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Determinants of Preterm Infants Language Environment
in the Neonatal Intensive Care Unit

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An abstract of

A dissertation submitted to the Faculty of the
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Abstract

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By: Lauren Head Zauche

Background/Objective: Brain development is shaped by early sensory experiences, including exposure to language and parent-infant interactions. However, preterm infants spend the first months of their life in the neonatal intensive care unit (NICU) where language exposure and parent-infant interactions may be limited. This study sought to characterize preterm infants' language environment and identify sociodemographic, clinical, environmental, and maternal psychological factors that predict language exposure and parental presence in the NICU.

Methods: Using a cross-sectional study design, sixty-six infants born <38 gestational weeks who were between 32-40 weeks corrected gestational age were recruited at two level III NICUs. The auditory environment was assessed for 48 consecutive hours using digital language processors and independent variables were collected through surveys, medical record abstraction, and observations. Duration of parent visits were collected from visitation logs. Negative binomial and gamma regression were performed on word count and meaningful speech, respectively. A general linear model was estimated to identify predictors of parent visits.

Results: The majority of the auditory environment was composed of silence and electronic noise, with little language exposure (3.61 $\pm$ 2.78%). Infants were exposed to an average of 304 words per hour. Infants with high parent visitation ($\geq$37%) were exposed to 1.84 times more words and 34% more meaningful speech than infants with low parent visitation (p<0.001). Each additional corrected gestational week increased both word count and meaningful speech by 13% (p<0.001). Preterm infants in open bay areas and on oscillators/ventilators were exposed to 27% and 43% less meaningful speech, respectively (p<0.03). The number of children at home, neurological comorbidity, surgical history, and perceived stressfulness of the NICU each had large main effects on parent visitation while room type and surgical history had a large interaction effect on parent visitation (p<0.04). These predictors accounted for 65.8% of the variance in parental presence.

Conclusion: Language represented a small percentage of auditory stimuli and was most strongly predicted by parent visits. Understanding factors that predict language exposure and parent visitation can help clinicians and researchers develop interventions and design NICUs that encourage parental presence, and thus improve preterm infants' neurodevelopmental and academic trajectory.

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CHAPTER ONE

INTRODUCTION

Preterm birth is a key determinant of infant health and affects 12% of live births **in the United States.[1] Preterm birth interrupts a critical period of auditory and brain** development and increases the risk for impaired auditory processing, delayed language acquisition, and poor academic achievement.[2-8] In addition to biological vulnerabilities conferred by preterm birth, the risk for language delays may be compounded by environmental exposures in the neonatal intensive care unit (NICU) that are not conducive to their development.[9,10] Studies suggest that fetuses begin to hear sounds as early as 23 weeks gestation and capacity for language acquisition develops by 35 weeks gestation.[11,12] During the third trimester, maternal voice is the most prominent auditory stimulus and influences the functional development of auditory circuits and regions of the brain that control language function.[13,14] Given that preterm infants are born before the third trimester is complete, the development of auditory and language brain circuits rely on auditory stimuli in the NICU. However, preterm infants typically spend the first 8-12 weeks of their lives in the NICU where they are exposed to loud, high frequency noise, and where parent and caregiver interactions are restricted, limiting opportunities for language-rich exchanges. Previous studies have characterized the noise of the NICU, including both the volume and the frequency; however, much less is known about the language environment of the NICU.[15-17] To date, only two studies have examined the language environment of the NICU, which found that language represented only 2-3% of the auditory environment in a single open bay NICU.[9,18] This language deprivation may contribute to language delays and poor academic achievement in preterm infants.

Early language exposure is critical for speech processing and language development.[19-22] Indeed, the number of words directed at a child (adult word count) more strongly predicts a child's language development than any other variable, including socioeconomic status and parent education.[19-24] Given the importance of early language exposure and knowledge that language learning begins in the third trimester, it is important to understand the language environment of preterm infants to identify whether interventions to prevent language deprivation, and thus promote language development in preterm infants, in the NICU are needed.

Various factors may contribute to language exposure in the NICU. Recent efforts have been made to reduce the exposure of preterm infants to toxic noise by creating single-family rooms rather than a multi-bed open bay.[25-27] However, it is possible that this design increases social isolation and language deprivation. Also, the number of people, including both nurses and family members, in the NICU may influence language exposure. Additionally, factors that influence parent-infant interactions, including infant acuity, parental stress, and self-efficacy, may affect the quality and quantity of language spoken to preterm infants. While previous studies suggest that term-born children in low-income families hear less words, studies have investigated whether family sociodemographics are associated with the language environment in the NICU.[28,29]

Given that research suggests that parent-infant interactions may help mitigate adverse effects of preterm birth, investigating determinants of parent visits is also important to consider.[30] Previous studies have suggested that distance from the hospital, number of children at home, and increased length of stay are associated with decreased parental presence in the NICU.[31-35] However, findings are inconsistent for the effect of clinical factors on parent visitation practices.[31,32,35-37] Understanding factors that influence parent visits may help identify infants who are at risk for low visitation and thus, decreased exposure to social interactions.

Purpose

This purpose of this study is to fill gaps in knowledge about the language environment of preterm infants in two ways. First, it will characterize the language environment of preterm infants in the NICU by examining adult word count and meaningful speech (percentage of the environment composed of language). Second, it will identify determinants of early language exposure of preterm infants in the NICU. Another purpose of this study is to identify predictors of parent visits in the NICU. By characterizing the language environment and identifying determinants of early language exposure and parental presence in the NICU, this study is a first step towards understanding the language environment of the NICU and developing interventions to address potential language deprivation and suboptimal parental presence in the NICU.

Specific Aims

Aim 1: To characterize the language environment of preterm and early term infants, as assessed by Language Environmental Analysis (LENA) recorders, in the NICU at 32-40 weeks postmenstrual age.

Research Question 1: What is the mean number of words that preterm and early term infants are exposed to per hour in the NICU?

Research Question 2: What percentage of the auditory environment of preterm and early term infants is language (meaningful speech) in the NICU?

Aim 2: To identify determinants of language exposure, or adult word count and meaningful speech, as assessed by LENA recorders, in the NICU at 32-40 weeks corrected gestational age.

Research Question 1: Does parental stress and self-efficacy, as measured by the Parental Stressor Scale: NICU (PSS:NICU), and Perceived Maternal Parenting Self-Efficacy Tool, respectively, or sociodemographics, including marital status, parental ages, household income, number of children, and level of education, influence language exposure?

Research Question 2: Does NICU design, nurse-to-patient ratio, or parent visits affect language exposure?

Research Question 3: Do infant comorbidities or infant acuity influence adult word count and meaningful speech?

Aim 3: To identify predictors of parent visits in the NICU for preterm and early term infants who are 32-40 weeks corrected gestational age.

Research Question 1: Does parental stress or self-efficacy, as measured by the Parental Stressor Scale: NICU and Perceived Maternal Parenting Self-Efficacy Tool, respectively, or sociodemographics, including marital status, race/ethnicity, household income, number of children, or level of education, influence language exposure?

Research Question 2: Does NICU design affect parental presence in the NICU?

Research Question 3: Do infant co-morbidities, surgical history, type of respiratory support, number of lines/drains, or infant acuity influence parental presence in the NICU?

CONCEPTUAL FRAMEWORKS

Usage Based Theory of Language Acquisition

The usage-based theory of language acquisition postulates that language learning occurs on the basis of language exposure and through generalizations made through exposure to language.[38] Based on this theory, language development results through the interaction of cognition and linguistic input.[38] Young children use several cognitive processes to understand and use language.[38] These cognitive processes include (1) categorization, or identifying words as part of a type, (2) chunking, or linking words together learned through repetition, (3) memory, or the storage of information, (4) analogy, or mapping of existing language knowledge to new linguistic input, and (5) cross modal association, or the cognitive ability to link form and meaning together.[38] This theory posits that children do not learn words directly, but rather try to comprehend the functional role a word plays in an utterance given commonalities of a role across many utterances.[38] As such, social interactions coupled with language exposure provide children with the context and sensory experience necessary for language development.

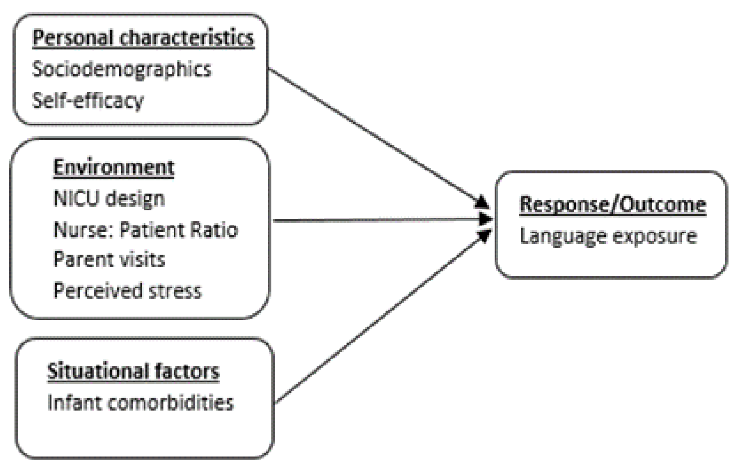
Vygotsky's Sociocultural Theory of Human Learning

Vygotsky's sociocultural theory of human learning describes the role of social interactions on the development of young children.[39] Vygotsky postulates that human learning occurs through social relations with others and that the potential for neurodevelopment is constrained by the "zone of proximal development."[39] This zone of proximal development refers to the areas of learning in which children are developmentally prepared for but require social interactions to develop.[39] In this way, adults are able to support learning by scaffolding children's development through their interactions with the child.[39] Language exposure through social interactions provide children with opportunities to learn new words and concepts, thus promoting their development.

Parental NICU Stress Model

The aims of this study can be understood through an adaptation of the Parental NICU Stress Model, which describes how personal, situational, and environmental factors influence a behavioral response.[40] Personal characteristics are defined as family resources and background and are operationalized as sociodemographics and self-efficacy in this study.[40] Situational factors are defined as severity of infant illness, which are operationalized as co-morbidities of the infant.[40] Environment is defined as perceptions of the environment, NICU staff, and physical characteristics of the NICU, and is operationalized by perceived stress, nurse-to-patient ratio, parent visits, and NICU design.[40] The response in this study is operationalized as language exposure provided by staff and parents in the NICU.

Figure 1: Theoretical framework



BACKGROUND

Language exposure

Early childhood is a critical period for language and cognitive development.[41,42] More neural connections form between the third trimester and the first three years of life than at any other time period in an individual's lifespan and provide the foundation on which all later learning builds.[41-44] A growing body of evidence in both animals and humans suggests that brain development is shaped by a dynamic interaction between both biology and environmental experiences.[41,42] Studies in the field of epigenetics have suggested that environmental experiences, such as parent-child interactions and sensory input, can affect the expression of genes through molecular mechanisms.[45] Social interactions and sensory input can also provide infants and young children with opportunities to learn, which results in the formation of new synaptic connections and the refining of existing neural pathways.[41,42,46]

Early language exposure strongly influences a child's language and cognitive development.[19,21,22,24,29,47] Decades of research have documented the profound effect of both the quantity and the quality of early language exposure on the developmental outcomes, particularly both the expressive and receptive vocabulary, of young children.[48-51] Language that is characterized by linguistic diversity, grammatical complexity, prosody, and varied intonation that is delivered within the context of a social relationship facilitates the acquisition, comprehension, and production of language. [19,23,29,52,53] Previous studies have suggested that a child's vocabulary at the age of three is a powerful predictor of a child's literacy and academic success and is more predictive of educational achievement than socioeconomic status. [20,54] As such, a young child's access to adequate language exposure is essential for optimal developmental outcomes.

