Examiing How Parents Respond to Their Infant: The Difference Between Full-term and Preterm Infants

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I am submitting herewith a thesis written by Rebecca R. Crum entitled "Examining How Parents Respond to Their Infant: The Difference Between Full-term and Preterm Infants." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Arts, with a major in Experimental Psychology.

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(Original signatures are on file with official student records.)
EXAMINING HOW PARENTS RESPOND TO THEIR INFANT: THE DIFFERENCE BETWEEN FULL-TERM AND PRETERM INFANTS

A Thesis Presented for the
Master of Arts
Degree
The University of Tennessee, Knoxville

Rebecca R. Crum
December 2023
Acknowledgements

I would first like to thank my advisor, Jessica Hay, for her support and guidance through this project. I thank all of my committee members: Greg Reynolds, Shannon Ross-Sheehy, and Katherine Newnam for their support through this process. I also thank the families for participating in this study because it is no small task to wrangle small children for activities like this. I would like to thank my undergraduate research assistants and lab manager, Daniela Santos-Oliveira, in the Infant Language and Perceptual Learning Lab for supporting me and helping me see this project to the finish line while caring for a little one myself.

Also, to my partner, Travis, for being my steadfast support and the best dad to our little boy through all of this. There were plenty of times you had to give 90% when I could only give 10%, and for that, I will always be grateful for your help in me seeing this through. Most importantly, I would like to dedicate this completed thesis to my baby boy, Charlie. You have taught me the depth of the importance of patience and perseverance, and you’ve given me perspective that I never would have seen without you.
Preterm infants born with a low birthweight are at risk for developmental delays both physically and cognitively. Research suggests that preterm infants struggle to meet developmental milestones in the same way that their full-term counterparts do, especially when it comes to their language development. This study examined the quantitative (i.e., number of words infants heard, amount of child vocalizations) and qualitative (i.e., contingent responding between infants and caregivers, proportion of infant-directed speech) in three cohorts of infants 1) infants born preterm (8-9-months chronological age; 6-months corrected age; n=6), 2) gestational age-matched full-term infants (~ 6 months chronological age), and 3) chronological age-matched full-term infants (~ 8-9 months chronological age) using the Language ENvironmental Analysis (LENA) system. Further quality measures included the types of vocalizations the infants made and the latency of response time between caregivers and infants during their interactions. Descriptive analyses of the LENA’s quantitative measures revealed that preterm infants do not vocalize nearly the same amount as their full-term counterparts. Further analyses of the quality of their interactions revealed that, in spite of preterm infants vocalizing less, parents responded to their infants quicker than their full-term peers’ parents did and interacted just as often. In sum, there is quite a bit of individual differences in infants’ language environments, and preterm infants seem to be behind in their vocal interactions than their full-term counterparts.
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Chapter One

Introduction

Infants born prematurely with low birthweight (LBW; ≤1800 grams) are at risk for developmental delays both physically and cognitively, including but not limited to deficits in hearing, memory, speech, and language development (Graven & Browne, 2008; Webb et al., 2015). Preterm infants have a very different early life experience than their full-term counterparts, which may at least partially account for developmental differences observed in these two populations. This includes exposure to an atypical distribution of noxious high-frequency noise versus protective low-frequency speech (Wachman & Lahav, 2011; McMahon et al., 2012). Further, some parents of preterm infants initially find it more challenging to connect with their newborns because preterm infants tend to provide fewer social cues for their mothers, such as decreased looking behaviors like returning their mother’s gaze and fewer facial expressions (Bozzette, 2007). As a result of the lack of reciprocation from the infant, parents of preterm infants may struggle to engage with their child in a way that best supports healthy language development. In the current work, we seek to examine differences in the quantity and quality of speech that preterm versus full-term infants hear. Although the extant literature supports the importance of both the quantity and quality of language input for language development in full-term infants, much less is known about how preterm birth impacts these dynamic interactions between infants and their caregivers. Thus, the current data will add to the extant literature by identifying potential factors that may contribute to risk and resilience in language development in infants born preterm and may provide an evidence base for developing targeted interventions in this vulnerable population.
Preterm Birth and Later Language Development

Development of Auditory Systems & the Neonatal Intensive Care Unit

Human auditory systems are fully functional by the time the fetus reaches 25 weeks of gestation and continue to mature over the remainder of their gestational period and for several months post-birth (Graven & Browne, 2008). In utero, due to the protective uterine wall, fetuses are exposed primarily to low-frequency sounds, such as the human voice, and shielded from other noxious sounds. These low-frequency sounds are necessary for the optimal development of both the peripheral and central auditory systems while in the womb and beyond (Webb et al., 2015). However, when the infants are born preterm, they are no longer shielded by the uterine environment and, in turn, are often exposed to high-frequency mechanical noises typical of the neonatal intensive care unit (NICU) environment. Although many of these sounds are produced by lifesaving machinery, preterm infants’ auditory systems are not yet prepared for these sounds, even if their auditory systems are functional (Lahav & Skoe, 2014). Preterm infants can spend up to three months in the NICU, exposed to noxious sounds from the necessary machinery for maintaining life and growth. However, this can cause trauma and put them at risk for later auditory, language, and attentional disorders.

