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Language-Deprived Environments: Neonatal Intensive Care Units and Hearing Loss

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Language-Deprived Environments: Neonatal Intensive Care Units and Hearing Loss

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Abstract

Adequate language exposure is crucial for speech-language development in children. Previous research suggests that decreased language exposure leads to an increased risk for speech-language developmental delays. This study aims to explore the language exposure of two arguably language-deprived environments: Neonatal Intensive Care Units (NICU) and severe-to-profound hearing loss. This is a two-part study that examines caregiver-infant interactions through the analysis of infant-directed speech (IDS). In the first part of the study, researchers transcribed and analyzed pre-recorded Language Environment Analysis (LENA) audio recordings of five (5) infants with severe-to-profound hearing loss (6-months post cochlear implantation). These LENA recordings collected speech, language, and sounds from the infant's surroundings for 24 hours. In the second part of the study, researchers collected, transcribed, and analyzed ten (10) recordings from a level III single-room NICU. These audio recordings consisted of three parts: (1) natural language sample, (2) caregiver book reading with words, and (3) caregiver book reading without words. In the analysis of both part one and part two audio recordings, linguistic (number and type of words, etc.) characteristics of IDS were measured and compared across participant groups. Results of this study show the effects of the NICU environment and severe-to-profound hearing loss on IDS and language exposure.

Introduction

Across fields of study, researchers have emphasized the importance of language exposure for successful language development of children. From the time in utero to years after birth, children actively learn components of language that eventually lead to a complete and complex communication system. In an analysis of the natural language environment of children, Lew (2011) suggested that children with advanced language skills hear nearly 22 million words in the first three years of their life with an average of 20,000 a day. Chonchaiva, Tardif, Mai, et al (2013) emphasized that normal language acquisition not only involves the development and coordination of sensory, motor, and cognitive pathways, but also the provision of an enriched language environment with responsive caregivers. Imagine a child who has spent time in the NICU and/or has a severe-to-profound hearing loss. How might their language environment be different and how might it affect their speech-language development?

The NICU environment is one that is different from a child's typical developmental environment. It is important to consider how much and what types of sounds NICU infants are exposed to and how they respond to these sounds. A neonatal brain develops and responds differently outside of the womb than it would have inside (Maitre et al., 2013; McGrath, 2013; Szymczak and Shellhaas, 2014). It is in the uterus where fetuses are exposed to low-frequency sounds that are believed to drive brain and auditory development (Liszka, Smith, Mathus, et al., 2019). A study by Rand and Lahav (2014) considered the types of NICU environment in which infants stay: single, open-bay, incubators, and open-air. They found that NICU infants were either in an

environment too isolated and where they missed crucial speech sounds (e.g., single), or an environment that was too noisy (e.g., open-bay) and where meaningful speech was drowned out by background noise (i.e., 2/3 sounds composed of background noise). Research suggests that the NICU presents a harmful environment – extended silence, few and brief interactions, constant electronic noises, and/or loud machinery – that may negatively influence long-term development (Chen et al., 2009; Liszka et al., 2019; McGrath, 2013; Szymczak and Shellhaas, 2014; Thomas and Uran, 2007). If a NICU environment is classified as "too quiet" or "too loud," how can professionals alter the setting to maximize the development of auditory, speech, and language abilities?

A study completed by Caskey, Stephans, Tucker, and Vohn (2011) takes a deeper look at the NICU environment, focusing on the types of sounds infants may be exposed to. It was found that NICU infants are cared for in an environment with very little adult language: an average of about 2-5% language, 26-38% monitor noise, and 27-39% silence in days-worth of recordings. However, when an adult (parent) is present and language content was added to the auditory environment, infant vocalizations increased by about 173% and conversational turns increased by about 524% at 32 weeks (Caskey et al., 2011). In a study that compared the NICU to a delivery/labor ward, it was found that the NICU on average consists of ~10% of language (14,110 less words), ~60% of silence, and ~30%of electronic noise (Liszka et al., 2019). The study additionally measured the sound level in the NICU and found the average sound level to be 56.4 dB, which is 11 dB above what the American Academy of Pediatrics recommends (45 dB) (Liszka et al., 2019). A similar study found a sound level average of 57 dB (Szymczak and Shallhaas, 2014). Another study which examined the sound level of the NICU found that when the

NICU was “quiet” the sound level was 47 dB, and when conversations were taking place the sound level was 49 dB (Thomas, and Uran, 2007). Additionally, this study investigated the sound levels of various events in the NICU, and it was found that the ones involving machinery were the loudest (closing incubators 73 dB, dropping mattress heads 87 dB) (Thomas, and Uran, 2007).