Language exposure may be a mediator of adverse effects of low levels of parent education, maternal depression, poverty, and preterm birth on children's language and cognitive outcomes.[23,30,55,56] A study was recently conducted in which the association between the quantity of language exposure and cognitive outcomes was evaluated in a sample of infants born less than 32 weeks gestation. [10] While the study failed to control for potential confounding variables, the study found that the number of words spoken to a preterm infant accounted for 20% of the variance in cognitive scores on the Bayley Scales of Infant Development at 18 months corrected gestational age.[10] However, this study was the only study that has evaluated the effect of language exposure on the developmental outcomes of preterm infants. Little is known about language exposure in the NICU.

Preterm infants and neurodevelopmental outcomes

Preterm birth, defined by the World Health Organization as birth occurring at less than 37 weeks gestation, is a significant contributor to neonatal mortality and morbidity, affecting one out of every nine babies born in the United States.[1] Medical advances over the past few decades have resulted in increased survival for preterm infants and a decreased gestational age for viability.[57] However, the prevalence of comorbidities and long-term health and developmental complications among infants and children born preterm has improved only slightly.[57] The neurodevelopmental implications of prematurity on the developing infants' brain have recently become a public health concern, as there is unequivocal evidence that shows that preterm birth adversely affects a child's neurodevelopmental outcomes.[5,8,58-61] It has been estimated that 25-50% of surviving preterm infants have a neurodevelopmental delay or disability in childhood, even in the absence of a known brain injury.[7] While the adverse effects of prematurity on an infant's developmental trajectory are most significant among infants born very preterm (<32 weeks gestation), increasing evidence demonstrates that all preterm infants regardless of gestational age are at a heightened risk for developmental delays.[8]

Extensive evidence has documented the association between prematurity and long-term deficits in executive functioning.[60,62-64] Executive functions are cognitive processes that are essential for the control of goal-oriented actions, and involve skills such as inhibitory control, attention, cognitive flexibility, memory, problem solving, and information processing.[65] These skills underlie children's performances on cognitive and language tasks and are critical for "school readiness".[65] Decades of research have shown that children and adolescents who are born preterm consistently perform more poorly in all domains of executive functioning and are outperformed by their term-born peers on measures of language and cognitive skills, controlling for IQ differences.[60,62-64,66-68]

Deficits in early executive functioning and language and cognitive skills likely contribute to the disparities seen between preterm-born and term-born school aged children in academic performance and attainment.[58,66,67,69-74] In comparison to children born at term, children born prematurely consistently have lower IQ, poorer test performance, greater special education referral, higher rate of grade retention, and lower academic attainment.[8,58,66,67,69-74] Studies have shown that these deficits are evident for both standardized tests as well as teacher reports starting as early as kindergarten and continuing throughout high school.[8,58,66,70,71,73,74] Large population-based studies linking birth records to standardized test scores of children at school entry have demonstrated that gestational age is inversely related to academic success across multiple educational domains, including mathematics, reading, grammar, writing, and science.[8,70]

Preterm birth predisposes children to neurodevelopmental delays for several potential reasons. Preterm birth interrupts a critical period of structural differentiation, synaptogenesis, myelination, and rapid brain growth that occurs in the third trimester.[75] Remarkably, brain volume increases approximately three-fold between 29 and 40 gestational weeks and infants born at 35 weeks have only two-thirds the brain volume of an infant born at term.[76] This decreased brain volume has been shown to persist throughout childhood and adolescence and has been found to be correlated with IQ and neuropsychological testing of executive function.[77] Additionally, the developing preterm infants' brain is more susceptible to injury and harmful exposures.[7] Prematurity is associated with a high prevalence of perinatal brain injuries that compromise neurological function.[7] Infants born preterm are at greater risk for complications during the perinatal period and birthing process, disturbances to cerebral blood flow, pulmonary insufficiency, fragile brain vasculature, high levels of inflammatory biomarkers, and postnatal sepsis.[78] These risks contribute to the pathogenesis of intraventricular hemorrhages, hypoxic ischemic-encephalopathy, and periventricular leukomalacia.[78] However, not all variance in preterm infants' developmental outcomes can be explained by biological factors. Thus, the environment in the neonatal intensive care unit (NICU) may also influence outcomes.

Intrauterine vs NICU Auditory Environment

Auditory development begins in utero. By 15 weeks gestational age, all structural components of the inner ear and auditory system are fully formed but are not yet functionally developed.[79] Functional development of the auditory system occurs throughout the third trimester, with the onset of hearing occurring between 23-26 weeks gestation.[79,80] Changes in fetal skeletal movement and heart rate in response to noise have been observed between 23-25 weeks.[80] Electrophysiological data have demonstrated that brainstem auditory evoked potentials become recordable starting at 25 weeks gestation and become more robust around 34 weeks gestation when a sufficient number of neural connections have been formed between the cochlea, auditory brainstem, and auditory cortex.[11]

The womb provides an optimal environment for the functional development of the auditory system.[81] Hair cells in the cochlea are arranged tonotopically, in which those that detect high-frequency sounds are located closer to the middle ear than those that detect low-frequency sounds.[82] Neural connections between the lower frequency-detecting hair cells and the auditory cortex matures sooner than the neural connections between high frequency-detecting hair cells and the auditory cortex.[83] The amniotic fluid, along with the uterine wall and other maternal tissues, filter out most high frequency sounds; thus, the fetus is exposed to primarily low-frequency sounds while the lower frequency-detecting hair cells are maturing.[11] As pregnancy progresses, the uterine wall thins and allows higher frequency sounds to be transmitted to the fetuses, allowing for the maturation of higher frequency-detecting hair cells.[11] Exposure to this timed spectrum of frequencies permits the normal tonotopic development of cochlear hair cells.[11]

Preterm birth disrupts the normal development of the functional auditory system.[81] The preterm infant abruptly transitions from the intrauterine environment to the NICU environment, where auditory exposures are drastically different.[81] While the auditory environment in utero is characterized by low-frequency, quiet noises with maternal biological sounds, including digestive noises and heartbeats, and maternal voice as the primary auditory stimuli, the NICU auditory environment exposes preterm infants to loud noises over a broad spectrum of frequencies with exposure to electronic, non-biological sounds and potentially minimal linguistic stimuli.[81] Noise from alarms, monitors, ventilators, infusion pumps, pagers, telephones, air conditioning units, staff and family member movements and conversations, and infants crying all contribute to the environmental noise in the unit. This noise exposure would not be present had the baby remained protected in the intrauterine environment.

It is well established that preterm infants are exposed to high levels of sound and noise in the NICU.[15,17,84] Current guidelines set by the American Academy of Pediatrics (AAP) indicate that sound levels should not exceed 45dB and that maximum transient sounds should not exceed 65dB.[85] Higher noise levels have the potential to induce physiological and psychological stress in the infant, increase apneic, bradycardic, and hypoxic events, decrease perfusion and oxygen saturation, increase feeding difficulties, slow weight gain, disrupt normal development, dysregulate sleep, and result in cochlear damage.[15,17,84,85] Evidence has consistently demonstrated that noise levels in the NICU often exceed the AAP recommended standards, possibly more than 70% of the time, even if the child is in an enclosed bed or in a single-family room.[86] While the AAP has not established any recommendations regarding noise frequency, there is evidence to suggest that the noise frequency in the NICU (>500Hz) is much higher than is appropriate for the preterm infants' developing brain and auditory system.[16]

While exposure to excess noise in the NICU and the effect of noise on preterm infants' outcomes have been well studied, there is much less research examining the influence of potential positive auditory stimuli, such as maternal biological sounds and voice in the NICU. Evidence suggests that exposure to maternal biological sounds and voice in utero provides the fetus with auditory stimulation necessary for the development of neural pathways in the brain that subsequently contribute to the development of language skills.[87-90] Studies with full-term neonates have demonstrated that exposure to their mother's voice, but not a stranger's voice, results in activation of language-related cortical regions of the brain and that this neural response is correlated with the amount of prenatal exposure to maternal voice.[91,92] These studies suggest that exposure to maternal voice in utero begins to shape the areas of the brain responsible for language learning.

Recently, several studies have been conducted that have investigated the influence of maternal voice in the NICU on preterm infants.[90,93-96] Randomized clinical trials have demonstrated that exposure to recordings of both maternal biological sounds and maternal voice may improve cardiorespiratory regulation, lower heart rate, improve oxygenation saturation and respiratory rate, reduce episodes of feeding intolerance, improve weight gain velocity, decrease pain responses, and lead to significantly larger auditory cortexes.[90,93-96] These results suggest that exposure to positive auditory stimuli, such as maternal voice, may help to mitigate the effects of the adverse noise exposures on early brain development.

Language exposure in the NICU has not been well studied. Previous studies have suggested that language exposure only represents a small percentage of the auditory environment in the NICU and that greater language exposure and reciprocity was associated with language comprehension and production skills at 18 months old. [9,10,18] As compared to the intrauterine environment, exposure to parental voice is usually not as frequent in the NICU.[10] Additionally, environmental and electronic noise in the NICU may mask linguistic stimuli. Given that the brain relies on language stimuli for maturation during the third trimester, it is important to understand and characterize language available to preterm infants in the NICU.

Factors contributing to the language environment in the NICU

Determining factors associated with language exposure may identify targets for interventions aimed at providing a developmentally-appropriate environment for preterm infants. Currently, only two studies have investigated factors that influence early language exposure in the NICU; however, parent visits, illness severity at day 1 and 3 of life, type of isolette, and respiratory support at the time of language assessment were the only factors examined.[9,18] There are multiple other factors that likely are associated the NICU language environment. As such, this study sought to confirm the single study findings (demonstrating reproducibility) by using a rigorous experimental design to fill the gap in the literature regarding these determinants of language environment.

<u>Personal determinants</u>

Sociodemographics: Various sociodemographics may influence the ability of parents to provide their preterm infant with access to language. Studies with term-born infants have found that language environments differ dramatically based on socioeconomic status;

children from low socioeconomic families are more likely to hear short sentences and directives, and are less likely to be exposed to as many words or engage in conversational turns compared to children of higher income or more educated families.[28,49,50,97,98] In addition to socioeconomic status, the infant's birth order and parent's marital status have been found to be related to differences in parent speech; first born children and infants of married parents are exposed to a greater amount of language.[99,100] While previous parenting experience may enhance the parent's self-efficacy and interactions with their infant, it is also possible that a greater number of children at home may prohibit parents from visiting and thus, talking with their infant in the NICU. Additionally, infants of married parents may be more readily afforded opportunities for language exposure by more than one person. Furthermore, cultural and racial differences in views regarding practices of communicating with infants may exist.[101] While previous studies have suggested that different sociodemographic factors may be associated with language exposure in the home environments of term-born infants, no studies have investigated if and how these factors influence preterm infants' language environment in the NICU.

