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Influence of paternal involvement on fathers' infant-directed speech and infants' brain activity to male and female speech

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An abstract of
A dissertation submitted to the Faculty of the Graduate School of Emory University in
partial fulfillment of the requirements for the degree of
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Abstract

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The present study investigated the relationship between paternal involvement and the speech fathers use with their infants, as well as, how experience with paternal speech affects patterns of brain activity to male speech for 6-month-olds. Both mothers and fathers alter their speech when talking to an infant relative to when they talk to an adult. This special speech register is called infant-directed speech (IDS) and is characterized by slower tempo, higher and more variable pitch, repetition, and simplified vocabulary. It was hypothesized that more involved fathers would use IDS to a greater degree than fathers who were less involved in caregiving. It was also expected that infants' brain activity to male speech would differ based on experience with paternal IDS.

Data were collected in two sessions. In the first session, mother-infant and father-infant interactions were recorded and analyzed to provide a descriptive account of parents' use of IDS, along with measures of parental involvement. Shortly after this session, infants' brain activity was recorded while they listened to familiar words in four conditions: male IDS, male ADS, female IDS, and female ADS. The findings revealed that paternal involvement was related to the amount of IDS fathers used but not the moderation of the acoustic characteristics of IDS, such as pitch. Moreover, infants' patterns of brain activity to male IDS were related to both paternal involvement in caregiving and fathers' use of IDS in the interactions. Overall, this study furthers our understanding of the unique contributions fathers' make to children's cognitive development and the ways infants' early experiences shape their neural development.

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The speech infant's hear on a daily basis can vary a great deal. For example, they may hear speech from their mother, other adults, siblings, their peers, or even from the television. Moreover, these different speakers may be communicating with adults, with children, or with young infants and each of these interactions may result in different acoustic signatures. It has been well documented that, when speaking to infants, mothers alter their speech in comparison to when they talk to other adults. This speech register, called "motherese" or infant-directed speech (IDS), is characterized by slower tempo, higher and more variable fundamental frequency, repetition, exaggerated vowels, and simplified vocabulary and syntax (Fernald & Morikawa, 1993; Fernald *et al.*, 1989; Garnica, 1977; Kuhl *et al.*, 1997), when compared to adult-directed speech (ADS). However, mothers are not the only ones to use IDS; fathers (Fernald et al., 1989), grandmothers (Shute & Wheldall, 2001), children (Weppelman *et al.*, 2003), and even adults who have little experience with infants (Jacobson, Boersma, Fields, & Olson, 1983) use IDS as well. The majority of research on infants' exposure to speech focuses on maternal speech; however, children experience a much broader array of language input from siblings and peers, fathers, grandparents, and other non-parental caregivers. These non-maternal interactions may have a great influence on an infant's language development. For example, a father's language input to a child at 24 months of age differs from a mother's (on verbal output, turn length, different word roots, and wh-questions) and is a better predictor of the child's language abilities at 36 months of age than maternal input (Pancsofar & Vernon-Feagans, 2006).

The varied functions for IDS across development will be discussed below, but one of the main functions IDS serves for the preverbal infant may be to direct and maintain attention. Fernald (1985) suggests that the properties of IDS that modulate infant attention and arousal may be due to predispositions of the infant to respond to the unique acoustic signature of IDS. Infants at a young age particularly prefer the higher fundamental frequency of female IDS (Fernald & Kuhl, 1987). However, the question remains whether or not male IDS can equally modulate infant attention. The present study is motivated by two broad goals. The first goal is to examine the production of IDS by fathers and how paternal involvement may influence paternal IDS. As will be detailed below, familial context plays a great role in shaping paternal involvement and the quantity of time that the father spends with his infant, which may also relate to the vocalizations a father produces when interacting with his children. The second goal is to examine how experience with paternal IDS may affect infant attention to male IDS reflected in patterns of brain activity and the organization of the underlying neural systems that are involved in processing IDS to male vs. female speakers.

This introduction begins with a definition of IDS and research on its varied functions. The bulk of this research has been conducted with female IDS and with infants under the age of one. This is followed by a discussion of what we know about fathers' use of IDS and how it is similar and dissimilar to maternal IDS. The ways in which paternal involvement may affect paternal vocalizations is then examined. After demonstrating that infants may have different levels of exposure to paternal IDS, the role these experiences play in shaping how infants attend to male IDS and methods to test developmental changes in the neural systems underlying infant attention to spoken language will be addressed. Finally, the hypotheses to be tested and a brief overview of the proposed study are provided.

Infant-directed speech

Characteristics of Infant-directed Speech

As defined above, IDS is typically characterized by slower tempo, higher fundamental frequency[1], repetition, exaggerated vowels, and simplified vocabulary and syntax (Fernald & Morikawa, 1993; Fernald & Simon, 1984; Fernald et al., 1989; Garnica, 1977; Grieser & Kuhl, 1988; Kuhl et al., 1997). Though most of the research has been conducted with American English and the specific modifications made may differ across languages, the use of IDS has been documented for many languages, including: Australian English (Kitamura, Thanavishuth, Burnham, & Luksaneeyanawin, 2002), British English (Fernald et al., 1989; Shute & Wheldall, 1989, 2001), French (Fernald et al., 1989), Italian (Fernald et al., 1989), German (Fernald & Simon, 1984; Fernald et al., 1989), Mandarin Chinese (Grieser & Kuhl, 1988; Papousek, Papousek, & Symmes, 1991), Japanese (Fernald & Morikawa, 1993; Fernald et al., 1989), and Thai (Kitamura et al., 2002). IDS has also been identified in both American Sign Language (Reilly & Bellugi, 1996) and Japanese Sign Language (Masataka, 1992). The research presented here will focus on IDS in American English unless otherwise specified. In the present study, IDS is defined by the experimental condition while recording speech (i.e., parent-infant interaction or parent-experimenter interaction) and experimental stimuli presented to the infant during a laboratory visit, where infants may hear IDS and ADS that was pre-recorded.

Fernald and Mazzie (1991) recorded mothers speaking to their 14-month-old infants. They found that IDS had a higher fundamental frequency minimum and maximum, and a larger range in fundamental frequency. They also found that IDS utterances contained fewer words on average and new words being introduced by the mother occurred during a peak in fundamental frequency. This was true for both the first and second time a new word was introduced to the infant. These words were judged by independent listeners to be linguistically stressed by the mother. New words were also typically placed in the utterance final position. The authors suggest that these particular characteristics of IDS may facilitate the infants' ability to match referents to words. Newport, Gleitman, and Gleitman (1977) report that IDS is also syntactically and morphologically simplified.

The use of IDS is pervasive and not only affects speech but also facial expressions (Reilly & Bellugi, 1996) and actions (Brand, Baldwin, & Ashburn, 2002). In fact, when shown videotapes of a female producing Japanese Sign Language to an infant or an adult, hearing infants (6-month-olds), who have never been exposed to a signed language, prefer to watch Japanese Sign Language directed to an infant (Masataka, 1998). Infant-directed Japanese Sign Language differed from adult-directed sign by including greater repetition, slower tempo, and exaggerated movements. These modifications are similar to those found in spoken IDS and the findings that IDS is present in both signed and spoken language point to its ubiquitous nature.

Infant preferences for IDS over ADS have been extensively researched for spoken language across a range of ages. IDS preferences have been documented at 48-77 hours after birth (Cooper, 1993), at 1 month (Cooper, 1993; Cooper & Aslin, 1990), 4 months (Fernald, 1985; Kaplan, Goldstein, Huckeby, & Cooper, 1995), and from 4.5-9 months (Werker & McLeod, 1989). Attentional preference for IDS is typically measured by examining looking times to a fixed stimulus while two different sound stimuli are presented.

When comparing the acoustic properties of IDS on fundamental frequency, amplitude, and duration measurements, Fernald and Kuhl (1987) provide evidence that the modulation of fundamental frequency may be the most acoustically salient characteristic of IDS for young infants. They prepared sine wave stimuli created from natural speech samples of IDS and ADS. Using sine waves allowed them to alter certain acoustic properties of the speech while holding others constant across IDS and ADS samples. At 4 months, infants did show a preference for IDS over ADS, measured by a difference in looking time, when changes in fundamental frequency were present, but did not show a preference when duration or amplitude was the independent variable. Conversely, Cooper and Aslin (1989) reviewed a body of research indicating infants' attention is modulated by ID speech because of its multi-dimensional nature and that any particular characteristic, such as frequency contour, does not work in isolation.

Although the use of IDS appears to be common in infant-adult interactions, an infant's own linguistic and affective behavior may also direct the use of IDS. In a case study reported by Niwano and Sugai (2003), a mother used IDS differently with her two twin infants based upon their own behavior. The mother directed more utterances to and used a higher fundamental frequency with the infant who made fewer vocalizations. The mother also used a rising intonation contour more frequently with this infant. A rising contour in IDS has been identified as a maternal bid for attention (Fernald, 1989). The authors report that the changes in the maternal speech appeared to be an attempt to encourage more vocalizations from this infant.

Moreover, even undergraduates will judge the behavior of infants who are listening to IDS as preferred or more favorable (McLeod, 1993). Infants were judged to show more affective responding to videos of females speaking IDS than ADS; however, important differences in the behavioral response of infant based on the gender of the speaker will be discussed below (Werker & McLeod, 1989). Therefore, adults may use IDS with infants frequently because infants respond positively to this type of speech, which reinforces the adults' use of IDS (Colombo et al., 1995; Cooper, 1993). However, it should be mentioned again, that even adults without experience with children and who do not plan on having children of their own, modify their speech in the same ways as parents (Jacobson et al., 1983), so the use of IDS is probably not entirely child-driven.

Some aspects of IDS are incorporated at the expense of important phonemic information. Studies have shown that mothers, who speak in tonal languages where the use of pitch determines the meaning of words or utterances, will sacrifice the integrity of the tonal meaning in favor of using IDS with their young infants, up to 9 months of age (Grieser & Kuhl, 1988; Kitamura et al., 2002). For example, Mandarin Chinese mothers will sacrifice the use of pitch for phonemic information to maintain the high pitch and exaggerated pitch contours of IDS (Grieser & Kuhl, 1988). Also, even in non-tonal languages, particular aspects of IDS may provide different information. For example, exaggerated intonation contours may help with vowel discrimination whereas the use of high pitch actually impedes vowel discrimination (Trainor & Desjardins, 2002). These findings indicate that, for young infants, mothers prioritize the use of the prosodic features of IDS and sacrifice other features of speech that are important for clarity and meaning. This pattern changes for older infants and these age-related differences are discussed further below.

Functions of Infant-directed Speech

Three main functions of IDS have been identified: directing attention, communicating affect, and teaching language (Fernald, 1991, 1992a, 1992b; Fernald & Simon, 1984; Fernald et al., 1989; Grieser & Kuhl, 1988; McLeod, 1993). Fernald and colleagues posit that the functions of IDS progress in an organized manner over the first year of life, from directing attention to emphasis on language training (Fernald, 1992b; Fernald & Simon, 1984; Fernald et al., 1989). In this section, evidence for each of these functions will be presented followed by age related changes in parental use of IDS that have been found.

Much research supports the claim that IDS can be used to direct and maintain infant attention. As reported above, many studies have shown that infants of differing ages show attentional preferences to IDS when compared to ADS. This has been documented with studies using a measure of the duration of overall looking time but also with studies using the number of total looks during the presentation of IDS. Additionally, Colombo *et al.* (1995) found that infants can detect IDS more easily than ADS in noisy environments. In this study, 4-month-olds were first habituated to white noise. During testing, infants heard simulated IDS and ADS (frequency-modulated sweeps) presented with white noise and showed increased recovery of looking times for the IDS condition.

IDS is used not only to direct attention but also to modify the infants’ affective state and to communicate affective information from the mother to the infant (Fernald, 1993; Katz, Cohn, & Moore, 1996; Papousek *et al.*, 1990). The first evidence of this is that adult listeners can reliably judge the meaning (attention bids, prohibition, comforting, etc.) of low-pass filtered IDS utterances with higher accuracy than ADS utterances (Fernald, 1989) in their own language. Adults can also judge the meaning of unfiltered IDS utterances in a non-native language more accurately than ADS utterances (Bryant & Barrett, 2007). The meaning conveyed by the prosody of the speech may also provide important affective information for a preverbal infant. Furthermore, young infants demonstrate the development of basic emotional understanding in the presence of IDS (Spence & Moore, 2002, 2003). Infants show more positive affect (positive attention or smiling) to approval vocalizations and more negative affect (tensed brow or frowning) to disapproving vocalizations (Fernald, 1993). Additionally, 6-month-olds can discriminate unfiltered and low-pass filtered IDS approval versus comfort utterances (Spence & Moore, 2002, 2003). However, there are developmental changes in the ability to distinguish speech samples of IDS. At 4 months, infants are able to reliably discriminate IDS and ADS but cannot discriminate IDS for filtered or unfiltered approval and comforting utterances. Papousek *et al.* (1990), however, demonstrated that infants at this age did show a preference for approving IDS utterances over disapproving IDS utterances. However, approval and comforting utterances are more closely acoustically related than approving and disapproving utterances. Spence and Moore (2002) posited that younger infants may only be able to categorize IDS utterances into those that convey positive and negative affect. Additionally, the authors state that infants at this age may need more perceptual information, such as a voice paired with a face, to make fine-grained discriminations.

IDS not only serves to support infants' understanding of emotion but also supports language development by highlighting important information in the speech stream. That is, IDS conveys many different linguistic cues to infants. Werker and colleagues (2007) suggest that English and Japanese IDS support native phonetic category learning. Many researchers have provided evidence that the characteristics of IDS make parsing the speech stream easier for infants (Brent & Cartwright, 1996; Redford, Davis, & Miikkulainen, 2004; Thiessen, Hill, & Saffran, 2005). IDS also includes cues to the grammatical structure of language (Fisher & Tokura, 1996) that infants can reliably detect. For example, infants prefer to listen to utterances that begin and end at proper clausal boundaries than utterances beginning within a clause, but only show this pattern for IDS and not ADS (Kemler Nelson, Hirsh-Pasek, Jusczyk, & Cassidy, 1989).

Fernald and colleagues have been the main proponents of arguments implicating that the function of IDS changes with the age of the child by way of how the adult uses IDS. There is much empirical evidence to support this argument. First, mothers use fewer target words in utterances and more attention-getting nonsense sounds when speaking to 6-month-olds than infants at 12 and 19 months (Fernald & Morikawa, 1993). In addition, mean fundamental frequency and the affective qualities of maternal speech change during the first year of life. For example, mothers of 6-month-olds use IDS that is higher in mean fundamental frequency, has more positive affect, has more attention bids, and expresses more affection and comfort than IDS for older infants (Kitamura & Burnham, 2003).

Stern *et al.* (1983) also demonstrated age related changes in IDS. They reported that pitch modulation in IDS is more pronounced for infants from 4 to 6 months, whereas for older children rhythmicity and segmental clarification are highlighted. We even see this pattern in infant-directed American Sign Language. When communicating with an infant prior to the age of two, a mother using American Sign Language concentrates on the affect of her facial expressions at the expense of correct grammatical information; however, by the time the infant turns two years of age, the mother is using grammatically correct facial expressions (Reilly & Bellugi, 1996). This indicates that mothers are making functional changes to their IDS based on the age of the child in both spoken and signed languages.

As stated above, in tonal languages where pitch of the speech is phonemic, some studies indicate that mothers will sacrifice the integrity of their tonal meaning in favor of using IDS with their young infants (Grieser & Kuhl, 1988; Kitamura et al., 2002). Yet, this too has age-related changes. The meaning of utterance-final tones in Thai are less identifiable in IDS utterances directed to infants up to 9 months than ADS suggesting, for this age group, Thai mothers sacrifice the meaning indicated by tone to use IDS. However, they do not do this for utterance-initial tones and stop altering utterance-final tones by 12 months (Kitamura et al., 2002). In summary, the functions of IDS change over development as mothers modify their emphasis on certain properties of speech. These are not the only differences in IDS that children experience. In the next section, IDS spoken by fathers is examined to show that it is both similar and dissimilar to the maternal IDS children experience.

Paternal Infant-directed Speech

Fathers modify their speech to infants in ways that are largely similar to how mothers modify their speech. Differences have been reported; however, they are not always consistent across studies. McRoberts and Best (1997) found that mothers' and fathers' mean fundamental frequency during IDS differed by about an octave. Mothers also modulated their mean fundamental frequency and variability in fundamental frequency for IDS relative to ADS more than fathers (Jacobson et al., 1983). In a study on British English, Shute and Wheldall (1999) noted that fathers increased their fundamental frequency mean and mode but not as much as mothers; however, fathers did not show changes in the range of their fundamental frequency for IDS compared to ADS as mothers did. Warren-Leubecker and Bohannon (1984) found similar results for American English speaking parents. They reported that fundamental frequency mode was increased for fathers relative to mothers but inconsistent with Shute and Wheldall, fathers had larger ranges in fundamental frequency. Fernald and colleagues (1989) present slightly different findings. They found that mothers but not fathers increase the range of their fundamental frequency for IDS relative to ADS. Also, mothers increased their fundamental frequency maxima by almost twice as much as fathers. Interestingly, fathers increased their pause duration for IDS more than mothers, but both increased their mean fundamental frequency, used more extreme fundamental frequency maxima and minima, and used shorter utterances. Therefore, while it is clear that fathers alter their speech when interacting with infants, paternal IDS is not identical to maternal IDS.

In addition to the specific modifications of their speech, fathers and mothers also differ in their overall amount of vocalizing during parent-infant interactions. In general, fathers engage in more physical and social play and less vocalizing with their infants than mothers. In a meta-analysis of 18 studies, Leaper, Anderson, and Sanders (1998) report that mothers are more talkative with their children than fathers on measures of quantity of speech (e.g. total words and number of conversational turns), length of speech (e.g. duration), and complexity of speech (e.g. mean length of utterance). This difference was particularly strong for infants (0 to 12 months) and toddlers (12 to 24 months) and was diminished for older children (25 months and above). These results indicating that fathers vocalize less to their infants than mothers have major implications for how much paternal IDS infants experience but it is unclear how much variation there is in paternal vocalization. One variable that may mediate the amount of paternal vocalizing is paternal involvement. With increased involvement in their infants' everyday lives, it is hypothesized that fathers will also vocalize more to their infants and use more exaggerated IDS.

Paternal Involvement

Paternal involvement can be demonstrated in many ways, but the most recognized ways are a father's involvement in caregiving and social activities with their children. According to Lamb and colleagues, paternal involvement has three components: engagement, accessibility, and responsibility (Lamb, Pleck, Charnov, & Levine, 1985, 1987; Pleck, Lamb, & Levine, 1985). Engagement is a measure of actual interaction time with the child, whether it is during playtime or caregiving. Accessibility is being available to the child, but not interacting with the child. Responsibility is ensuring that the resources are available for the child's well-being and care. The present study will focus on measures of engagement and accessibility.

Children in two-parent families with high paternal involvement are much more well-adjusted (see Lamb & Tamis-LeMonda, 2004; Pleck & Masciadrelli, 2004 ; Radin, 1988 for reviews). Having a highly involved father positively affects cognitive development in multiple domains, such as locus of control, problem-solving and social skills ((Radin, 1988; Yogman, Cooley, & Kindlon, 1988). Tamis-Lemonda, Shannon, Cabrera, and Lamb (2004) found that children's verbal ability at 36 months was higher when fathers' were more sensitive, regarded the child positively, and provided cognitive stimulation. Although a few studies have examined effects of paternal involvement on child outcomes, not much research has been conducted to investigate how family context and paternal involvement may affect paternal vocalization.

In general, we know that fathers typically devote a higher proportion of their time to social activities than to caregiving with infants (Bailey, 1994; Lewis, Feiring, & Weintraub, 1981). Within two-parent families, fathers spend roughly three quarters of the time that mothers spend with their children on measures of engagement and accessibility (Pleck & Masciadrelli, 2004). Within measures of engagement, the majority of the time fathers spend with infants is not during caregiving activities (Pleck & Masciadrelli, 2004). Involvement is influenced by many different variables, such as stress, marital relationships, and cultural practices (Barnett and Baruch, 1988; Pleck and Masciadrelli, 2004; Yogman, Cooley, & Kindlon, 1988). Support from the mother and perceptions of caregiving as "woman's work" seem to play a large role in determining paternal involvement (Radin, 1988; Yogman, Cooley, & Kindlon, 1988).

Family structure also plays a large role in determining paternal involvement. For example, Bailey (1994, 2001) presented evidence that paternal caregiving increases with maternal employment. Lamb and Tamis-Lemonda (2004) report similar findings; when the mother is employed the father's engagement time increases from roughly one-forth to one-third of the mother's time in engagement and accessibility increases from one-third of mothers' accessibility time to two-thirds. With respect to engagement, it has also been shown that 54% of fathers' vocalizations to their infants occur during caregiving activities, such as diapering or feeding, over the first 3 months of life (Rebelsky & Hanks, 1971). It is hypothesized that, due to the high percentage of paternal vocalizing occurring during caregiving activities, infants with a highly involved will experience a larger amount of paternal IDS.

While there has been research documenting the differences in the *amount* parents talk to their infants based on specific measures of paternal involvement, the relationship between paternal involvement and *how* parents' talk with their infants has not been investigated. With this in mind, it is hypothesized that highly involved parents will modulate the characteristics of their IDS more in comparison to ADS because during caretaking, in particular, they will need to be able to direct and maintain the infants' attention. Moreover, because a majority of the work documenting rates of paternal involvement was conducted more than 10 years ago, the present study will describe the present day patterns of engagement and accessibility for fathers.

Paternal Infant-directed Speech and Infant Attention

In addition to investigating variations in how mothers and fathers use IDS, it is important to examine how differences in the amount and quality of maternal and paternal IDS affects infant speech perception and brain activity to IDS. Prior behavioral studies have investigated infant attention to male and female IDS, as well as the ability of infants to categorize the emotional meaning of utterances in male and female IDS. For example, Werker and McLeod (1989) demonstrated that infants (18 to 30 weeks) preferentially respond to IDS over ADS, regardless of whether it is spoken by a male or a female. Although infants preferred male IDS to male ADS, similar to preferences for female IDS, they did show differences in behavioral response to male IDS compared to female IDS. In Experiment 1, Werker and McLeod (1989) report slight differences in infant attention to male and female speech at 18-30 weeks (4.5 – 7.5 months) with longer looking times for female IDS. At 4-5.5 months and 7.5-9 months, infants showed more *affective* responses to female IDS than male IDS (Experiment 2) but not more attentional responses. To record affective responses, trained observers (who were blind to the condition) were asked to judge how favorably the infant responded to the speech. Untrained undergraduates blind to the condition also judged infants listening to female IDS as more attractive than infants listening to male IDS (McLeod, 1993).

Infants as young as 7 weeks of age also show attentional preferences for male IDS over male ADS but they have significantly longer looking times for female speech relative to male speech (Pegg, Werker, & McLeod, 1992). Although they showed a preference for male IDS over male ADS, 4-month-olds fail to show a preference for their own father's IDS over an unfamiliar male's IDS (Ward & Cooper, 1999). The same is true for their own father's ADS. This is similar to the pattern we see with 1-month-old infants and maternal IDS; however by 4-months infants are showing a preference for their own mother's IDS (Cooper, Abraham, Berman, & Staska, 1997). This is possibly due to the sheer amount of experience infants have with the maternal voice in relation to the paternal voice. Not only do we know that mothers are vocalizing more with their infants' than fathers but infants also have prenatal exposure to the mother's voice in the womb (DeCasper & Fifer, 1980).

It does not appear that young infants categorize the intonation patterns of male IDS utterances as accurately as female IDs utterances based on behavioral measures. Infants at 4 months do not show a significant difference in looking time between approving and disapproving utterances for male IDS (Papousek et al., 1990). By this age, they do show categorization of these utterances for female IDS. Because infants fail to distinguish male utterances, this may suggest that a male voice may not direct attention as much as a female voice or infants simply do not have as much experience with male voices. Findings such as this lead us to question whether or not the prosodic patterns of paternal IDS are less salient to the infant than a female voice or is it just merely experience with the voice. The impact of paternal involvement on infant attention to male voices may help elucidate this question.