In NICU language development the role of the caregiver is particularly important. In a study conducted by Reissland and Stephenson (1999) it was shown that preterm infants recently discharged from the NICU, compared to term infants, were less likely to respond vocally to their mother’s spoken utterances. This could be due to less maternal speech exposure experienced in the NICU. Furthermore, in a study concerning altered pathways for auditory discrimination in preterm infants, Therien, Worwa, Mattia, and deRegnier (2004) found no evidence of maternal voice recognition in preterm infants at term postmenstrual age. Perhaps less exposure to maternal speech in the NICU leads to these altered auditory pathways and lack of voice discrimination/recognition in NICU infants. However, in a more recent study by Kuhn, Dufor, and Zores (2017), contrasting patterns were found suggesting that vocal sounds seem to elicit different patterns of responses in preterm babies, and how preterm babies seem to be particularly sensitive to the biologically meaningful and attractive sounds of their mothers’ voices. Additionally, Fillipa, Devouche, Arioni, et al. (2013) discuss how maternal language decreases critical events, increases oxygen saturation, and increases the amount of time in a quiet and alert state (“positive state”). Furthermore, the study suggests that maternal language improves mother-infant bonding and induces the vocalization in preterm infants.

A study conducted by Foster-Cohen, Edgin, Champion, and Woodward (2007)

examined a pattern of delayed language development in two-year-old children who were born prematurely. The group found that decreasing gestational age is associated with poorer parent-reported language skills. Specifically, vocabulary size, quality of word use, morphological complexity, and syntactic complexity were poor. In a study conducted by Caskey, Stephans, Tucer, and Vohr (2014) it was found that 7- to 18-month-old preterm infants produced expressive/receptive communication scores that were either delayed or below-average. However, as they noted in their 2011 study, an increase in parent talk with premature infants in the NICU is associated with higher 7-18 month cognitive and language scores (Caskey et al., 2011). Additionally, a study predicting the outcome of specific language impairment (SLI) in developmental assessments of premature infants found a high incidence of SLI predictors in their sample (one-in-five, N=24). However, it was noted that continued developmental assessment beyond pre-school age would lead to more accurate SLI identification.

A second factor to consider in the NICU is auditory development. Following a premature birth, the sequence of auditory exposure is interrupted, increasing the risk for deficits in auditory development (Szymczak and Shellhaas, 2014). Multiple research outlines a timeline in which a fetus becomes responsive to sound and auditory development occurs in the 2nd and 3rd pregnancy trimesters: at 24-25 weeks gestation the fetus can already perceive and respond to sound, at 26 weeks hair cells in the cochlea allow for the fine tuning of frequencies, at 30-31 weeks the auditory cortex is developed, at 32-36 weeks a can distinguish sounds and voice (specifically the voice of their mother), and when a fetus is closes to full term they begin to perceive pitch and temporal features of speech (Filippa et al, 2013; Liszka et al., 2019; Rand and Lahav, 2014;

Szymczak and Shallhaas, 2014). These researchers also emphasized that early acoustic stimulation is known to significantly impact the functional development of the auditory brain system. Furthermore, studies using rat pups have shown that auditory deprivation leads to decreased expression levels of selective receptors in the rat auditory cortex during early postnatal development (Rand, 2014). In other words, sensory deafness conditions lead to the abnormal development of the primary auditory cortex. Some may suggest that NICU environments mimic some aspects of sensory deafness conditions, as there are few meaningful auditory signals that may facilitate speech-language development. Another study considering the NICU environment and hearing development suggests that ambient noise in the NICU may cause language and auditory processing disorders in preterm neonates (Chen et al., 2009). For instance, decreased ability to localize and differentiate a sound source may stem from excessive background noise and/or the use of incubators (Thomas and Uran, 2007). Another study investigated cortical language/sound differentiation with event-related potential (ERP) measurements in infants in the NICU at 12 and 24 months (Maitre et al., 2013). Results showed that infants in the NICU had only a moderate effect size in the differentiation of sound pairs /du/ and /gu/, /ba/ and /ga/, and /da/ and /ga/. These effect sizes suggest only some ability to differentiate sound (Maitre et al., 2013). One could suggest that the NICU environment, due to ambient noise, may be one factor of these results.