To mitigate the harsh noises and their harmful effects, the American Academy of Pediatrics recommends that the NICU sound environment not exceed 45dBA. This recommendation is grounded on evidence that exposure to sounds above 45dBA, especially if sustained, could result in hearing loss or other adverse health effects, such as but not limited to hypoxemia (Committee on Environmental Health, 1997). With this recommendation, some NICUs have changed to housing infants in single-family rooms instead of in open-bay NICUs.
This change has led to decreased levels of parental stress (van Veenendal et al., 2020). However, a possible unintended consequence of these guidelines and the move to single-family rooms is decreased language exposure during this critical time in auditory development, especially when parents do not have the flexibility to visit often due to inability to take leave or having to travel from long distances to the hospital. This may partially contribute to preterm infants' atypical language development patterns (Rand & Lahav, 2014).

Previous research has demonstrated that the mother’s voice is important for development in both preterm and full-term infants (Filippa et al., 2017). For example, newborn infants prefer their mother's voice over speech from another female voice (DeCasper & Fifer, 1980). Furthermore, it has been shown that as early as 32 weeks gestation, exposure to that maternal voice leads to heart rate deceleration (Kisilevsky et al, 2009). Indeed, in-utero fetal neuroimaging at the beginning of the third trimester has revealed cortical activation while listening to their mother’s voice (Jardri et al., 2012), suggesting that this is necessary for healthy brain development and readiness of the infant for processing their auditory environment (Rand & Lahav, 2014). While the mother’s voice could provide the necessary stimulation for infants’ healthy development, most human conversations end up drowned out by ambient noise from equipment in the NICU. It is likely that given that only 2-5% of the stimulation to infants in the NICU is meaningful adult language (Caskey et al., 2011), these infants are not receiving the same amount of necessary stimulation for adequate auditory system development.

Stress of Preterm Birth on Parent-Child Relationships

While language input in and of itself is vital to preterm infants for the development of their auditory systems and later language acquisition, social interactions, especially those early
interactions with caregivers, are important for many aspects of development, including language (Roseberry et al., 2018; Tomasello, 1992). However, this socialization process is bidirectional, and some mothers report having difficulty connecting with their preterm infants (Bozzette, 2007). Some studies have posited that preterm infants can be less attentive, less expressive, and fussier than their full-term counterparts (Goldberg, 1978; Crnic et al., 1983; Minde et al., 1983), and they also tended to look at their mothers and vocalize less (Holditch-Davis & Thoman, 1988). As a result, some mothers find it difficult to interact with their infants at appropriate levels (Holditch-Davis & Thoman, 1988; Muller-Nix et al., 2004).

While numerous confounding variables exist in a preterm infant’s overall language development, consistent evidence points to the importance of the quality of infant-caregiver interactions on their language development (Vandormael et al., 2019). For example, when mother-child dyads with infants born prematurely were followed longitudinally to assess their attachment and linguistic outcomes, the quality of the relationship between the mother and child seemed to be related to later linguistic development (Costantini et al., 2011). In the existing literature examining premature infants’ interactions with their mothers, there seems to be a theme that persists of the possibility of difficult interactions between mother and child (e.g., Crnic et al., 1983; Minde, 2000), which could, in turn, be affecting the responsiveness of parents and the quality of language parents use to speak their infants.

Later Developmental Disparities for Preterm Infants

Although there is evidence that some preterm infants show language development delays up into school-age (Barre et al., 2011), it remains unclear why preterm infants end up falling behind their full-term counterparts for so long. Previous research has demonstrated that infants not only
fall behind in expressive language and vocabulary, but they also show lower comprehension, auditory memory, and verbal reasoning at three years of age (Grunau et al., 1990). Children born preterm, when compared to full-term children, have lower scores in verbal comprehension and executive functioning that hold even after accounting for differences in maternal education and cognitive development (Dall’Oglio et al., 2010). This holds true independent of major disabilities and socioeconomic status (van Noort-van der Spek et al, 2012). On the other hand, healthy children born slightly preterm (as in only experiencing a week or two in the NICU) have been demonstrated to have the same probability of having language development delay risk (Pérez-Pereira, 2021), implicating that it could be the length of time in the NICU and the infants’ experience there, such as not experiencing as much language input, that has a major effect on their later language development.

The Importance of Language Environment on Language Development

Parental language input is a key predictor of later language development (Ferjan Ramírez et al., 2020). For example, children who hear more speech have larger vocabularies and are more efficient at processing speech (Fernald et al., 2008; Hurtado et al., 2008). While some previous research focused on the importance of the quantity of linguistic input (e.g., Hart & Risley, 1992; Hoff-Ginsburg & Shatz, 1982), it is clear now that both quantity and quality are important for language development (Fernald & Weisleider, 2015; Golinkoff et al., 2018; Rowe, 2012). Specifically, more recent research with full-term infants demonstrates that the use of both infant-directed speech (IDS), sometimes called “parentese,” and conversational turns are associated with more advanced language outcomes in children (Donnelly & Kidd, 2021; Pretzer
Infant-Directed Speech

Infant-directed speech (IDS) is the term used to describe the speech caregivers and other adults typically adopt when addressing infants and younger children (Ferguson, 1964; Fernald, 1985). Infants tend to prefer listening to IDS as early as two days after birth (Cooper & Aslin, 1990), indicating that something about the speech is salient for them. It is likely that the exaggerated pitch provides information about the speech stream and gives infants a richer language experience for learning about their native language (Cooper & Aslin, 1994).