Parental well-being: Preterm birth is a highly stressful experience for families. The abrupt transition of the infant from the womb into the NICU environment and the change of parental roles and expectations presents families with a variety of stressors.[102-104] These stressors can relate to the appearance and acuity of the infant, physical separation from the infant, alteration of parental role, and sights and sounds in the NICU.[102,105] Studies have suggested that the severity of prematurity and the infant's acuity is associated with increased parental stress, which is highly correlated with maternal postpartum depression.[102,106,107] Prevalence of postpartum depression of mothers of preterm infants is 30-40% compared to 6-12% in mothers of healthy, term infants.[40] High rates of stress and depression among parents of preterm infants poses challenges to parent-infant attachment, which can influence parents' interactions with their infant.[108] As a result, it is possible that parent stress and depression affect the quality and quantity of language delivered by parents.

*Parental self-efficacy***:** Self-efficacy, as described by Bandura's social cognitive theory, is defined as an individual's perception of his or her capability of managing a task successfully and effectively.[109] Parenting self-efficacy has been demonstrated to predict actual competence of parenting tasks and nurturing behaviors.[110] While there is lack of research investigating parental self-efficacy of parents of preterm infants, a few studies have suggested that low self-efficacy is associated with high levels of parental stress and that parents of preterm infants experience a low level of parenting self-efficacy compared to parents of term-born infants.[111,112] Given that self-efficacy may influence the quality of the interactions between parents and infants, it may be possible that self-efficacy also affects the quantity and quality of language spoken to preterm infants.

Environmental determinants

NICU design: Efforts to improve the NICU environment have focused on reducing noise levels by changing its architectural design to include single family rooms rather than the traditional multi-bed, open bay design.[25-27,113] While shown to significantly reduce the infant's exposure to toxic noise, it is unclear as to what effect this design has on language exposure in the NICU.[27] Research suggests that a single family room increases family visits by providing more privacy and by reducing parent stress, which could lead to more frequent and positive language-rich parent-infant interactions.[25,26] However, it is possible that preterm infants whose families who do not visit often are subjected to more social isolation and language deprivation compared to preterm infants in an open bay NICU.[14] Given the recent push to transition NICUs to the single family room design, it is important to understand how the NICU design influences language exposure.

Opportunities for adult-infant interactions: Without opportunities to hear speech and engage in conversational turns with adults, the auditory environment of preterm infants would be without language. As a result, the more time adults spend with the preterm infant, the more likely it seems that the preterm infant will be exposed to language. While one study found that adult word count and conversational turns significantly increased during parent visits, no studies have examined nurse-to-patient ratio, which may also affect language exposure by affecting the time and ability of staff to talk and interact with the preterm infant.[9]

<u>Situational determinants</u>

Infant acuity and/or comorbidities: Preterm birth interferes with normal parent-infant interactions and reduces the ability and time parents are able to spend with their baby. Greater infant acuity presents additional physical barriers as well as safety concerns that further limit parental interaction. In addition to limiting parent-infant interactions, the extent of prematurity and severity of complications related to prematurity are associated with greater stress, anxiety, and depression in parents, which affects the quality of the parent-infant bond.[106,107] One previous study demonstrated that an increase in illness severity at day three of life, as measured by the Score for Neonatal Acute Physiology Perinatal Extension-II, resulted in a slight decrease in adult word counts but did not examine infant acuity at the time of language assessment except for respiratory support.[9]

Indeed, high respiratory support at the time of language assessment was associated with decreased adult word count and conversational turns.[9] As a result, it is possible that higher infant acuity affects language exposure due to the challenges associated with parent-infant interactions.

Parent Visits in the NICU

Parent-infant interactions have been found to be a potent mediator of variations in developmental outcomes and may lessen the adverse effects of prematurity on neurocognitive development.[114] Studies with both term-born and preterm-born children have suggested that parental behaviors characterized by sensitivity, responsiveness, and supportiveness, are associated with better cognitive, language, and socioemotional skills.[30,53,115-118]

Preterm infants spend the first weeks to months of their lives in the NICU, in which they are physically separated from their parents. This separation coupled with the medical condition of the premature infant present challenges to normal parent-infant interactions and attachment.[114] Results from multiple studies using animal models demonstrate the profound negative effect of early, prolonged maternal separation on neurodevelopmental outcomes. [13,87,114,119,120]

Lack of parent visits in the NICU is a frequent concern reported by NICUs across the country.[31,37,121,122] Many units have begun to implement policies that encourage frequent visitation and rooming-in with the infant, such as transitioning to single family rooms from the traditional open bay design, allowing parents 24/7 access to the NICU, and providing free parking passes for parents.[121,123] While there is some evidence to suggest that these policies have encouraged parental visits, low parental visitation rates persist.

Parental visitation is likely influenced by numerous factors. Previous studies have suggested that distance from the home to the hospital, number of children at home, and length of stay in the hospital are associated with parent visits.[31,32,34,35] Inconsistent results have been reported for clinical factors.[31-36] Understanding factors that predict parent visits may help guide interventions aimed at increasing parental presence in the NICU.

METHODS

Research Design

A cross-sectional design was used to characterize the auditory environment of the NICU and to determine determinants of language exposure and parent visits in the NICU for preterm infants. Data collection was conducted over a period of 48 hours for each research participant.

Setting

Emory University School of Nursing was the coordinating site. Participants were recruited from NICUs in two hospitals within the Children's Healthcare of Atlanta hospital system in Atlanta, Georgia: Egleston and Scottish Rite. These sites were selected due to their diverse patient population and existing relationships with staff in these NICUs. Both NICUs had both an open bay area and single family room. Annually, there are approximately 400 NICU admissions. The NICUs are designed to deliver developmentally focused care specifically for newborns. Both NICUs feature a medical and surgical NICU. Each NICU is staffed by interdisciplinary team members including audiologists, nurses, lactation consultants, respiratory therapists, dieticians, occupational and physical therapists, pastoral staff, pharmacists, physicians, speech-language pathologists, social works, and transport teams.

Sample

Inclusion criteria included infants born less than 38 gestational weeks who had reached less than 40 weeks postmenstrual age in the NICU of a participating hospital. Infants who met these criteria were included regardless of birth complications, such as brain injuries or postnatal infections, as early language exposure may be most beneficial for those at highest risk. *Exclusion criteria* included infants whose mothers could not understand written and spoken English and infants who were wards of the state. Using Power Analysis and Sample Size software, it was determined that a sample size of 44 was needed to detect a large effect size at 80% power at α=0.05.

Variables and Measures

Figure 2. LENA digital language processor

LENA (Language ENvironmental Analysis) was used to collect data on the principal dependent variables for this study −adult word count and meaningful speech − during 48 hours between 32-40 weeks postmenstrual age.[124] LENA captures up to 16 hours of continuous speech data at a time, recorded through a digital language processor that can be placed near the child in a corner of the incubator.[124] The language processor, pictured to the right, is of minimal weight (<2 oz) and is compact (3-3/8" x 2 3/16" x ½").[124] It captures every utterance in a child's environment and then uses advanced algorithms and statistical modeling to automatically process and segment each recording to generate reports for child vocalizations, adult word count, conversational turns, and other components in the audio environment, such as distant or overlapping speech, electronic noise, and silence.[124] It can filter out words over electronic noise as well. Distant and overlapping speech are not included in the adult word count as these forms of speech are not considered to be directed at the infant.[124] Distant speech is speech that is spoken greater than five feet from the language processor; a variable coded into the algorithm.[124] Reliability and validity studies have demonstrated LENA's high degree of fidelity in coding when compared to human transcribers using samples of children and parents of various socioeconomic status and language spoken.[124] While normative data are based on children older than two months, LENA was validated in preterm infants by comparing adult word count reported by a transcriber to adult word count detected by LENA.[124] Results found that r=0.93, which was similar to reliability studies conducted in term-born infants.[10] Feasibility of LENA use in the preterm population in the NICU has been demonstrated in three prior studies and a protocol for use in preterm infants has been established.[9,10,18]

NICU design: The type of room (open bay vs. single family room vs. double occupancy room) in which the patient was being cared for was recorded each time language data were collected by LENA.

Nurse-to-patient ratio: The number of patients that the nurse who was caring for each participant was recorded each time language data were collected by LENA.

Parent visits: Parent or caregiver visits in the NICU are recorded by the unit. Total visitation time and the number of people visiting during each visit was abstracted from unit records at the end of each shift. If more than one person visited at the same time, the total visiting time was counted in such a way to prevent overlapping time. Parents were required to sign in on a visitor log at CHOA Egleston NICU but not at CHOA Scottish

Rite NICU. Parental presence was determined at CHOA Scottish Rite NICU through medical records and were verified by nurses.

Parental Stressor Scale: Neonatal Intensive Care Unit (PSS: NICU) was used to assess the mothers' perceptions of stressors in the NICU. [105] The PSS: NICU is a 34-item self-reported questionnaire that asks parents to rate the stressfulness of experiences in the NICU on a Likert scale from 1 (not at all stressful) to 5 (extremely stressful). [105] Items not experienced are marked as 1 to obtain the best assessment of the overall stressfulness of the NICU environment. [105] The assessment consists of three subscales: infant behavior and appearance, relationship and parental role, and sights and sounds. [105] This measure has internal consistency as evidenced by Cronbach's α=0.89 and construct validity, supported with significant correlations with the State Trait Anxiety Inventory.[105] The subscales are correlated with the total score (49-82% of variance).[105] Mothers were asked to complete this questionnaire at the time of study enrollment.

Perceived Maternal Parenting Self-Efficacy Tool (PMPS-E) was used to assess parental self-efficacy in the NICU.[111] The PMPS-E is a self-administered questionnaire that consists of 20 statements, which are scored on a Likert scale from 1 (strongly disagree) to 4 (strongly agree), and represent four domains of self-efficacy, including care-taking, evoking behaviors, reading behaviors, and situational beliefs.[111] This tool was developed and tested for use with mothers of preterm infants in the NICU.[111] It has high internal consistency with Cronbach's α=0.91 and high test-retest reliability at r=0.96.[111] Each individual statement is significantly correlated with overall score (r=0.30-0.77).[111] Mothers were asked to complete this questionnaire at the time of study enrollment.

Demographics including parental age, race/ethnicity, religion, level of education, household income, number of children, marital status, and previous NICU experience with another child was collected with a survey that was filled out by the mother at the time of study enrollment.

Nurse-education about language exposure: Mothers were asked if a nurse in the current NICU had ever talked to them about early language exposure or talking with their baby. Separate from this study, all nurses at one NICU site had received a one-hour continuing education training (Talk With Me Baby™) about the importance of early language exposure and about educating parents why and how to talk with their baby. No nurses at the other NICU site received this training. This question was asked to control for any effect of this nurse-led education on the language environment.

Clinical variables, including birthweight, gestational age, infant acuity, presence of central line, type of oxygen, source of nutrition, and presence of a comorbidity was collected from medical records. Infant acuity was determined based on the American Academy of Pediatrics/American College of Obstetrics and Gynecology guidelines. Medical records were abstracted for the shift in which language data were collected.

Procedures

After obtaining a partial HIPPA waiver, potential participants were identified through medical chart review. All patients meeting eligibility were given a flyer about the study by a NICU nurse inviting them to participate in the study. Screening for recruitment occurred on an ongoing basis until the total sample size was achieved.

The PI coordinated with the nurse regarding when to approach mothers in the NICU about study participation. The PI approached mothers whose infants were eligible for the study and asked permission to describe the study to the mother. If the mother agreed, a one to two minute description of the study was presented after which the mother was given a chance to read the informed consent and ask any questions. A signed written consent was obtained for each mother-infant dyad prior to any data collection.

