, maternal IDS changes across different groups of individuals as a function of caregiver gender, language, infant age, infant hearing abilities, and infant feedback.

**Maternal Sensitivity and Acoustics of Maternal IDS**

One of the primary goals of this thesis was to examine whether highly sensitive mothers enhanced their IDS to a greater degree than mothers who were not very sensitive to their infants’ cues. I had hypothesized that mothers with higher sensitivity scores
would produce more enhanced IDS in terms of mean pitch and pitch variability. However, the results indicate that there is a lack of a correlation between maternal sensitivity and maternal IDS features (i.e., mean, median, SD, and IQR). This lack of correlation between maternal sensitivity and maternal IDS features may be due to several different reasons. It is possible that measures of maternal sensitivity differ across toy play (i.e., when the mother uses toys while playing with the infant) and free play (i.e., when the mother does not use any toys while playing with the child). The IDS audio samples collected for this thesis were of mothers talking to their children during toy play as well as free play; these two play contexts were not separately analyzed. Maternal behavior varies quite a bit across contexts, and the extent to which parents experience challenge during parent-child interactions influences the quality of parental behavior (Seifer, Sameroff, Anagnostopolou, & Elias, 1992; Kogan & Carter, 1996). Contexts presenting a low amount of challenge (e.g., free unstructured play) may be more representative of parental behavior in everyday life (due to lower emotional/instrumental demands on parents) while more challenging situations may make parents exert more effort to stay calm and regulated (Isabella, 1998; Miller et al., 2002; Kogan & Carter, 1996). Ciciolla and West (2013) found that when the parenting demand was low on mothers (e.g., during unstructured free play), maternal sensitive responses to infant cues were high with those parents’ preschoolers and remained high over time. In more challenging situations that increased parenting demand (e.g., teaching, behavior/emotional management), sensitivity was lower for younger children and increased across preschool years (Ciciolla & West, 2013). So, maternal behavior (including sensitivity) changes based on children’s developmental demands and particular child-rearing contexts (Ciciolla & West, 2013).
Therefore, it is possible that maternal sensitivity varied across free play and toy play in the sample analyzed for this thesis.

Low maternal sensitivity captures three different parenting dimensions, which are detachment, intrusiveness, and negative regard. A parent is considered detached when they appear uninvolved/disengaged/unaware of the child’s cues for interaction and do not sufficiently scaffold the child’s engagement with objects or people (Frosch & Owen, 2016). This parent does not provide contingent responses to the child’s utterances or actions, and their response timing is not in synchrony with the child’s affect/responses (Frosch & Owen, 2016). An intrusive parent interacts with the child in an adult-centered fashion rather than in a child-centered fashion. Intrusive parents continue or escalate their interaction with the child even after the child responds negatively (e.g., averts his/her gaze, turns away, displays negative affect) to the interaction (Frosch & Owen, 2016). A parent who has negative regard for their child experiences negative feelings about their child. These three traits were not explored individually in this thesis. This diversity/heterogeneity in parenting traits represented overall by maternal sensitivity may have contributed to a lack of significant findings between maternal sensitivity and maternal IDS.

It is possible that maternal sensitivity and IDS speech modifications could be unrelated phenomena. IDS may vary significantly according to a number of factors (e.g., age, culture, infant feedback), but and that sensitivity is not one of those factors. Perhaps maternal sensitivity does not influence mothers’ vocal behavior. This is possible, but does not seem very probable, given that IDS is so heavily and dynamically influenced by parental factors (e.g., parental gender, depression) as well as infant factors (e.g., age,
feedback). As mentioned above, more sensitive mothers may be using a more exaggerated IDS prosody because they are more in tune with their infants’ particular emotional needs and expression of affect. Highly sensitive mothers may also be using more exaggerated IDS to convey positive emotions to continue a positive interaction with their child. Highly sensitive mothers also respond sensitively to their child’s cues by reducing the length of their vocal tract (so that there in an increased similarity in terms of acoustics between maternal and infant utterances) to produce IDS during contingent mother-child interactions (Kalashnikova, Carignan & Burnham, 2017), and by changing the pitch of their IDS according to their infants’ cues (Smith & Trainor, 2008). So, it is not very probable that maternal sensitivity and IDS pitch modifications are unrelated phenomena.