The idea that IDS might be providing infants with more information about their native language is evidenced in other studies examining IDS in parent-child interactions. The effects of IDS on language development in full-term infants over time have been examined directly, and infants who hear more infant-directed speech one-on-one tend to have a better expressive vocabulary by 18 months ((Ramírez-Esparza et al., 2014; Rosslund et al., 2022). Further, research suggest that IDS helps full-term infants recognize word forms (Singh et al., 2009), learn and retain new wordforms (Ma et al., 2011), provides perceptual cues to their native language with clear articulation (Cristia, 2011), and allows them to better parse the language input (Kemler Nelson et al., 1989). An aspect of IDS that has been demonstrated to assist infants in learning about their native language is when parents are receptive to their infants’ needs and adjust their use of IDS accordingly (Ramírez-Esparza et al., 2017). Furthermore, infants with hearing impairments seem to also prefer hearing IDS over ADS (Robertson et al., 2012), which
could contribute to the evidence that IDS provides infants with more attentional cues and information about their language environment.

**Conversational Turns and Contingent Responding**

Quality of language input includes providing attentionally important information about the infant’s language, such as through IDS, but it also includes interacting with the infant and providing them with the experience of receiving responses, allowing them to carry a “conversation” (Fernald & Weisleider, 2015; Golinkoff et al., 2018; Rowe, 2012; Zimmerman et al., 2009). These conversational turns, where an infant vocalizes and their caregiver responds, are vital to language development (Zimmerman et al., 2009). It is not enough to simply give them quality input, but instead, to provide them with a quality *interaction*, or “conversational turns” (Donnelly & Kidd, 2021; Zimmerman et al., 2009) or “temporal contingent responding” (Pretzer et al., 2019; Tamis-LeMonda et al., 2014). Conversational turns and parental responses provide infants with the information about social interactions—infants tend to follow their parents’ cues, resulting in a bidirectional relationship where infants who respond more, in turn, have more responsive parents and vice versa (Kurchirko et al., 2018).

Much of the research surrounding temporal contingent responding has taken place in the confines of a research lab with full-term infants, usually using prompted interactions, such as through reading books or playing (Kurchirko et al., 2018; Tamis-Lemonda et al., 2013) or in the home with a videographer or cameras present (Bornstein et al., 2015; Bornstein et al., 1999; Donnellan et al., 2019). With the development of the Language ENvironmental Analysis (LENA) recorder, more entirely naturalistic recordings can be collected, and more recent studies have begun to implement this technology into their methodology. With the LENA already
charting conversational turns (CT), some individuals have looked at the automatically reported
counts of conversational turns in relation to vocabulary development, finding a bidirectional
relationship between the two across early development (Donnelly & Kidd, 2021). Others have
delved deeper into the reported numbers, going further to code the speech responses for their
quality and supporting the idea, once again, that this is a mutually dependent relationship
between infant and caregiver and also discovering that infant vocalizations are more likely to
promote their caregiver’s use of IDS (Pretzer et al., 2019). Indeed, it seems that parent-infant
interactions are essential for language development as a whole, and new technologies are making
it easier to explore these interactions more effectively.

The Current Study

As stated above, most previous research looking at contingent language input has taken
place in a more controlled environment rather than a naturalistic, day-long setting (Kurchirko et
al., 2018; Tamis-Lemonda et al., 2013; Bornstein et al., 2015; Bornstein et al., 1999; Donnellan
et al., 2019). While informative, this might not provide an ecologically valid example of how
parents generally respond to their children over a normal day. Some studies have begun to use
the LENA to identify more about infants’ language environment and how their parents respond
to their vocalizations (Pretzer et al., 2019) as well as the amount and quality of language input
(Lany & Shoaib, 2020; Ramirez-Esparza et al., 2014); however, much less is known about the
language environment of preterm infants and how it compares to that of their full-term
counterparts.

The current study explores how parents respond to their infants and the quantity and
quality of their language environment. To take this further, these aspects will be compared
between three groups: a set of 8- to 9-month-old preterm infants, which puts them at a corrected age of 6 months; a set of 8- to 9-month-old full-term infants (chronological age-matched); and a set of 6-month-old full-term (gestational age-matched). This is an ideal age at which to study qualitative interactions between infants and their caregivers as it typically represented the onset of marginal babbling, where infants begin to vocalize more and produce vowel sounds (Masapollo et al., 2016). By comparing these three groups, we will be able to answer the question of whether there is a difference in how parents are responding contingently to their infants, whether there is a difference in the quantity and quality these infants are receiving, and whether preterm infants are demonstrating language development more like their full-term counterparts at their corrected age (6 months) or their actual age (8-9 months). If we can identify that there is a difference between preterm and full-term infants’ language environments, it will allow for pinpointing areas for intervention in order to help preterm infants’ language development over time.
Chapter Two