One way to investigate the relationship between experience with IDS and infant attention to IDS is to examine infants with altered early experience with maternal or paternal IDS. Infants who have a parent with depression provide us with an example of altered early experience with IDS because parents (mothers and fathers) with depression use less IDS and do not modulate their IDS as much as parents with no history of depression. Because of their experience with maternal IDS, infants of mothers with depression do not learn associations with their own mother's IDS (Kaplan, Bachorowski, Smoski, & Hudenko, 2002; Kaplan, Dungan, & Zinser, 2004). In a conditioned-attention experiment, infants of mothers with depression (based on BDI-II scores) did not appear to learn that their own mother's IDS predicted the presentation of a picture. Similarly, Kaplan, Sliter and Burgess (2007) provide evidence that early experience with altered paternal IDS affects infant attention to IDS. In the same conditioned-attention experiment they used with infants of mothers with depression, infants of fathers with depression also did not learn that their father's IDS predicted the presentation of a picture. Fathers with depression had IDS with lower variability in fundamental frequency than fathers without depression. The results of this study indicate that infant exposure to altered paternal IDS affects their learning, similar to their findings with maternal IDS (Kaplan et al., 2002; Kaplan et al., 2004).

Mothers from the Kalpan, Sliter and Burgess study (2007) also gave ratings on paternal involvement in caretaking and play. In this study, paternal involvement in caretaking did not correlate with the measures of variability in fundamental frequency for IDS. This could be due to the selective nature of the stimuli and the population studied. Some of the fathers had altered IDS due to depression, which may influence the relationship between these acoustic measurements and the measure of caregiving. In addition, the speech samples were not generated in a natural interaction, which could influence the acoustic characteristics of the IDS. Fathers in this study were instructed to say a particular phrase during a short play session that was analyzed for IDS. In the present study, acoustic analysis will be conducted on speech samples taken from a play session designed to elicit naturalistic speech and utterances from a book reading so that they same exact utterances can be analyzed for all participants.

Cooper, Abraham, Berman, and Staska (1997) found developmental differences in the attentional preference for maternal IDS over maternal ADS that also point to experiential factors. Although it has been reported that infants show a preference for IDS at birth, most of these studies have been conducted with an unfamiliar female voice and not the maternal voice. Cooper and colleagues demonstrated that while 4-month-olds show an attentional preference for maternal IDS over ADS, 1-month-olds do not. This is not because 1-month-olds did not show preferences for IDS; they did show a preference for non-maternal IDS over non-maternal ADS. Additionally, newborns (27-95 hours old) show a preference for *maternal* IDS over *non-maternal* IDS (Hepper, Scott, & Shahidullah, 1993). Cooper et al. suggest that the mother's voice is very salient for very young infants so they did not show a preference for maternal IDS over maternal ADS, but that preferences for maternal IDS develop with experience. This raises the question of whether or not paternal IDS will direct attention in the same way as maternal IDS. If infants are indeed experiencing less paternal IDS than maternal IDS then it could be predicted that they may show differences in attention and/or differences in the patterns of brain activity to paternal and maternal IDS.

Event-related Potentials and Infant-directed Speech

Infant attention to IDS can be investigated using a technique called event-related potentials (ERPs). This technique can also be used to examine the neural systems underlying infant attention and the processing of IDS and ADS. ERPs are a particularly good technique to investigate developmental changes in the processing of IDS and ADS because unlike behavioral methods such as Preferential Looking or Habituation, ERPs do not require an overt behavioral response. Moreover, the same ERP paradigm can be used across a wider developmental period than behavioral methodologies used with infants. ERPs can be recorded while an infant simply listens to the stimuli. ERPs provide a safe, non-invasive, and practical tool for investigating the organization of brain activity in infants and adults. ERPs are averages of epochs of brain activity time-locked to a particular event. They are characterized by fluctuations in positive and negative voltage called components. The latency, amplitude, and distribution of ERP components reflect information about the timing, amount, and to some extent physiological source of the associated brain activity respectively (Rugg & Coles, 1995). One particular ERP component, called the Nc component, has been linked to the allocation of attention resources (Nelson & Monk, 2001). This component peaks around 800 ms and its amplitude is thought to be modulated by attention, such that the larger the amplitude of the component, the more attentional resources are devoted to processing that particular stimulus.

Zangl and Mills (2007) conducted an ERP study with typically developing infants at age 6 and 13 months. In this study, ERPs were recorded while infants listened to both familiar and unfamiliar words in both IDS and ADS. Zangl and Mills hypothesized that if IDS serves to increase attention to certain words then the amplitude of the N600-800 component for IDS would be larger compared to ADS. This component is similar to the Nc component above in that it has the same temporal characteristics and also appears to index attentional resources; however the distribution across the scalp is different. In support of their hypothesis, they found that for 6- and 13-month-olds, the N600-800 was larger to IDS relative to ADS for familiar words over the left hemisphere. At 13 months, the N600-800 was also larger to IDS relative to ADS for unfamiliar words and this effect was bilaterally distributed across the scalp. This was the first ERP study to investigate differences in neural processing of IDS and ADS. Additionally, the patterns of brain activity exhibited support the hypothesis that IDS functions to increase attention and that there are developmental changes in the function of IDS for infants. For younger infants, IDS seems to highlight words that are already familiar to the infant, whereas IDS seems to highlight both familiar and unfamiliar words for older infants.

In addition to age-related changes, ERPs have been used to document different levels of language experience. Mills and colleagues have demonstrated that with increased experience with language (measured by vocabulary comprehension and production), infants exhibit more localized patterns of brain activity to spoken words (Mills, Coffey-Corina, & Neville, 1997; Mills, Plunkett, Prat, & Schafer, 2005; Mills *et al.*, 2004). For example, when infants were divided into two groups based on vocabulary size, infants with a larger vocabulary size had ERP differences to known and unknown words that were more focally distributed (larger over the left hemisphere) rather than bilaterally distributed (Mills et al., 1997). Moreover, Zangl and Mills (2007) reported that at 13 months, ERPs from 600-800ms to familiar words were significantly different for IDS and ADS but only over the left hemisphere. However, for unfamiliar words, this effect was more broadly distributed and significant for both the right and the left hemispheres. In the present study, it is possible that paternal IDS is less familiar than maternal IDS so infants may show a more broadly distributed pattern of activation to male IDS compared to female IDS.

Huot and colleagues (2005) investigated the link between experience with IDS and the neural processing of IDS. It has been documented that mothers diagnosed with depression use less IDS in their speech to their own infants than healthy mothers. ERPs were recorded while 6-month-old infants listened to IDS and ADS produced by a female speaker. Infants of healthy mothers showed an increase in amplitude for the N600-800 component for familiar words spoken in IDS relative to ADS replicating the results of Zangl and Mills (2007). Interestingly, infants of depressed mothers did not show difference in the patterns of brain activity to IDS and ADS. A negative correlation was also identified between the mother's severity of depression, as measured by the Beck Depression Inventory (Beck, Steer, & Brown, 1996), and the infants' receptive language development, as measured by the MacAurthur-Bates Communicative Development Inventory (Fenson *et al.*, 1994), with higher severity indicating lower language scores (Chinitz, Bitsko, Sheehan, & Mills, 2008). A three-minute interaction was also recorded for these mother-infant dyads. It was found that maternal use of IDS during the interaction was related to increased brain activity to IDS (Xiao *et al.*, 2008). Additionally, the ratings of maternal emotional state were associated with increased infant attention to their mother, increased infant vocalizations, and more positive ratings of infant emotion. Importantly, the combined data from these studies demonstrate the influence of experience with IDS on patterns of brain activity and later language development.

Similar to the Zangl and Mills study, the present study also investigates the relationship between experience with IDS and patterns of brain activity; however, instead of studying cases of altered IDS, like IDS used by mothers with depression, the IDS of different caregivers (mothers and fathers) was examined. It is hypothesized that the patterns of brain activity to male and female speech would change with respect to the familiarity of the speech to the infant. As in the prior studies on IDS and ADS from our lab, the N600-800 was examined. Based on the infant's familiarity with maternal and paternal IDS, two different results can be predicted. The first pattern of results would be consistent with past studies by Mills and colleagues indicating with increased language experience, infants show a more focalized pattern of brain activity over the left hemisphere to words spoken in female IDS but a more broadly distributed effect for words spoken in male IDS (Mills et al., 1997; Mills et al., 2005; Mills et al., 2004). However, based on the findings from Zangl and Mills (2007), it could be expected that a difference in the N600-800 will not be present for male IDS versus male ADS, if male speech is less familiar to the infant than female speech. This would be consistent with Zangl and Mills' results that, for 6-month-old infants, the N600-800 to unfamiliar words was not different for IDS and ADS. Moreover, Houston and Jusczyk (2000) demonstrated that 7.5-month-olds do not recognize familiar words when spoken by the opposite gender. They briefly familiarized infants with a word spoken by an unfamiliar male or female speaker and then tested the infants' recognition of the word when it was spoken by someone of the opposite gender. Infants did not how recognition of the word when the gender was switched. This indicates that word familiarity may be tied to additional cues, such as speaker's voice, and an infant may not necessarily recognize a familiar word if they typically hear it from only one caregiver.

Present Study and Hypotheses

The present study has two broad goals. The first goal is to examine the production of IDS by fathers in a variety of familial contexts, such as families with a stay-at-home mother, a stay-at-home father, or two working parents, who vary in the amount of time they spend with their infants. Because parents highlight the prosodic information for infants at 6 months, this is a particularly good age at which to study how IDS facilitates recognition of individual spoken words. We also know by this age, infants are just breaking into the language system and are becoming familiar with words used regularly in their language environment and are becoming sensitive to the prosodic characteristics of their native language (Nazzi, Jusczyk, & Johnson, 2000). By studying male and female speech, we can examine experience with a particular caregiver (mother or father) and possible relations between the acoustic variability of speech input and infant attention. To investigate infants' experiences with paternal IDS in comparison to maternal IDS, a home visit was conducted to record mother-infant and father-infant interactions. Building on past research demonstrating differences in maternal and paternal IDS, the first portion of the present study is designed to test the following specific hypotheses:

- Like mothers, fathers will alter their speech when interacting with their infants and there will be variability in the acoustic characteristics of fathers' IDS.
- The variability in paternal IDS will be related to paternal involvement. In particular, due to the high percentage of paternal vocalizing occurring during caregiving activities, fathers, who are highly involved in caregiving, will vocalize more and alter the fundamental frequency of their speech to a greater degree. It is hypothesized that this will be because IDS is needed to maintain and direct the infant's attention more during caregiving activities than other types of interactions but that involvement in caregiving activities will affect a fathers IDS overall.

The second goal of the present study is to examine how experience with paternal IDS may affect infant attention to male relative to female IDS and the organization of the underlying neural systems that are involved in processing IDS. While it is clear that mothers and fathers differ in their interactions with infants, the potential impact of these different experiences on brain organization in response to ID speech has not been explored. In addition, variability among infants' experiences with their father's vocalization may be linked to differences in attention to paternal IDS and ADS (exhibited by N600-800 amplitudes) and the organization of brain activity to IDS and ADS (exhibited by either localized or more broadly distributed brain activity). Similar to Zangl and Mills (2007), the second portion of the present study examined patterns of brain activity to IDS and ADS with ERPs, using both male and female speech. The component of interest was also the same, the N600-800, which indexes the allocation of attentional resources. Regarding the relationship between infants' IDS experience and infant attention to male and female IDS and neural processing of IDS, it is hypothesized that:

- Infants will show greater activity to IDS than ADS from 600-800ms, which has been linked to increased attention. A larger N600-800 would be consistent with previous research showing increased attention linked to increased ERP amplitudes within this time window. This finding would also be consistent with past behavioral research indicating that IDS directs attention more than ADS. This finding is expected for ERPs to the female voice but the amount of experience with paternal IDS may influence this effect for the male voice (see hypotheses below).
- Infants will experience more maternal IDS than paternal IDS, and that familiarity with a given speech register and gender will be related to changes in the patterns of brain activity to IDS relative to ADS. Based on the amount of experience with maternal IDS relative to paternal IDS, it is predicted that either the ERP effect (the difference between the N600-800 for IDS and ADS) will be distributed in a more focal pattern for the female speech relative to

male speech or the effect will be larger for the female speech relative to the male speech.

- Paternal involvement and amount of vocalization to the infant will influence the amplitude differences for the N600-800 between IDS and ADS. Based on related findings from our lab (Xiao, *et al.*, 2008) that experience with IDS impacts ERP amplitudes indexing attention to IDS, it is expected that increased paternal involvement and vocalizations to the infant will result in increased amplitudes to male IDS.

METHOD

Participants

Thirty-one infants (M = 6.97 months at home observation, M = 7.29 months at ERP testing, 12 males, 19 females) participated in this study. Infants were excluded if they had a family history of neurological or language disorders and/or exposure to languages other than English according to parental report. Parents gave their informed consent (see Appendix A for form). All infants were healthy and full-term. Emory University's Institutional Review Board approved this study. Infants were recruited through a mailing sent out by the Department of Psychology at Emory University and through visits to new mothers at a local hospital. Eight infants did not participate in the ERP portion of the study due to scheduling conflicts or discomfort with the technique. Data for these families collected during the home visit is included in the analysis. One additional infant was excluded from the analysis because she did not participate in the ERP portion of the study and her video recording during the father-infant interactions did not contain audio, due to a microphone malfunction.

Procedure

Over the course of the study, three types of data were collected: parental report questionnaires, event-related potentials to speech, and behavioral observations. A description of each is provided below. An effort was made to collect the ERP data within two weeks of the behavioral observation; however, do to scheduling constraints, this was not always possible.

Parental Report Questionnaires

During the visit to the family's home, parents were asked to complete a series of questionnaires: medical history (Appendix B), a vocabulary checklist (as employed by Zangl & Mills, 2007, Appendix C), and a measure of parental involvement for both mother and father (modified from Ward & Cooper, 1999, Appendix D).The vocabulary checklist was used to compile a list of words that are familiar to each infant. On the checklist, parents assessed their child's familiarity for 55 different nouns that could be used in the stimuli set. These words were selected from the MacArthur-Bates Communicative Development Inventory (Fenson *et al.*, 1994). Parents rated each word for familiarity on a scale of 1(low familiarity) to 4 (high familiarity). Familiarity was based on how frequently the child hears the word on average per week. A rating of "1" signifies that the child never, or almost never, hears that word. In contrast a rating of "4" means that the child hears the word daily. Words that were rated the highest were chosen for creating the stimuli set for a participant. An effort was made to only use words that were given a rating of 3 or 4 but for a couple participants some words given a rating of 2 were used. It is important to note that parents were asked to rate each word on the amount of exposure, which does not imply comprehension.

During the home visit to record the parental interactions (described below), parents completed the parental involvement questionnaire for their self and their partner. The form completed for their self was used for data analysis and the form completed by the spouse was used to measure reliability. Each parent completed the forms while the other was participating in the interaction. Having the parents fill out the forms independently was a way to increase the accuracy of reporting because parents were not be able to compare their answers. See Table 1 for the reliability statistics comparing the consistency between the mothers' and fathers' data. This questionnaire provided measures of accessibility and engagement. Accessibility was measured with overall time spent with the infant on weekdays and weekend days (in hours). Engagement was measured with the amount of vocalizing to the child during interactions (on a likert scale, 1, no talking, to 8, talk all the time), and a relative measure of the typical activities in which the parent is involved with the child (who typically performs the activity: mother, father, or both equally). Pleck and Masciadrelli (2004) review the most common measures of accessibility and engagement. The questionnaire used in the present study has questions very similar to those used in other studies: Bailey (1994), Barnett and Baruch (1988), Rustia and Abbot (1993), and Volling and Belsky (1991) used the relative measure (last question on self-report form) and Nino and Rinott (1988) used the measure of accessibility. Furthermore, these self-report measures are consistent with other ways of measuring paternal involvement, such as time diaries or interviews. The measures collected from the parental involvement questionnaire were used to assess the association between parental involvement and the mean amplitude of the ERPs. One set of parents is not included for the analyses requiring the relative time item on the questionnaire because their forms were incomplete; however, they are included in all other analyses.

Parent-infant Interaction Recordings and Analysis

An experimenter conducted an at-home visit with the parents and the infant. During this visit, separate interactions between the mother and infant and the father and infant were video recorded (see description below).

Recordings

Both parents were video recorded separately during an interaction with their infant. The infant was placed in front of the parent and a seat was used in the infant could not sit well on his/her own. The video camera was placed behind the parent and focused on the infant. The video camera was focused on the infant so that behavioral measures of infant attention to the parent's speech could be recorded and analyzed at a later date. The parent wore a Sony lapel microphone that attached to the video camera. The parent was instructed to interact with the infant in two different ways: natural interaction with a set of toys and a book reading. These two types of interactions are described below and the order was counterbalanced across participants. Additionally, recordings were taken of the parent reading the same book to the experimenter and answering questions for the experimenter to obtain a measure of ADS. The experimenter asked each parent to describe their typical day, how many hours a week they typically work, and how much time per week the infant spends in non-parental care. Additionally, the parents provided a familiarity rating of 1 (not at all familiar) to 5 (very familiar) for the toys and the book used for the interaction. The parent-experimenter interaction took place before the parent-infant interaction in order to familiarize the parent with the camera and give them instructions prior to the infant interaction. Speech samples from the parent were extracted using iMovie software and analyzed using Praat Software (Boersma & Weenink, 2006). The acoustic measures taken for the natural interaction and book reading are the mean duration of utterances (in seconds), mean fundamental frequency, range of fundamental frequency, and standard deviation of fundamental frequency. These measures were chosen based on past research indicating that they discriminate between mothers' and fathers' IDS (Fernald, et al., 1989; Jacobson et al., 1983; McRoberts & Best, 1997; Shute & Wheldall, 1999; Warren-Leubecker & Bohannon, 1984).

Natural Interaction

Parents were asked to interact naturally with their infant for three minutes. The parent was given four toys that could be used during the interaction: a plastic hippopotamus, a plastic tiger, a plastic car, and a string of 12 large plastic beads that could be taken apart. These toys remained constant across the study. Familiarity ratings (1 do not own to 5 play with frequently) for the toys were collected and the average ratings are presented in Table 2. This interaction was designed to elicit a spontaneous occurrence of IDS. A transcription was made of this interaction. Twenty-five percent of each transcription was checked for reliability by another experimenter. Any transcriptions that were not at least 95% accurate ($n = 2$) were discussed and completed again by two experimenters. Ten random utterances were selected from the 3-minute interaction. An utterance was defined as speech bounded by pauses greater than 300 ms (Cooper et al., 1997; Fernald & Simon, 1984; Fernald et al., 1989; Kitamura & Burnham, 2003). Utterances containing significant background noise, infant vocalizations, singing, or other nonverbal sounds (e.g. laughter or animal noises) were not included in the analysis.

In defining an utterance as infant-directed, any utterance spoken by the parent during the interaction with the infant could be chosen. Based on past research, it would be possible to carefully select utterances that conform to the typical acoustic signature of infant-directed speech to use in our analyses and to exclude any utterances that did not meet certain acoustic criteria (e.g. significant change in fundamental frequency for IDS compared to ADS). However, this practice might lead to faulty conclusions because it would not include the speech of the parent in its entirety. It is also possible that for some parents, while their ADS and IDS may differ acoustically, their IDS would not conform to the typical acoustic signature. Therefore, IDS was defined as any utterances spoken during the parent-infant interaction and ADS was defined as any utterance spoken during the parent-experimenter interaction.

Book Reading

Parents were asked to read “Goodnight Moon” to their infant to get a measure of IDS and to the experimenter to get a measure of ADS. When conducting speech analysis, it is important to be able to directly compare the same speech acts across participants. During this interaction, parents were speaking the same sentences and 2 utterances were chosen for analysis from all of the utterances that were free from background noise in both the IDS and ADS samples. Parents were instructed to read the book to the experimenter as if they were talking to an adult and to read the book to their infant in the way they normally read with their child. Many parents already owned and read this book to their child. Familiarity ratings (1 never read to 5 read daily) for the book were collected and the average ratings are presented in Table 2. It was acceptable for the parents and children to be familiar with the book because this may increase their comfort during the interaction and allow for a more naturalistic reading.

Event-related Potentials Collection and Analysis

Stimuli

The stimuli consisted of 55 total words recorded once in IDS and once in ADS by a male and a female speaker, resulting in 220 different tokens. The words were presented in 4 conditions: male IDS, male ADS, female IDS, and female ADS. Five different words, selected as familiar to the infant and drawn from the total list, were played in each condition for a total of 20 different words. Each word was played 10 times resulting in 200 total trials. Two standard lists (of 20 words counterbalanced across conditions) were created for the words identified as most familiar at this age and used whenever possible. If the parent did not rate a word in the standard list as familiar to the infant, it was replaced. Table 3 shows the standard word list, as well as the possible replacements. See Table 4 for the average word ratings, which did not differ by condition (*ns*, p = 9.46).

Recordings for the female speaker. The recordings for the female speaker have been used in prior studies in our lab (Zangl & Mills, 2007) and were recorded in a sound-attenuated chamber using a high quality microphone. An adult female native speaker of English was instructed to speak the words pretending she was talking to an infant (ID speech) and again pretending she was talking to another adult (AD speech). The stimuli were digitized using Sound Designer software for the Macintosh at a sampling rate of 11.025 kHz with a 16-bit quantization. Each word token was edited for precise time of onset and offset; careful onset editing guaranteed the synchronization with the digitization of the ERPs. In order to ensure that the 220 different samples of target words were appropriate tokens for both IDS and ADS, all tokens were first played back to 38 undergraduate students. These listeners ranked each of the AD and ID items on a 4-point scale in terms of appropriateness as speech directed to an infant or speech directed to an adult. Only the items garnering the best ratings were selected for the final stimulus list (i.e. for ID ratings of 4 where 1 = AD and 4 = ID; for AD ratings of 1 where 1 = AD and 4 = ID). Less appropriate examples were re-recorded and ranked again until a high level of rating was achieved for all stimuli. Based on previous studies (Cooper & Aslin, 1990; Werker & McLeod, 1989; Zangl & Mills, 2007) the IDS and ADS items were analyzed for the following parameters: average fundamental frequency (F0), fundamental frequency maximum (F-Max), frequency range (F-range) and duration. Fundamental frequency and duration analyses of the recordings were conducted using *Signalyze* (Keller, 1994). Statistical comparisons of IDS and ADS instances of each word were then conducted using two-tailed *t*-tests. The analyses indicated that the fundamental frequency and fundamental frequency maximum of words in IDS were significantly higher than those of words in ADS. Words in IDS also had a higher frequency range and were longer in duration than words in ADS.

Recordings for the male speaker. The male voice was recorded in a similar manner. A speaker was chosen based on his experience interacting with children and an understanding of the characteristics IDS. The stimuli were be digitized using *Sound Studio* software for the Macintosh at a sampling rate of 11.025 kHz with a 16-bit quantification (the same settings used for the female voice recordings) and the words were edited for precise time of onset and offset to eliminate any dead space from the beginning and ending of the word. Word onset is particularly important for ERP recordings to ensure that the ERPs are time-locked to the beginning of the word. Ratings and analyses were carried out for the recordings done by the male speaker similar to those carried out for the female speaker. A normalization procedure was used to control volume across the male and female speech samples. Statistical comparisons of IDS and ADS instances of each word were conducted using two-tailed *t*-tests. The analyses indicated that the mean fundamental frequency and fundamental frequency maximum of words in IDS were significantly higher than those of words in ADS. Words in IDS also had a higher frequency range and were longer in duration than words in ADS. See Table 5 for a summary of the speech analyses and significant differences.

Electrode Placement

The electroencephalogram (EEG) was recorded continuously from tin electrodes at 29 channels affixed to an electrode cap, with two individual electrodes placed on the mastoids, and one electrooculogram (EOG) channel. The channels located on the cap were at 20 of the standard 10/20 locations including FP1/FP2, F3/F4, F7/F8, C3/C4, P3/P4, T5/T6, O1/O2, Fz, Cz, Pz, A1/A2, and nonstandard locations including: L22/R22 (1/2 distance between F7/F8 and T3/T4), L41/R41 (2/3 distance from C3/C4 to T3/T4, i.e. closer to T3/T4), WL/WR (1/2 the distance between P3/P4 to T3/T4), PO3/PO4 (1/2 distance between P3/P4 to O1/O2), FC1/FC2 (1/2 distance between Fz and C3/C4), and CP1/CP2 (1/2 distance between Cz and P3/P4). See Figure 1 for a visual display of the electrode site locations on the electrode cap. One electrode was placed to record EOG under the left eye to monitor vertical eye movement and blinks. EEG recordings were taken from the 32 sites and referenced online to A2. The electrodes were mathematically re-referenced offline to an average of A1 and A2. The EEG was digitized at 250 Hz with a band-pass filter from 0.1 to 100 Hz. All impedances were maintained at or below 20 kΩ and most were under 10 kΩ.