Another possibility is that the acoustical measure of mothers’ IDS recordings analyzed here are not fully representative of the mothers’ true vocal behavior. As mentioned above, the mean ADS pitch of mothers in this study is much higher than the mean ADS pitch of mothers in previous studies. For example, the mean ADS pitch of mothers in Kondaurova and Bergeson (2011) is 189 Hz, while that of mothers in this thesis is 223 Hz. This difference may be due to a variety of reasons including due to an increase in the mothers’ anxiety level in the recordings used for this thesis. This difference may also be due to these mothers telling parent-infant related stories to the researchers and not just communicating with other adults.

Another possibility is that this result is due to the short duration and setting of the analyzed recordings. I analyzed the IDS of mothers over a duration of approximately 10 minutes. Furthermore, it is unclear how stable maternal IDS is across time, and so it may
be difficult to generalize each mother’s IDS in the short recording to her IDS in general. Mothers’ IDS may also have been influenced by the fact that the mothers knew they were being audio- and video-recorded during the lab activities, and the mother-infant dyad were in a foreign setting. Also, the recordings were very noisy, so important acoustic information may have been lost in the noise.

Lastly, the sample size analyzed for this thesis was relatively small for the examination of individual differences in IDS and ADS across mothers and for correlations between maternal sensitivity and maternal IDS. This small sample size may have reduced the power (i.e., the likelihood of finding an effect in the sample when such an effect exists in the target population of mothers and their infants) of finding significant associations between acoustic features of maternal IDS and maternal sensitivity.

In conclusion, this thesis presents some findings regarding mother-child interactions that have been explored very extensively in past research, and other findings that need to be explored more in the future.

**Future Directions**

This thesis found that maternal IDS was significantly higher-pitched and more variable in pitch as compared to maternal ADS. This result confirms and replicates several previously done research studies. It was found that there is plenty of individual variability in the extent to which different mothers enhanced their IDS as compared to their ADS. Also, no significant correlation was found between the acoustic features of maternal IDS and maternal sensitivity.

As mentioned above, sensitive mothers may be unconsciously (but measurably) exaggerating their speech while interacting with their infants because these mothers are
more accustomed to their infants’ particular emotional requirements and expressions of affect, and sensitive mothers may also be using exaggerated IDS to convey positive emotions and continue a positive interaction with their infants (Spinelli & Mesman, 2018). Also, mothers make modifications to their voice while interacting with infants in response to infant cues. Therefore, it was rather surprising and seems improbable that maternal sensitivity is not related to maternal IDS, according to my thesis. As discussed above, this nonsignificant relationship between maternal sensitivity and maternal IDS could be due to a variety of reasons. The causal relationship between maternal sensitivity and maternal IDS should be explored further in future studies. In other words, more research needs to be done on what factors (if not sensitivity) underlie individual differences in IDS.

As discussed above, the highly variable prosody of prototypical IDS may serve to convey non-aggression and positive emotions, as well as to help maintain the infant’s attention on linguistic input; highly variable IDS may help improve early language processing (Kuhl, 2000; Parise & Csiabra, 2013; Naoi, Minagawa-Kawai, Kobayashi, Takeuchi, Nakamura, Yamamoto, Kojima, 2012; Saito, Aoyama, Kondo, Fukumoto, Konishi, Nakamura, Kobayashi, Toshima, 2007; Zangl & Mills, 2007). So, it is possible that if mothers’ IDS is not very variable in terms of prosody, this could have an adverse impact on children’s language development. Therefore, it is important to explore the individual variability in maternal ADS and IDS found in this thesis on a larger scale along with the effect of this individual variability on children’s language development.

Collecting and using more extensive voice samples, analyzing a larger sample size, and better-quality recordings along with other measures of maternal sensitivity will
perhaps help shed more light on the relationship between maternal sensitivity and maternal IDS as well as explain the individual variability in maternal IDS. Also, since maternal sensitivity varies across different contexts, future research should also investigate the relationship between maternal IDS and maternal sensitivity assessed in different parenting situations (e.g., during toy play and free play).

There has been plenty of research done in the past on mother-infant interactions. Relatively less is known about the impact of paternal sensitivity on child language development. It would be interesting to explore the relation between paternal sensitivity and paternal IDS, and to explore the individual variability in paternal IDS.

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