Methods

Participants

There were three groups of participants: infants born prematurely with an average corrected age of 6 months but an actual average age of 8-9 months; infants born full-term at 8-9 months; and infants born full-term at 6 months. All infants were from English-speaking, monolingual families. Preterm infants’ language input was collected as a part of a longitudinal study following the language development of preterm infants in conjunction with the University of Tennessee’s College of Nursing. Full-term infants were recruited using the Child Research and Development Group’s database maintained by the Psychology Department at the University of Tennessee. The full-term infants were identified as having no other health disparities, including but not limited to hearing impairment, more than three prior ear infections, or other disabilities. The preterm infants were considered low birthweight (≤1800 grams at birth) and were born between 25-32 weeks gestation, but to our knowledge, had no other existing health disparities. See Table 1 for a comparison of ages at time of recording collection for the participants.

Language Input Collection

Preterm infants’ language input was collected as part of the longitudinal study in partnership with the College of Nursing at six months corrected age. Full-term 8-month-olds’ language input was collected as part of a two-part study examining auditory working memory in relation to statistical learning. Full-term 6-month-olds were recruited after participation in the Developmental Cognitive Neuroscience Lab’s masking study. The Language ENvironment
Analysis (LENA) was either sent home with participants or mailed to participants’ homes with detailed instructions on how to use the LENA as well as with two vests for the parents to put the LENA device in while recording. All participants were instructed to collect a total of 16 hours of language input or 8 hours per day for two consecutive days. They were asked not to pause the recorder for naps or any other activities so that we were able to have a full snapshot of the participant’s day. Participants also received a daily journal to fill out and return with the LENA once their recording was completed to give context to who we might hear at certain times or what they might have been doing during the recording (i.e., when was meal time, when was nap time, etc).

**Measures from LENA**

*Quantity measures*

The Language ENvironment Analysis (LENA) system automatically analyzes certain aspects of the language environment at intervals of either 5-minutes, hourly, or daily. These measures include adult word count (AWC), child vocalizations (CV), and conversational turns (CT). After the device’s recording is uploaded, all of this information is available for researchers’ use. We used the AWC to gauge the *quantity* of words infants hear overall, CV to understand how much children are making sounds, and CT to understand how often parents are responding to their children and how often children are responding to their parents. Using CV and CT, we generated a proportion to demonstrate how parents respond to their children’s vocalization. This will be a quick way to understand the percentage of time that parents respond to their children quantitatively.
The generated percentage of responding provided the opportunity to compare percentages between groups to determine if parents across groups respond to their children differently. AWC numbers will allow us to examine whether there is a difference in the quantity of language infants hear. CV numbers will allow us to see if children vocalize differently, allowing us to see if preterm infants at eight months are vocalizing similarly to their actual full-term age or corrected age counterparts—or if they are in their own group entirely.

**Quality measures**

**Infant-directed speech (IDS) audio preparation and coding.** Using a method adapted from Ramirez-Esparza et al. (2014) and Lany and Shoaib (2020), we identified the quality of the language infants heard by coding the amount of IDS infants heard. Using the LENA Advanced Data EXtractor (ADEX), 80 5-minute segments (40 per day) were identified with word counts of at least 110. The ADEX allowed us to identify *male and female adult utterances* and use these segments for further coding for the purposes of this portion of the study. (See Figure 1 for what ADEX’s interface looks like.) Intervals that were not of interest (i.e., TV/electronic noise or silence) were ignored. Each segment was listened to using Audacity (Figure 2), and the first 30-second clip that contained speech to the infant was selected for further coding. If there were not 80 clips with at least 110 words, a different 30-second interval was selected from the 5-minute segments with the highest AWC. We chose 110 words because this is the criteria that Lany and Shoaib (2020) identified. For cases with only a few 5-minute segments with more than 110 words, the segments with the highest word counts over the recordings were pulled. Coders listened to all 80 five-minute segments to identify the first occurrence of speech to the infant. For example, if the coder heard speech directed to the infant in the first 30 seconds, then the start
time of 0:00 to 0:30 would serve as the 30-second interval for coding. If no speech was directed to the child in the five-minute segment, coders were asked to select a different 30-second interval that did not overlap with a previous interval. Coders assigned to select the 30-second interval were not involved in the coding of speech input.

The Infant Social Environment Coding of Sound Inventory (Ramirez-Esparza et al., 2014; See Appendix A) was used to assess the language input. The Infant SECSI includes 73 categories for coding; however, we only coded using four subcategories from the inventory: *speech partners, speech style, social context, and infant-speech utterances.* The *speech partners* category involves whether the mother, father, or a different adult was speaking to the infant. The *speech style* category denotes whether the speech to the infant was in an infant-directed or adult-directed register. The *social context* category indicates whether the infant is with one adult or two or more adults. The *infant-speech utterances* subcategory describes the types of utterances the child makes (i.e., babbling, nonsense words, or utterances that qualify as speech and in word-like strings). Coders were given additional training on the distinction between ID and AD register and heard samples of both ID and AD styles of speech as well as examples of infant utterances. Coders were provided with information relevant to coding, including, but not limited to, the daily journal that families are asked to fill out upon returning the LENA. This daily journal includes relevant people that might be heard during the recording and activities done during the time of recording. Using a media player (iTunes, QuickTime, or Windows Media Player), coders played each 30-second interval. For each interval, coders determined whether each of the four categories occurred by entering “YES” or “NO.” Multiple categories could be coded within an interval. For example, coders could indicate “YES” for “Father speaks to
infant” and also code “YES” for “Father using IDS” and “Infant with two or more adults.” Thus, the Infant SECSI categories are not mutually exclusive or exhaustive. Specifically for the purposes of this study, the focus was on the categories of speech partners, speech style, and social context. Infant utterances were coded for future data analyses; however, they were not involved in the analysis for this study. See Table 2 for more detail about milestones of infant utterances. A quarter of the segments were re-coded by another coder to ensure reliability.