Electrophysiological Testing

After the electrode cap placement, the participant was tested in a sound attenuated booth. The child sat on the lap of the caregiver approximately 30 inches in front of a Bose speaker located behind the curtain of a puppet theater. The words were presented with a stimulus onset asynchrony (SOA) of approximately 2500 ms (10% probability of being in the range of 1500-2000m s and 3000-3500, and 90% probability of being in the range of 2000-3000ms). A puppet was moving in front of the infant as the words are played to ensure that the infant faced forward and attended to the stimuli. Each child heard words in all four conditions. The words were played in blocks of 50 words by the gender of the speaker. Within each block of 50 words, words were played in alternating blocks of 10 by speech register. For example, the first block of 50 words was spoken by a male and within this block the infant heard 10 words in ADS, 10 words in IDS, 10 words in ADS, 10 words in IDS, and 10 words in ADS. The order of the blocks was counterbalanced.

Averaging and Artifact Rejection

ERPs were averaged separately for each condition. Averaging and artifact rejection was completed offline using Event-related Potential Software System (ERPSS), a custom data analysis tool. Artifact rejection thresholds was determined for each individual after inspection of that individual's trials to reduce artifact that may be due to eye movements, blinking, or other artifact in the data from muscle movements (Luck, 2005). Individuals were not included in the analysis if they had fewer than 10 artifact-free trials per condition (n = 4) or refused to wear the ERP cap (n = 3). Data for 16 infants were included in the final analysis. Infants included in the final analysis and those who were excluded did not differ in gender (*ns*, p = 0.57), paternal involvement (*ns* p = 0.79), or maternal involvement (*ns*, p = 0.74).

Measurement of Components

All measurements in the analysis were calculated relative to a baseline of 100 ms prestimulus onset. The N600-800, identified by Mills and colleagues (Mills et al., 2005; Zangl & Mills, 2007) in prior studies, is similar in latency to the Nc component, which has been linked to attentional processing. If more attention is being allocated to a particular condition (male IDS, male ADS, female IDS, female ADS), we expected that the amplitude would be larger for that condition within the time window from 600 to 800 ms[2]. Mean amplitude was measured for this time window for ERPs to each of the four conditions. A repeated measures ANOVA was conducted on the entire window to compare the patterns of brain activity for IDS and ADS and for male and female speech.

The mean amplitude measurements were analyzed using an analysis of variance and the Hyundt-Feldt correction for repeated measures. The overall repeated measures ANOVA included 2 levels of speaker's gender (male, female), 2 levels of speech register (IDS, ADS), 2 levels of hemisphere (left, right), 2 levels of laterality (lateral, medial), and four levels of electrode site (frontal, anterior-temporal, temporal, and temporal-parietal). For data analysis, electrode locations were divided into 4 regions from the front to the back of the head for lateral and medial sites respectively: frontal (F7/F8 and F3/F4), anterior-temporal (L22/R22 and FC1/FC2), temporal (L41/R41 and C3/C4), parietal (WL/WR and CP1/CP2). The software Statistical Package for Social Sciences (SPSS) was used for all analyses. The significance level of p = 0.05 was used and partial eta squared (η_p^2) is reported for effect size. Planned comparisons and analyses related to the specific hypotheses of the present study are detailed below in the *Results* section.

RESULTS

Description of Participating Families

Family Characteristics

The average number of hours of childcare per week for the group was 17.27 (SD = 18.58). The minimum was zero hours of nonmaternal childcare and the maximum was 47.5 hours. Types of childcare and frequencies are presented in Figure 2. Fathers worked an average of 48.10 hours per week (SD = 10.02) and mothers worked an average of 22.65 hours per week (SD = 19.10). Fathers worked outside of the home (n = 21), from the home (n = 4), or a combination of both (n = 6). Twelve mothers did not work outside of the home. Three mothers worked fewer than 20 hours a week. Of the mothers who worked, 14 worked outside of the home and 2 worked from home part of the time. See Figure 3 for a display of the parents' occupations. Twenty-one of the infants had no siblings. Seven infants had one sibling and only three infants had two siblings. The majority of parents had continued their education past high school (Figure 4).

Parental Involvement Questionnaire

Mothers and father's answers for items on the parental involvement questions were consistent for most items (see Table 1). Mothers gave a slightly higher rating for the number of hours she spends with the infant during the week compared to fathers' ratings. Fathers gave themselves a higher rating for who bathes the infant and who puts the child to bed compared to mothers ratings. A higher rating indicates that fathers performed this action more often (1 = mother always does, 5 = father always does). Mothers were more involved in caregiving activities (irregardless of who was rating) and spent more weekend and weekday hours with the infant than fathers. Contrary to past research, most of the measures for paternal involvement did not differ based on maternal employment status (Tables 6 and 7). The only exceptions were that stay-at-home mothers feed their infant more often than mothers working outside of the home, mothers' rating of who burps the infant was higher, and fathers' rating of who feeds the infant were higher. Mothers' number of hours of work outside the home was negatively correlated with the rating of who puts the infant to sleep (1 = mother always does, 5 = father always does). As mothers' hours of working outside the home increased, mothers were more likely than fathers to complete this activity, $r_s = -0.35$, $p = 0.03$. Even when both parents were working, mothers spent more time with the infant and performed more of the caregiving activities than the father. However, it is not surprising that fathers were rated as feeding the infant less often than mothers because 19 of the 31 mothers reported breastfeeding.

A composite variable was created for parental involvement to measure caregiving using the mean of the ratings given for diapering, feeding, bathing, burping, and putting to bed. This composite variable, along with the individual scores, was used to examine the relationship between paternal involvement in caregiving and the acoustic variables, as well as the ERP data. From this point on the composite variable is called the caregiving score. The a priori hypotheses included the caregiving score and not the individual caregiving ratings. Because of this, any tests conducted with the individual caregiving ratings are reported with a Bonferroni correction for multiple comparisons. This correction is calculated by dividing the alpha level (0.05) by the number of comparisons (5) resulting in a new corrected alpha of 0.01.

To investigate the hypothesized relation between the caregiving score and the frequency of fathers' vocalizations, mothers and fathers were asked to rate the amount of talking that fathers do when interacting with their infant on a scale of 0 (no talking) to 8 (talk all the time). This rating of vocalization was positively correlated with the number of weekday hours, $r_s = 0.37$, $p = 0.04$, and weekend hours, $r_s = 0.47$, $p = 0.008$, the father reported spending with his infant (Figures 5 and 6). It was also correlated with the number of utterances he produced during the IDS natural interaction, $r_s = 0.35$, $p = 0.05$ (Figure 7), signifying that the rating was reliable. Although the rating of vocalization was correlated with the measures of accessibility, this rating was not correlated with the caregiving score, a measure of engagement.

Parent-infant Interactions

Natural Interaction

Table 8 lists the means and standard deviations for the acoustic variables for the natural interaction. Table 9 has the ANOVA values and scores for post-hoc comparisons using the Tukey Honestly Significant Difference Test. See Figure 8 for a bar chart showing the total number of IDS and ADS utterances that parents used. Only utterances that were coded as clear from background noise, infant vocalizations, and experimenter vocalizations were included in the acoustic analyses. The total number of utterances (clean utterances and disrupted utterances) did not differ across mothers' IDS, mothers' ADS, fathers' IDS, and fathers' ADS (*ns*, $p = 0.17$).

Mean Fundamental Frequency

Consistent with past research, mean fundamental frequency was significantly higher for IDS when compared to ADS for mothers' and fathers' speech. Additionally, mothers' mean fundamental frequency was higher than father's fundamental frequency for both IDS and ADS. To characterize variation in IDS, a difference score of mean fundamental frequency for ADS subtracted from the mean fundamental frequency for IDS was created for further analyses. This difference score depicts the modulation of speech acoustics and how much a parent changes their speech depending on the listener. This measure also controlled for the baseline measures of the speaker's voice making it possible to compare parents' IDS and ADS despite the fact that their mean fundamental frequency may differ. Mothers' difference score (M = 95.97, SD = 39.09) was significantly higher than fathers' difference score (M = 58.53, SD = 36.05), t = 3.787, p = 0.001.

Range

Mothers' IDS and ADS did not differ in range of fundamental frequency. Fathers' ADS had a significantly larger range in fundamental frequency than fathers' IDS. This pattern is opposite of the expected pattern. Mothers' IDS had a significantly larger range in fundamental frequency than fathers' IDS.

Standard Deviation

Standard deviation of fundamental frequency did not differentiate mothers' IDS and ADS or fathers' IDS and ADS. It also did not differentiate between mothers' and fathers' speech.

Duration of Utterances

Mothers' ADS utterances were significantly longer than mothers' IDS utterances and fathers showed the same pattern. Mothers ADS utterances were longer than fathers' ADS utterances. Further analysis indicated that utterances spoken by parents in IDS contained fewer words than utterances spoken in ADS (Table 10). It is important to note here that although duration was measured in seconds it actually reflects the number of words in the utterances and not how long it took to say the words. The latter measure was not possible because the IDS and ADS speech samples in this interaction did not consist of the same words; however it was possible to measure this for the book reading task described below.

Variation in Infant-directed Speech

To proceed with our investigation of the relationship between fathers' speech and paternal involvement, we needed to document whether or not the different acoustic measures vary across individuals. A correlation with paternal involvement can only be found if the parents vary on these measures. Histograms of the distribution of values for the acoustic measurements depict the variation in mothers' and fathers' speech during the interaction (Figures 9-14). Kurtosis was measured for each of the variables as well and shown in Table 11. Kurtosis provides an indication of the shape of the distribution of scores around the mean (Decarlo, 1997). Leptokurtic distributions (a higher peak and heavier tails with less variability around the mean) have positive kurtosis values and platykurtic distributions (a flatter shape and lighter tails with more variability around the mean) have negative kurtosis. A lower number indicates more variability. For purposes of comparison, a normal distribution has a kurtosis value of 0 and a uniform distribution has a value of -1.2 and in the present study a score of 1 will be used as the determination of sufficient variability to continue with correlations. For parents' IDS, standard deviation, mean fundamental frequency, and range all show sufficient variation across individuals, but duration does not. Parents' also showed variability in the difference score created for mean fundamental frequency. Variation across individuals is necessary to investigate the relationship between the acoustic variables and paternal involvement. Based on the measures reported here, there is adequate variation in the scores to warrant further analyses.

Relationship of Speech Measures with Paternal Involvement

Once individual variability of the speech measures was established, the relationship between paternal involvement and the speech measures was tested with the expectation that as involvement increased the difference between IDS and ADS would increase. With respect to engagement, the caregiving score was not related to the mean fundamental frequency difference scores for the mother-infant interaction or the father-infant interaction. Furthermore, the difference score for mean fundamental frequency did not correlate with the individual measures of caregiving (Table 12). Mean fundamental frequency was also tested because it adhered to the predicted pattern for mothers' and fathers' speech and showed sufficient variability. As with the difference score for mean fundamental frequency, mean fundamental frequency for IDS was also not correlated with the caregiving score for fathers (*ns*, $p = 0.22$) or mothers (*ns*, $p = 0.48$). However, the score fathers gave for who burps the infant (a higher score indicates more paternal involvement) was marginally correlated with the number of utterances the father spoke, $r_s = 0.32$, $p = 0.04$, when using the corrected alpha of 0.01. At least for this measure, as fathers' involvement increased, their amount of speech also increased, as was predicted. The acoustic measures for the natural interaction were not correlated with the fathers' reporting of accessibility.

Book Reading

Table 8 lists the statistics for the acoustic variables from the book reading and Table 9 displays the ANOVA values and results from the Tukey Honest Significant Difference Test. The book reading task was important for the acoustic measurements because the words could be controlled. Acoustics can change based on the words being spoken, as well as the words that precede and follow a word so controlling the content of the utterances allows for direct comparison of IDS and ADS utterances.

Mean Fundamental Frequency

Corresponding with past research, mothers' IDS book reading had a significantly higher fundamental frequency when compared to mothers' ADS book reading and fathers' IDS book reading. Mothers' ADS book reading was also significantly higher in fundamental frequency than fathers' ADS book reading. The fundamental frequency for fathers' IDS and ADS book reading was not significantly different. However, it is possible that there may be a significant difference when paternal involvement is taken into account. This relationship is tested below. A difference score of mean fundamental frequency for ADS subtracted from the mean fundamental frequency for IDS was created for further analyses but did not differ for mothers' and fathers', $F(1, 60) = 2.33$, $p = 0.13$.

Range

Range of fundamental frequency did not differentiate mothers' IDS and ADS or fathers' IDS and ADS. It also did not differentiate between mothers' and fathers' speech.

Standard Deviation

Standard deviation of fundamental frequency did not differentiate mothers' IDS and ADS or fathers' IDS and ADS. It also did not differentiate between mothers' and fathers' speech.

Duration

The duration of the utterances read during this session were longer for IDS than ADS for both mothers and fathers. This finding is in the expected direction but opposite of the pattern found for the natural interaction. Because parents were speaking the same words during these utterances, it can be inferred that they were elongating their utterances and not just increasing the number of words spoken during the IDS reading.

Variation in Infant-directed Speech

Figures 15-19 depict the variation in the acoustic variables for mothers' and fathers' speech during the book reading. Kurtosis was again measured for each of the variables and shown in Table 11. For fathers' IDS, standard deviation, mean fundamental frequency, and range all show variation across individuals, but not duration. For mothers' IDS, all of the measurements, except mean fundamental frequency varied across individuals. Fathers' difference score for the mean fundamental frequency for the IDS and ADS book reading did not meet our criteria for kurtosis, but mothers' difference score did

Relationship of Speech Measures with Paternal Involvement

Similar to the acoustic variables for the natural interaction, the engagement measure of caregiving score was not related to the mean fundamental frequency difference scores for mothers' or fathers' book reading (see Table 13). The difference score did not correlate with the individual measures of caregiving either (but this could be due to lack of variation for fathers on this score). Because mean fundamental frequency did not differentiate between fathers' IDS and ADS for the book reading, duration was also tested. The caregiving score and the individual measures of caregiving did not correlate with duration. The acoustic measures for the book reading were also not correlated with the fathers' reporting of accessibility.

Summary of Results for Speech Analyses

For the natural interaction, mean fundamental frequency was higher for IDS relative to ADS for mothers and fathers. Fathers' ADS had a larger range in fundamental frequency than fathers' IDS but mothers' IDS and ADS did not differ on this measure. Fathers and mothers had a longer duration for ADS utterances than IDS utterances. A relationship was not found between the acoustic measures of parents' speech and most measures of paternal involvement (engagement and accessibility), but this was not due to lack of variation in the acoustic measures. We did find a marginal correlation between fathers' participation in burping the infant and the number of IDS utterances he produced during the natural interaction.

For the book reading, mean fundamental frequency was higher for IDS relative to ADS for mothers and duration was longer for IDS than ADS for mothers and fathers. Again, most of the acoustic measures evidenced variation across individuals but this variation was not explained by the paternal involvement measures. These results did not support our hypotheses that increased paternal involvement would be positively correlated with the modulation of fathers' IDS. Some possible reasons for these findings and ideas for future research are presented in the discussion section.

Event-related Potentials

Based on past studies of patterns of brain activity to IDS (Zangl & Mills, 2007), we predicted different ERP effects for speech register (IDS and ADS) for male and female speech in the 600 to 800 ms time window. Specifically, we expected that overall IDS would have more negative ERPs within the 600-800 time window, N600-800, than ADS but that the N600-800 difference effect (the difference between ERPs to IDS and to ADS) would be distributed differently across the scalp for female and male speech (an interaction for Speaker's Gender X Speech Register X Hemisphere X Electrode Site). Our results supported this interaction but the effect differed in polarity and distribution across the scalp [Speaker's Gender X Speech Register X Hemisphere X Laterality X Electrode Site, $F(1, 15) = 4.26$, $p = 0.01$]. The mean amplitude of the N600-800 was more negative to ADS than to IDS for both female and male speech (Figures 20-22), opposite in polarity to the previous results reported by Zangl and Mills (2007). Further investigation of the interaction revealed that the N600-800 difference effect was more broadly distributed for male speech. Figures 20 and 21 indicate where a significant N600-800 difference effect was found across the scalp. A bar graph showing the mean amplitudes of the ERPs for each condition can be found in Figure 22. Mean amplitudes were calculated using only sites evincing a significant effect for speech register. When this score was compared across conditions, mean amplitudes were more negative to female and male ADS than IDS (female, $t = -4.06$, $p < 0.001$, male, $t = -3.17$, $p = 0.003$), more negative to female IDS than male IDS ($t = -2.57$, $p = 0.01$), but not different for female ADS and male ADS ($t = 0.64$, $p = 0.52$). The N600-800 difference effect (the difference in mean amplitude for ERPs to IDS and to ADS) appeared to be larger for male speech (M = -10.97, SD = 23.94) than female speech (M = -6.15, SD = 10.51) but this difference was not significant, t = 1.34, p = 0.18. Inspection of each participant's data revealed that 10 out of the 16 infants showed the N600-800 difference effect for female speech and 10 showed this effect for male speech. The N600-800 for these participants was more negative to ADS relative to IDS but they did not all show an effect at all of the sites. Seven infants showed the effect for both male and female speech.

Relations to Paternal Involvement and Infant-directed Speech

The mean amplitudes of ERPs to IDS and ADS for male and female speech were examined for correlations with the measures of paternal involvement and the measures from the natural interaction and book reading. The mean amplitude to male IDS was marginally correlated with the caregiving score, r = 0.48, p = 0.07 (alpha = 0.05), and the number of times fathers feed the infant, r = 0.54, p = 0.03, corrected alpha = 0.01. This effect indicates that as paternal involvement increases, the mean amplitude of the N600-800 to male IDS becomes more positive or decreases. The N600-800 to male IDS was more negative when fathers produced more utterances, r = -0.52, p = 0.04, and increased their range in fundamental frequency, r = -0.58, p = 0.02, in the natural interaction with their infant. No significant correlations were found for the measures from the book reading or with the paternal involvement measures of accessibility.

The mean amplitudes to female ADS became more positive when mothers increased their range in fundamental frequency during the ADS natural interaction, r = 0.56, p = 0.02. No significant correlations were found for mean amplitudes to female IDS and the measures for the speech analysis from the natural interaction or paternal involvement. No significant correlations were found for the measures from the book reading.

Overall, these findings are complex. It appears that paternal involvement results in decreased negativity for mean amplitudes to male IDS, whereas increased amount of speech and increased variability in speech result in increased negativity for ERPs to male IDS. For female speech, the N600-800 decreased for ADS when mothers' range in fundamental frequency increased. Mean amplitudes for the conditions did not differ based on mothers' employment status, whether or not the father worked from home, mothers' and fathers' history of depression, gender, nor age of the infant at the ERP session.

Summary of Results for Event-related Potentials

It was hypothesized that infants would show different patterns of brain activity to male and female IDS and ADS speech from 600 to 800 ms. The results did indicate differences in this time window but the mean amplitudes were opposite in polarity to what was expected. Brain activity to ADS was more negative overall than brain activity to IDS. The distribution of the N600-800 difference effect was more anterior for female speech compared to male speech. A complex relationship emerged between the patterns of brain activity and the measures of paternal involvement, as well as the speech that parents used in the natural interaction.

DISCUSSION

The present study investigated the relationships between paternal involvement, and paternal IDS, and infant patterns of brain activity to male and female speech. As discussed in the introduction, the hypotheses were: 1) acoustic measurements of IDS and

ADS would differ, as well as the amount of speech used in interactions, for mothers and fathers, 2) with increased paternal involvement a greater difference would be found between the above measures of fathers' IDS and ADS, 3) patterns of brain activity to IDS and ADS would be affected by the gender of the speaker, and 4) increased experience with IDS would be related to enhanced differences between patterns of brain activity to IDS and ADS. The data relevant to each of these hypotheses are discussed below, in succession, and suggestions are made for future research.

Characteristics of Infant-directed Speech

Mothers and fathers altered their speech when interacting with their infants relative to their interactions with an adult, as predicted based on past research. Mean fundamental frequency was higher for IDS compared to ADS for parents. Other studies report consistent findings for recordings of IDS during natural interactions (Fernald *et al.*, 1989, McRoberts & Best, 1997; Shute & Wheldall, 1999). Mean fundamental frequency for the book reading task was also higher for mothers' IDS relative to mothers' ADS but fathers' IDS and ADS did not differ. The lack of difference in fathers' IDS and ADS could be due to a number of reasons. Parents were reading a children's book to the experimenter and fathers may have not been able to inhibit their use of IDS during the book reading. Also, fathers gave lower familiarity ratings for the book than mothers and this may have also affected their use of IDS. If book reading is not part of their usual interactions with their infant, they may have felt more uncomfortable and this could have some bearing on their speech.

For both the natural interaction and the book reading task, IDS and ADS for mothers and fathers did not differ on standard deviation of fundamental frequency.

Standard deviation of fundamental frequency demonstrates how much fundamental frequency varies over the course of an utterance. Other studies are mixed on this finding. Jacobson and colleagues (1983) found that standard deviation was increased for IDS compared to ADS for both males and females. However, in a study by Shute and Wheldall (1999), standard deviation was larger for mothers' IDS relative to her ADS but not for fathers. Differences in range are also inconsistent across studies. For the natural interaction in the present study, range in fundamental frequency was increased for fathers' ADS compared to his IDS and mothers' IDS range was larger than fathers' IDS range. Fernald, *et al.* (1989) found the opposite pattern. In their study, range for mothers' IDS was larger than their ADS range but fathers' range did not differ. It is likely that some of the inconsistent findings across studies are due to the setting of the experiment. Some studies give exact utterances that need to be spoken during a play session or use a book reading task to directly compare words from an IDS and an ADS reading. Some use a non-structured play session to collect natural speech. There are also differences in where the interaction takes place (in the home or in the laboratory) that could affect the comfort level of the participants, which in turn, affects their speech.

With respect to the measure of duration for the natural interaction, duration of the utterance (measured in seconds) was related to the number of words in each utterance and ADS utterances for both mothers and fathers contained more words than IDS utterances. Supporting this finding, Fernald and colleagues (1989) report that mothers and fathers use fewer words in their IDS utterances. In the present study, utterance duration for the IDS book reading was longer than the duration for the ADS book reading. Shute and Wheldall (1999) also used a book reading task and report the same results for duration.

To proceed with our investigation of the influence of paternal involvement on IDS, variation in fathers' IDS needed to be demonstrated. The present study documented variation in almost all of the acoustic measures analyzed. The only other study, to date, to report variability in IDS was conducted by Shute and Wheldall (1999), who report variation in mean fundamental frequency across individuals. They found variation in paternal IDS for both a book reading task and natural conversation. This lends support to our findings of individual variation on the acoustic measures and allowed for the subsequent search for factors that would account for this variation. Paternal involvement was of particular interest because it was hypothesized that fathers' activities with their infant would affect their speech during interactions.

Paternal Involvement

Our hypothesis regarding the relationship between paternal involvement and fathers' use of IDS was partially supported by our results. Although our composite score for caregiving did not relate to our acoustic measures (i.e. mean fundamental frequency difference score or mean fundamental frequency), it may be that these measures do not correlate because fathers are making these changes in their speech regardless of their involvement in caregiving. This interpretation fits with similar findings that men and women increase their mean fundamental frequency and standard deviation of fundamental frequency when talking with children, despite their experience (or inexperience) with children (Jacobson et al., 1983). On the other hand, we did find a relationship between fathers' involvement and his *amount* of vocalization. First, the rating of how much the father vocalizes during interactions was related to the number of weekend and weekday hours spent with his infant (accessibility). Second, fathers' involvement in burping the infant (engagement) was related to the number of IDS utterances he produced during the natural interaction. Based on these associations, some aspects of paternal involvement affected the amount of speech that fathers used when interacting with their infant. Further research is needed in this area, particularly because all of our paternal involvement measures did not relate to our acoustic measures of IDS or the amount of speech that parents used. Because our measures of IDS and variation in IDS were consistent with past research, the lack of association may be due to our measures of paternal involvement

Before turning to how the measures of paternal involvement in the present study could be changed, it is worth mentioning that the present findings on engagement (the time a parent spends in interactions with an infant) and accessibility (the time a parent is available to their infant) are consistent with past research. Similar to a number of prior studies, mothers participate in caregiving more often than fathers (e.g., Ahmeduzzaman & Roopnarine, 1992; Bailey, 2001; Ninio & Rinott, 1988; Volling & Belsky, 1991; Yeung, Sandberg, Davis-Kean, & Hofferth, 2001). Examining fathers' reports of the weekend and weekday hours they spend with their child, they spent 50% of the time that mothers spend on weekdays and 88% of the time that mothers spend on weekends. These numbers are similar to those reported by Yeung, Sandberg, Davis-Kean, and Hofferth (2001). Fathers in their study spent 67% of their time on weekdays and 86% of their time on weekends relative to the time mothers spend with children under the age of two. Also congruent with our findings, mothers in their study performed more of the caregiving activities with the child than the father, regardless of whether or not she worked. This discrepancy in caregiving between mothers and fathers mimics the discrepancies seen between males and females for others types of household work, such as cleaning and cooking, and holds true even when women are employed outside of the home (Blair & Johnson, 1992; Hochschild, 1989).