Hearing loss, overall, is another factor that may compromise the effects of a language environment. When a child suffers from hearing loss, there is an anatomical boundary that keeps that child from receiving rich speech and language. In a study completed by Wiggin (2015), it was emphasized that this inadequate auditory reception

may lead to speech and language delays in children with hearing loss. Similarly, researchers Ledeberg, Schick, and Spencer (2013) point out that language development has long been recognized as the most important area affected by hearing loss. In their study, they found language was impacted by hearing loss on multiple levels: impaired articulation, smaller lexicon and average mean length of utterances, simplistic syntax, delayed acquisition of grammatical morphemes such as *-s*, deficit in phonological awareness, and delayed literacy outcomes (average of a 3-year delay) (Lederbery, Schick, and Spencer, 2013). In addition, research suggests that even when a child received hearing aids or cochlear implants to help with auditory reception, they still do not receive signals the same way hearing people do (Lederberg, 2013; Wiggin, 2015). Factors such as speaker-listener distance, reverberation, and background noise make it difficult to receive and perceive the details of spoken language (Wiggin, 2015).

A longitudinal study completed by Ching, Crowe, Martin, et al. (2010) investigated the speech-language outcomes of children with hearing impairment. It was found that children with hearing loss fell at or below 1 standard deviation from the normative mean in expressive and receptive Preschool Language Scale Scores (PLS-4) and were well below the normal range in the Child Development Inventory (CDI) and Parent's Evaluation of Aural Performance of Children (PEACH). All in all, hearing loss was shown to be negatively associated with language, development, and everyday functioning. Similarly, in a different longitudinal study completed by Vohr, Jodoin-Krauzyk, Tucker, et al. (2008), children (12-16 months of age) with moderate-to-profound hearing loss exhibited delayed receptive and expressive language skills compared to children with minimal-mild and no hearing loss. Specifically, children with

moderate-to-profound hearing loss had significantly lower numbers of phrases understood, words understood, and total gestures understood. In another study completed by Briscoe, Bishop, and Norbury (2001) language skills were compared between children with mild to moderate hearing and specific language impairment (SLI). Both of these populations similarly performed poorly on tests of phonological memory, discrimination, and awareness. These three studies display patterns of speech-language delay in children with various degrees of hearing loss, suggesting that hearing loss may have a long-term effect on speech-language development.

As it was emphasized in NICU language development, child-caregiver interactions are important in the speech-language development of children with hearing loss. In an investigation of mothers' speech to infants and children with hearing loss conducted by Bergeson, Miller, and McCune (2006), it was found that mothers are sensitive to the hearing experience, linguistic abilities, and language exposure of their children with hearing loss. With this awareness, infant-directed speech, which infants with hearing loss prefer (Bergeson et al., 2012), is continued and helps to facilitate meaningful caregiver-child interactions. Specifically, as discussed by Robertson, von Hapsburg, and Hay (2013), infant-directed speech plays a fundamental role in early linguistic acquisition, facilitating phonetic category learning (basic sounds) and speech parsing (word and sentence boundaries).

These studies offer numerous outlooks on the speech-language environment of the NICU, the language development of children who have spent time in the NICU, and the language development of infants with hearing impairment. However, little, if any, research has been done that compares the language environment and exposure between

infants with and without hearing loss who have spent time in the NICU. When a child spends time in the NICU, their language exposure is compromised due to the environment in which they live. Similarly, when a child comes into the world with severe-to-profound hearing loss, their language exposure is also drastically compromised, but instead is due to anatomical complications. In the end, with a poor language introduction, infants with hearing loss are at a much greater risk for a speech-language delay. Finding patterns in the speech-language environments of hearing-impaired infants in the NICU can help professionals establish ways to decrease the chance of developmental delay, ensuring that the necessary speech-language exposure is met. The purpose of this study was to examine the NICU environment and how it affects language exposure in infants with and without hearing loss. We hypothesized that there will be greater observable evidence of deprived speech-language exposure in infants who have spent time in the NICU compared to infants with hearing loss. Moreover, we hypothesized that the impoverished auditory environment of the NICU will negatively affect speech-language exposure in infants.

Methodology

This study consisted of the analysis of one-hour-long audio recordings of language environments and caregiver-infant interactions of two participant groups: (1) five infants with severe-to-profound hearing loss (*referred to as HL*) and (2) ten infants with NICU exposure (*referred to as NICU*). Audio recordings were collected and analyzed over an eleven-month period to make up a two-part study.