Once the quality of the language input is coded, we determined the proportion of IDS infants heard and created a proportion for each infant. Segments of IDS were divided by the entirety of segments with speech to the infant. This was how the quality of the infants’ overall language input will be gauged.

**Contingent responding proportion and quality.** The LENA automatically charts the child vocalizations (CV) as well as the conversational turns (CT). Taking both of these measures into account, a proportion was created to determine the percentage of time that parents are responding to their infants whenever they make vocalizations. To take this further, we also used the LENA ADEX to identify the top three five-minute segments containing at least 110 adult words with the most child vocalizations for further coding. Like the coding scheme used for the IDS proportion described above, coders were asked to detail the speech style (ID or AD register) the parent uses when responding to their infant. This will help us discern the quality of response infants are receiving from their caregivers. Another aspect of quality was the response time, or time that it takes for the parent to respond to the child. We identified the interaction between parent and child and identified the length of time it takes for the parent to respond if they respond.
at all. EUDICO Linguistic Annotator (ELAN) was used for the annotations of audio. See *Figure 3* for user interface.
Chapter Three

Results

LENA Quantitative Measures

Due to the small sample size within the group subsets, this study was predominately descriptive of the infants’ language environments. Looking at the LENA’s automated values of adult word count (AWC), child vocalizations (CV), and conversational turns (CT) provided information about both of the infants’ entire 8-hour recordings. Values per participant were averaged across the two days of recording. Full-term 6-month-olds (n=6) heard the most adult words on average in a day at 11,304 (SD = 7984), with preterm infants (n=6) being close behind at 11,114 (SD = 5485), and full-term 8-month-olds (n=6) heard the least amount at 9,702 (SD = 5208), see Figure 4. Preterm infants produced the least amount of vocalizations, with an average of 352 per day (SD = 236), see Figure 5. On average, full-term 8-month-olds vocalized 939 times per day (SD = 252), and full-term 6-month-olds vocalized 826 times per day (SD = 181). Conversational turns revealed a similar pattern – on average caregiver-preterm dyads engaged in 114 conversational turns per day (SD = 78), with 8- and 6-month full-term infant-parent dyads engaging in 223 conversational turns per day (SD = 109), 210 conversational turns per day (SD = 70), respectively—see Figure 6. This data suggests that 6-month-olds’ vocalizations lead to a conversational turn 25% of the time, 8-month-olds’ vocalizations lead to a conversational turn 23.7% of the time, and preterm infants’ vocalizations lead to a conversational turn 32.4% of the time. See Table 3 for a comparison.
Conversational Contingency Measures

The conversational contingency measures were manually coded across three 5-minute segments from each participant. In these segments, the pauses preterm infants (n = 4) experienced during interactions were generally shorter (M = 0.75s SD = 1.13s) than both sets of full-term infants (8-month-olds [n = 4]: M = 1.01s SD = 2.53s; 6-month-olds [n = 4]: M = 1.11s SD = 1.60s). There were more direct interactions, or direct responses between preterm infants and their parents (M = 46 interactions in 5-minutes SD = 38.8) than either set of full-term infant groups (8-month-olds: M = 38 interactions in 5-minutes SD = 15; 6-month-olds: M = 39 interactions in 5-minutes SD = 13.45). This reported number was not considered directionally and is considered to be bidirectional. In addition, preterm infants’ parents seemed to speak to them similarly in frequency (M = 89 parent vocalizations in 5-minutes SD = 23.1) to full-term 8-month-old infants’ parents (90 parent vocalizations in 5-minutes SD = 39.2), which is understandable given the AWC measures in the previous section being close in number.