Once written consent was obtained, the mother was given a demographic survey and the questionnaires. Mothers were allowed to complete them in the NICU or were allowed to take them home and bring them back within 48 hours. Data collection using the LENA digital language processors was started at the time of informed consent. Upon completion of the 48 hours of language exposure collection, mothers were compensated with a $25 gift card.

Protection of Human Subjects

This study meets Federal Regulations defining minimal risk: "minimal risk means that the probability and magnitude of harm or discomfort anticipated in the research are not greater in and of themselves than those ordinarily encountered in daily life or during the performance of routine physical or psychological examinations or tests." [§46.102]. This study does involve research with a vulnerable population, namely, neonates who do warrant special considerations [§46.205]. Related to these special considerations, we provide the following information: This study does not involve any experimental intervention or procedures, but rather is observational in nature, examining early language exposure, and subjects the mother and neonate to no more than minimal risk while offering no direct benefit to either. Neonates of uncertain viability were not included in this research, and the research team was not present at the delivery and did not have any role in determining the viability of the infant. As such, the consent of only one parent was required. Because identifiable private information about the neonate during the delivery hospitalization was collected, and because aspects of the mothers' psychological well-being (including maternal stress and self-efficacy) were explored as determinants of the language exposure of the neonate in the NICU setting, we specifically sought the consent of the mother for her own participation and the participation of her infant.

Human Subjects Involvement

Infants born less than 38 gestational weeks and their mothers were recruited as dyads from Children's Healthcare of Atlanta in Atlanta, Georgia. Sixty-six mother-infant dyads were recruited. The mother of each participant provided consent for her own participation and for her neonate's participation for the:

- Collection of language input data from LENA digital language processors placed in the neonate's crib in the NICU to obtain data on early language exposure
- Collection of questionnaire data including the Parent Stressor Scale: NICU, Perceived Maternal Parenting Self-Efficacy Tool, and a sociodemographic survey while in the NICU
- Review and abstraction of the neonate's medical records for the NICU stay

Target Population

This study planned to enroll between 50-70 mother- infant dyads in which the infant was born less than 38 gestational weeks and were under 40 weeks corrected gestational age/postmenstrual age. Inclusion/exclusion criteria for study participants are given in Table 1, along with the rationale for the criterion. Based on the demographics of the infants born at the enrolling institution, the recruitment pool was expected to be approximately 50% female, 50% African American, 6% Hispanic/Latino, and have very small numbers of Asian/Pacific Islander or American Indian racial/ethnicity groups. All study participants were recruited from the NICU at Children's Healthcare of Atlanta. Potential subjects were not excluded due to comorbidities. Presence of these complications were collected as variables in the study.

Table 1: Inclusion/Exclusion criteria

Inclusion Criteria	***Rationale***
Infants born <38 gestational weeks, as verified by hospital records	Preterm and early term infants are vulnerable to neurodevelopmental delays, delayed growth, insufficient nutrition, and inadequate language exposure.
Admitted to the Neonatal Intensive Care Unit at Children's Healthcare of Atlanta	The study's purpose is to study language exposure in the NICU setting
Under 40 weeks corrected gestational age	Data was collected between 32-40 weeks corrected gestational age; this age range represents a time when the majority of preterm infants become stable and benefit from sensory stimulation and the time in which they are typically discharged home.
Exclusion criteria	***Rationale***
Consenting parent must understand the English language	Informed consent process and questionnaires were conducted in the English language.
Wards of the state	If the infant is a ward of the state, informed consent cannot be given by the mother and there would not be a mother-infant dyad

Recruitment and Informed Consent

This study followed HIPAA regulations and obtained IRB approval. A partial HIPAA waiver was obtained from Emory University IRB to allow for screening of medical records to identify potential subjects under 40 weeks postmenstrual age who were admitted to the NICU setting. When a potentially-eligible neonate was identified, the NICU nurse initially informed the mother about the study and if the mother indicated interest in learning more about the study, the PI arranged to meet with her to give her detailed information about the study. If eligibility criteria were met, the PI oriented the mother to the study, provided detailed information, and answered questions. The PI discussed the informed consent form with the mother. The informed consent form explained all procedures and questionnaires, and details regarding collection of data sources. The mothers were informed that participation in this study was voluntary and that they may withdraw themselves and their child from the study at any time without consequences to themselves, their child, family, or community. Study descriptions ensured that mothers understood that they may withdraw their child's or their own participation in the study at any time and to tell a nurse if they decided to withdraw participation while the LENA digital language processor was collecting data. Nurses were shown how to turn the LENA digital language processor off if mothers withdrew from the study while LENA was collecting data. In addition, the consent provided a clear explanation that the LENA digital language processor recorded audio input (sound) and stored it; however, the LENA is designed to connect to a computer for processing. The computer processor does not recognize words or their meaning; it only counted them. The processed data includes information on counts of words, conversational turns, and percentages of various components of sounds in the NICU (silence, electronic noise, etc.) only. The consent forms also included statements indicating that the mother did not have to answer any survey question that she did not want to. The mothers were given the contact information of the study team in case they had any questions or concerns while the study was occurring or after the study concluded.

Sources of Materials

For recruitment purposes, medical records were reviewed to determine eligibility.

In addition, data about the clinical variables during the NICU stay were abstracted from medical records. Language input was collected for four 12 hour shifts with LENA technology in the NICU. As detailed above, the LENA recording provided processed data on counts of words and conversational turns. The mother of each infant was asked to fill out a sociodemographic survey, the Parental Stressor Scale: NICU, and the Perceived Maternal Parenting Self-Efficacy Tool. Data about the NICU variables and parental visits were obtained through unit records.

Table 2. Data sources

Type of Data	Instrument/Measure	Source of data	Time
Demographic data	Survey	Mother self-administered	Study enrollment
Clinical variables	Medical record	PI	End of each LENA recording
Parent visits	Unit record/Medical record	PI	End of each LENA recording
NICU variables	Unit record	PI	End of each LENA recording
Perceived stress	Parent Stressor Scale: NICU	Mother self-administered	Study enrollment
Perceived self-efficacy	Perceived Maternal Parenting Self-efficacy Tool	Mother self-administered	Study enrollment
Language exposure: adult word count and meaningful speech	Language Environment Analysis (LENA)	PI	Four 12-hour shifts between 32-40 weeks corrected gestational age

Potential Risks and Protection against Risks

Potential risks to the participant were expected to be minimal and included (1) unintentional violation of confidentiality or privacy and (2) possibility of parent anxiety when language data was recorded and when questionnaires were administered.

The following precautions and procedures were followed to reduce potential risks to the participants:

(1) Unintentional violation of confidentiality or privacy

- Each study dyad was assigned an identification number. This information was kept separate from other study data and a document linking the personal information to study data was in a password-protected file only accessible by the PI. Unique identifiers appeared on all study documents so that no personal identifiers appeared on questionnaires or data printouts.
- Hard copies of all study documents were stored in a locked file cabinet in a locked room and was only accessible to the PI
- Data on an electronic database was kept on a password-protected computer in a password protected file.
- All data is being kept according to regulations in a locked file.

(2) Possibility of anxiety when language data is recorded or questionnaire is administered

- The PI educated the mother that the LENA does not analyze the content or meaning of the words spoken; it only counts those words.
- The PI encouraged the mother to interact with her child as though the digital language processor was not present.
- The PI informed mothers that the data would be de-identified and that the language input and their responses to the survey and questionnaires would not be specifically linked to them.
- The PI informed mothers that at any time during the study, she could

withdraw herself and her child from the study or have a nurse turn the digital language processor off without any consequences.

Mothers of participants were given contact information in case they had any questions or concerns while the study was occurring or after the study had concluded. All study staff completed Human Subjects training and training on the use of digital language processors with online modules from the LENA Research Foundation prior to the study.

LENA use in preterm infants has been demonstrated to be safe and feasible in two previous studies and no known risks are known to be associated with LENA use.

Potential Benefits of the Proposed Research to Human Subjects and Others

The potential risks to the participants were minimal. The study was not designed to provide direct benefit to participant,s but participants may have benefited in that parents could have become more aware of the importance of early language exposure. As a result, these parents may have talked more to their child than they otherwise would have, which could result in improved neurodevelopmental outcomes. Participants had the opportunity to help us understand more about the language environment in which preterm infants spend the first few months of their life. Mothers were compensated for their time with $25 in the form of a visa gift card.

Plans to Inform Participants about Research Findings

Manuscripts detailing the research findings will be submitted to peer-reviewed journals for publication. In addition, the staff in the NICUs at the recruiting hospitals were informed of the study results.

Importance of Knowledge to be Gained

The language environment of infants and factors that influence their language environment in the NICU are largely unknown. Characterizing the language environment and understanding factors that contribute to the language environment may inform future interventions aimed at providing a developmentally-appropriate NICU environment or aimed at improving language and cognitive outcomes of preterm infants. Gaining an understanding of the language environment in the NICU is crucial for designing and implementing future health interventions to increase early language exposure in at-risk newborns.

Inclusion of Women, Minorities, and Children

Both female and male children were included. We expected a nearly equal gender distribution; however, we had more males in the study than female children. More male children were eligible for the study based on study inclusion criteria. Additionally, the mother for each infant was consented as a research participant for the study as we explored maternal characteristics (stress, self-efficacy) as determinants of language exposure, thus, the mothers completed these questionnaires for themselves as part of their participation.

Ethnicity or race were not used as exclusion criteria in this study. Preterm birth is more common in minority populations, particularly among African Americans. Approximately 60% of our study participants were racial/ethnic minorities; 45% of study participants were African American.

Given that the study focused on the language environment of infants, children were included in the sample. The study recruited neonates and collected data on these infants when the infant was between 32-40weeks corrected gestational age.

Statistical analysis

Descriptive statistics were analyzed for all study variables and reviewed for normality assumptions, outliers, and implausible values. The extent of missing data was reviewed and assessed for any significant associations. Initial bivariate associations were assessed using correlation (Pearson's correlations for continuous measures, Spearman's rho for ordinal and non-normally distributed measures). Multicollinearity was assessed using variance inflation factors and condition index. Confidence intervals were calculated for all effect sizes associated with the predictor variables and other significant outcome effects. The effect size estimates will be used to design a future K study. All data was analyzed using SPSS version 24 with α=0.05.

Specific Aim 1—To characterize the language environment of NICU-admitted infants born < 38 weeks gestation: Adult word count, number of conversational turns, and percentage of language in the audio environment were generated automatically and downloaded from the LENA digital language processors.

Specific Aim 2—To identify determinants of language exposure: The dependent variables were adult word count (count data) and meaningful speech (continuous) as measured by LENA. The predictor variables were sociodemographics, parental self-efficacy, stress, type of NICU design, nurse-to-patient ratio, and clinical risk factors. Non-parametric methods were used to analyze the data because the dependent variables did not follow a normal distribution. Negative binomial regression and gamma log-link regression were used to identify predictors of adult word count and meaningful speech, respectively. The scaled deviance and likelihood chi-square were used to determine the best fitting model.

Specific Aim 3—To identify determinants of parent visits in the NICU: The dependent variable was the percentage of time in which parents visited during data collection. Predictors variables included sociodemographics, parental self-efficacy, perceived NICU-related stress, type of NICU design, and clinical risk factors. Initial bivariate relationships between parent visits and predictor variables were determined using Pearson's correlation. A general linear model was used to evaluate determinants of parent visits. Goodness of fit was determined by chi-square.