The fact that the mothers in our study were all primary caregivers could have been problematic. Even when mothers are employed, they still continue to do the majority of caregiving. Moreover, a study by Pedersen, Zaslow, Suwalsky, and Cain found that when mothers are employed paternal involvement sometimes decreases because mothers take over the responsibilities when they get home and perform “gate-keeping” (as cited by Yogman, Cooley, and Kindlon, 1988). Gate-keeping is when a mother actually interferes with the father’s involvement so that she retains the responsibility. Although this may seem counterintuitive, Allen and Hawkins (1999) suggest that it may be a way for mothers to deal with their guilt about leaving their child to return to work. Our finding that paternal involvement was negatively correlated with the father putting the child to bed might be explained by this phenomenon. Other variables such as the perception of caregiving as a female task also decrease paternal involvement. Understanding the influences on paternal involvement is important because it may not solely reflect fathers’ own personal choices of how they spend their time. Even so, it is important to note that mothers’ and fathers’ perceptions of who completes caregiving tasks are consistent in the present study and other studies (Ahmeduzzaman & Roopnarine, 1992; Rustia & Abbott, 1993). Although our measures of engagement and accessibility concur with past research, there are a few ways in which the measures of paternal involvement could be modified that could affect their relationship with fathers’ speech.

First, it is possible that the relative scale of engagement was not sensitive enough to exhibit sufficient variation in caregiving. The scale used in this study was a 5-point likert scale, with 1 being mother always does, 3 being equal involvement, and 5 being father always does. Fathers' involvement in the caregiving activities all had an average rating lower than 3, indicating that the mother was more involved in these activities. One solution would be to expand the scale beyond a 5-point likert scale. Because parents were predominately using only half of the scale, they only had only a range of three answer choices (1, mother always does, 2, mother mostly does, and 3 equal). Increasing the assortment of answers increases the sensitivity of the measurement and may also differentiate between different patterns of fathers' involvement. For example, if fathers' were participating in an activity once a day or once a week, they would have given the same rating on the current scale (2, for mother mostly does). For a frequently occurring activity, such as diapering, this difference would be a large one.

Another solution would be to include fathers who take a larger role in caregiving, such as stay-at-home fathers. For families with a mother who works outside the home, 23% have fathers as the primary caregiver (Doherty, Kouneski, & Erickson, 1998). Another study reported only about 12% of families overall have primary caregiving fathers when the infant is six months of age (Han, 2004). Because these fathers are highly involved, their interactions with their infants may be very different from those of other fathers. In fact, primary caregiving fathers are more sensitive to their infant's signals of distress than mothers and are more responsive in general to their infant than other fathers (Pruett, 1987, 1991, 1998). The original design of this study included stay-at-home fathers but they were not successfully recruited, mostly likely because families with a stay-at-home father are rare.

On the other hand, for all of the caregiving tasks, mothers' and fathers' ratings of paternal involvement listed the father as somewhat involved (i.e. a 2 on a 5-point scale for mother mostly does). This indicates that this study lacked fathers who were primary caregivers and fathers who were very low in engagement. These ratings might have changed with an expanded scale, as suggested above. It is also a possibility that fathers who are not involved with their infant would not choose to participate in the study. This could be for a number of reasons. During recruitment, families are told that this is a study on fathers' involvement with their child. If the father is not involved in caregiving than he may not want to participate in a study focused on it. Moreover, lower rates of involvement may be due to strenuous work schedules or other time commitments. In this case, they may simply not have the time to participate.

Third, the individual aspects of paternal involvement may have different outcomes.

As presented in the introduction, paternal involvement can be categorized into engagement, accessibility, and responsibility. The latter measure was not included in our study. Responsibility for caregiving may achieve different results because it monitors a different aspect of caregiving tasks. Prior research has shown that fathers may perform caregiving activities but that mothers still take most of the responsibility for seeing that the tasks are completed (Barnett & Baruch, 1988; Lamb & Tamis-Lemonda, 2004). Introducing a measure of responsibility and a subset of fathers who are primary caregivers (as mentioned above) may make paternal involvement more varied resulting in a different pattern of relationships between paternal involvement and fathers' IDS. Responsibility for infant care may relate to parental sensitivity. Sensitivity is related to parental speech to infants and greatly promotes cognitive and language development of the child (Hirsh-Pasek & Burchinal, 2006).

Finally, it should be recognized that the speech analyzed in this study was collected during play sessions. Past research indicates that a majority of paternal vocalizing occurs during caregiving activities (Rebelsky & Hanks, 1971). Just as IDS varied across the natural interaction and book reading tasks in the present study, IDS may also differ during play and caregiving. This variation has already been observed for the amount of speech fathers use during caregiving but also may apply to the acoustic properties of their IDS (Reblesky & Hanks, 1971). Because fathers may need to direct infants' behavior more often during caregiving, speech during this time may be very different from speech during play and should also be analyzed in comparison to paternal involvement measures. Now that the first broad goal of the study (to describe fathers' production of IDS) has been addressed, we can turn to the second goal of the study. The second goal was to examine how experience with IDS would affect patterns of brain activity to IDS for infants.

Event-related Potentials to Male and Female Speech

Based on past research, differences in amplitude and distribution of the N600-800 for IDS and ADS were expected to relate to infants' experience with parental speech. With regard to differences in amplitude, Xiao, et al. (2008) found relations between mothers' use of IDS during a natural interaction and the mean amplitude of the N600-800 to female IDS. The present findings are consistent with their study. The mean amplitude of the N600-800 to male IDS increased (became more negative) with increased experience with paternal IDS and increased range in paternal IDS. This effect indicates that experience with paternal IDS enhances attention to male IDS. On the other hand, the mean amplitude of the N600-800 to male IDS decreased (became more positive) with increasing paternal involvement. These findings suggest that paternal speech and involvement in caregiving are related to differentiated patterns of brain activity to IDS.

An effect was also found for neural activity to female speech and mothers' ADS. As mothers increased the range in their fundamental frequency during the ADS interaction, the mean amplitudes to female ADS speech became more positive. In the present study, a decreased N600-800 to female ADS would decrease the difference between the N600-800 to ADS and the N600-800 to IDS, making the two more similar. This makes sense when considering that range in fundamental frequency tends to be larger for female IDS. Thus, if the range in mothers ADS is becoming more like their range in IDS, then infants' neural activity to female ADS becoming more like neural activity to female IDS would be expected.

Although we initially expected that the N600-800 would be more negative to IDS in relation to ADS, the polarity of the Nc component (which is most likely related to the N600-800) varies across studies due to an array of factors, such as familiarity or novelty, attention, and task difficulty. Novelty effects on the Nc component have been demonstrated using oddball tasks where one stimulus is presented more frequently (80% of the time) than another (20% of the time). The Nc to the infrequent stimulus is larger and has been interpreted as novelty detection or increased attention to the novel stimulus (Courchesne, Ganz, & Norcia, 1981; Karrer & Ackles, 1987). A novelty effect would explain the difference in polarity, where ADS (in a male or female voice) is more novel than IDS.

Other research on the Nc component attributed changes in polarity to difficulty in processing. de Haan and Nelson (1997) examined the Nc component while 6-month-olds viewed pictures of their mother, pictures of a stranger who looked similar to their mother, and pictures of a stranger who did not look like their mother. ERPs to a mother's face were more negative than ERPs to a dissimilar stranger's face; however when the stranger's face was similar ERPs were more negative to the stranger's face. The authors interpreted this as an interaction between allocation of attention and the effortful processing needed to encode a face that is similar to one they already know. Moreover, Bauer and colleagues (2006) report age-related changes in polarity over development. At 9 months of age, ERPs to pictures of an event infants had not seen were more negative than ERPs to pictures of an experienced event. At 10 months of age, this pattern was reversed. The authors attributed this age-related difference to an increase in task difficulty for 9 month olds relative to 10 month olds. Therefore, the reverse in polarity in our study, compared to the results of the Zangl and Mills (2007) study of female IDS and ADS, could be interpreted as a response to the difficulty of processing ADS.

Task difficulty is influenced by changes in stimuli presentation, which differed for the present study and the Zangl and Mills study. Zangl and Mills only present stimuli in female speech and half of the words were unfamiliar to the infant based on parental report. It is possible that introducing male speech increased the effort needed to process differences between ADS and IDS words, resulting in the polarity change. The N600-800 for 6 month olds did not differ for unfamiliar words presented in IDS and ADS in the

Zangl and Mills study. For this reason, the present study was limited to familiar words. Infants were switching between processing blocks of male speech and female speech which may have made discriminating between ADS and IDS more difficult. In addition, according to parental report, the words rated as familiar in the Zangl and Mills study had higher ratings (M = 3.8) than the familiar words in the present study (M = 3.48). Less familiar words would also increase the difficulty of the task. One way to investigate these differences in patterns of brain activity would be to test infants on the same exact procedure employed by Zangl and Mills but to use only male speech. This would allow for direct comparison across the studies without the increased difficulty of processing stimuli in both a male and female voice.

None of the factors mentioned above (familiarity/novelty, attention, difficulty) are necessarily mutually exclusive. It is possible that the ERP components related to these factors overlap over the time window measured for the Nc (and the N600-800) and that they are all related to the resulting waveform. Because ERPs record a summation of activity at the scalp, a given ERP waveform may actually consist of multiple components that occurred in the same time window. When this happens, the observed ERP waveform may need to be broken down into the individual contributors. The differing influences of paternal involvement and paternal IDS on the mean amplitude of the N600-800 to IDS observed in the present study might be explained by overlapping components. There are two ways to investigate overlapping components. First, a study can be designed to isolate the ERP response to familiarity with task difficulty controlled, or vice versa. For example, as mentioned above, the task difficulty could be lessened by testing infants in a paradigm that only used male IDS and ADS, eliminating the need to switch back and forth between processing on male and female speech. Familiarity could be tested by changing the stimuli presentation so that a certain speech register is presented more often during the task (such as an oddball design) or by familiarizing the infant with a set of words prior to testing. The second way to investigate overlapping components is called Independent Components Analysis (ICA; Luck, 2005; Makeig, Bell, Jung, & Sejnowski, 1996). ICA is a mathematical method to isolate ERP components. Our data meet the main requirements for ICA that the sources are independent (familiarity vs. difficulty) and the latencies of the components are similar, making this set of data a good candidate for this type of analysis. In the end, ICA would be able to tell us if there are differentiated patterns of brain activity for familiarity and task difficulty on ERPs related to attention, as measured by the mean amplitude of the N600-800. ICA has been successfully used in the past to separate out multiple components using a predetermined algorithm (Makeig, Jung, Ghahremani, & Sejnowski, 2000).

Visual inspection of the ERPs also reveal differences prior to the 600 to 800ms time window. This window was chosen in an attempt to replicate the findings of similar studies by Zangl and Mills (2007) and Huot and colleagues (2005). Analysis of the time windows prior to the N600-800 indicated differences between male IDS and male ADS. In this time window, it appears that infants show a P300-like effect to male IDS relative to ADS. The P300 effect occurs in response to infrequent stimuli. Although in the present study male IDS and ADS were presented at the same frequency, this result would go along with research suggesting that infants do not hear male IDS frequently and that fathers use more physical interaction with infants than verbal interaction. The ERP difference in this time window could contribute to the mean amplitude measurements in the 600 to 800ms window. An ICA analysis would also allow for separation of the possible overlapping components. ERPs to female speech were not significantly different for IDS and ADS in the window directly preceding the N600-800.

Finally, with regard to distribution of the effect across the scalp, the N600-800 difference effect to female speech was more focally distributed than the N600-800 difference effect to male speech. These results supported our hypothesis that the ERP effect was significant at more electrodes across the scalp for male speech relative to female speech, indicating a broader distribution for male speech. As discussed in the introduction, this finding is consistent with past research from Mills and colleagues (Mills et al., 1997; Mills et al., 2005; Mills et al., 2004) indicating that increased experience with language results in more focal patterns of brain activity to language stimuli. Past research indicates that mothers speak more during interactions with children than fathers; thus, infants would have more experience with female speech than with male speech. If this were true, we would also expect the N600-800 difference effect to be distributed differently for infants with fathers who speak more to them than infants with fathers who speak less. Due to the low number of infants who had enough artifact-free ERP data, there are two few infants to conduct a group analysis like this so further testing is necessary. However, as discussed above, relations were observed between fathers' amount of speech and the mean amplitudes of the ERPs to male IDS, partially supporting this supposition.

Similar to the study by Xiao and colleagues, in the present study, a relationship was found between experience with IDS and patterns of brain activity to IDS. Findings such as these provide further evidence that learning may be linked to experience-related changes in brain areas used to process language. Past research has indicated that social interaction is the best method for language learning when compared to other more passive types of learning, such as viewing a video (Kuhl, Tsao, & Liu, 2003). Kuhl (2007) has developed a model, Native Language Magnet-Expanded, that incorporates social interaction into language learning and corresponding changes in the brain. In this model, when a social interaction is taking place (like the parent-infant interactions recorded in the present study), an infants' ability to learn language is maximal. Kuhl goes on to propose that these early interactions involve changes in the brain areas used to process speech, called neural commitment. Kuhl defines neural commitment as changes in the brain's neural circuitry corresponding with learning to discriminate the sounds of the infants' native language from those of non-native languages. Neural commitment in the early stages of language learning affects future learning by making infants more sensitive to sounds from their own native language and more efficient processors. The significance of this work for the present study is that it suggests that, while exposure to IDS may help infants acquire language, the importance of quality social interaction should not be ignored. Our study also provides support for the proposal of neural commitment by showing that experience with maternal and paternal IDS (i.e. social interaction) is related to specific patterns of brain activity. For example, as was expected, the N600-800 difference effect was distributed more broadly across the scalp for male speech relative to female speech. If past studies are correct in that infants have more experience with female speech, it is possible that the results of our study evidence more efficient processing of female speech than for male speech. This would lend support for neural commitment leading to more efficient processing of familiar speech.

Additionally, Kuhl suggests that more efficient processing of sounds in the infants' native language affects later language development. Her proposal is that infants are able to filter out the information that they do not need and increase their attention to the information that is important for learning their language. With regard to the present study, IDS may enhance attention to the sounds of the native language, which in turn, facilitates later language development. Kuhl's proposal suggests that changes in language-relevant brain areas would be related to increased attention.

Conclusions

The aim of this study was to provide new information about factors that may contribute to fathers' use of IDS, which in turn relates to the early development of the neural systems used to process language in infancy. As highlighted in the introduction, research on infants' exposure to language has mainly focused on maternal speech; however we know that other caregivers make important contributions to infants' cognitive development. Our descriptive account of the speech recorded from the parent-infant interactions provides further evidence that mothers and fathers alter their speech directed to infants, compared to their speech to adults. The speech analyses revealed that mothers and fathers make comparable alterations to their IDS but their speech was not identical. This finding supports past research suggesting that mothers and fathers make unique contributions to the cognitive development of their child.

Moreover, this study documented patterns of paternal speech in particular and that rates of paternal vocalization are related to fathers' involvement in particular aspects of caregiving and the time he is available to his child. The present study also contributes to and extends the existing body of literature on paternal involvement. Modern day rates of paternal caregiving were documented, as well as the consistency of paternal involvement over the last few decades, despite increasing rates of maternal employment. Further research should incorporate the numerous caregiving roles that fathers play, including responsibility for caregiving and primary caregiving.

Furthermore, this study brings us one step closer to understanding the relationship between experience and neural development by demonstrating a possible interaction between patterns of brain activity to IDS, parents' use of IDS, and fathers' involvement in caregiving. Differences in patterns of brain activity to IDS and ADS were linked to both parental involvement and use of IDS. The data presented here provide evidence that early experiences with language may shape the underlying neural systems used to process speech and offer a number of pathways for future research. Some of these include differentiating between the effects of familiarity and task difficulty on patterns of brain activity. Past research has separately documented age-related changes in parents' use of IDS with a child and age-related changes in patterns of brain activity to speech. However, no study to date has explored both in concert. This next step is important for investigating the longitudinal effects of parent-infant interactions and experience on neural development.

The present study focused on a narrow age range of 6 to 8 months. Future research should be conducted to investigate the effects of paternal involvement on fathers' use of IDS and children's brain activity to male and female speech. Past research demonstrated that paternal involvement changes over time, depending on the age of the child (Lamb & Lewis, 2004). Additionally, parents' use of IDS also changes over time. Fernald and colleagues propose that IDS changes as the child grows older because parents are using IDS for different functions, from maintaining attention to teaching the properties of language. The work examining changes in the function of IDS has all been completed with mothers. It is possible that fathers' IDS may not change as the child grows older or the changes may be different than those exhibited by mothers. Increases in the amount of paternal involvement as infants age and infants' growing understanding of language may interact to produce changes in the patterns of brain activity to male and female speech. It could be expected that at later ages, infants and children would show more efficient processing of male speech, resulting in a change in the distribution of the N600-800 difference effect found in the present study. Findings such as these would support the results reported in past studies demonstrating increased proficiency with language comprehension corresponds to more focal patterns of language-relevant brain activity.

The research conducted here has advanced our understanding of possible paternal influences on infants' cognitive development and also neural development. It was found that infants' early experiences, even in the short time span of six months, have an impact on their patterns of brain activity to speech. Many factors were identified as making possible contributions, including maternal employment, hours of accessibility, and the ways parents interact with their infants. Over the course of data collection, it was increasingly evident that no two families were exactly alike and that parents are becoming increasingly sensitive to how they spend time with their infants. Overall, these findings allow us to recognize that the relationship between early experience and developmental outcomes is complex and each child's path is unique.

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Appendix A: Consent Form

EMORY UNIVERSITY, DEPARTMENT OF PSYCHOLOGY
BRAIN AND COGNITIVE DEVELOPMENT LAB
PARENTAL CONSENT FOR A CHILD TO ACT AS A RESEARCH SUBJECT
TWO VISITS- ERP TESTING AND AT-HOME INTERACTION FORM

TITLE: ***Neurobehavioral Development in Normal, Language Impaired, & Deaf Children***

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CO-INVESTIGATORS: HELEN NEVILLE, Ph.D., PROFESSOR, DEPARTMENT OF PSYCHOLOGY, UNIVERSITY OF OREGON.

NAME:________________________________ DATE:_____________________

INTRODUCTION:
Debra Mills, Ph.D., is conducting a research study to find out more about how the brain works. We are particularly interested in how the brain might be organized in a special way for children who get a late start in talking, or have a family history (parent or sibling) of language problems or depression. Approximately 280 participants will be enrolled in the study over a 5 year period.

Your child has been asked to participate:

A. because he/she is a normal volunteer

or

B. because he/she has a small vocabulary for his/her age or has a parent or sibling who has been diagnosed with language problems.

or

C. because his/her mother was depressed (or treated for depression) during pregnancy or postpartum

If you agree for your child to be in this study, the following will take place over a 1 hour period with an additional home visit of approximately an hour. If you and your child enjoy these activities, we may ask you to participate in other studies, or to come back when your child is a little older.

PROCEDURES:

a) Your child’s brain waves will be recorded by: An appropriately fitting cap with small metal disks (electrodes) sewn into it will be placed on your child's scalp and will be removed after the experiment. A small amount of electro-gel will be applied at each small metal disk position.

b) Your child will sit in a chair in a dimly lit room (pointed out to subject) and listen to auditory stimuli, including sentences in English or tones preceded by different amounts of silence, and/or see visual stimuli such as pictures of faces or objects.

c) Brain waves are to be recorded from your child's scalp while he/she pays attention to auditory and/or visual stimuli as described above. The brain waves will indicate how your child's brain operates when your child hears these stimuli.

d) Within a week of the ERP testing, an experimenter will visit you at home to record a mother-infant interaction and a father-infant interaction. These interactions will be of two types: the parent interaction with the infant using toys and the parent reading a book to the infant. This will allow us to measure how parents individually interact with their child.

This study has been explained to you and your child and we have answered your questions. If you have other questions or research-related problems, you may reach Dr. Mills at (404) 727-5030.

RISKS:
This study may involve the following discomforts to your child: (risks are negligible).

The procedures involved in his study will not place your child under any stress. The risks associated with this procedure are negligible. However, under rare circumstances, children with very sensitive skin may have a reaction to the application of the electro-gel. A small red mark may be apparent at one or more electrode locations. It has been our experience that this reaction is very rare, i.e., fewer than one in every hundred children. Additionally, the stickers used to secure the hat may leave a red mark when removed, much like a Band-Aid. Additionally, a little electrode gel will remain in your child's hair until it is washed.

BENEFITS:
Taking part in the research study may not benefit you or your child directly, however the information gathered may help the scientists learn more about neurobehavioral development.

CONFIDENTIALITY:
Research records will be kept confidential to the extent provided by law. Your name and other facts that might point to you will not appear when the data collected from this study is presented or published. These records will only be identified by number and are accessible only to Dr. Debra Mills and assistants.

COMPENSATION:
Your child will receive $6.00 per hour for his/her participation in the study, and select a toy of their choice from our laboratory worth approximately $5.00.

VOLUNTARY PARTICIPATION/WITHDRAWAL:
Participation in this research is entirely voluntary. You may refuse for your child to participate or withdraw at any time without jeopardy to the medical care she/he may receive at this institution.

CONTACT PERSONS:
For further questions concerning this research, contact Dr. Debra Mills at (404) 727-5030. If you have any questions about your rights as a study participant, please contact James W. Keller, MD, Chair of the Emory University Institutional Review Board at (404) 712-0720.

ENTITLEMENT OF CONSENT FORM TO SUBJECT:
A copy of this consent form will be given to you.

Your signature below indicates that you consent to, or give consent for your child to be a volunteer for this study:

Participant's name	Date	Time
Parent or guardian signature	Date	Time
Signature of Witness	Date	Time
Signature of Person obtaining consent	Date	Time

Appendix B: Medical History Form

Medical and Family History Questionnaire

Date:__________________

Child's Name:____

Date of Birth:____

Parents: Name, Age, Occupation, Education

Mother:____

Father:____

Address:____

____

____

Phone Number: (___)_________________________

Marital Status: Married_____ Single______Divorced_____ Separate_____

Handedness: Mother: **LEFT RIGHT** Father: **LEFT RIGHT**

Siblings:

AGE	SEX	HANDEDNESS
	M F	**L R**
	M F	**L R**
	M F	**L R**

If you had to say, does your child prefer to use his/her right or left hand?

____

Is your child regularly exposed to a language other than English?

Please specify (i.e., language, and how often):____________________________

____

What was the mother's age at the time of pregnancy?______________________

Where there any medical problems during this pregnancy?__________________

____

Did the mother take any prescription and/or nonprescription medication during this pregnancy?____

If yes, what kinds?____

Was the child full term?____

Birth weight____________________

Apgar Score___________________

Birth complications______________

At what age did your child first sit up on his/her own?_________________________

At what age did your child first walk on his/her own?___________________________

At what age did your child say his/her first recognizable word (other than "mama" or "dada"?____

What was the word?____

What was going on when the child said the word?_____________________________

Does your child attend nursery or preschool?________________________________

Does your child attend day care?____

How frequently does your child attend?______________________________________
Has your child ever had the below? If yes, describe frequency or duration:

seizures?____

Prolonged illness?____

Ear infections?____

Has your child ever had problems with hearing?_____________________________

If yes describe:____

Has any family member ever had the below? If yes, note relation to the child:

Language problems:____

Speech problems:____

Reading problems:____

Hearing problems:____

Did the mother experience depression during pregnancy or during the postpartum period?
Yes No
If yes, was this diagnosed by a healthcare professional, and how was the depression treated? ____

Has the mother and/or father EVER been depressed?