Preterm infants seemed to vocalize less frequently (M = 75.75 vocalizations, SD = 34.74) than their full-term counterparts (6-month-olds: M = 137 vocalizations, SD = 42.64; 8-month-olds: M = 115.75 vocalizations, SD = 37.43). Preterm infants only produced protophones (76 protophones). Full-term 6-month-olds produced more protophones on average than preterm infants (128 protophones); however, they also produced marginal babbling (7 marginal babbles) and began demonstrating some canonical babbling (3 canonical babbles). Full-term 8-month-olds produced less protophones than 6-month-olds (83) and began demonstrating more marginal babbling (20 marginal babbles) and canonical babbling (13 canonical babbles). See Table 4 for comparisons.
**IDS Proportions**

Proportion of IDS heard was generated by adding up the segments that infants heard IDS divided by the total number of segments of speech to the infant (80). Looking at the proportions of IDS infants heard, preterm infants seemed to hear more IDS on average (n = 3, M = 71 segments, SD = 10) than either group of full-term infants (8-month-olds [n = 3]: M = 48 segments, SD = 31; 6-month-olds [n = 3]: M = 63 segments, SD = 17). When the segments with IDS are divided by total segments, this means that preterm infants heard IDS in 88.75% of the segments, 8-month-olds heard IDS in 60% of the segments, and 6-month-olds heard IDS in 78.75% of the segments. See Table 5 for a comparison and Figure 7 for visualization.
Chapter Four

Discussion

The current study aimed to add information about preterm infants’ language environments by comparing them with full-term age matches in both corrected and actual age to better understand where differences in these infants’ environments might be occurring. To achieve this, we examined infants’ quantitative values of adult word counts, their vocalizations, and experienced conversational turns. We then further examined three instances of interactions with their caregivers, and created an overview of how much IDS they heard. All language samples were naturally observed using the LENA device.

LENA Data

Quantitatively, the groups each experienced a similar amount of adult words in a day; however, there was quite a bit of variability within groups, so much so that none of the standard deviations were less than 5000 words. When it comes to child vocalizations, preterm infants were incredibly behind their full-term peers. There was quite a bit of variability within this subsection of data as well, which was a common theme amongst all of the measures. The variability points to there being serious individual differences within groups. Understandably, likely due to fewer vocalizations, there were fewer conversational turns as well compared to their full-term counterparts.

While the LENA system is a powerful tool to help gauge an infant’s naturalistic language environment, it is important to note that there are inconsistencies with how the LENA device charts the adult words infants are hearing, the infant vocalizations, and the conversational turn counts. For example, while LENA is supposed to be able to identify when language is coming a
TV or other electronic device in the background, we found that often the LENA would chart background noise like the TV or radio as adult words, which would skew the amount of words infants are actually hearing if this is a consistent problem. If these intervals were identified as having the most adult words, different intervals were chosen after listening and confirming they were from a caregiver.

Furthermore, in coding the interactions between parent and infant, the conversational turns did not match up with the generated value from LENA. Previous research with preterm infants using LENA has suggested that using the LENA with younger children might not provide as accurate of a picture of language environment due to there not being a normative data set to reference (Caskey et al., 2011). It is possible that there is not a clear way for the system to differentiate between utterances and simply noises that infants make, generating an inaccurate number of conversational turn counts and child vocalizations.

**Conversational Contingency**

Looking at the quality of interaction between infants and their parents allowed us to see how parents are responding to their children and vice versa. In previous literature that suggests parents might have a harder time connecting with their preterm infants, it led us to expect that preterm infants might not have been as responsive to their parents or that their parents might not have been as responsive to them. We found that this was not the case, as preterm infants experienced the shortest latency between when the child vocalized and the most parental responses; however, the quantitative measures given by the LENA put preterm infants behind on both child vocalizations and conversational turns.
Additionally, it seemed that 6-month-olds were the most vocal of the three groups; however, it is worth noting that infants at this age were generally producing more protophones (i.e., vocants, squeals, grunts) than canonical or marginal babbling. While infants are vocalizing more, this does not necessarily mean that they are producing “meaningful” speech so much as they are practicing and playing with their vocal tract and preparing for babbling and later developed speech (Jang & Ha, 2019). We also saw an increase in marginal and canonical babbling at 8-months, which is what has been demonstrated previously in the literature (e.g. Jang & Ha, 2019; Oller, 1995).

**Infant-Directed Speech Proportions**

Within the full-term population, we see the use of IDS decrease, which is to be expected according to existing literature suggesting that IDS use decreases as infants get older (Ramírez-Esparza et al., 2017). This could be because parents deem it not as pertinent to their child’s needs or because as their child begins vocalizing more, the use of IDS begins to decrease and gravitate more toward using more ADS. While we cannot be certain of the exact reasoning, our proportion of IDS found in these infants’ language environments seems to be consistent with the extant literature (Ramírez-Esparza et al., 2014).

On the other hand, because preterm infants are at risk for language development delays, we expected that preterm infants likely were not receiving the same amount of quality experience with their native language as their full-term counterparts, which could have included hearing less IDS. We were surprised to find that preterm infants actually experienced the most IDS of the three groups with the smallest variability as well. It seemed that parents of preterm infants are consistently using more IDS, which is the opposite of what we expected. There are a few
possibilities for why this might be—parents could feel as though their infants need more IDS. Looking at overall child vocalizations from the LENA and taking the IDS proportions into account, it could be that because infants are not vocalizing as much, parents are trying to elicit more vocalizations from their infants by using more IDS. Parents could also feel differently about their preterm infants in that they feel as though they need more support and more information about their native language, even subconsciously.