Limitations

A child's individual language environment likely differs from day to day. Given this natural variation, the LENA Research Foundation advises researchers to assess the language environment at least 12 hours for three times for maximum validity.[124] For this reason, language was assessed four times for a period of 12 hours each. There also may have been a Hawthorne effect in that parents and staff may have changed how much they talked with the infant in response to the study and the presence of LENA. However, previous studies have demonstrated that this effect is generally only seen within the first one to two hours of the recording as it is difficult to sustain a change in behavior over the entire length of time in which the language processor is recording.[124] It is not clear whether the infant could hear all the words recorded by the language processor due to other NICU noise or deficits in hearing. While this is an important consideration for future studies evaluating the effect of language on infant outcomes, it was not necessary to deduce whether the infant hears all words recorded by LENA in order to achieve the aims of this study. Also, the time in which parents visited may not be accurate. Parents may have forgotten to sign in on the visitor log or put the incorrect time or nurses may have not been exact in what time they charted parental presence. Finally, participants were recruited from two NICUs at non-birthing hospitals, potentially limiting the generalizability of findings as the language environment may be very different in a NICU setting at a birthing hospital or a NICU with a different design.

Summary

Preterm infants, who represent 12% of infants in the United States, have disproportionately higher rates of language delays and poor educational outcomes compared to term infants.[125] Given the importance of early language exposure for a child's language development and academic trajectory, it is possible that high rates of language delays in preterm infants may be related to the language environment in the neonatal intensive care unit (NICU). This study is an important first step in characterizing and identifying determinants of preterm infants' language environment in the NICU, as understanding the language environment is necessary to identify whether interventions are needed to prevent language deprivation, and thus promote language development, in preterm infants. Given that early parent-infant interactions are known predictors of children's developmental outcomes, this study also sought to identify predictors of parent visits in the NICU. Three manuscripts written for publication in a peer-reviewed journal are included in this dissertation, including a detailed, updated integrative review on the influence of early language exposure on children's language and cognitive outcomes (Chapter Two), a manuscript characterizing and identifying determinants of preterm infants' language environment in the NICU (Chapter Three), and a manuscript identifying predictors of parental presence in the NICU (Chapter Four). A comprehensive summary of the results of this dissertation along with implications for future research and clinical practice are included in Chapter Five.

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CHAPTER TWO

Influence of Language Nutrition on Children's Language and Cognitive Development: An Integrated Review

Abstract

Background: Early childhood is a critical period for language and cognitive development. Evidence suggests that children need "language nutrition", or language-rich interactions with caregivers, for optimal language and cognitive development. This integrated review was conducted to evaluate the influence of language nutrition, through talking, interacting, or reading, in early childhood and language or cognitive development.

Methods: Articles published from 1990-2014 were identified through PubMed, CINAHL, and Web of Science databases and through reference lists of identified articles. Of the 1273 articles identified, 103 articles met the search criteria.

Results: Aspects of speech, including the quantity of words, lexical diversity, linguistic and syntactical complexity, intonation, and prosody, all contribute to the comprehension and production of language through enhancing speech processing, phonemic awareness, word segmentation, and knowledge of grammatical rules. In addition to features of language, the delivery of language contributes to variance in developmental outcomes. Language delivered in the context of an adult-child interaction characterized by responsiveness and positive regard helps to scaffold a child's learning and encourages verbal behaviors. Additionally, shared reading increases language and literacy skills by introducing new vocabulary and facilitating dialogue between children and adults.

Conclusion: In conclusion, studies consistently demonstrate that quantity and quality of talking, interacting, and reading with a child in the first three years of life are strongly

associated with language and cognitive development as well as school readiness and academic performance. As a result, interventions aimed at increasing the quality and quantity of language nutrition have the potential to leverage dramatic results for children's developmental outcomes.

Introduction

Early childhood is a critical period for developing language skills, including learning to understand and speak language (National Research Council, 2000; National Scientific Council on the Developing Child, 2007). Research suggests that neural networks for language acquisition are present before birth and that children begin to learn language in utero, suggesting that infants' brains are primed to learn language (Kisilevsky et al., 2009; Perani et al., 2011). Throughout the first three years of life, 85% of all neuronal connections, including those involved in language learning, are formed in response to environmental experiences and the majority of children begin to talk by the age of three (National Research Council, 2000).

Language learning is crucial for a child's developmental trajectory. Language skills enable a child to communicate with others in his or her environment, which encourages the development of cognitive skills and promotes socio-emotional regulation through social interactions. Evidence indicates that a child's vocabulary at the age of three is a key predictor of a child's ability to read at third grade, which is a powerful predictor of subsequent academic success; children who cannot read at grade level by the end of third grade are four times more likely to drop out of high school than those who can read (Dickinson & Porche, 2011; Fiester & Smith, 2010; Rowe, Raudenbush, & Goldin-Meadow, 2012). In fact, a child's language skills more strongly predict third grade reading comprehension than parent income, ethnicity, and level of parent education (Dickinson & Porche, 2011). In the 2013 Nation's Report Card, the National Assessment of Educational Progress reported that only 35% of fourth graders in the United States could read at grade level (National Center for Education Statistics, 2013). This low literacy rate among school children has enormous educational, health, and economic implications, not only for the individuals but also for the nation (Fiester & Smith, 2010; Foundation, 2009; National Center for Health Statistics, 2012; Sum, Khatiwada, McLaughlin, & Palma, 2009). Given that a child's language skills predict third grade reading comprehension, strategies to promote language learning in early childhood are needed in order to improve educational outcomes in our nation's children.

One strategy to promote language learning may be through improving the child's early language environment by increasing a child's access to "language nutrition," or early language exposure that is rich in both quantity and quality and may occur in a variety of different ways—simply through talking, interacting, or reading with a child. "Language nutrition" refers to the idea that an environment with sufficient language exposure is critical to facilitate, or nourish, a child's brain (The Campaign for Grade Level Reading, 2014). Indeed, research has demonstrated that language nutrition from parents and caregivers is critical for a child's neurodevelopment, including both language and cognitive skills (Forget-Dubois et al., 2009; Hoff, 2013). In a renowned study by Betty Hart and Todd Risley, children in low-income families heard, on average, thirty-million fewer words than children in more affluent families from birth to the age of three (Hart & Risley, 1995). This inequality in language nutrition, referred to as the "word gap", has been shown to result in disparities in language and cognitive outcomes for children as young as 18 months old and recently has become a key target for improving educational opportunities on a national level (Fernald, Marchman, & Weisleder, 2013; Halle et al., 2009).

The critical role of language nutrition for language and cognitive development can be understood through the usage-based theory of language acquisition (Tomasello, 2009). The usage-based theory of language acquisition posits that language learning occurs on the basis of linguistic input and through generalizations made by understanding how others use language (Tomasello, 2009). In order to learn language, children must discern the intentions of speakers through social cognitive processes and must find patterns in language to create abstract linguistic constructions (Tomasello, 2009). In other words, children learn language by extracting it from a larger utterance and connecting it to the relevant aspects of the experience shared with another person. This can be done through identifying words of a particular type (categorization), forming sequential units (chunking), memory, mapping a known pattern onto a new form (analogy), and linking form to meaning (cross-modal association) (Tomasello, 2009). As such, this theory suggests that language learning occurs through language input by means of social interactions and cognitive processes that serve to make sense of social communication.

Vygotsky's sociocultural theory and Bronfenbrenner's ecological systems theory further describes the role of social interactions on the language and cognitive development of young children (Brofenbrenner, 2005; Vygotsky, 2005). Vygotsky's sociocultural theory illustrates this relationship through the concept known as the "zone of proximal development" (Vygotsky, 2005). The zone of proximal development focuses on the area between what children are able to do independently and what they are capable of doing with guidance from another, more capable person (Vygotsky, 2005). Language nutrition may help a child's learning by providing children with the opportunity to learn new words and concepts and to participate in conversations. Likewise, Bronfenbrenner's ecological systems theory proposes that a child's development is influenced by the environment and the people with whom the child interact (Brofenbrenner, 2005). Thus, these theories provide additional support that learning and development occurs through social relationships and interactions between a child and the people in his or her surrounding environment (Vygotsky, 2005; Brofenbrenner, 2005).

As interventions to "bridge the word gap" develop around the country, it is important to understand the relationship between language nutrition during the first three years of life and subsequent language and cognitive outcomes in children. The purpose of this integrated review was to investigate the influence of language nutrition in the first three years of life on language and cognitive outcomes by examining available literature.

Methods

An integrated review of the literature was conducted on the influence of language nutrition, which includes caregiver language input, social interactions, and shared reading experiences, during early childhood, on subsequent language and cognitive outcomes. An integrative review is a research review method that allows for the simultaneous inclusion of diverse methodologies, variables, issues, and populations; as such, the integrative review methodology enables a variety of perspectives to be synthesized systematically (Whittemore & Knafl, 2005). Talking was defined as any word input, including both quantity and quality of speech. Engagement was defined as parent interactions with the child. Vocabulary included both receptive and expressive vocabulary. Language outcomes included language acquisition and conversational skills and cognitive outcomes included measures of executive function and academic achievement. A search strategy was developed by three of the authors with terms related to outcomes, exposures, and population of interest. The following search terms were used: (infant OR baby OR newborn OR toddler) AND (infant-directed speech OR child-directed speech OR talk OR read OR engagement OR interact) AND (parent OR caregiver) AND (literacy OR language acquisition OR vocabulary OR cognition OR language development OR neurodevelopmental outcomes). To maximize the sensitivity of the search strategy, no filter for type of study was used. The search was limited to articles published in the English language between January 1990 and August 2014. A systematic search protocol was followed using the defined search terms and was conducted through the following electronic databases: PubMed, Web of Science, and Cumulative Index to Nursing and Allied Health Literature (CINAHL). Reference lists of identified relevant articles were manually searched for additional eligible articles not detected by the electronic search.

All observational studies, randomized control trials, meta-analyses, and systematic reviews assessing the relationship between language nutrition (talking, interacting, or reading during early childhood) and language, vocabulary, or cognitive outcomes were included. Inclusion criteria were defined prior to beginning the search. For inclusion, the articles had to meet the following criteria: 1) examine talking, interacting, or reading by caregiver; 2) children had to be 0-36 months old at the first or all assessments; 3) evaluate language or cognitive outcomes; 4) be a primary-research article, secondary data analysis, meta-analysis, or systematic review; and 5) be in a peer-reviewed journal. Studies were included even if the primary objective of the study was not to evaluate the relationship between language nutrition (talking, reading, or interacting) and language or cognitive outcomes as long as they included data on these exposures and outcomes. Titles, abstracts, and full-text articles were reviewed for eligibility.

The combined search strategy yielded a total of total of 1480 articles. After 207 duplicates were removed, 1,273 articles remained for the initial review of titles and abstracts were marked for inclusion or exclusion by the first author using the criteria defined by all authors. Following title and abstract review, 392 articles were identified as potentially relevant and were included for full text review. Following full text review, a total of 103 articles were identified as meeting all of the specified criteria of the search. Questions regarding the inclusion or exclusion of certain articles were discussed amongst the authors. The most common reasons for article exclusion based on title, abstract, or full-text review were related to the age of study participants, purpose of article, exposure of interest and outcome measures, and type of study. Figure 1 details the process of article identification.

Information about each article was coded and entered into a table. Information extracted from each article included: the purpose and design of each study; study size, participant ages, and characteristics of the sample; instruments used to assess parent talk, reading, or engagement; outcome measures; results; and limitations. Two authors entered information about each article into the tables under the supervision of another author. A summary table can be found in the supplementary material of this article.