Mother (other than pregnancy or postpartum): YES NO

Father: YES NO

If YES, please briefly describe frequency, duration, severity and treatment of episodes.
____

Ethnicity (<u>Optional</u>)

NOTE: This information is required for research that meets the National Institute of Health's definition of clinical research (Notice: NOT-OD-01-053, 8/8/2001) and will not be used for the purpose of any statistical analyses. It is to ensure that individuals are not being excluded from this research project on the basis of ethnicity. If you have any questions, please call Dr. Debra Mills at 404-712-8472.

	American Indian or Alaska Native	Asian	Black, not of Hispanic Origin	Hispanic or Latino	Native Hawaiian or Other Pacific Islander	White, not of Hispanic Origin	Other
Female							
Male							
Unknown							

Appendix C: Form for Parental Ratings of Word Familiarity

VOCABULARY CHECKLIST: ADS vs. IDS

Child's Name: ____
Date of Birth: ____
Remarks: ____
Today's Data: ____
Parental Checklist filled in: yes no
CDI filled in: yes no
Medical History Questionnaire filled in: yes no
****

We are going to compare brain waves to words your child is **FAMILIAR** with to words your child is **NOT FAMILIAR** with. Please go through this list and check under:

DK= if you **DON'T KNOW** if your child is familiar with the word
1 = if your child **NEVER HEARS** the word
2= if your child **HEARS** the word at least **ONCE A MONTH**
3= if your child **HEARS** the word **SEVERAL TIMES PER WEEK** (3 or more)
4= if you child **HEARS** the word **SEVERAL TIMES PER DAY** (3 or more on average)

If your child hears a different word from the one we have on the list (for example, "nana" instead of "grandma", or "buggy" instead of stroller") or a different pronunciation of a word, (for example, "raffe" instead of "giraffe"), check the word, but write your child's version next to it. Thank you.

WORDS	DK	1 Never Hears	2	3	4 Hears Daily		WORDS	DK	1 Never Hears	2	3	4 Hears Daily
1. Bottle							21. Knife					
2. Ball							22. Cookie					
3. Book							23. Hair					
4. Dog							24. Hand					
5. Diaper							25. Cheese					
6. Cup							26. Apple					
7. Car							27. Bread					
8. Juice							28. Bear					
9. Nose							29. Bunny					
10. Shoe							30. Duck					
11. Milk							31. Boy					
12. Keys							32. Doll					
13. Bird							33. Ear					
14. Cat							34. Hat					
15. Foot							35. Light					
16. Mouth							36. Chair					
17. Eye							37. Truck					
18. Brush							38. Cow					
19. Bed							39. Fish					
20. Door							40. Tree					

WORDS	DK	1 Never Hears	2	3	4 Hears Daily		WORDS	DK	1 Never Hears	2	3	4 Hears Daily
41. Pig							81. Score					
42. Frog							82. Norm					
43. Horse							83. Oath					
44. Lion							84. Prime					
45. Bowl							85. Broth					
46. Box							86. Bulk					
47. Train							87. Chart					
48. Meat							88. Chive					
49. Cake							89. Claim					
50. Clock							90. Cortex					
51. Shirt							91. Craft					
52. Jeans							92. Sense					
53. Sun							93. Term					
54. Swing							94. Tone					
55. Girl							95. Trade					
56. Barrel							96. Crop					
57. Breed							97. Deem					
58. Court							98. Dice					
59. Judge							99. Fake					
60. Nerve							100.Frame					
61. Shrub							101. Grain					
62. Clone							102. Half					
63. Flood							103. Hinge					
64. Dove							104. Hope					
65. Bay							105. Law					
66Domain							106. Load					
67. Bias							107. Mind					
68. Dent							108. Hail					
69. Code												
70.Clutch												
71. Maze												
72. Blame												
73.Morph												
74. Board												
75. Oak												
76. Add												
77.Blizzard												
78.Bloom												
79. Bolt												
80. Boost												

Appendix D: Parental Involvement Questionnaires

PARENTAL QUESTIONNAIRE (FOR SELF)

Participant ID: ______________________

Filled out by: ___________________________

1. Were you present at the birth of the child? Yes No
If not, how long have you been involved in caregiving for the child (in months)? _______

2. If the child is bottle fed, how many times do you feed him/her in a 24-hour period? (circle one)

1 2 3 4 5 (or more) times

3. Approximately how much time **PER WEEK DAY** (Monday through Friday) do you spend with your infant? (please circle the appropriate number):

0-30 min	6 hours
1 hour	7 hours
2 hours	8 hours
3 hours	9 hours
4 hours	10 hours
5 hours	> 10 hours

4. Approximately how much time **PER WEEKEND DAY** (Saturday–Sunday) do you spend with your infant? (please circle the appropriate number):

0-30 min	6 hours
1 hour	7 hours
2 hours	8 hours
3 hours	9 hours
4 hours	10 hours
5 hours	> 10 hours

5. Generally speaking, how much do you talk to your infant during your daily interactions? (please circle the appropriate number):

0	1	2	3	4	5	6	7	8
no talking		talk a little bit		talk a fair amount		talk most of the time		talk all the time

6. We are interested in the typical activities that you engage in with your infant. Please rate the following activities:

1	2	3	4	5
Mom Always Does		Equal		Dad Always Does

vocal play	________	reading	________
burping	________	putting to sleep	________
physical play	________	diaper changing	________
bathing	________	rocking	________
consoling	________	feeding	________

7. Please add any additional comments here about ways that you may be involved with your infant and his/her well-being.

PARENTAL QUESTIONNAIRE (FOR PARTNER)

Participant ID: ____________________

Filled out by: _________________________

1. Was your partner present at the birth of the child? Yes No
If not, how long has your partner been involved in caregiving for the child (in months)?
____

2. If the child is bottle-fed, how many times does your partner feed him/her in a 24-hour period? (circle one)

1 2 3 4 5 (or more) times

3. Approximately how much time **PER WEEK DAY** (Monday through Friday) does your partner spend with your infant? (please circle the appropriate number):

0-30 min	6 hours
1 hour	7 hours
2 hours	8 hours
3 hours	9 hours
4 hours	10 hours
5 hours	> 10 hours

4. Approximately how much time **PER WEEKEND DAY** (Saturday–Sunday) does your partner spend with your infant? (please circle the appropriate number):

0-30 min	6 hours
1 hour	7 hours
2 hours	8 hours
3 hours	9 hours
4 hours	10 hours
5 hours	> 10 hours

5. Generally speaking, how much does your partner talk to your infant during his/her daily interactions? (please circle the appropriate number):

0	1	2	3	4	5	6	7	8
no talking		talk a little bit		talk a fair amount		talk most of the time		talk all the time

6. Please add any additional comments here about ways that your partner may be involved with your infant and his/her well-being.

Appendix D

Occupations were categorized using the Occupational Outlook Handbook from the Bureau of Labor Statistics (2008). Mothers and fathers provided the description of their occupation on the Medical History Questionnaire. The following list shows the categories and which occupations (provided by parents) were included in each category. Two categories were added for fulltime student and not employed fulltime.

1. Management: Sales Manager, Project Manager, Marketing Manager, Human Resources Manager, Operations Manager, Branch Manager, Executive, Product Manager, Manager
2. Professional: Health Scientist, Psychologist, Teacher, Scientist, Lawyer, Therapist, Vehicle Repair Specialist in a car rental company, Investor, Accountant, Software Engineer, Information Technology, Engineer, Information Technology Consultant, Pharmacist, Consultant, Advertising, Financial Rep, Publicist, Analyst
3. Service: Nurse, Property Management, Police Officer
4. Sales: Sales
5. Administrative: Bookkeeping
6. Farming: None
7. Construction: None
8. Installation: None
9. Production: None
10. Transportation: Transportation, Shipping
11. Armed Forces: None

Footnotes

[1] One clarification should be noted because many researchers use two similar terms when referring to the acoustic properties of IDS: Fundamental Frequency and Pitch. Fundamental frequency is a physical measurement of pitch, which is a perceived phenomenon (Fernald & Kuhl, 1987; Fernald et al., 1989; Shute & Wheldall, 2001). It is important to note however that the relationship between pitch and fundamental frequency is nonlinear, such that a 100 Hz change in fundamental frequency from 200 to 300 Hz will be not be perceived as equivalent to a 100 Hz change from 1000 to 1100 Hz (Fernald et al., 1989; Ladefoged, 1996). Because some authors use the two terms interchangeably, an effort has been made in this paper to report fundamental frequency, a physical measurement, whenever possible. If subjective measures of pitch were used in a study, then this term will be used.

[2] Visual inspection of the ERPs show clear differences between conditions outside of the 600-800 ms window. Measurements of the ERPs were taken for 100 ms bins to determine the onset and offset of the N600-800 difference effect. The statistics revealed that the effect (the difference between the ERPs to IDS and ADS) began at different times for the male and female stimuli. In order to compare the conditions, a window was chosen where the effect (the difference between the ERPs to IDS and ADS) was significantly different for both male and female speech. To make the results section more concise, only the statistics for our predicted time window (600 to 800 ms) are reported.

Table 1

Consistency Scores for Parental Involvement Measures

	Fathers' Mean Rating (SD)	Mothers' Mean Rating (SD)	Cronbach's Alpha
# of times father feeds in 24hr	1.44 (1.16)	1.44 (1.23)	0.83
# of fathers' weekday hours	3.97 (2.51)	4.63 (2.95)	0.83
# of fathers' weekend hours	8.84 (2.38)	9.24 (2.62)	0.67
Rating of fathers' vocalizations	5.32 (1.51)	5.26 (1.77)	0.74
# of times mother feeds in 24hr	3.84 (1.32)	4.29 (1.22)	0.38
# of mothers' weekday hours *	8.02 (3.33)	8.73 (3.10)	0.91
# of mothers' weekend hours	10.00 (1.59)	9.24 (2.62)	0.05
Rating of mothers' vocalizations	6.42 (1.26)	6.26 (1.06)	0.55
Vocal Play	2.57 (0.57)	2.40 (0.56)	0.23
Burping	2.23 (0.57)	2.43 (0.82)	0.51
Physical Play	3.00 (0.64)	2.93 (0.74)	< 0.01
Bathing *	2.53 (1.25)	2.27 (1.17)	0.90
Consoling	2.37 (0.67)	2.17 (0.65)	0.29
Reading	2.47 (0.82)	2.33 (0.88)	0.74
Putting child to bed *	2.40 (1.16)	2.07 (0.91)	0.76
Diapering	2.60 (0.81)	2.63 (0.67)	0.74
Rocking	2.50 (0.73)	2.43 (0.86)	0.73
Feeding	2.10 (0.61)	2.10 (0.66)	0.25

*Parents ratings are significantly different, $p < 0.05$.

Table 2

Familiarity Ratings for Book and Toys

	Fathers' Mean Familiarity Rating (SD)	**Mothers' Mean Familiarity Rating (SD)**
Book	2.58 (1.46)	3.26 (1.45)
Toys	1.48 (1.00)	1.43 (0.73)

Table 3

Standard Word List

Standard List 1	Standard List 2	Standard List 3	Standard List 4
Male ADS	**Male IDS**	**Female ADS**	**Female IDS**
Bottle	Bottle	Bottle	Bottle
Ball	Ball	Ball	Ball
Cup	Cup	Cup	Cup
Juice	Juice	Juice	Juice
Nose	Nose	Nose	Nose
Male IDS	**Male ADS**	**Female IDS**	**Female ADS**
Shoe	Shoe	Shoe	Shoe
Cat	Cat	Cat	Cat
Foot	Foot	Foot	Foot
Door	Door	Door	Door
Brush	Brush	Brush	Brush
Female ADS	**Female IDS**	**Male ADS**	**Male IDS**
Diaper	Diaper	Diaper	Diaper
Book	Book	Book	Book
Dog	Dog	Dog	Dog
Car	Car	Car	Car
Keys	Keys	Keys	Keys
Female IDS	**Female ADS**	**Male IDS**	**Male ADS**
Milk	Milk	Milk	Milk
Bird	Bird	Bird	Bird
Mouth	Mouth	Mouth	Mouth
Bed	Bed	Bed	Bed
Eye	Eye	Eye	Eye

Note. The alternative word list included: apple, bear, bread, bowl, box, boy, bunny, cake, chair, cheese, clock, cookie, cow, doll, duck, ear, fish, frog, girl, hair, hand, hat, horse, jeans, knife, light, lion, meat, pig, shirt, sun, swing, train, tree, truck. IDS = Infant-directed speech, ADS = Adult-directed speech.

Table 4

Word Familiarity Ratings

Condition	**Mean Word Rating (SD)**
Female ADS	3.46 (0.43)
Female IDS	3.46 (0.30)
Male ADS	3.49 (0.33)
Male IDS	3.52 (0.31)
Total	3.48 (0.43)

Note. Scale of ratings was 1 (never hears) to 4 (hears daily). Ratings for the conditions are not significantly different (p = 0.946). IDS = Infant-directed Speech, ADS = Adult-directed Speech.

Table 5

Analyses of Male Adult-directed and Infant-directed Speech Stimuli

Register	**Duration (Ms)**	**Mean F_0 (SD)**	**F_0 Range**	**F_0 Maximum**
ADS	514.92*	101.46 (14.04)*	51.29*	129.54*
IDS	899.03	163.31 (40.11)	137.18	231.49

Note. IDS = Infant-directed Speech, ADS = Adult-directed Speech, $\mathbf{F_0}$ = Fundamental Frequency (Hz). The p values refer to two-tailed t-tests of a difference between IDS and ADS.
* $p < 0.001$

Table 6

Analysis of Variance for Parental Involvement Measures by Maternal Employment

Source	Mean for Employed mothers (SD)	Mean for Stay-at-home Mothers (SD)	F^A
Mothers Hours of Work	39.21 (6.56)	4.70 (8.38)	83.42**
# of times Father feeds baby	1.86 (1.17)	1.10 (1.14)	1.78
# of Fathers' weekday hours	4.50 (2.88)	3.80 (2.14)	1.34
# of Fathers' weekend hours	9.21 (2.01)	8.47 (2.75)	0.34
# of times Mother feeds baby	3.57 (1.34)	4.93 (0.70)	6.14**
# of Mothers' weekday hours	6.82 (3.16)	11 (0.01)	16.58**
# of mothers' weekend hours	10.64 (0.93)	10.47 (1.81)	0.15
Relative Ratings by Mother			
Vocal Play	2.36 (0.63)	2.50 (0.52)	0.75
Burping	2.86 (0.95)	2.00 (0.39)	4.89*
Physical Play	3.14 (0.77)	2.64 (0.63)	2.45
Bathing	2.07 (1.00)	2.43 (1.40)	0.35
Consoling	2.29 (0.73)	2.00 (0.55)	0.96
Reading	2.43 (1.02)	2.21 (0.80)	0.23
Putting to Bed	2.07 (0.73)	2.14 (1.10)	0.42
Diapering	2.79 (0.80)	2.50 (0.52)	0.67
Rocking	2.57 (0.94)	2.36 (0.84)	0.47
Feeding	2.29 (0.83)	1.93 (0.47)	1.05
Relative Ratings by Father			
Vocal Play	2.50 (0.52)	2.57 (0.65)	0.66
Burping	2.29 (0.61)	2.14 (0.53)	0.44
Physical Play	2.93 (0.73)	3.07 (0.62)	0.16
Bathing	2.36 (1.15)	2.79 (1.42)	0.59
Consoling	2.50 (0.65)	2.21 (0.70)	0.67
Reading	2.64 (0.84)	2.29 (0.83)	0.65
Putting to Bed	2.07 (1.00)	2.86 (1.23)	2.47
Diapering	2.71 (0.83)	2.64 (0.74)	2.14
Rocking	2.71 (0.83)	2.36 (0.63)	1.37
Feeding	2.36 (0.50)	1.79 (0.58)	4.40*

Note. The ratings for number of weekday hours, number of weekend hours, and number of times the parent feeds the baby are the ratings they gave themselves.
^{A}df = 2 *$p < 0.05$ ** $p < 0.01$

Table 7

Correlations Matrix for Maternal Employment and Paternal Involvement

	Mothers' # of Work Hours	**Caregiving Score for PI**	**# of times Father feeds the infant**	**Burping Relative Score**	**Diapering Relative Score**	**Bathing Relative Score**	**Feeding Relative Score**	**Putting to Bed Relative Score**
Mothers' # of Work Hours	-	-0.045	0.228	0.277	0.056	-0.154	**0.535**	**-0.350**
Caregiving Score for PI		-	0.272	**0.339**	**0.576**	**0.792**	**0.457**	**0.608**
# of times Father feeds the infant[A]			-	0.183	-0.009	0.164	**0.453**	-0.027
Burping Relative Score				-	0.091	-0.034	0.391	0.199
Diapering Relative Score					-	**0.375**	0.180	0.089
Bathing Relative Score						-	0.173	**0.351**
Feeding Relative Score							-	0.081
Putting to Bed Relative Score								-

Note. Bolded text indicates $p < 0.05$. PI = Paternal Involvement.
[A]The paternal involvement measures are from the fathers' report.

Table 8

Acoustic Measurements for Natural Interaction and Book Reading

	Mothers' IDS	**Mothers' ADS**	**Fathers' IDS**	**Fathers' ADS**
Natural Interaction				
Mean F_0	296.25 (44.86)	200.28 (31.36)	194.10 (35.73)	135.57 (25.31)
F_0 SD	71.80 (18.53)	62.39 (25.95)	58.90 (20.93)	65.39 (31.73)
F_0 Range	256.18 (63.42)	269.01 (72.01)	195.47 (70.02)	256.25 (94.33)
Duration (s)	1.29 (0.33)	2.37 (0.69)	1.20 (0.41)	1.95 (0.61)
# of Utterances	49.61 (14.16)	43.32 (23.45)	45.23 (17.61)	39.06 (19.00)
Book Reading				
Mean F_0	244.49 (49.04)	207.06 (30.44)	157.75 (32.30)	135.30 (32.74)
F_0 SD	59.04 (23.15)	53.50 (34.10)	59.77 (38.22)	56.17 (50.98)
F_0 Range	237.51 (96.78)	195.48 (104.48)	220.03 (126.09)	203.33 (144.57)
Duration (s)	1.50 (0.25)	1.15 (0.23)	1.54 (0.60)	1.18 (0.29)

Note. Mean (SD) are reported for each measure. IDS = Infant-directed Speech, ADS = Adult-directed Speech, F_0 = Fundamental Frequency.

Table 9

Analysis of Variance for Acoustic Measures from Natural Interaction and Book Reading

	Natural Interaction	Book Reading
Mean F_0	104.24**$_{abcd}$	54.89**$_{acd}$
F_0 SD	6.49**$_{bc}$	0.76
F_0 Range	1.77	0.177
Duration (s)	35.00**$_{abd}$	9.58**$_{ab}$

Note. F-values are reported in the table with df = 3. Tukey HSD was used to compare mothers' and fathers' IDS and ADS. Mean and SD values for these measures are reported in Table 8. IDS = Infant-directed Speech, ADS = Adult-directed Speech, F_0 = Fundamental Frequency.

**p < 0.01

[a] Mothers' IDS was significantly different than mothers' ADS

[b] Fathers' IDS was significantly different than fathers' ADS

[c] Mothers' IDS was significantly different than fathers' IDS

[d] Mothers' ADS was significantly different than fathers' ADS

Table 10

Analysis of Speaking Rate for Natural Interaction

	Duration	**Syllables**	**Speaking Rate**
Mothers' IDS	1.42 (0.34)$_a$	5.22 (1.41)$_a$	0.33 (0.08)
Mothers' ADS	2.44 (0.46)	10.55 (2.88)	0.29 (0.07)
Fathers' IDS	1.17 (0.34)$_b$	4.52 (1.98)$_b$	0.35 (0.10)
Fathers' ADS	1.86 (0.63)	7.70 (2.92)	0.31 (0.09)

Note. Mean and SD values for these measures are reported here. Duration is in seconds and speaking rate is syllables per second. IDS = Infant-directed Speech, ADS = Adult-directed Speech.

$_a$ Mothers' IDS was significantly different than mothers' ADS, $p < 0.01$

$_b$ Fathers' IDS was significantly different than fathers' ADS, $p < 0.01$

Table 11

Kurtosis for Acoustic Measures

	Mothers' IDS	**Mothers' ADS**	**Fathers' IDS**	**Fathers' ADS**
Natural Interaction				
Mean F_0	-0.92	0.13	0.11	0.21
F_0 SD	0.15	2.92	-1.09	0.34
F_0 Range	0.40	0.05	0.85	-0.48
Duration (s)	1.79	-0.58	2.90	-0.65
Difference Score for Mean F_0 (IDS-ADS)	0.03		0.97	
Book Reading				
Mean F_0	1.31	0.94	-0.68	0.97
F_0 SD	-0.68	3.81	-0.16	1.33
F_0 Range	-0.06	0.87	-0.86	-0.52
Duration (s)	-0.06	-0.97	9.15	2.13
Difference Score for Mean F_0 (IDS-ADS)	-0.87		2.74	

Note. High kurtosis (a value of 1 or above) indicates less individual variability. IDS = Infant-directed Speech, ADS = Adult-directed Speech, F_0 = Fundamental Frequency.

Table 12

Correlation Matrix for Natural Interaction Measures and Paternal Involvement Measures

	Caregiving Score	# of times Father feeds the infant	Burping Relative Score	Diapering Relative Score	Bathing Relative Score	Feeding Relative Score	Putting to Bed Relative Score
Difference Score for F_0	-0.16	-0.40	-0.04	0.09	-0.10	0.004	-0.30
# of IDS utterances	-0.24	-0.15	0.32*	0.05	-0.39	-0.03	-0.12

Note. Spearman rank correlation was used because the caregiving ratings are on a likert scale. A Bonferroni correction was used for multiple comparisons for the individual caregiving ratings (not the composite caregiving score). The corrected alpha = 0.01 and the uncorrected alpha = 0.05. The difference score is the mean fundamental frequency for fathers' ADS subtracted from mean fundamental frequency for fathers' IDS. IDS = Infant-directed speech, ADS = Adult-directed speech, F_0 = Fundamental Frequency.

* $p < 0.05$ but not 0.01

Table 13

Correlation Matrix for Book Reading Measures and Paternal Involvement Measures

	Caregiving Score	Burping Relative Score	Diapering Relative Score	Bathing Relative Score	Feeding Relative Score	Putting to Bed Relative Score
Difference Score for F_0	0.11	0.02	-0.02	0.05	0.12	0.23
Duration	0.10	0.29	-0.07	0.03	-0.08	0.23

Note. Spearman rank correlation was used because the caregiving ratings are on a likert scale. A Bonferroni correction was used for multiple comparisons for the individual caregiving ratings (not the composite caregiving score). The corrected alpha = 0.01 and the uncorrected alpha = 0.05. The difference score is the mean fundamental frequency for fathers' ADS subtracted from mean fundamental frequency for fathers' IDS. IDS = Infant-directed speech, ADS = Adult-directed speech, F_0 = Fundamental Frequency.

Figure Captions

Figure 1. Locations of the electrode sites used in the study.

Figure 2. Barchart depicting the different types of childcare used by the families in the study.

Figure 3. Mothers' and Fathers' Occupations. See Appendix D for an explanation of the categories of occupation.

Figure 4. Barchart of education of mothers and fathers.

Figure 5. The relationship between fathers' rating of the amount of vocalizing during father-infant interactions by the number of hours he is available to the infant on a weekday.

Figure 6. The relationship between fathers' rating of the amount of vocalizing during father-infant interactions by the number of hours he is available to the infant on a weekend day.

Figure 7. The relationship between fathers' rating of the amount of vocalizing during father-infant interactions by the number of IDS utterances he produced during the natural interaction. IDS = Infant-directed Speech.

Figure 8. Number of utterances produced during the natural interaction. IDS = Infant-directed Speech, ADS = Adult-directed Speech

Figures 9. Histogram of mean fundamental frequency for the natural interaction depicting individual variation in the measure. F0 = Fundamental Frequency.

Figure 10. Histogram of range in fundamental frequency for the natural interaction depicting individual variation in the measure. F0 = Fundamental Frequency.