Part One

Part one of this study consisted of the transcriptions and analyses of audio recordings for participant group one. These audio recordings were supplied by BabyTalk Research at The Ohio State University, a NIH-NIDCD funded research study. The participants in this group were identified as recipients of cochlear implants with severe-to-profound hearing loss. These audio recordings were collected at 6-months post-amplification, meaning the infants had a hearing age of 6-months.

Audio recordings for participant group one were collected via Language Environment Analysis (LENA) devices. These LENA recordings gathered speech, language, and sounds from each infant's surroundings for 16 hours. Researchers in this study narrowed in on play-time sessions throughout the day where there was caregiver-infant interaction (bath time, regular play, and book reading, etc.).

Part Two

Part two of this study consisted of the transcriptions and analyses of audio recordings for participant group two. These participants (30-40 weeks post-menstrual age) were recruited from Riley Hospital for Children at Indiana Health North Hospital's level III NICU with help from Dr. Sandra J. Hoesli and Dr. Mark L. Edwards.

Audio recordings for participant group two were collected by the researchers of this study. These one-hour long recordings consisted of three parts. The first part was a 30-minute natural recording. The second part consisted of reading a book with words: *Frog and Toad Are Friends* (Lobel, 1970). The third part consisted of reading a book without words: *One Frog Too Many* (Mayer & Mayer, 1975).

In addition to audio recordings in participant group two, two sound level measurements were collected. This was done using a sound level meter at level A-weighted slow minimum (unit: dBA). Level-A weighting mimics the human ear, cutting off the lower and higher frequencies that the average person cannot hear. The first measurement was recorded during the natural recording ("quiet") and the second was recorded during the book readings ("reading"). This provided researchers with sound level measurements of the NICU environment in times of "quiet" (no direct/caregiver conversation occurring) and "conversation" (caregiver talking at a relative conversation level).

Linguistic Measurements

The data that was collected from the audio recordings was linguistic measurements. Such measurements included mean length utterance (MLU), number of different words (NDW), number of total words (NTW), type token ration (TTR = NDW/NTW), etc. (please see *Results and Appendix* for all linguistic measurements). These measurements were attained through audio recording transcription and analysis via Semantics and Linguistic Theory (SALT) program.

Comparison Measurements

Comparisons of linguistic measurements were made across participant groups. Such comparisons suggest differences and similarities of language and speech across the two language environments. The purpose was to examine whether NICU exposure and severe-to-profound hearing loss affect caregiver-infant language-based interactions. Specifically, these comparisons help to answer the following research questions:

(1) Will there be less speech-language exposure for infants with NICU exposure than infants with hearing loss?

(2) Will the impoverished auditory environment of the NICU negatively affect speech-language exposure for infants with and without hearing loss?

(3) How does book reading language compare to natural/spontaneous language in caregivers' speech to infants?

Results

The linguistic measurements across participant groups include number of utterances (NOU), mean length utterance in morphemes (MLU), number of different words (NDW), type-token ration (TTR = NDW/NOU), instances of infant directed speech (#IDS), and IDS Ratio (IDS Ratio = #IDS/NOU). These measurements are important to examine how much language, the variety of language, and what type of language (IDS) is present in each infant sound-language environment.

Within participant group one (HL) there was an average of 2 speakers within the child's natural environment. In all language samples the mother was present, and 4/5 of language samples had an additional speaker. The table below (*Table 1.1*) displays summary averages, medians, and ranges of participant group one. Within this data set, MLU, TTR, and IDS Ration showed consistency across the five participants of group one, and thus are a good representation of the HL sample. *Table 1.2* in the *Appendix* displays individual participant data for group one.

Table 1.1
Hearing Loss: Natural Sample Summaries

	#speakers	NOU	MLU (m)	NOW	NDW	TTR	#IDS	IDS Ratio
AVERAGE	*2*	*359.4*	*3.01*	*984.8*	*164.5*	*0.404*	*216.6*	*0.60*
MEDIAN		*262*	*3.06*	*743*	*140*	*0.45*	*210*	*0.58*
RANGE		*445*	*0.83*	*1,326*	*206*	*0.24*	*168*	*0.48*

Within participant group two, *NICU*, there was an average of 2.3 speakers in the child's natural environment. It is important to note that only 9/10 NICU participants were included in the natural language sample; participant NBI7 is not included because the spoken language during this time was Spanish. In all language samples the mother was present and there are multiple speakers. Six of the nine samples had a NICU staff member present. The table below (*Table 2.1*) displays summary averages, medians, and ranges of participant group two. Within this data set, MLU, TTR, and IDS Ratio showed consistency across the 9 participants. *Table 2.2* in the *Appendix* displays individual participant data for group two.