Results

Description of samples

The samples included in this review varied greatly in terms of the children's current developmental status, socioeconomic background, and languages spoken in the home. Eight studies (7.8%) included samples of very preterm infants, four study samples (3.9%) consisted of children with permanent hearing loss, and nine studies (8.8%) included samples of children with language delays. Information about socioeconomic background was not always reported but was primarily reported using maternal education or income as a proxy based on actual household income, eligibility for Early Head Start programs, eligibility for Medicaid, or geographic area. Other socioeconomic factors that were considered in studies included neighborhood safety, stressful life events, and unemployment. Nearly a quarter of the studies (N = 23) specifically mentioned that their sample consisted of children from low-income families. The entire sample of four studies were enrolled in an Early Head Start program. There were twelve studies (11.8%) in which the children's first language was not English; of these studies, 75% (N = 8) spoke Spanish. Other languages included German, Swiss, Italian, and Mandarin. Mothers represented the majority of parents or caregivers for which language nutrition was assessed. Only 8.8% of the studies (N = 9) considered the contributions of language nutrition provided by fathers.

Sample size ranged from three participants to 6,270. Excluding reviews, the sample size of 39% of studies (N = 37) was less than 50, with 25% of studies (N = 24) less than 30 participants. Twenty-seven percent (N = 26) of studies had between 51-100 participants. Studies with a sample size over 500 represented 12.6% (N = 12) of the studies.

At the time at which the input of the caregiver was assessed, participants ranged in age from 32 weeks corrected gestational age to thirty-six months. Less than 10% (N = 9) of studies assessed caregiver input to children less than six months old. Twenty-nine percent of studies (*N* = 28) assessed infants between 6-11 months. Nearly half of studies (47%) assessed toddlers between 12-17 months old; similarly, toddlers between 24-29 months old and 30-36 months old were assessed in 48% and 43% of the studies, respectively. Thus, the majority of the findings in this review are reflective of language nutrition provided between the ages of 12-30 months and a minority of findings relate to language nutrition received by children less than one year old.

At the time at which language or cognitive outcomes were assessed, participants ranged in age from six months to eight years old. Six studies (6.2%) assessed children who were six to eleven months old; 20 studies (20.6%) assessed children between 12-17 months; 16 studies (16.5%) assessed children who were 18-23 months old; 34 studies (35.0%) assessed 24-29 month olds; 17 studies (17.5%) assessed children who were 30-35 months old; 23 studies (23.7%) assessed children between the ages of three and four years old; ten studies (9.7%) assessed four to five year old children; and five studies (4.9%) assessed children over the age of five.

Description of study designs and methods

The studies employed a variety of research designs. Seventy-four (72%) of the articles were prospective cohort studies, in which the outcome was assessed at a different time point than the initial assessment of the child's language environment. The majority of these articles assessed caregiver speech or parent-child interactions at more than one time point. Eleven studies were experimental (10.7%) in which the primary aim was to evaluate an intervention aimed to improve shared book reading, increase caregiver talk, or promote caregiver-child interactions. Of these experimental studies, eight were randomized control trials. Ten studies (9.7%) were cross-sectional and six were reviews (5.8%).

Excluding reviews, 69 (71.2%) of the studies assessed caregiver input through observations, primarily through free play or semi-structured play sessions that were video- or audio-recorded and then either transcribed or coded for features of interest to the study. Additionally, 17 studies (17.8%) assessed language nutrition through parent self-report and thirteen studies (13.4%) used either the StimQ or Home Observation of Measurement of the Environment, which assess parental verbal responsivity, parental involvement in developmental activities, availability of learning materials, and reading activities in the home (Caldwell & Bradley, 2003; Dryer, Mendelsohn, & Tamis-LeMonda, 2014). Other measures were also used within individual studies but were not consistently used across studies in the review.

Several studies used multiple instruments to assess children's developmental outcomes. The most commonly used standardized assessment to measure language or cognitive development was the MacArthur-Bates Communicative Development Inventories (MCDI). The MCDI are parent-completed instruments that capture information about the development of vocabulary comprehension and production, gesture use, and grammar in children ages 8-30 months (Fenson et al., 2007). Thirty-six (37.1%) of studies in the review assessed receptive and expressive language skills using the MCDI. Other commonly used language tests included the Peabody Picture Vocabulary Test (PPVT) (*N* = 16), which assesses receptive language skills in children over 30 months, the Preschool Language Scale, (*N* = 9), which assess developmental language skills of children up to eight years old and the Sequenced Inventory of Communication

Development (*N* = 9), which assess receptive and expressive language skills in four month old children through the age of four years (Dunn & Dunn, 2007; Hendrick, Prather, & Tobin, 1984; Zimmerman & Castilleja, 2005). The majority of studies that assessed cognitive development used the Bayley Scales of Infant Development Mental Development Index (BSID), which tests for children's expressive and receptive language development, sensory-perception knowledge, memory, attentional control, and problem solving skills up to the age of 42 months (Bayley, 2006). Twenty-two studies in the review (22.6%) used the BSID. The Reynell Developmental Language Scales and the Woodcock Johnson Tests of Achievement were most commonly used for children whose language or school readiness was assessed over the age of three. The Reynell Developmental Language Scales is used to assess vocabulary comprehension and expression in children ages three to seven years old and the Woodcock Johnson Tests of Achievement assess various aspects of academic achievement including letter/word identification, vocabulary comprehension and production, reading, writing, and mathematics (Edwards, Garman, Hughes, Letts, & Sinka, 1999; Woodcock, McGrew, & Mather, 2007) .

Description of study purposes

Studies included in this review examined the influence of the quantity of words, lexical diversity, grammatical complexity, syntactic diversity, and intonation and prosody in caregiver speech and caregiver's use of gestures on children's receptive and expressive language skills, cognitive development, grammar, syntax, and school readiness. Many studies looked at multiple features of caregiver speech. Additionally, studies addressed the contributions of contingent and responsive speech, joint attention, and interactions built on positive affect. Twenty studies (19%) in this review specifically evaluated the influence of the frequency, duration, and quality of shared book reading on children's development.

The majority of studies, or 88% (N = 91), evaluated the relationship between language nutrition and expressive vocabulary skills whereas slightly fewer (80%, N = 83) looked at receptive language skills. Most of the studies that evaluated language skills assessed both receptive and expressive language together. In addition, two studies assessed the relationship between language nutrition and syntactical complexity of children's speech and two studies assessed children's linguistic productivity, as measured by mean length of utterance. Four studies evaluated the relationship between caregiver language input and speech processing abilities.

Far fewer studies (31%, N = 33) examined the contributions of caregiver language, interactions, and reading on children's cognitive development, or executive function. Three studies specifically assessed literacy skills, three studies assessed school readiness, and two studies assessed mathematical ability.

Findings related to parent or caregiver talk and child development

Quantity of words. Nineteen studies were categorized as evaluating the relationship between the quantity of words spoken to a child and language outcomes. Eight of these studies specifically focused on overall quantity whereas eleven studies focused on word frequencies. Significant variability in the quantity of caregiver speech directed towards infants or young children was observed in these studies, with differences in linguistic input as large as eighteen-fold (Hurtado, Marchman, & Fernald, 2008; Weisleder & Fernald, 2013). Although variation in caregiver speech was observed across socioeconomic groups, large differences were also noted within samples that consisted of all middle-socioeconomic or all low-socioeconomic families. This variation highlights the importance of considering a methodological approach that unpacks the definition of SES and evaluates the contributions of parent education, stress, living conditions, access to resources, neighborhood safety, and household income as individual factors.

A variety of measures were used to quantify caregiver speech, including recordings of mother-child interactions in which the words were counted by study personnel or through digital language processors that were developed by the LENA (Language Environmental Analysis) Research Foundation to capture all words spoken in the infant's or child's environment. Studies that utilized the LENA digital language processors were able to assess child-directed speech over a much longer period of time in the home environment, or up to 16 hours each day, compared to studies that video or audio recorded a parent-child interaction for five to ten minutes in either the home environment or a laboratory setting. As a result, studies that utilized the LENA digital language processors may have greater validity as this technology may minimize the potential artifacts introduced by observers.

Studies assessed the quantity of speech directed at children ranging in age from 32 weeks corrected gestational age to 19 months old and assessed child-directed speech between 18 months to 3.5 years. Outcome measures included word production during recorded parent-child interactions as well as various standardized tests of language development and cognitive development.

One study evaluated the association between the quantity of child-directed speech and cognitive outcomes. In a sample of very preterm infants, language input was assessed through LENA digital language processors in the neonatal intensive care unit when the infant was 32 weeks corrected gestational age (Caskey, Stephens, Tucker, & Vohr, 2014). The number of words spoken to an infant accounted for 20% of the variance on cognitive scores on the Bayley Scales of Infant Development at 18 months corrected gestational age (Caskey et al., 2014). While the study lacked sufficient power and only controlled for birthweight as a potential confounder, these results suggest that the quantity of child-directed speech in the earliest stages of infancy are significantly related to a child's long-term cognitive development.

All studies suggested that the quantity of linguistic input predicts later vocabulary of a child. Quantity of child-directed speech resulted in significant variability in both expressive and receptive language (Hurtado et al., 2008; Rowe, 2008; Rowe, 2012; Shneidman & Goldin-Meadow, 2012; Weisleder & Fernald, 2013; Zimmerman et al., 2009). These results remained the same even when controlling for earlier child vocabulary, ruling out the explanation that more talkative children elicit more speech from caregivers. In one study that assessed the quantity of child-directed speech using LENA digital language processors one day a month for 6-18 months in children 2-36 months old (13.8 $\pm$ 10.0), each additional 1000 words spoken to a child was associated with a 0.44 point (95% CI: 0.09-0.79) increase on the Preschool Language Scale-4th edition, which measures both receptive and expressive language (Zimmerman et al., 2009). Additionally, another study found that each increase in standard deviation in the number of words from a primary caregiver at 30 months old was positively associated with a 0.54 standard deviation in the child's Peabody Picture Vocabulary Test (PPVT) scores at 42 months old (Shneidman, Arroyo, Levine, & Goldin-Meadow, 2013).

Interestingly, the relationships observed in both studies were completely mediated by caregiver engagement with the child through contingent comments or the back-and-forth communication between a child and a caregiver (Shneidman et al., 2013; Zimmerman et al., 2009). These results suggest that while the quantity of child-directed speech promotes the acquisition of vocabulary, the social context in which these words are delivered matters.

More linguistic input also shapes children's lexical processing efficiency. Two studies evaluated the relationship between language input and the lexical processing speed of children using the look-while-listening task (Hurtado et al., 2008; Weisleder & Fernald, 2013). This task involved presenting a child with pictures of two familiar objects and with speech naming one of the objects. The gaze pattern of these children were videotaped in order to capture the child's reaction time to look towards the target picture. Greater child-directed speech of caregivers was associated with faster processing speed and accounted for 18-26% of the variance in the mean reaction time to words, controlling for sociodemographics (Hurtado et al., 2008). Additionally, processing speed mediated the relationship between child-directed speech and vocabulary knowledge, suggesting that faster processing speech reflects a more efficient uptake of lexical input provided by caregivers (Hurtado et al., 2008; Weisleder & Fernald, 2013). Vocabulary knowledge and processing efficiency are interdependent and thus, it may also be possible that as vocabulary develops, more refined processing skills mature (Weisleder & Fernald, 2013).