Figure 11. Histogram of standard deviation of fundamental frequency for the natural interaction depicting individual variation in the measure. F0 = Fundamental Frequency.

Figure 12. Histogram of duration (in seconds) for the natural interaction depicting individual variation in the measure.

Figure 13. Histogram of the difference score for mean fundamental frequency for natural interaction depicting individual variation in the measure. F0 = Fundamental Frequency.

Figure 14. Histogram for number of IDS utterances produced during the natural interaction depicting individual variation in the measure. IDS = Infant-directed Speech.

Figure 15. Histogram of mean fundamental frequency for the book reading depicting individual variation in the measure. F0 = Fundamental Frequency.

Figure 16. Histogram of range in fundamental frequency for the book reading depicting individual variation in the measure. F0 = Fundamental Frequency.

Figure 17. Histogram of standard deviation of fundamental frequency for the book reading depicting individual variation in the measure. F0 = Fundamental Frequency.

Figure 18. Histogram of duration (in seconds) for the book reading depicting individual variation in the measure.

Figure 19. Histogram of the difference score for mean fundamental frequency for the book reading depicting individual variation in the measure. F0 = Fundamental Frequency.

Figure 20. Event-related potentials to female IDS And ADS. Shaded areas indicate a significant difference for the N600-800 for IDS and the N600-800 for ADS at the electrode site. IDS = Infant-directed Speech, ADS = Adult-directed Speech.

Figure 21. Event-related potentials to male IDS And ADS. Shaded areas indicate a significant difference for the N600-800 for IDS and the N600-800 for ADS at the electrode site. IDS = Infant-directed Speech, ADS = Adult-directed Speech.

Figure 22. Barchart depicting the mean amplitude of the N600-800 for each condition. Only sites with a significant effect were included in the mean. Error bars indicate standard error. IDS = Infant-directed Speech, ADS = Adult-directed Speech.

Figure 1

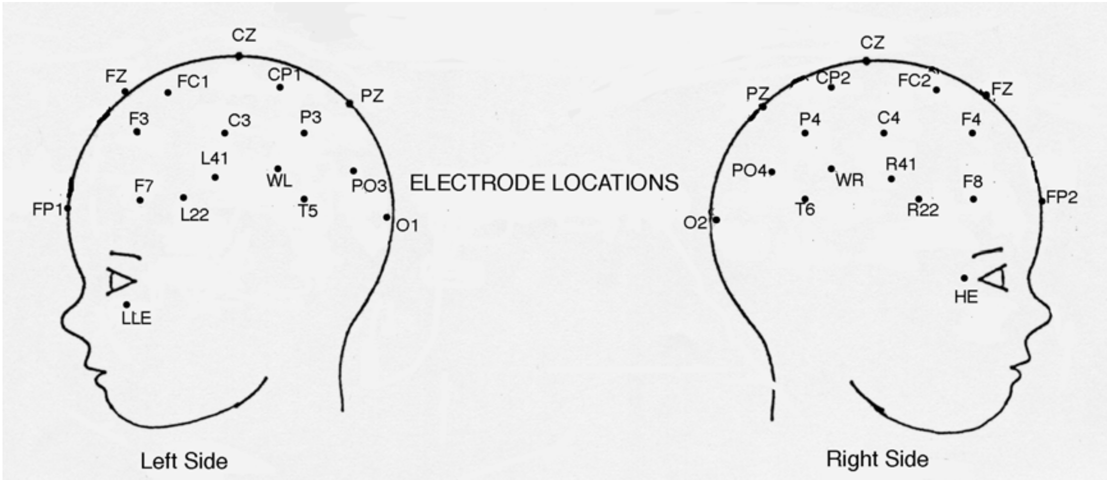
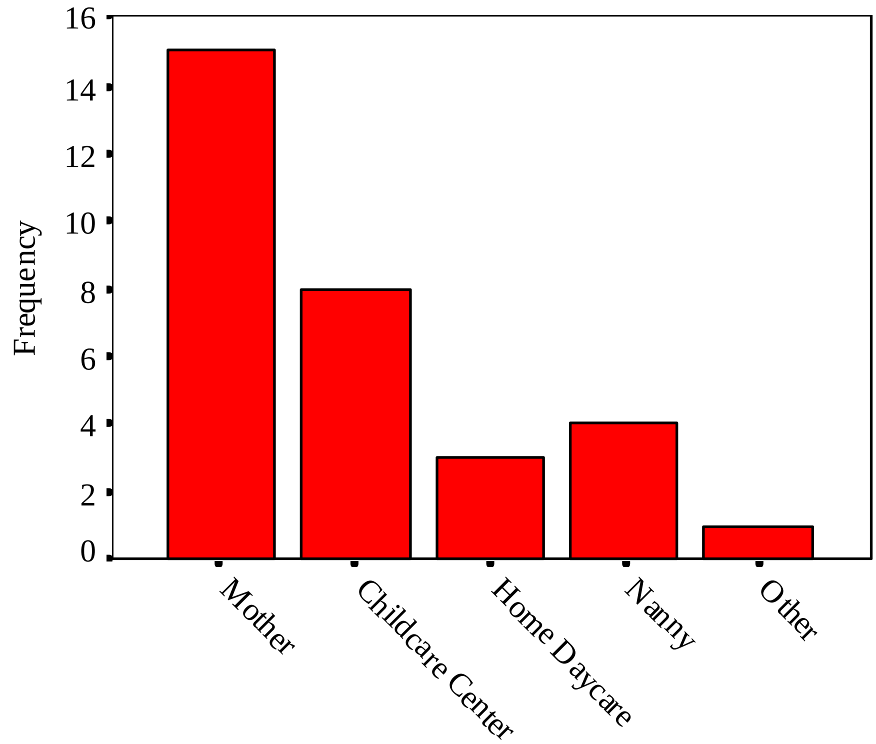
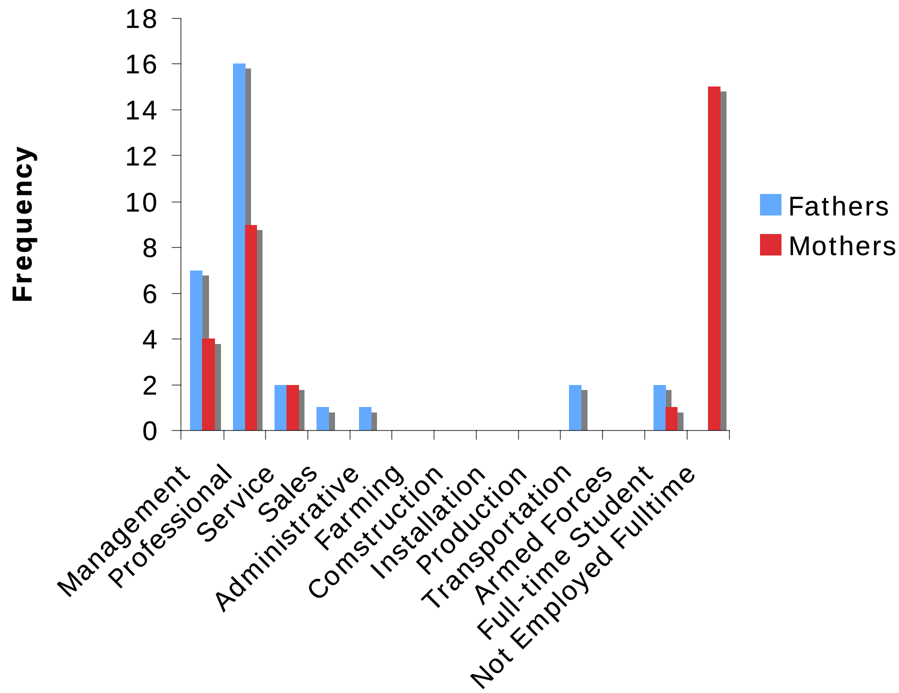

ELECTRODE LOCATIONS
CZ
FZ
FC1
CP1
PZ
F3
C3
P3
L41
WL
F7
PO3
FP1
L22
T5
O1
LtE
Left Side
CZ
PZ
CP2
FC2
FZ
P4
C4
F4
PO4
WR
R41
F8
FP2
O2
T6
R22
HE
Right Side

Figure 2



Frequency
16
14
12
10
8
6
4
2
0
Mother
Childcare Center
Home Daycare
Nanny
Other

Figure 3



Frequency
18
16
14
12
10
8
6
4
2
0
Management
Professional
Service
Sales
Administrative
Farming
Comstruction
Installation
Production
Transportation
Armed Forces
Full-time Student
Not Employed Fulltime
Fathers
Mothers

Figure 4

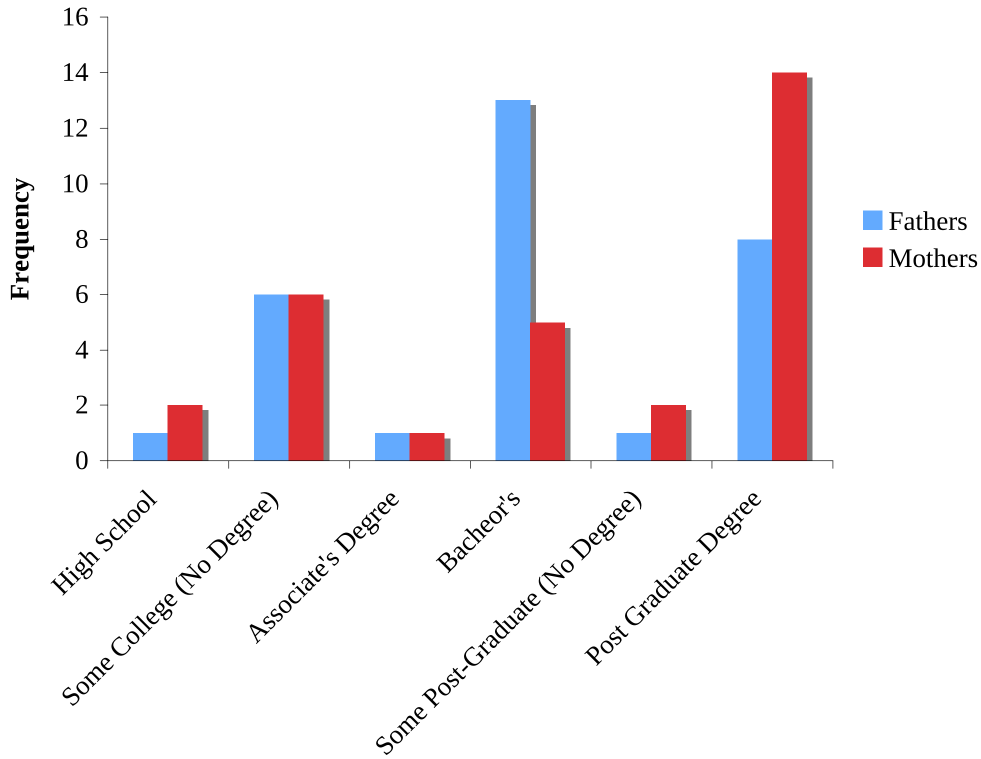

Frequency
16
14
12
10
8
6
4
2
0
Fathers
Mothers
High School
Some College (No Degree)
Associate's Degree
Bacheor's
Some Post-Graduate (No Degree)
Post Graduate Degree

Figure 5

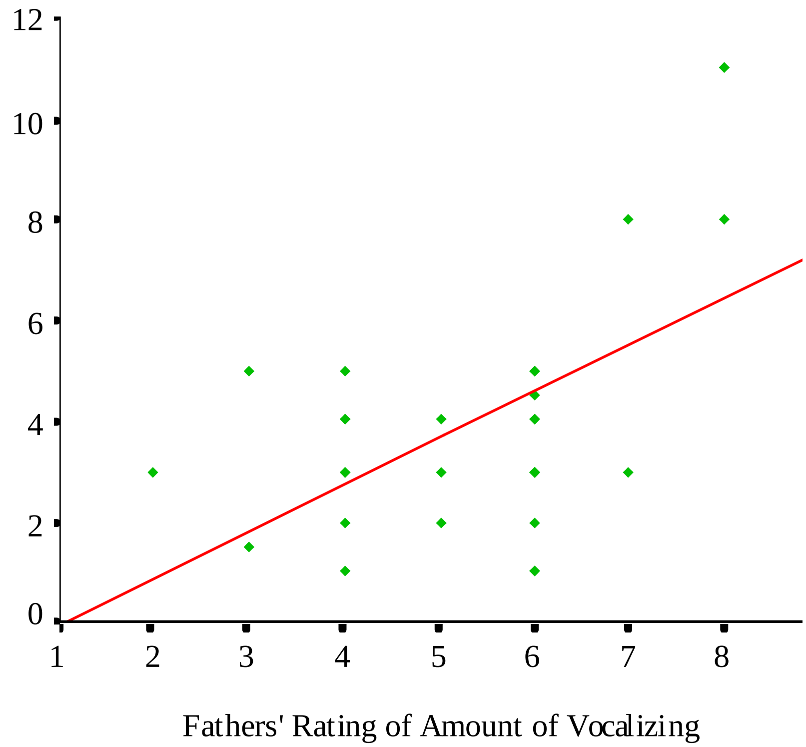

12
10
8
6
4
2
0
1
2
3
4
5
6
7
8
Fathers' Rating of Amount of Vocalizing

Figure 6

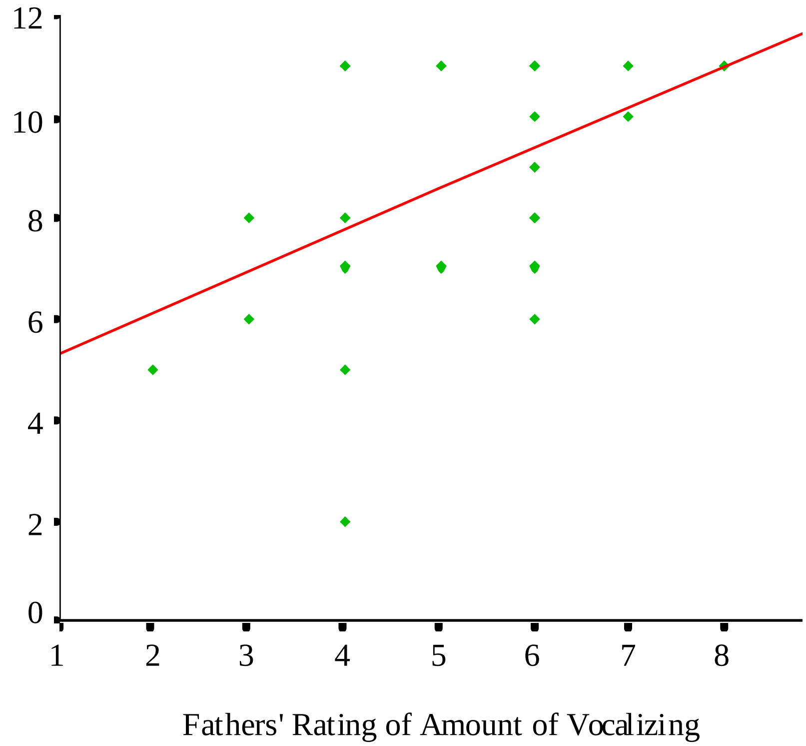

12
10
8
6
4
2
0
1
2
3
4
5
6
7
8
Fathers' Rating of Amount of Vocalizing

Figure 7

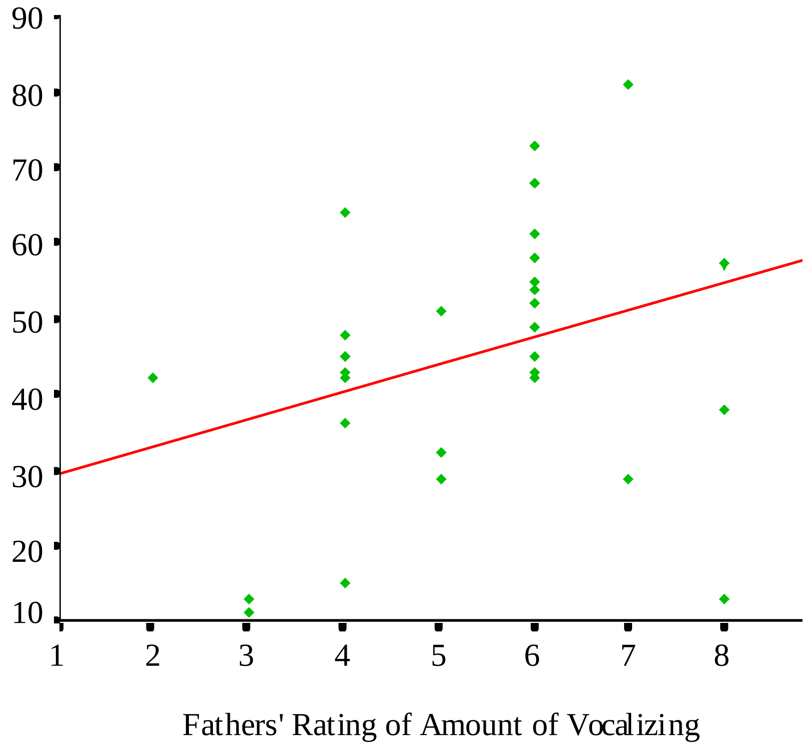
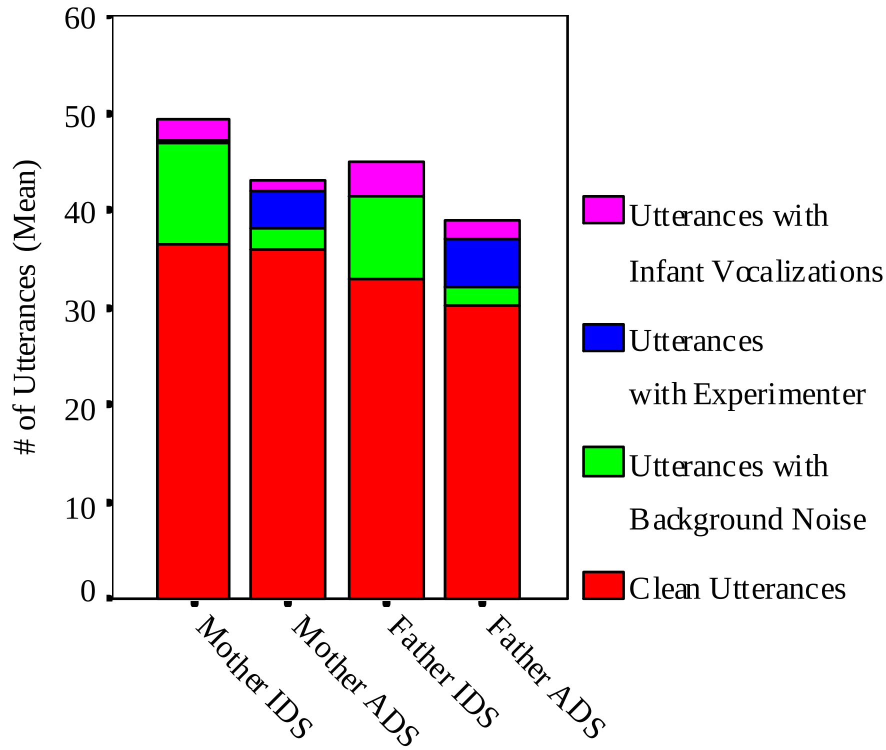

90
80
70
60
50
40
30
20
10
1
2
3
4
5
6
7
8
Fathers' Rating of Amount of Vocalizing

Figure 8



60
50
40
30
20
10
0
# of Utterances (Mean)
Mother IDS
Mother ADS
Father IDS
Father ADS
Utterances with Infant Vocalizations
Utterances with Experimenter
Utterances with Background Noise
Clean Utterances

Figure 9

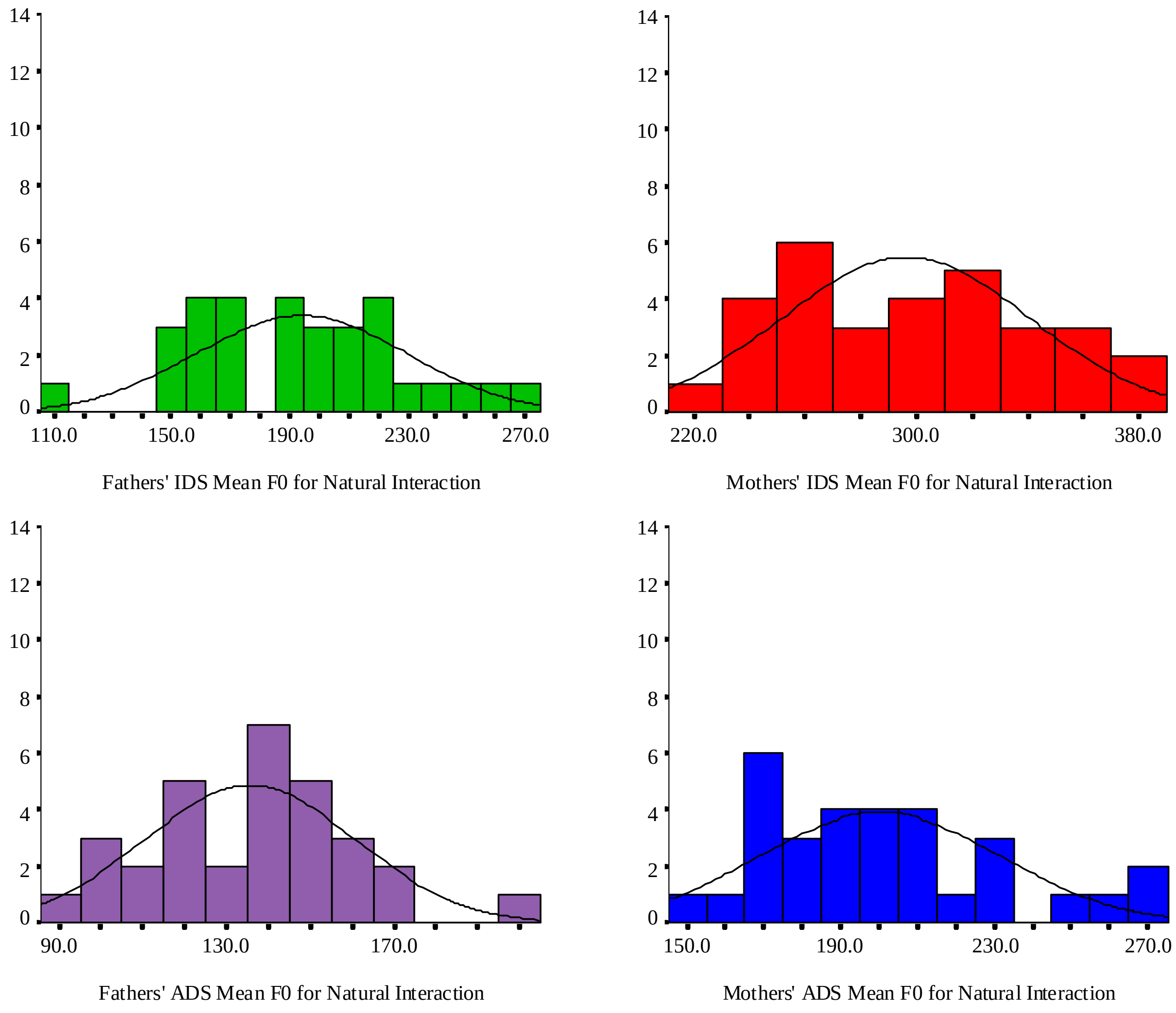

14
12
10
8
6
4
2
0
110.0
150.0
190.0
230.0
270.0
Fathers' IDS Mean F0 for Natural Interaction
14
12
10
8
6
4
2
0
220.0
300.0
380.0
Mothers' IDS Mean F0 for Natural Interaction
14
12
10
8
6
4
2
0
90.0
130.0
170.0
Fathers' ADS Mean F0 for Natural Interaction
14
12
10
8
6
4
2
0
150.0
190.0
230.0
270.0
Mothers' ADS Mean F0 for Natural Interaction