Table 2.1
NICU: Natural Sample Summaries

	#speakers	NOU	MLU (m)	NOW	NDW	TTR	#IDS	IDS Ratio
AVERAGE	*2.3*	*262.67*	*3.99*	*1,007*	*159.78*	*0.46*	*48.33*	*0.36*
MEDIAN		*163*	*4.32*	*628*	*119*	*0.41*	*41*	*0.38*
RANGE		*980*	*4.15*	*4,153*	*454*	*0.7*	*165*	*0.997*

Within participant group two book reading linguistic measurements were also taken. The comparative measurements across the two books include NOU, MLU (morphemes), #IDS, and IDS Ratio. These measurements allow researchers to examine

how much and what type of language is present when reading. The book *Frog and Toad are Friends* includes words and pictures. The table below (*Table 3.1*) displays summary averages, medians, and ranges of participant group two readings. *Table 3.2* and *4.2* in the *Appendix* displays individual participant data for participant group two readings. It is important to note that participant NBI4 is included in the collection of data from the reading *Frog and Toad are Friends*, but not in *One Frog too Many* due to reading incompletion.

Table 3.1
NICU: Book Reading Summaries

BOOK AVERAGES		**NOU**	**MLU (m)**	**#IDS**	**IDS Ratio**
Average	*FT*	71.2	6.927	3	0.03
	OFTM	69. 8	8.37	5	0.07
Median	*FT*	73.5	6.53	1	0.02
	OFTM	59.0	8.26	3	0.08
Range	*FT*	43.0	3.97	7	0.10
	OFTM	115.0	4.86	14	0.08

The book reading of *One Frog too Many* provided additional linguistic measurements due to the requirement of spontaneous language to relay the story told by the pictures. These other measurements are similar to the other linguistic measurements recorded during the natural language samples: NOW, NDW, and TTR. These measurements gave insight to the variety of language in a sample. It is important to note that NBI4 was not included in these measurements due to reading incompletion. The table below (*Table 4.1*) displays summary averages, medians, and ranges of the *One Frog too Many* readings in participant group two. *Table 4.2* in the *Appendix* displays *One Frog too Many* reading data of individual participants in group two.

Table 5.1
NICU: "One Frog too Many" Additional Summaries

	NOW	NDW	TTR
Average	475	154	0.34
Median	448	155	0.35
Range	403	91	0.16

Data collection within the participant group two also included sound pressure level measurements (dB) when "quiet" and "reading." These measurements tracked how loud it was in each child's NICU environment. The average "quiet" dB-level is 47.99 dB with a maximum of 55.3 dB and minimum of 42.1 dB. The average "reading" dB-level is 58.28 with a maximum of 61.1 dB and minimum of 56.2 dB. The table below (*Table 6*) displays each participant dB level when "quiet" and "reading."

Table 6
NICU: Sound Pressure Level Measurements

	Quiet	Reading
NBI1	46.6	58.2
NBI2	53.3	57.9
NBI3	46.8	56.2
NBI4	48.7	58.2
NBI5	55.3	59.2
NBI6	54.2	61.1
NBI7	46.1	57.7
NBI8	44.5	57.8
NBI9	42.1	57.7
NBI10	42.3	58.8
Average	*47.99*	*58.28*

Note: The unit of the numbers above is dB (decibels).

Discussion

The main purpose of this study was to explore the speech-language environments of infants in the NICU and infants with severe-to-profound hearing loss. Additionally, this study juxtaposed two arguably language-deprived environments; environments which often yield delays in speech-language development. The data collected helped to compare linguistic differences between the two environments; something that has not been done by previous researchers.