Limitations and Future Directions

This study served as a pilot study for a greater grant that better encompasses preterm infants’ language environment and development, and it provided many opportunities to identify points of concern. The entire sample was not finished being coded before deadlines for this project due to the qualitative coding being incredibly time intensive, but the Infant Language and Perceptual Learning lab will continue to work with this sample to provide a more complete image of infants’ language environments. As stated in the LENA portion of the discussion, there are inconsistencies with what the system charts and what is manually found when looking at actual audio segments. Reliability and validity should be checked before going forward with younger populations’ vocalizations in order to assure accurate information is being pulled from the LENA device itself. Furthermore, the LENA charted background TV/radio noise as adult word counts, which could lead to inflated overall counts.

These participants were pulled from groups ranging from 16-20 participants total. To keep the participants in each group even, the participants were age- and sex-matched, but the total amount used for this study only ended up being 12 for conversational contingency and infant-directed speech coding. The entirety of the 18 selected for this study were pulled in the
LENA quantitative values. The results could potentially change entirely whenever the entirety of the groups are coded and analyzed; however, this is the next step for this study to provide a full image of what these preterm infants are experiencing and how they are interacting with their speech partners.

While we see these differences in interaction between groups of infants, such as preterm infants vocalizing less, it remains unclear as to why these disparities are occurring. As mentioned before, previous research implicates the length of time in the NICU as a potential reason for developmental differences due to healthy preterm infants not having the same risks associated with their language development as low-birth weight preterm infants (Pérez-Pereira, 2021). It is possible that the time that preterm infants spend completing their gestation in the NICU, which is sometimes up to three months, provides crucial input to developing their auditory systems and learning about their language environment. To determine if this is possible, a study might be designed to have pregnant women wear a LENA to determine how much language input infants are hearing and experiencing in-utero. This could be compared to the infants at the same gestational age in the NICU and provide a clearer image of just how much language experience these infants in the NICU are missing out on.
References


Donnellan, E., Bannard, C., McGillion, M.L., Slocombe, K.E., & Matthews, D. (2019). Infants’ intentionally communicative vocalizations elicit responses from caregivers and are the


with later language. *Applied Psycholinguistics, 24*(2), 221-234.

https://doi.org/10.1017/S0142716403000110


https://doi.org/10.1177/0956797617742725


https://doi.org/10.1111/j.1467-8624.2012.01805.x


Appendices

Appendix A: Coding Scale

INFANT SOCIAL ENVIRONMENT CODING OF SOUND INVENTORY ITEMS

Speech Partner Clusters
1. Mom speaks to infant
2. Dad speaks to infant
3. Other adult speaks to infant

Speech Style Clusters
4. Mom using IDS
5. Dad using IDS
6. Other adult using IDS
7. Mom using ADS
8. Dad using ADS
9. Other adult using ADS

Social Context Clusters
10. Infant with one adult
11. Infant with two adults

Infant Speech Utterances
12. Infant Utterances
   Canonical babbling (e.g., “baba”)
   Marginal babbling (e.g., “baaa,” “maaaa”)
   Other protophone vocalizations (e.g., squeals, growling, vocants [vowel-like sounds])
Appendix B: Tables

Table 1. Participant Ages and Matched Groups

<table>
<thead>
<tr>
<th>Participant</th>
<th>Group</th>
<th>Corrected Age (months)</th>
<th>Actual Age (months)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CC_M_S17</td>
<td>FT6</td>
<td>5.83</td>
<td></td>
</tr>
<tr>
<td>CC_M_S3</td>
<td>PT</td>
<td>6.07</td>
<td>8.8</td>
</tr>
<tr>
<td>CC_M_S5</td>
<td>FT8</td>
<td></td>
<td>8.9</td>
</tr>
<tr>
<td>CC_M_S13</td>
<td>FT6</td>
<td></td>
<td>6.2</td>
</tr>
<tr>
<td>CC_M_S11</td>
<td>PT</td>
<td>6.03</td>
<td>8.03</td>
</tr>
<tr>
<td>CC_M_S1</td>
<td>FT8</td>
<td></td>
<td>8.07</td>
</tr>
<tr>
<td>CC_M_S15</td>
<td>FT6</td>
<td></td>
<td>6.5</td>
</tr>
<tr>
<td>CC_M_S7</td>
<td>FT6</td>
<td></td>
<td>6.5</td>
</tr>
<tr>
<td>CC_M_S9</td>
<td>FT8</td>
<td></td>
<td>8.4</td>
</tr>
<tr>
<td>CC_F_S4</td>
<td>FT6</td>
<td></td>
<td>5.9</td>
</tr>
<tr>
<td>CC_F_S10</td>
<td>PT</td>
<td>5.9</td>
<td>8.1</td>
</tr>
<tr>
<td>CC_F_S18</td>
<td>FT8</td>
<td></td>
<td>8.1</td>
</tr>
<tr>
<td>CC_F_S6</td>
<td>FT6</td>
<td></td>
<td>6.13</td>
</tr>
<tr>
<td>CC_F_S2</td>
<td>PT</td>
<td>6.27</td>
<td>9.17</td>
</tr>
<tr>
<td>CC_F_S12</td>
<td>FT8</td>
<td></td>
<td>8.83</td>
</tr>
<tr>
<td>CC_F_S8</td>
<td>FT6</td>
<td></td>
<td>6.4</td>
</tr>
<tr>
<td>CC_F_S14</td>
<td>PT</td>
<td>6.4</td>
<td>9.4</td>
</tr>
<tr>
<td>CC_F_S16</td>
<td>FT8</td>
<td></td>
<td>9.03</td>
</tr>
</tbody>
</table>