Figure 10

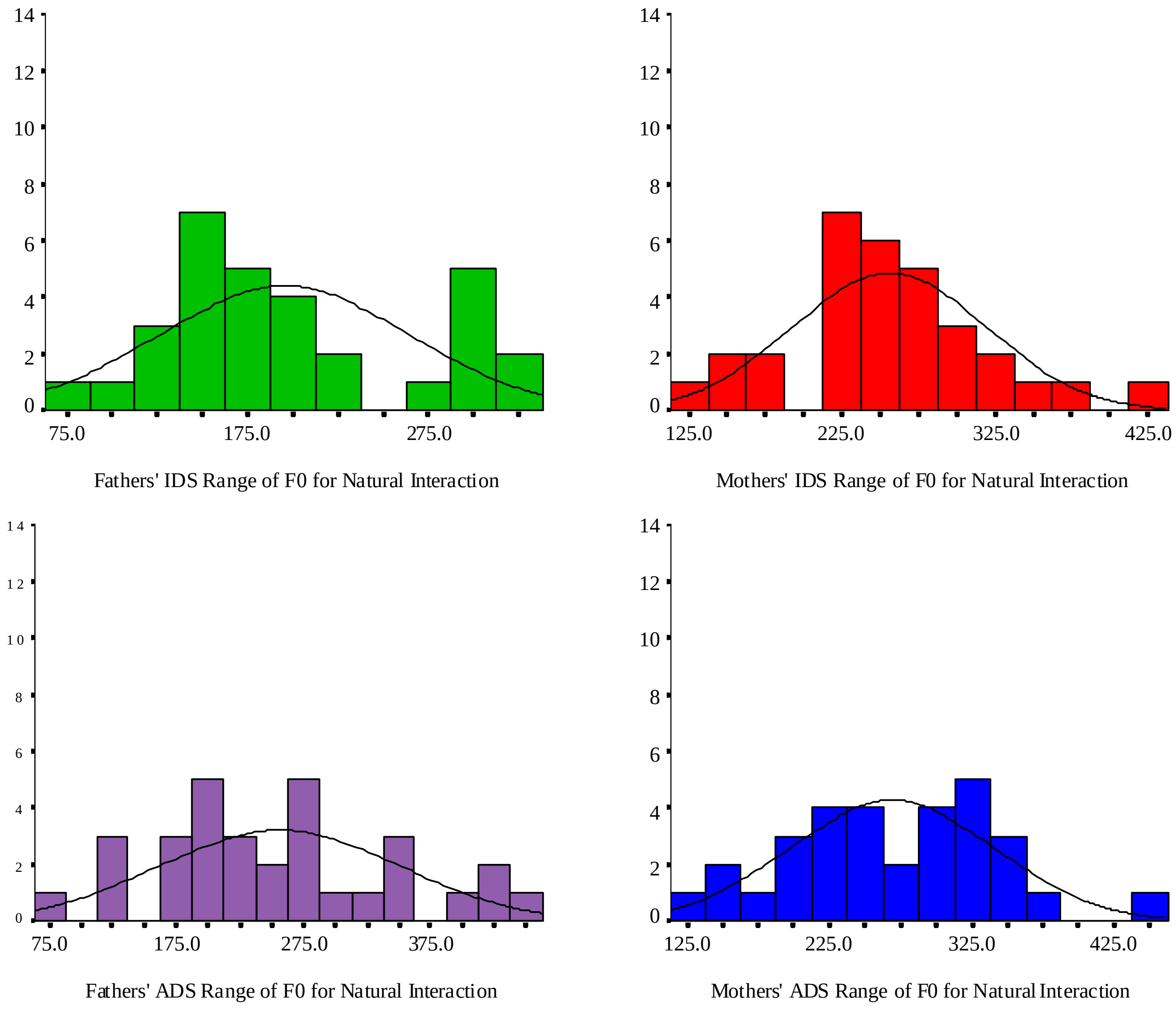

14
12
10
8
6
4
2
0
75.0
175.0
275.0
Fathers' IDS Range of F0 for Natural Interaction
125.0
225.0
325.0
425.0
Mothers' IDS Range of F0 for Natural Interaction
75.0
175.0
275.0
375.0
Fathers' ADS Range of F0 for Natural Interaction
125.0
225.0
325.0
425.0
Mothers' ADS Range of F0 for Natural Interaction

Figure 11

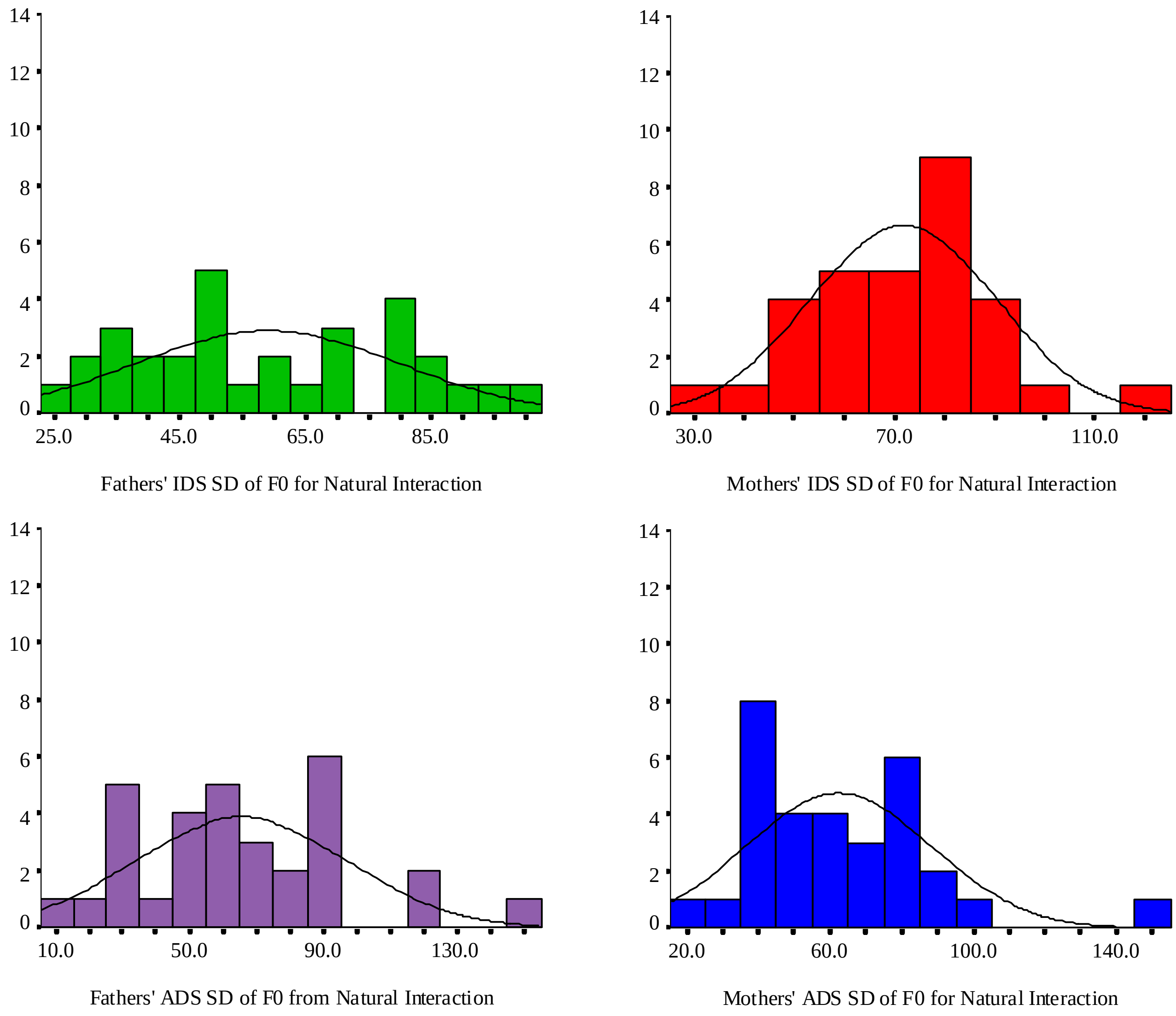

14
12
10
8
6
4
2
0
25.0
45.0
65.0
85.0
Fathers' IDS SD of F0 for Natural Interaction
14
12
10
8
6
4
2
0
30.0
70.0
110.0
Mothers' IDS SD of F0 for Natural Interaction
14
12
10
8
6
4
2
0
10.0
50.0
90.0
130.0
Fathers' ADS SD of F0 from Natural Interaction
14
12
10
8
6
4
2
0
20.0
60.0
100.0
140.0
Mothers' ADS SD of F0 for Natural Interaction

Figure 12

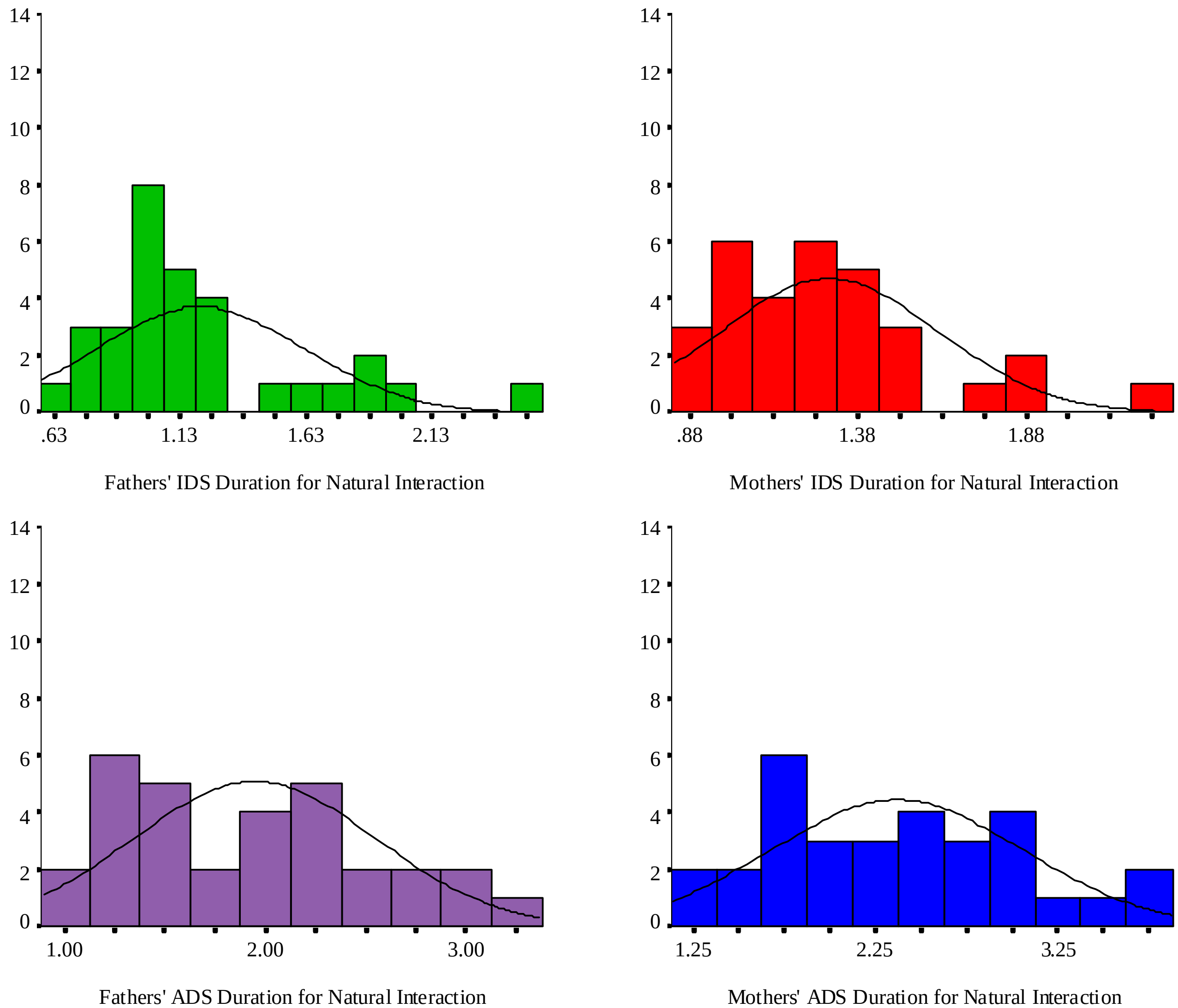

14
12
10
8
6
4
2
0
.63
1.13
1.63
2.13
Fathers' IDS Duration for Natural Interaction
.88
1.38
1.88
Mothers' IDS Duration for Natural Interaction
1.00
2.00
3.00
Fathers' ADS Duration for Natural Interaction
1.25
2.25
3.25
Mothers' ADS Duration for Natural Interaction

Figure 13

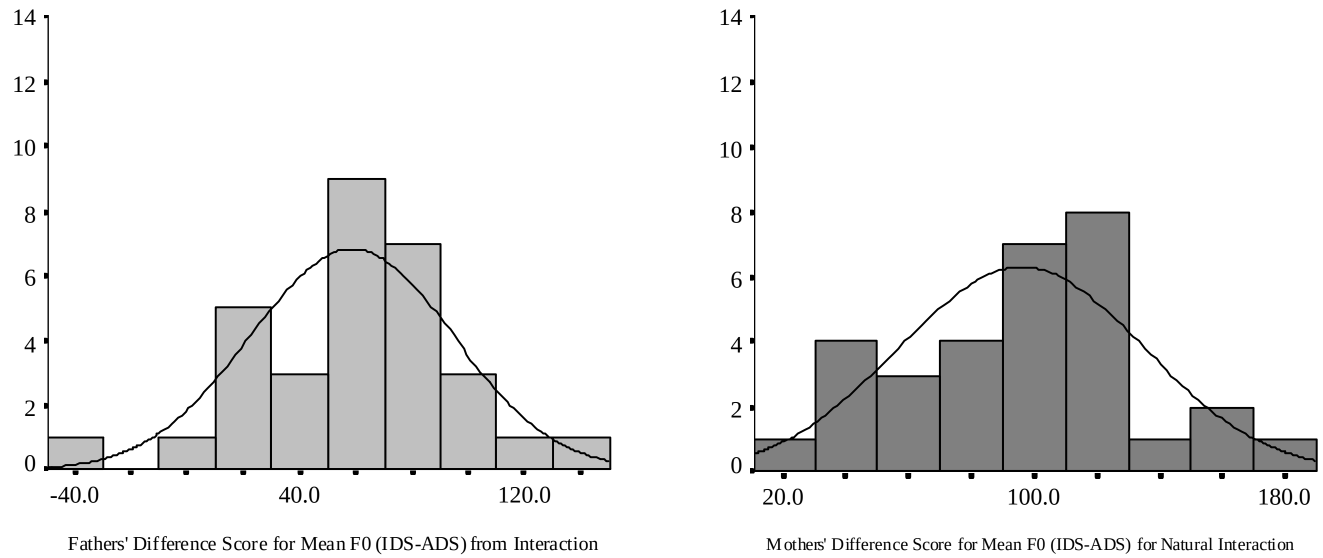

14
12
10
8
6
4
2
0
-40.0
40.0
120.0
Fathers' Difference Score for Mean F0 (IDS-ADS) from Interaction
14
12
10
8
6
4
2
0
20.0
100.0
180.0
Mothers' Difference Score for Mean F0 (IDS-ADS) for Natural Interaction

Figure 14

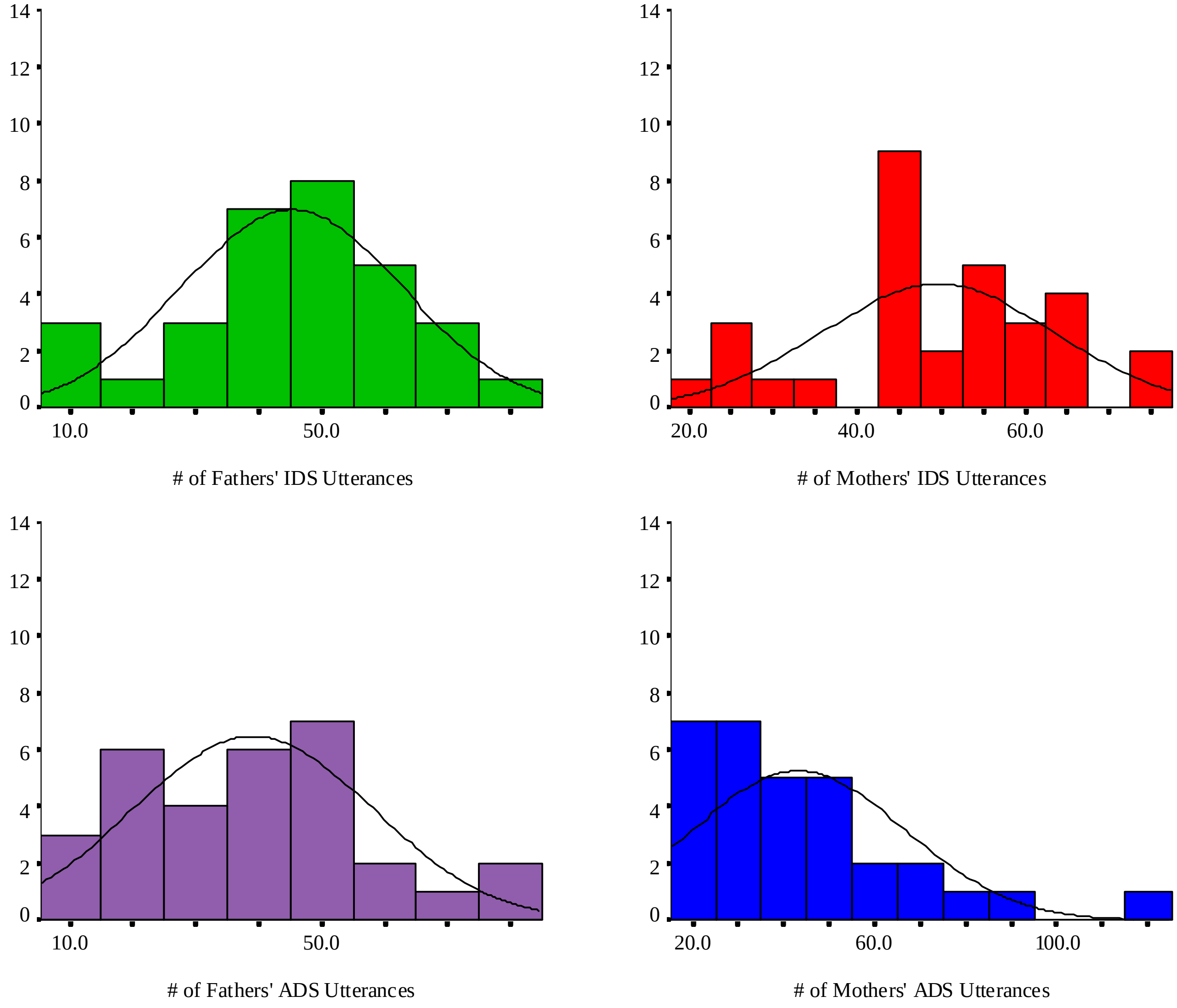

14
12
10
8
6
4
2
0
10.0
50.0
# of Fathers' IDS Utterances
20.0
40.0
60.0
# of Mothers' IDS Utterances
10.0
50.0
# of Fathers' ADS Utterances
20.0
60.0
100.0
# of Mothers' ADS Utterances

Figure 15

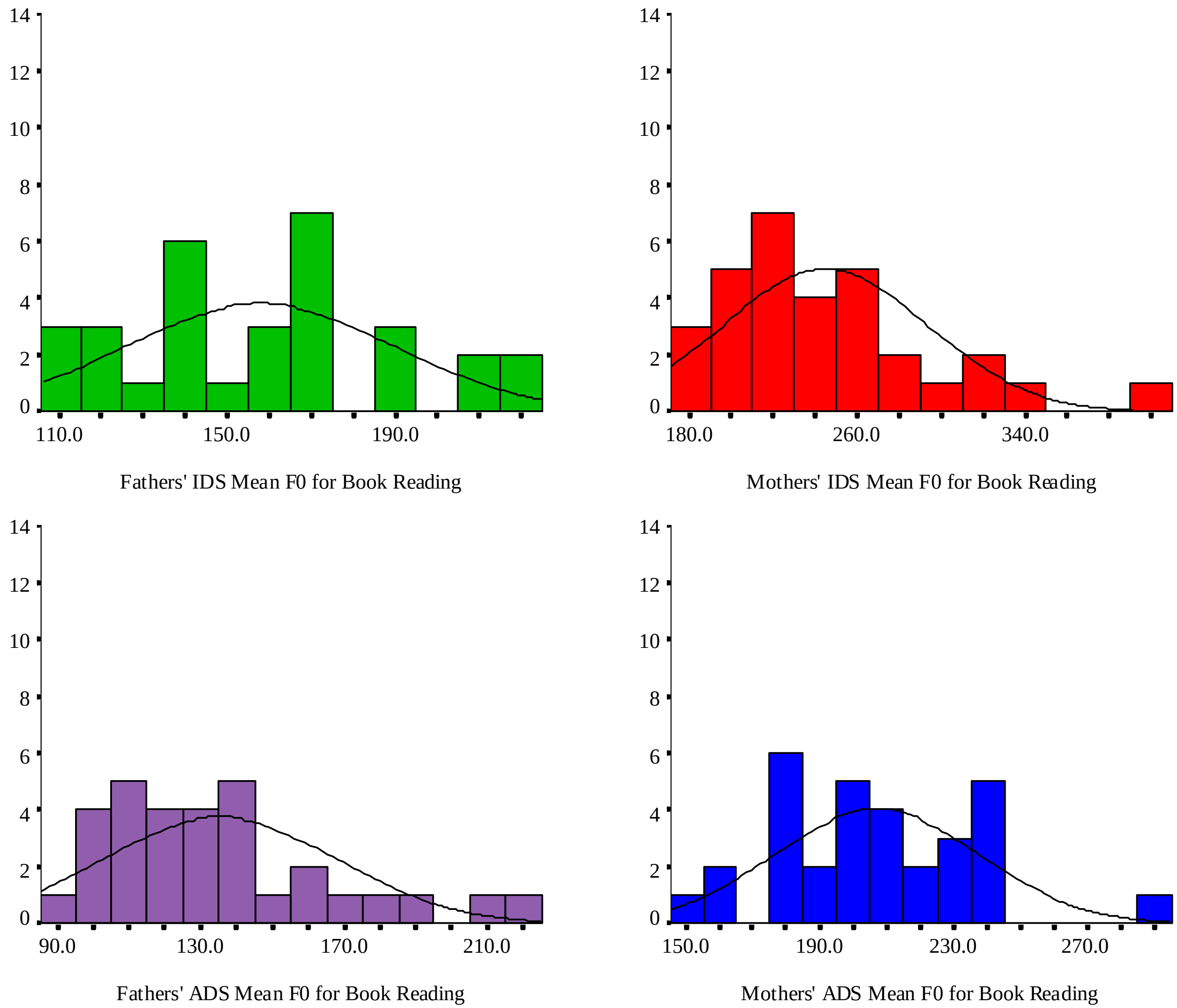

14
12
10
8
6
4
2
0
110.0
150.0
190.0
Fathers' IDS Mean F0 for Book Reading
14
12
10
8
6
4
2
0
180.0
260.0
340.0
Mothers' IDS Mean F0 for Book Reading
14
12
10
8
6
4
2
0
90.0
130.0
170.0
210.0
Fathers' ADS Mean F0 for Book Reading
14
12
10
8
6
4
2
0
150.0
190.0
230.0
270.0
Mothers' ADS Mean F0 for Book Reading