Like many other researchers, Lew emphasized the importance of the number of words a child is exposed to in the critical years after birth. According to Lew, children with advanced language skills heard an average of 20,000 words day within their first three years of life (Lew, 2011). In this study the number *and* variation of words was examined across participants and participant groups. It was found that in hearing loss environments there was a greater number of words (+296.733) and a slightly a slightly larger number of different (+4.722) than in NICU environments. When examining the average number of words and mean length utterance of both environments, the NICU showed slightly higher averages (NOW+22.2, MLU+7). However, the averages do not accurately portray the environment comparison. This is because the NICU has a number of words range of 4,153 and a mean length utterance range of 4.15. While the hearing environment has a number of words range of 1,326 and a mean length utterance range of 0.83 These data better suggests that the hearing loss environment has a more consistent number of words and mean length utterance.

Another well-studied aspect of language development is infant-directed speech. Bergeson found that infants with hearing loss prefer infant-direct speech, and Caskey

demonstrated that an increase in infant-directed speech is associated with higher cognitive and language scores (Bergeson et al., 2006; Caskey et al., 2011). The current study found that within the hearing loss environment there were more instances of infant-directed speech (+168.267) and a larger infant-directed speech ratio (+0.239) than in the NICU. This may suggest that there is more infant-directed speech in hearing loss environments than in the NICU. One main factor to consider when comparing these data is the number of opportunities for language. At home in a hearing environment, there is more play (toys, siblings, books, etc.), while in the NICU infants are in strict schedules (sleeping, eating, etc.) with little "play" stimulus.

The results of the current study also built upon previous linguistic research in neonatal care and hearing loss. One topic which this study can expand is the sound pressure levels present inside the NICU. Previous studies by Liszka and Szymczak consistently found the sound-pressure level within different NICUs to be above the 45 dB level that the American Academy of Pediatrics recommends (Liszka et al., 2019; Szymczak and Shallhaas, 2014). Similarly, in the current study NICU sound-pressure level averages were above 45 dB. The "quiet room" average was 47.99 dB with a maximum of 55.3 dB, and the "reading" (mimicking conversation levels) average was 58.28 with a maximum of 61.1 dB.

Another topic the current study contributed to is the type of language the NICU contains. Previous studies by Caskey and Liszka have broken down the sound environments in the NICU into language, silence, machinery, etc. Caskey found that NICU environments consisted of 2-5% of language, while Liszka found the NICU environment consisted of about 10% of language (1.5 hours) (Caskey et al., 2011; Liszka

et al., 2019). However, no studies have compared the amount of adult-directed speech and infant-directed speech in NICU language. This study found that the NICU consisted of an average of 262.7 total number of utterances. Of this total, there were an average of 48.3 instances of infant-directed speech. This means the average NICU natural language sample consisted of 35.4% of infant-directed speech.

One aspect that was similar across the language environments of infants with hearing loss was the presence of singing and/or reading (4/5 participants). Both of these oral modes of language provide children with rhythmic, varied, and rich language. For instance, in book reading there is repetition, varied intonation, multiple characters/speakers, and general linguistic creativity. What type of language does book reading may elicit in the NICU, and can book reading provide more benefits than spontaneous language for infants in the NICU?

Researchers provided participant caregivers with two books: one with words (*Frog and Toad are Friends*) and without words (*One Frog too Many*). The purpose of this was to explore differences in scripted and creative (spontaneous) book reading. Similar to natural language samples in the NICU, number of utterances, mean length utterance, infant-directed speech occurrences, and infant-directed speech ratios were calculated. It was found that the reading of *Frog and Toad are Friends* averaged slightly more number of utterances (+1.42), while *One Frog too Many* averaged a greater mean length utterance (+1.44), instances of infant-directed speech (+2.3), and infant-directed speech ratio (+.12).

Researchers were also able use compare book reading measurements to natural language measurements. Some noteworthy observations that were made were: (1) book

reading averaged a greater mean length utterance (+3.65), and (2) natural language averaged only 5.45 more different words than the average number of different words when reading *One Frog too Many*. Additionally, it is noted that the type-token ratio of the average number of words and number of different words for reading *One Frog too Many* was greater than the type-token ratio of averages for the natural language sample (+.166). These differences between type-token ratios and mean length utterances may suggest that reading facilitates greater semantic and morphemic diversity in language.

There are some limitations of this study that one must consider. However, these limitations can be improved in future studies. One limitation is the number of participants. Given the time frame of this project, the total number of participants (N=19) was appropriate. However, a greater number of participants would provide researchers with more thorough data collection, analysis, and comparison. For future studies, expanding the number of participants and NICUs involved in the study could provide a more accurate analysis of what type of language is present in infant environments.