There are several mechanisms by which a greater quantity of speech directed towards a child results in improved vocabulary knowledge and development. First, more speech may provide children with more opportunities to interpret language and be exposed to words. This possible mechanism is supported by evidence that suggests that the frequency of exposure to a certain word predicted knowledge of this specific word. This relationship is seen both before and after a child begins talking with words. Production of nouns, verbs, pronouns, numbers, and wh-question words (eg. where, what, why, when) are all associated with the frequency of concurrent or prior exposure to the word (Brent & Siskind, 2001; Gunderson & Levine, 2011; Hampson & Nelson, 1993; Huttenlocher, Haight, Bryk, Seltzer, & Lyons, 1991; Lyytinen, Eklund, & Lyytinen, 2003; Majorano, Rainieri, & Corsano, 2013; Naigles & Hoff-Ginsberg, 1998; OshimaTakane, Goodz, & Derevensky, 1996; Rowland, Pine, Lieven, & Theakston, 2003; Tardif, Shatz, & Naigles, 1997; Taumoepeau & Ruffman, 2006). Second, it is possible that more exposure to language provides more opportunities for children to develop and refine the skills necessary for language learning, such as segmentation of words in speech and phonological awareness. Third, children may be exposed to more semantics, syntactical compositions, and grammatical combinations from which they can learn new words and develop their vocabulary as well as become more familiar with the structure and rules of the language spoken to them. Being able to better understand or predict the meaning of language input from caregiver may facilitate their ability to identify and interpret unfamiliar words in sentences and contribute to greater vocabulary growth and language skills. Each of these possible explanations are consistent with the usage-based theory of language acquisition (Tomasello, 2009).

Lexical Diversity**.** Quantity of words is highly correlated with lexical diversity, or the number of different words a parent speaks to his or her child. Five prospective cohort studies examined the association between lexical diversity and language or cognitive outcomes. All studies assessed lexical diversity through videotaping interactions between the parent and the child. Ages of the children in the samples at the assessment of lexical diversity ranged from one month to 36 months old. Sample size was very different as studies ranged in size from 15 to 1292 children. All studies that examined the influence of lexical diversity on language or cognitive outcomes reported significant findings.

Evidence suggests that the number of different words in adult speech is a predictor of language development apart from the quantity of words (Pan, Rowe, Singer, & Snow, 2005; Pancsofar, Vernon-Feagans, & Family Life Project, 2010; Shneidman & Goldin-Meadow, 2012). In a study of 24-month-old Mayan children, each increase in standard deviation for the amount of different words in adult speech was associated with an increase of 0.89 standard deviations in vocabulary scores on the PPVT and Early One Word Picture Vocabulary Test and accounted for 55% of variance in scores at 35 months (Shneidman & Goldin-Meadow, 2012). In fact, lexical diversity may be a stronger predictor of language development than the total amount of words directed at an infant (Pan et al., 2005). In a prospective cohort study with a sample of 108 low-income mother-child dyads, the independent roles of quantity of words, lexical diversity, and gestures of maternal communication on children's vocabulary production were assessed for one to three year old children during free play sessions (Pan et al., 2005). Diversity of maternal vocabulary predicted growth in child vocabulary production and more strongly predicted child vocabulary compared to the quantity of words (Pan et al., 2005). This relationship was strongest around 24 months of life, suggesting that the developmental timing of lexical diversity may be related to vocabulary outcomes (Pan et al., 2005). This result also suggests that it may be possible that developmental timing may be important for other features of caregiver speech.

Interestingly, two studies have suggested that the relationship between socioeconomic status and child language outcomes is at least partially mediated by differences in caregiver lexical diversity (Burchinal, Vernon-Feagans, & Cox, 2008; Huttenlocher, Waterfall, Vasilyeva, Vevea, & Hedges, 2010). In one study with a sample of 1,292 children from rural low-income communities, lexical diversity at six months was a mediator of the negative association between social risk factors, including maternal education, family income, single parent family, number of children in the home, number of stressful life events, unemployment, and neighborhood safety, and infant cognitive outcomes at 15 months, as measured by the Bayley Scales of Infant Development—II (Burchinal et al., 2008). In addition to lexical diversity, maternal sensitivity and warmth as well as learning and literacy activities both mediated this association as well (Burchinal et al., 2008). These results suggest that the lack of access to learning opportunities and parental engagement may account for reasons why social risks negatively affect child outcomes (Burchinal et al., 2008).

Exposure to speech characterized by lexical diversity provides children with more opportunities to expand their vocabulary by learning new words. Hearing a different word not only enables a child to learn the meaning of this word but also exposes a child to various phonological patterns. Additionally, exposure to a variety of words allows children to hear words in different contexts or with different descriptions, which may help children learn about that word. For instance, the same word (ex. "ball") may be used in two different sentences (ex. "The ball is round and red" and "I'm rolling the ball to you!") to convey different information about that word. This diversity also helps a child learn more about that word. Similarly, if a caregiver uses a variety of words in a sentence or phrase, the child may know some but not all of the words the caregiver says. Knowing other word meanings in a sentence constrains possible interpretations of a new word and thus, the lexical diversity of the sentence may contribute to children learning the meaning of a new word. These studies highlight the importance of lexical diversity in caregiver speech.

Linguistic productivity. Linguistic productivity refers to the ability to use language to construct new phrases or sentences. Mean length of utterance (MLU), or the average number of words in an utterance, is commonly used to assess linguistic productivity because generally longer utterances tend to be more grammatically complex, with a greater diversity of grammatical categories, such as verbs, nouns, and adjectives. While linguistic productivity is typically examined as a measure of language proficiency and grammatical competencies in children, five studies assessed the relationship between linguistic productivity of parent speech and the language outcomes of young children. Four of these studies were prospective cohort studies whereas the other study was cross-sectional. Three of the five studies utilized the same study population consisting of 63 children ages 18-29 months in middle to high-income families (Hoff-Ginsberg, 1998; Hoff, 2003; Hoff & Naigles, 2002). All studies assessed linguistic productivity through determining the MLU during audio-recordings of a parent-child interaction, and used either a standardized measure to assess vocabulary outcomes or assessed language production in the audio-recordings.

Evidence suggests that increased MLU is associated with increased lexical diversity in parent speech and advances a child's language learning (Bornstein, Haynes, & Painter, 1998; Hoff, 2003; Hoff & Naigles, 2002). Both increases in vocabulary as well as increased MLU in children's speech have been observed as a result of greater MLU in parental speech directed at an infant or young child (Hoff-Ginsberg, 1998; Szagun & Stumper, 2012). These results suggest that greater MLU is associated with advancing more complex linguistic development.

Syntax**.** Few studies have examined the relationship between the syntax in parent language and children's language outcomes. Three studies have explored whether a possible association exists between syntactic structures in parent language and a child's language development (Huttenlocher et al., 2010; Naigles & Hoff-Ginsberg, 1998; Read, 2014). Of these studies, one was a randomized control trial that manipulated the location of various words and ways in which language was presented whereas the other two studies were prospective cohort studies. All three studies assessed parent syntax by videotaping or observing an interaction between a child at least 14 months old and his or her parent.

Differences in syntactic structures in language input may affect a child's language growth. In addition to promoting vocabulary and grammatical complexity of child speech, syntactical diversity in parent speech may contribute to a child's understanding and use of syntax. In a study of 146 infants ages 14-46 months, clausal diversity, or ways of combining clauses, in child speech was predicted by maternal clausal diversity and the frequency of clausal use (Huttenlocher et al., 2010). Similarly, a child's constituent diversity, or the use of adverbs, adjectives, prepositions, and possessives in a clause, was also predicted by maternal constituent diversity (Huttenlocher et al., 2010). In other words, the frequency of specific syntactic structures by mothers predicted the timing of acquisition of those structures in children's speech. Syntactic structures that were more frequently used in maternal speech occurred earlier in children's speech. These findings suggest that more syntactically diverse maternal speech leads to more advanced syntactic development in a child's productive language.

Syntactic frames may contribute to the ability of the child to learn a word by providing additional clues about the word's meaning. For example, verbs that appear with a prepositional phrase usually involve motion, mental state verbs usually are accompanied by sentence complements, and causative verbs usually appear with a direct object (Naigles & Hoff-Ginsberg, 1998). By introducing words to children in predictable ways, children can better understand the meaning of new words being presented, given their knowledge of the words usually associated with such syntax.

Similarly, the position of words in a sentence may affect the ease of language acquisition. Positional salience, or the position where the word is most noticeable, may help infants and young children extract the word from the rest of the sentence. For instance, verbs positioned in the final position of an utterance were found to be predictors of verb acquisition (Naigles & Hoff-Ginsberg, 1998). In another study, children ages two to four years identified more target words in predictive rhyme conditions, or when the target word was at the end of a rhyming stanza or when there was a pause before the word (Read, 2014). These studies show that the way in which new words are set up affects how well children learn and retain new words.

Intonation and prosody. "Parentese", sometimes also referred to as "motherse" or "infant-directed speech", is a style of communicating with infants and young children that is seen across most cultures and languages. This speech is characterized by varied intonation and prosody, expanded pitch range, elongated vowel and consonant sounds and repetition. Two studies, one of which was a systematic review of 144 studies, investigated whether the intonation and prosody of caregiver speech affected the acquisition of language in children (Saint-Georges et al., 2013; Song, Demuth, & Morgan, 2010).

To evaluate the role of specific aspects of "parentese", one study manipulated the characteristics of speech directed at 19 month old toddlers. In this study, toddlers were presented with pictures of a target word and a distractor after listening to "Where's the ___?" in either typical "parentese" style or in a way that lacked one acoustic property of "parentese" (Song et al., 2010). The toddlers were slower to look at the target word when vowels were not hyper-articulated or when the speech was not slow, suggesting that slow speech and vowel hyper-articulation help a young child pick out words from sentences (Song et al., 2010). A systematic review on "parentese" suggested that word segmentation may also be facilitated by the prosodic quality of "parentese" as varying pitch or lengthening words at the end of sentences may provide clues about grammatical units and saliently denote utterance boundaries (Saint-Georges et al., 2013). Faster word segmentation and recognition allows infants to process speech faster, which affects the growth of language acquisition. This review also suggested that differences in characteristics of speech directed at infants have been noted between mothers of late talkers and mothers of early talkers, as mothers of earlier talkers were more likely to use more prosodic features in their speech (Saint-Georges et al., 2013).

Another mechanism by which "parentese" may aid in language acquisition is through the social aspects associated with parentese. "Parentese" usually is accompanied by positive affect of the speaker and used most commonly for praising, playing, teaching, and comforting a young child (Saint-Georges et al., 2013). This emotion is conveyed through "parentese" and the actual intonation and prosodic patterns of "parentese" provide cues about a speaker's communicative intent, whether it be to give comfort, approval, or ask for a child's attentional focus (Saint-Georges et al., 2013). "Parentese" may also help infants learn about objects from other by conveying their feelings about these objects.

Findings from a systematic review have suggested that "parentese" changes as children develop in response to the child's language abilities. The pitch of "parentese" increases from birth until about six months at which the pitch begins to decrease slowly (Saint-Georges et al., 2013). Additionally, exaggeration of vowel or consonant sounds is more frequently heard in parents speaking with infants compared to parents speaking with toddlers (Saint-Georges et al., 2013). These changes may be related to the change in pragmatic functions of speech directed at a child as caregiver speech becomes more informative and less affective as the child develops. However, no studies have evaluated changes over time with "parentese" and how these changes affect children's language or cognitive development.