Figure 16

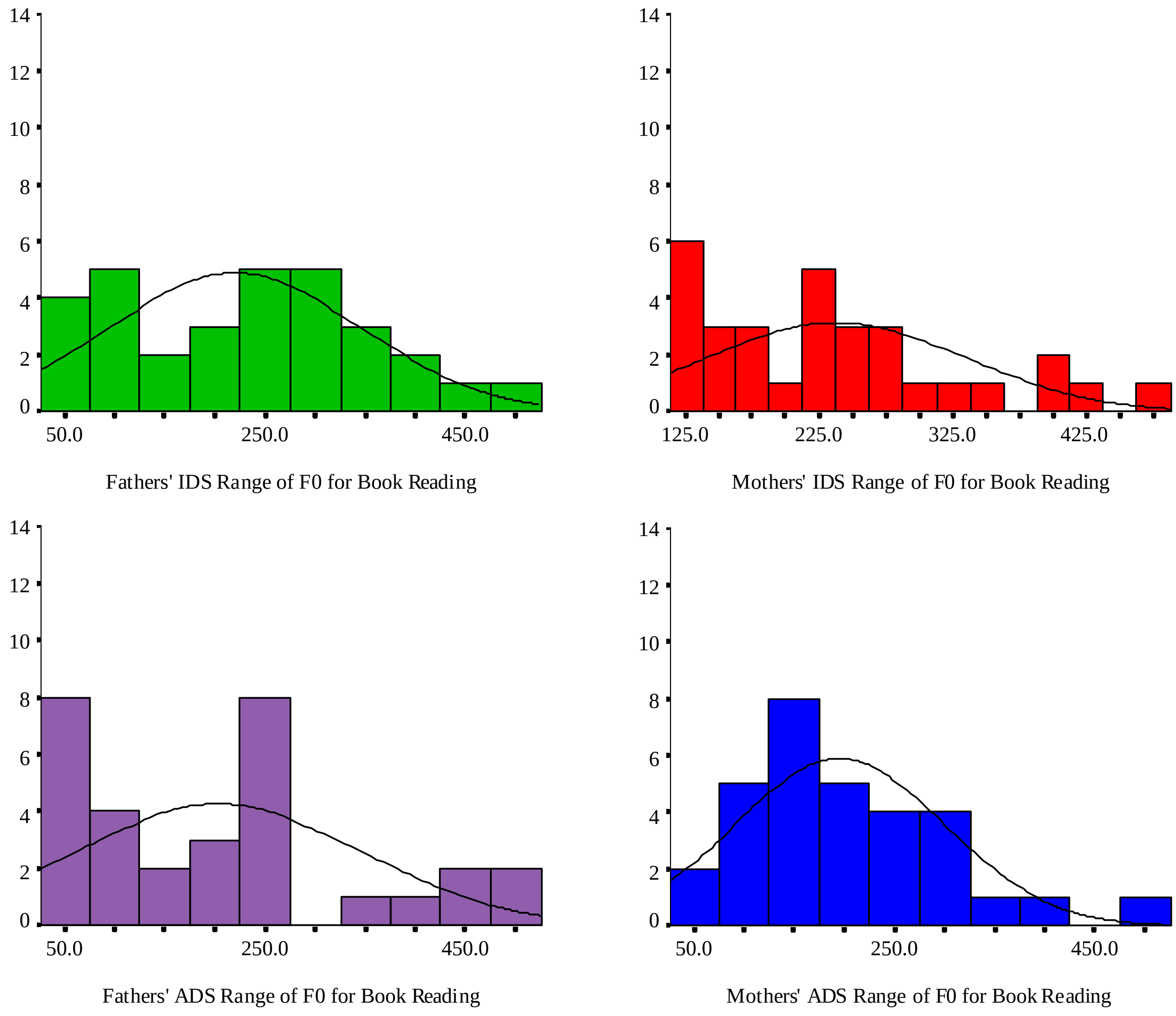
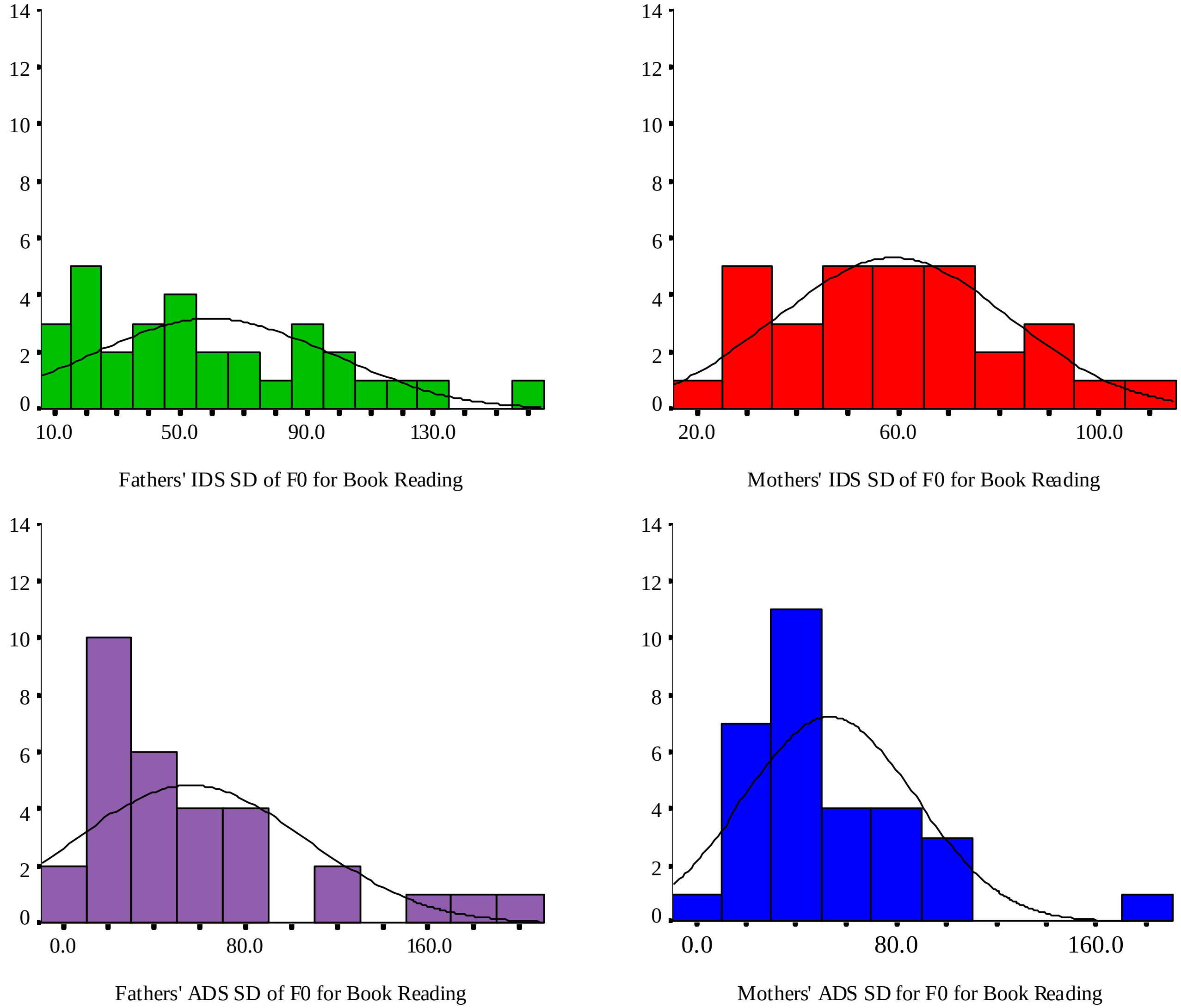

14
12
10
8
6
4
2
0
50.0
250.0
450.0
Fathers' IDS Range of F0 for Book Reading
14
12
10
8
6
4
2
0
125.0
225.0
325.0
425.0
Mothers' IDS Range of F0 for Book Reading
14
12
10
8
6
4
2
0
50.0
250.0
450.0
Fathers' ADS Range of F0 for Book Reading
14
12
10
8
6
4
2
0
50.0
250.0
450.0
Mothers' ADS Range of F0 for Book Reading

Figure 17



14
12
10
8
6
4
2
0
10.0
50.0
90.0
130.0
Fathers' IDS SD of F0 for Book Reading
20.0
60.0
100.0
Mothers' IDS SD of F0 for Book Reading
0.0
80.0
160.0
Fathers' ADS SD of F0 for Book Reading
Mothers' ADS SD for F0 for Book Reading

Figure 18

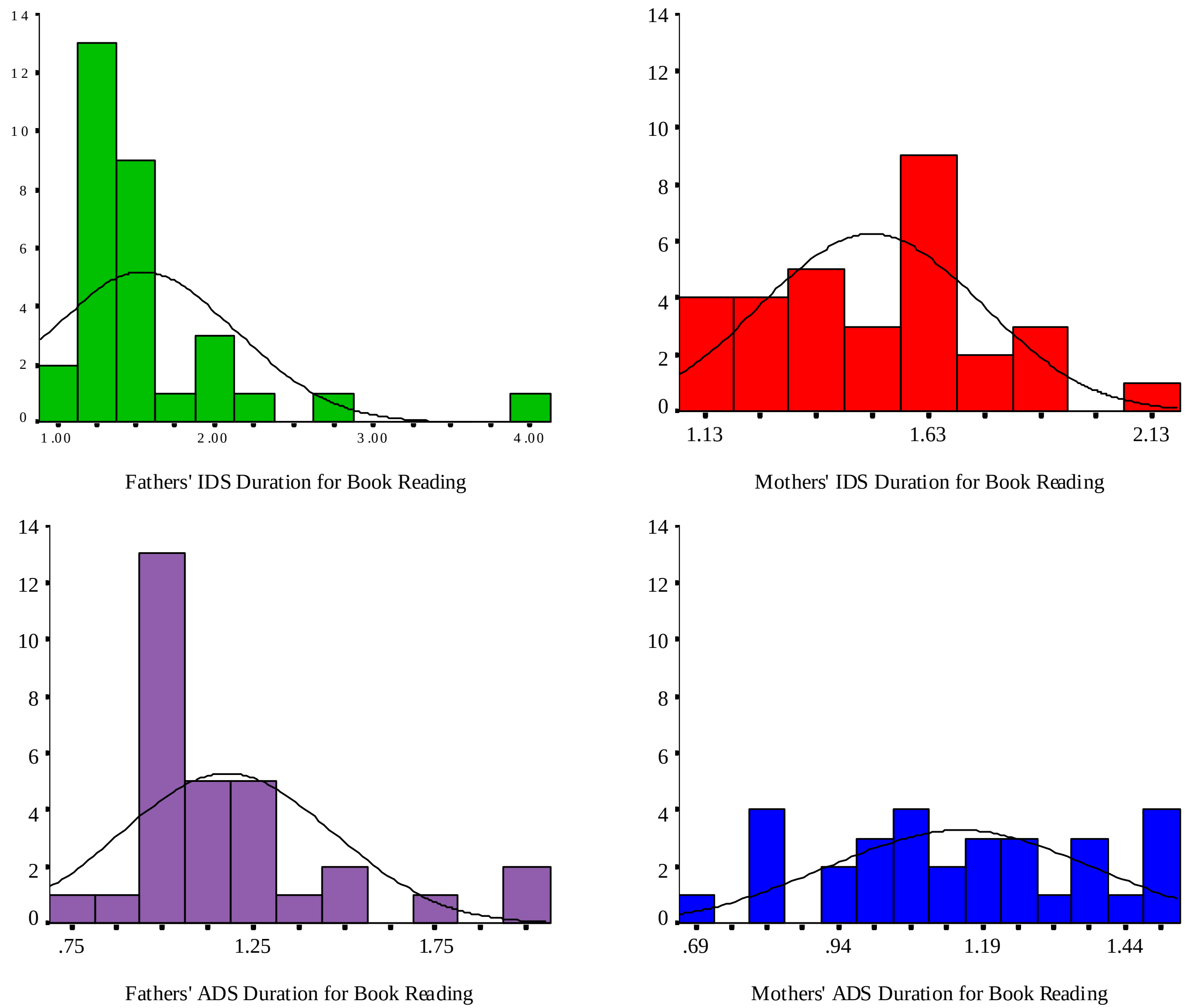

14
12
10
8
6
4
2
0
1.00
2.00
3.00
4.00
Fathers' IDS Duration for Book Reading
14
12
10
8
6
4
2
0
1.13
1.63
2.13
Mothers' IDS Duration for Book Reading
14
12
10
8
6
4
2
0
.75
1.25
1.75
Fathers' ADS Duration for Book Reading
14
12
10
8
6
4
2
0
.69
.94
1.19
1.44
Mothers' ADS Duration for Book Reading

Figure 19

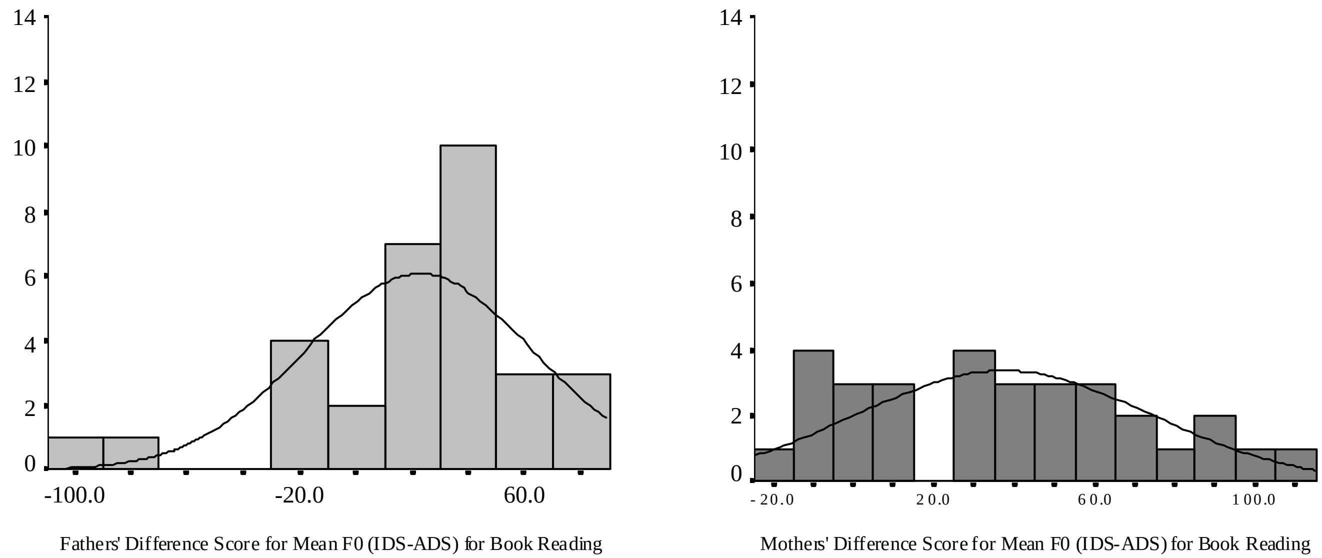

14
12
10
8
6
4
2
0
-100.0
-20.0
60.0
Fathers' Difference Score for Mean F0 (IDS-ADS) for Book Reading
14
12
10
8
6
4
2
0
-20.0
20.0
60.0
100.0
Mothers' Difference Score for Mean F0 (IDS-ADS) for Book Reading

Figure 20

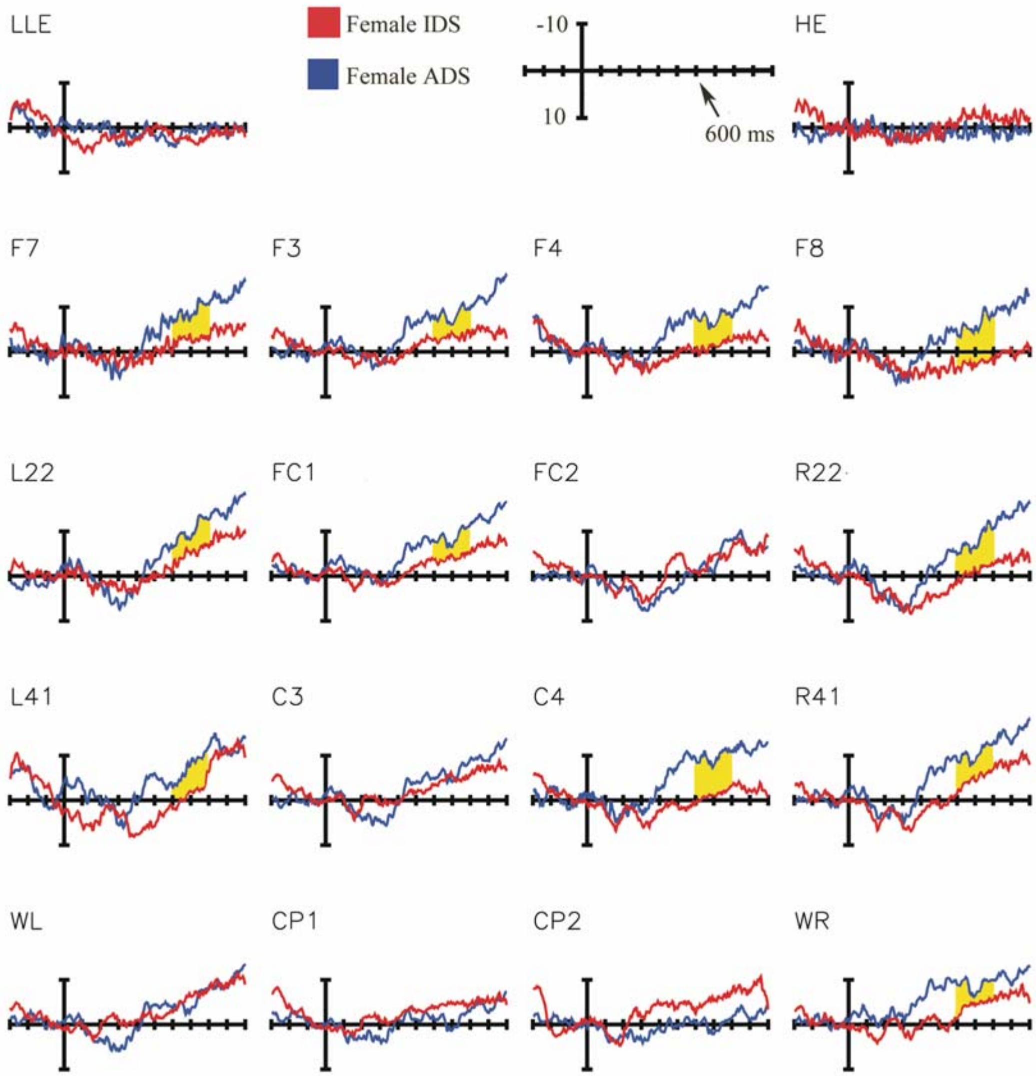

LLE
Female IDS
Female ADS
-10
10
600 ms
HE
F7
F3
F4
F8
L22
FC1
FC2
R22
L41
C3
C4
R41
WL
CP1
CP2
WR

Figure 21

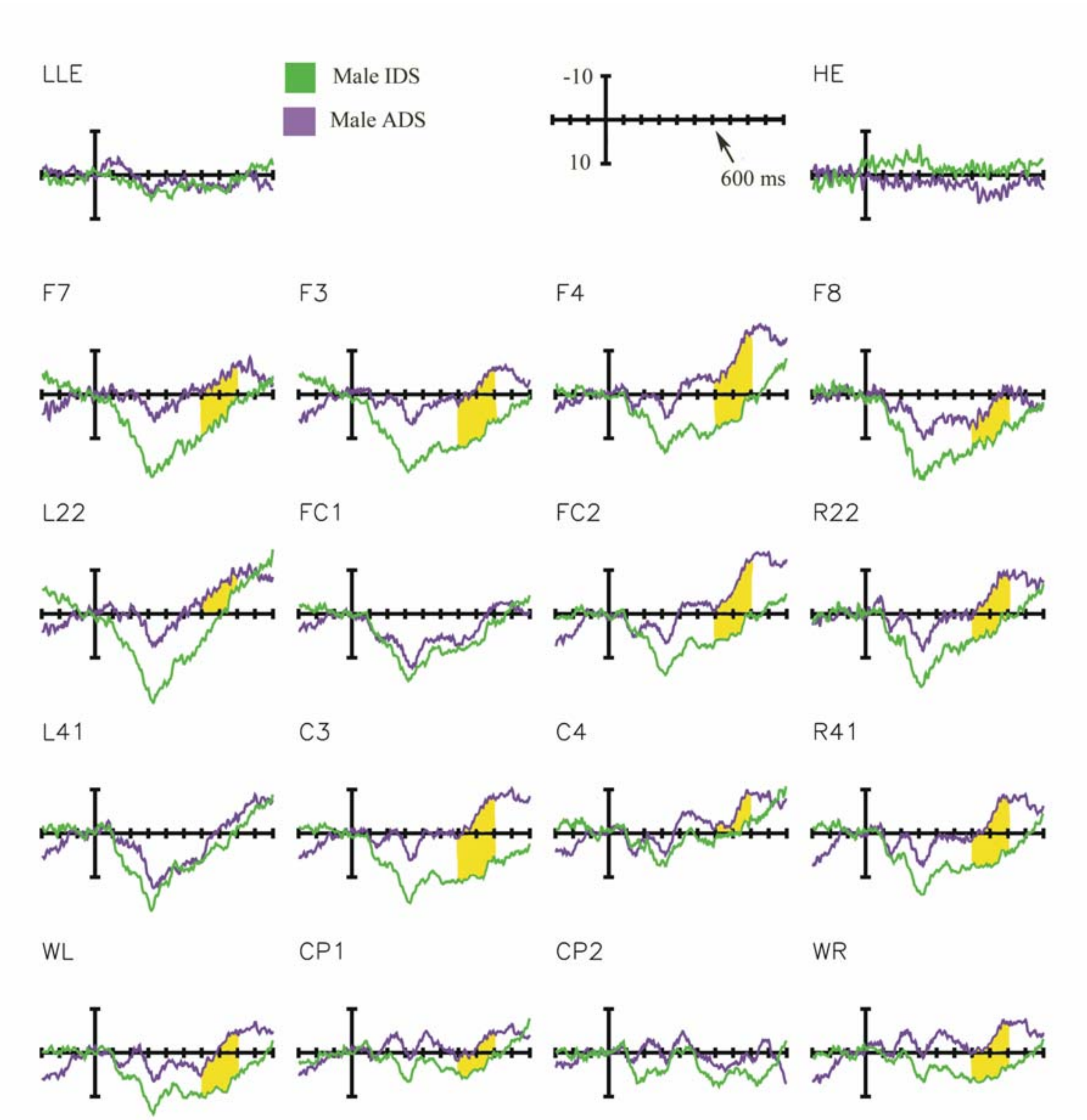
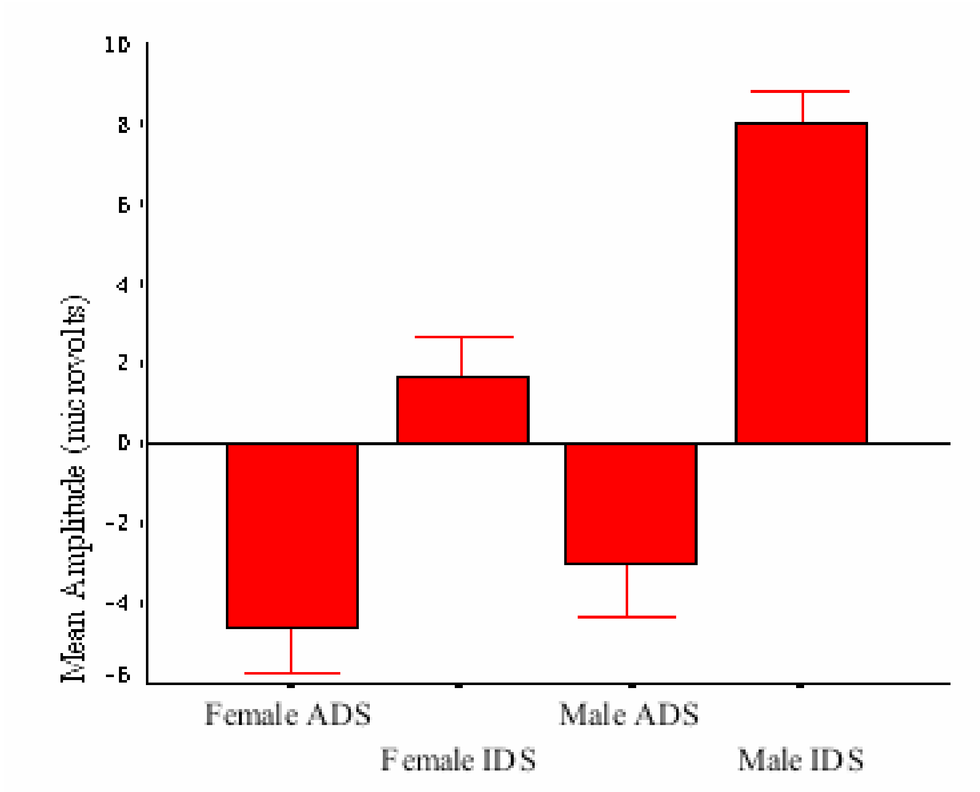

LLE
Male IDS
Male ADS
-10
10
600 ms
HE
F7
F3
F4
F8
L22
FC1
FC2
R22
L41
C3
C4
R41
WL
CP1
CP2
WR

Figure 22


10
8
6
4
2
0
-2
-4
-6
Mean Amplitude (microvolts)
Female ADS
Female IDS
Male ADS
Male IDS