Another limitation of this study is the recording device type. The recording device selected for the second part of this study was suitable, however other devices such as LENA would allow for consistent transcriptions and measurements across all participants. Additionally, the recording device that was used was unable to record a day's worth of material like the LENA device is capable of doing. Due to this limitation, researchers were confined to 20-30 minutes of natural language collection. This 20-30-minute collection may not accurately represent total language exposure within the NICU. In future studies, the use of a LENA device or comparable audio recorder would allow for a greater collection and representation of NICU language.

A final thought for future studies is to use this study as a base for a longitudinal study. Early language exposure is just the beginning of language development. Future studies could analyze the language exposure and abilities of children from the earliest age of exposure to three years of age. Such a study would expose what type of infant-directed speech and language is present in the critical years of language development. Furthermore, the relationship between language exposure and language abilities could be examined.

Overall, this study provides a glimpse into how much language, the variety of language, and what type of language (IDS) is present in NICU and severe-to-profound hearing loss environments. It was found that infants with hearing loss tend to be exposed to more language and infant-directed speech than infants in the NICU. Additionally, linguistic benefits of book reading, specifically "creative" book reading such as in *One Frog too Many*, were observed. Book reading produces more utterances and words, allows for greater use of different words and grammatical structures, and encourages infant-directed speech and caregiver-infant interactions. As previous research has shown, a child's environment is critical to their overall development; facilitate their growth with the power of language.

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Appendix

Table 1.2
Hearing Loss: Natural Samples

	#speakers	speakers	NOU	MLU (m)	NOW	NDW	TTR	#IDS	IDS Ratio
BT0032	3	mother, father, sibling	244	3.06	597	291	0.45	141	0.58
BT0179	1	mother	223	2.55	558	85	0.53	210	0.94
BT0189	2	mother, sibling	668	3.38	1,884	213	0.3	307	0.46
BT0191	2	mother, father	400	3.32	1,142	140	0.29	286	0.72
BT0195	2	mother, grandmother	262	3.02	743	94	0.45	139	0.53

Table 2.2
NICU: Natural Samples

	#speakers	speakers	NOU	MLU (m)	NOW	NDW	TTR	#IDS	IDS Ratio
NBI1	2	Mother, Father	353	5.70	1,558	275	0.36	1	0.003
NBI2	3	Mother, Father, Nurse	990	5.12	4,169	461	0.23	166	0.17
NBI3	2	Mother, Nurse	10	1.55	16	7	0.93	6	0.60
NBI4	1	Mother	74	2.63	144	66	0.46	41	0.55
NBI5	2	Mother, Nurse, Infant	129	3.20	254	76	0.61	13	0.10
NBI6	4	Mother, Grandmother, Sister, Nurse	392	4.57	1,327	236	0.36	2	0.005
NBI8	1	Mother	51	3.44	140	57	0.41	51	1
NBI9	3	Mother, Nurse, Social Worker	163	5.42	825	141	0.41	63	0.39
NBI10	3	Mother, Grandmother, Nurse	202	4.32	628	119	0.38	92	0.46

Note: NBI7 is not included due to spoken language being Spanish.

Table 3.2

NICU: "Frog and Toad are Friends"

	Reader	NOU	MLU (m)	#IDS	IDS Ratio
NBI1	mother	54	8.65	0	0
NBI2	mother	92	5.71	9	0.10
NBI3	mother	78	5.79	0	0
NBI4	mother	77	6.26	4	0.05
NBI5	mother	71	6.42	0	0
NBI6	mother	49	9.45	0	0
NBI7	mother	90	5.48	5	0.06
NBI8	mother	76	6.63	7	0.09
NBI9	mother	59	7.93	1	0.02
NBI10	mother	66	6.95	1	0.02

Table 4.2

NICU: "One Frog too Many"

OFTM	Reader	NOU	MLU (m)	NOW	NDW	TTR	#IDS	IDS Ratio
NBI1	mother	58	8.12	348	146	0.42	0	0
NBI2	father	150	5.75	697	200	0.29	14	0.09333333
NBI3	mother	83	8.26	599	178	0.3	7	0.08433735
NBI5	mother	48	6.67	294	109	0.37	2	0.04166667
NBI6	mother	35	10.26	320	114	0.36	3	0.08571429
NBI7	mother	55	7.76	388	142	0.37	6	0.10909091
NBI8	mother	75	8.99	590	188	0.32	8	0.10666667
NBI9	mother	59	8.88	448	155	0.35	3	0.05084746
NBI10	mother	65	10.61	594	157	0.26	2	0.03076923

Note: NBI4 is not included due to incompletion of reading task.