This table demonstrates the age- and sex-matched participant groups.
Table 2. *Milestones for Types of Infant Utterances*

<table>
<thead>
<tr>
<th>Milestones for Types of Infant Utterances</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>4-6 months</strong></td>
</tr>
<tr>
<td>Protophones</td>
</tr>
<tr>
<td>• Cooing/vocants (“ooo,” “aaa”)</td>
</tr>
<tr>
<td>• Laughing</td>
</tr>
<tr>
<td>• Screeching</td>
</tr>
<tr>
<td>Marginal babbling</td>
</tr>
<tr>
<td>• Single syllables (“ba,” “ga”)</td>
</tr>
<tr>
<td><strong>6-8 months</strong></td>
</tr>
<tr>
<td>Canonical babbling</td>
</tr>
</tbody>
</table>
| • Babbles with duplicated/repeated syllables (“Bababa, “dadada”)

*This table demonstrates the ages around when types of babbling begin.*
Table 3. *LENA Data*

<table>
<thead>
<tr>
<th></th>
<th>Preterm Infants (n = 6)</th>
<th>FT 6-month-olds (n = 6)</th>
<th>FT 8-month-olds (n = 6)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
<td>M</td>
</tr>
<tr>
<td>Adult Word Count</td>
<td>11114</td>
<td>5485</td>
<td>11304</td>
</tr>
<tr>
<td>Child Vocalizations</td>
<td>352</td>
<td>236</td>
<td>826</td>
</tr>
<tr>
<td>Conversational Turns</td>
<td>114</td>
<td>78</td>
<td>210</td>
</tr>
</tbody>
</table>

*The quantitative averages of AWC, CV, and CT.*
Table 4. Conversational Contingency Data

<table>
<thead>
<tr>
<th></th>
<th>Preterm Infants (n = 4)</th>
<th>FT 6-month-olds (n = 4)</th>
<th>FT 8-month-olds (n = 4)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
<td>M</td>
</tr>
<tr>
<td>Pause Length (s)</td>
<td>0.75</td>
<td>1.13</td>
<td>1.11</td>
</tr>
<tr>
<td>Interactions in 5-mins</td>
<td>46</td>
<td>38.8</td>
<td>39</td>
</tr>
<tr>
<td>Vocalizations in 5-mins</td>
<td>75.75</td>
<td>34.74</td>
<td>137</td>
</tr>
</tbody>
</table>

The averages of pause length, interactions within 5-minute periods, and vocalizations in 5-minutes.
Table 5. Infant-Directed Speech Proportions

<table>
<thead>
<tr>
<th></th>
<th>Preterm Infants (n = 3)</th>
<th>FT 6-month-olds (n = 3)</th>
<th>FT 8-month-olds (n = 3)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
<td>M</td>
</tr>
<tr>
<td>Number of segments with IDS</td>
<td>71</td>
<td>10</td>
<td>63</td>
</tr>
<tr>
<td>Percentage of segments with IDS</td>
<td>88.75</td>
<td></td>
<td>78.75</td>
</tr>
</tbody>
</table>

The number of segments with IDS and the percentage of IDS infants heard.
Appendix C: Figures

Figure 1. LENA ADEX User Interface

An image from LENA’s ADEX to demonstrate what the program looks like.
Figure 2. Audacity User Interface
An image from Audacity’s user interface to demonstrate what the program looks like.
Figure 3. ELAN User Interface
An image from a participant’s conversational contingency coding to demonstrate how the user interface works.
Figure 4. AWC by Group

This bar graph represents the averages of the three groups with individual data points for the participants’ adult word count with the error bars representing the standard deviation.
Figure 5. CT by Group

This bar graph represents the averages of the three groups with individual data points for the participants’ conversational turns with the error bars representing the standard deviation.
Figure 6. CV by Group

This bar graph represents the averages of the three groups with individual data points for the participants’ child vocalizations with the error bars representing the standard deviation.
Figure 7. IDS Segments by Group

This bar graph represents the averages of the three groups with individual data points for the participants’ total IDS segment with the error bars representing the standard deviation.
Rebecca Robb Crum was born in Riverside, CA, to Robert and Patricia Robb. She grew up in Troy, TN and graduated from Obion County Central High school in Troy, TN in 2015. She attended the University of Tennessee at Martin where she graduated with a Bachelor of Arts degree in Psychology, summa cum laude, with minors in both German and French in 2019 under the mentorship of Dr. Joseph Ostenson. Following graduation, she accepted a graduate teaching assistantship and doctoral student position at the University of Tennessee, Knoxville, in the Experimental Psychology program to work with Dr. Jessica Hay. Rebecca is currently at the end of her fourth year as a graduate student and graduate teaching assistant. She has elected to take a terminal Master’s degree in Experimental Psychology from the University of Tennessee, Knoxville, with intentions to graduate in August 2023 to enjoy time with her partner, Travis Crum, and her son, Charles.