Table 7

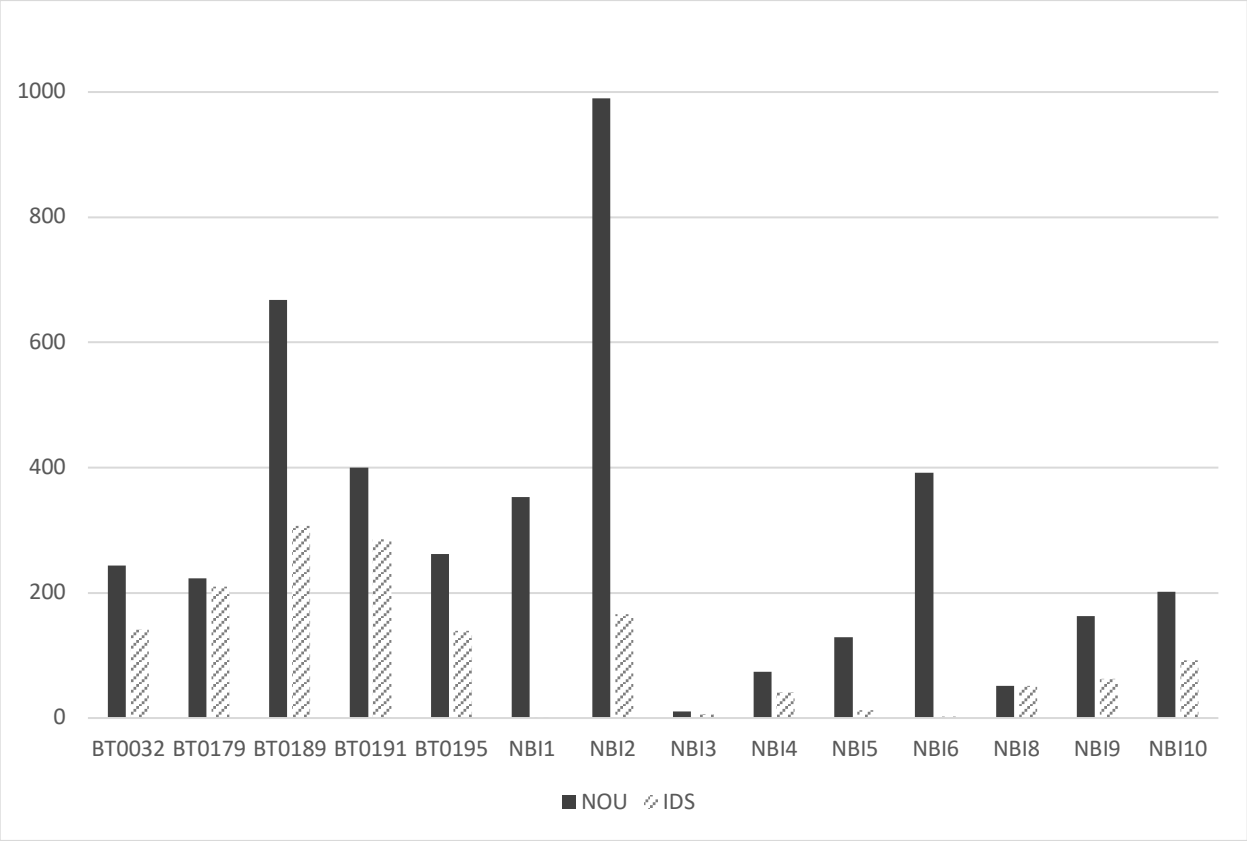
NICU: Natural Sample & "One Frog too Many" Comparison

	NOU	MLU (m)	#IDS	IDS Ratio	NOW	NDW	TTR	TTR of averages
Natural	262.67	3.99	48.33	0.36	1,007	159.78	0.46	0.16
Reading	70.49	7.65	3.85	0.05	475.3	154.33	0.34	0.33

Note: NBI7 is not included in the "Natural" recordings and NBI4 is not included in the "Reading" recordings.

Figure 1

IDS Occurrence Across Participants



This figure helps to display (1) the difference between NOU and #IDS in each participant's environment, (2) the difference in NOU between participant groups, and (3) the difference in #IDS between participant groups. Note: NBI7 is not included due to spoken language being Spanish.