Gestures. Four studies examined the relationship between gestures and language development in children. All four studies suggested that greater gesture use during speech is related to more advanced receptive and expressive language skills of children ranging in age from 11 months to four years (Goodwyn, Acredolo, & Brown, 2000; Hahn, Zimmer, Brady, Swinburne Romine, & Fleming, 2014; Schmidt & Lawson, 2002; Topping, Dekhinet, & Zeedyk, 2013). This relationship was also observed in children who were at risk for language delays (Hahn et al., 2014; Schmidt & Lawson, 2002). While overall gesture use resulted in improved language skills, two studies examined specific types of gestures. Both studies found that gestures that focused attention, such as proximal pointing, resulted in the greatest number of speech responses from children and better expressive language skills (Hahn et al., 2014; Schmidt & Lawson, 2002). In fact, gestures that did not focus attention or were not coupled with speech did not account for any variance in verbal skills (Hahn et al., 2014; Schmidt & Lawson, 2002). It is possible that language improvements were seen only with gestures that focused a child's attention because these gestures may help a child attend to his or her environment and thus, help scaffold the child's learning. These results suggest that the way parents combine gestures with speech is important.

Another way that gestures may be associated with vocabulary development is through enhancing the ability of children to use gestures themselves. One review discussed findings that gesture use by children was a significant predictor of vocabulary and comprehension and that the relationship between parent gestures and a child's vocabulary size was mediated by the child's use of gesture (Topping et al., 2013). Infants initially communicate through non-linguistic means, such as through gazes, sounds, and gestures, and thus, some words are initially learned and then produced through gesture rather than through language. As a result, early gesturing may be the first step in the comprehension and production of a new word and may lay a foundation for verbal language development.

Findings related to parent/caregiver conversations and child development

Responsiveness. Nearly one-third of articles, or 34 studies, identified in this review addressed the role of responsiveness, most often through contingent speech or joint attention, on children's language or cognitive development. Contingent speech refers to caregiver speech that is delivered as a response to a child's communicative attempts (Hoff, 2006). The content of such speech is dependent upon the focus of the child's communication (Hoff, 2006). Contingency is closely related to the concept of joint attention as well, which refers to the focus of both the caregiver and child on an object and is achieved when one individual cues another to focus their attention on an object through either a verbal or non-verbal communication exchange (Hoff, 2006). The establishment of joint attention involves contingent communication, and thus, the results of studies that looked at either contingent speech or joint speech are presented together.

All but seven studies had a prospective cohort design and assessed contingent speech and joint attention by observing a parent-child interaction, either in a free play session or a semi-structured session designed to facilitate teaching opportunities for caregivers or to elicit play behaviors from the child. Ten of the studies had sample sizes less than 30 and nearly half of the studies had samples less than 50. Interestingly, the samples of fourteen studies were composed of children who had or were at risk for a language or cognitive delay. Six studies included very low birthweight children in their samples, three studies included children with hearing loss, and five studies included children who had a confirmed neurodevelopmental delay. While a range of standardized assessments for language, cognition, and school readiness were used, the MCDI was used in half of the studies. When studies followed children past four years of age, the Stanford Binet Intelligence Scale and Woodcock Johnson Tests of Achievement were regularly utilized to assess various domains of development and school readiness.

Multiple studies suggest that joint attention and speech contingent on the vocalizations or attention of children promotes their acquisition of language and improves both their receptive and expressive vocabulary outcomes (Camp, Cunningham, & Berman, 2010; Girolametto, Sussman, & Weitzman, 2007; Haebig, McDuffie, & Ellis Weismer, 2013; Hoff, 2006; Majorano et al., 2013; Poehlmann & Fiese, 2001; Roberts & Kaiser, 2011; Rollins, 2003; Trautman & Rollins, 2006; Warren, Brady, Sterling, Fleming, & Marquis, 2010; Yoder & Warren, 2002). In fact, 10-18 month old children whose parents scored less than four on the Parental Verbal Responsivity subscale of the StimQ, an assessment of the home learning environment, were 4.33 times more likely to score below the twenty-fifth percentile on the MCDI between 18-30 months compared to children of parents who scored four or greater (Camp et al., 2010). These findings are consistent with other studies that suggest that caregiver verbal responsivity and joint attention are predictive of the timing at which language developmental milestones, such as first word, use of two-word combinations, and use of past-tense, are achieved and may account for up to 64% of variance in vocabulary outcomes in toddlers (Nicely, Tamis-LeMonda, & Bornstein, 1999; Rollins, 2003; Tamis-LeMonda, Bornstein, & Baumwell, 2001; Topping et al., 2013). Additionally, greater grammatical complexity and syntax development has been observed in children of verbally responsive caregivers (Hoff, 2006; Trautman & Rollins, 2006). Remarkably, these results are observed from toddlerhood into early school age as evidenced by improved school readiness, academic performance, and reading comprehension (Dodici, Draper, & Peterson, 2003; Landry, Smith, & Swank, 2003; Martoccio, Brophy-Herb, & Onaga, 2014; Taylor, Anthony, Aghara, Smith, & Landry, 2008). Thus, joint attention and contingency help children develop receptive and expressive vocabulary, phonemic awareness, and school readiness skills.

Improvements in language and cognition are not only observed in normally developing children but also in children who have or are at risk for language or cognitive delays, such as children affected by autism spectrum disorder, preterm birth, sensorineural hearing loss, or fragile X syndrome (Haebig et al., 2013; Janjua, Woll, & Kyle, 2002; Landry et al., 2003; Landry, Smith, Swank, Assel, & Vellet, 2001; Poehlmann & Fiese, 2001; Schmidt & Lawson, 2002; Smith et al., 1996; Warren et al., 2010). Greater reciprocity during play sessions at six months predicted higher cognitive skills as measured by the Mental Development Index of the Bayley's Scale of Infant Development at 12 months, controlling for infant and maternal risks (Poehlmann & Fiese, 2001). Interestingly, the quality of the interaction mediated the relationship between risk and cognitive development for low birthweight infants (Poehlmann & Fiese, 2001). Some evidence suggests that the relationship between the quality of interactions and cognitive development is stronger in high-risk children compared to low-risk children as the shared engagement may promote the development of complex attentional processes that often are compromised in children with developmental delays (Landry et al., 2003;

Landry et al., 2001). By being a child's conversational partner, a caregiver encourages the child to shift his or her attention between the caregiver, an object, and back to the caregiver and coordinate his or her gestures and own vocalizations. Periods of joint attention and contingent comments may held scaffold the child's learning by providing children with opportunities to establish references for words and receive feedback from parents within a shared context. As a result, both the rate of language and cognitive growth increase.

Examples of verbal strategies parents or caregivers use to facilitate joint attention and ways in which parents or caregivers speak contingently include using imitations, interpretations, questions, repetitions, object descriptions, and expansions. A few studies have closely examined the use of these strategies and their influence on language outcomes and found that they were all correlated with larger vocabularies, greater language production, and more grammatically complex speech in children (Cruz, Quittner, Marker, & DesJardin, 2013; Girolametto et al., 2002; Girolametto, Weitzman, Wiigs, & Pearce, 1999; Hampson & Nelson, 1993; Hoff, 2006; Levickis, Reilly, Girolametto, Ukoumunne, & Wake, 2014; Majorano et al., 2013; Pancsofar & Vernon-Feagans, 2006; Szagun & Stumper, 2012). Interestingly, one study suggested that explanations and descriptions in parent speech may be a stronger predictor of a child's vocabulary near the start of pre-kindergarten compared to when the child is younger. These results indicate that the relationship between specific measures of input and language skills may be observed differently at various stages in development.

However, consistent verbal responsiveness throughout infancy and the toddler years appear to both be necessary for improvements in developmental outcomes. The role of maternal responsiveness in predicting cognitive development at various ages was examined in a sample of 282 children at 6, 12, 24, 36, and 48 months (Landry et al., 2003; Landry et al., 2001). Mothers were classified as providing either high or low amounts of contingent responses during both infancy ($\leq$24 months) and toddlerhood (36 and 48 months) (Landry et al., 2003; Landry et al., 2001). Greatest cognitive growth was observed throughout the toddler years up to second grade in children whose mothers provided high amounts of contingency in infancy and toddlerhood, and no developmental differences were seen between children of mothers who provided only high amounts in either infancy or toddlerhood (Landry et al., 2003; Landry et al., 2001). These results suggest that developmental timing for the benefits of contingent speech begin in infancy and continue throughout toddlerhood.

Contingent communication and joint attention may be positive predictors of a child's language outcomes by facilitating the development of language processing skills. Joint attention has been found to be significantly correlated with faster habituation times to looking-time displays, suggesting that shared attention and social engagement play a role in the learning and understanding of language (Dunphy-Lelii, LaBounty, Lane, & Wellman, 2014).

Contingent speech may also provide a mechanism by which pre-verbal infants begin to learn phonological patterns and speech morphology. In a randomized control trial, 64 mothers of nine month old infants were instructed to provide speech to their infant that was either timed to be contingent or non-contingent on their infant's babbling (Goldstein & Schwade, 2008). Infants of mothers who provided a contingent response to their babbling modified their babbling to reflect phonological patterns of their mother's speech; however, infants of mothers whose responses were not contingent did not (Goldstein & Schwade, 2008). These results suggest that infants may incorporate phonological patterns of their caregiver's speech into their own communication, even before they are able to speak words (Goldstein & Schwade, 2008). Given the contingent timing of the caregiver's speech, these results support Vygotsky's Sociocultural Theory, suggesting that language acquisition may occur through social guidance.

If language acquisition occurs through social guidance, it would be expected that language delivered in the context of social engagement would be more predictive of language acquisition than the quantity of words alone. Indeed, several studies have reported greater significance of contingency compared to the quantity of caregiver speech (Camp et al., 2010; Rollins, 2003; Zimmerman et al., 2009). In fact, some studies found that the relationship between the quantity of words and language outcomes is mediated by caregiver contingent comments, joint attention, or the back-and-forth conversation between children and adults (Martoccio et al., 2014; Rollins, 2003; Zimmerman et al., 2009). This finding suggests that quantity of words alone do not predict language skills but rather, that the quality of caregiver speech, namely the conversational aspect of speech, accounts for varying courses of language development in children.

The importance of social engagement through back-and-forth communication is highlighted further through evidence that suggests that the words that a child hears need to be directed at the child in order for them to benefit the child. Overheard speech and media exposure are not positively associated with children's language outcomes, suggesting that language heard but not delivered in the context of an engaged adult-child interaction is not supportive of early lexical development (Weisleder & Fernald, 2013).

Even in a Mayan community, where most of the speech heard by children is overheard speech, overheard words failed to relate to subsequent receptive and expressive vocabulary (Shneidman & Goldin-Meadow, 2012). Furthermore, in three separate studies, adult-child conversations mediated the adverse effects of media exposure on children's language development (Ambrose, VanDam, & Moeller, 2014; Mendelsohn et al., 2010; Zimmerman et al., 2009). These studies indicate the importance of the serve and return of conversations for early childhood language development.

Positive affect and sensitivity. Parent or caregiver communication occurs within the context of social interactions. As such, eleven studies, nine of which were prospective, considered the quality of the social interaction when investigating the relationship between parent or caregiver linguistic input and language or cognitive development. All studies labeled parental behaviors and linguistic input during free or semi-structured play sessions as being characterized by positive or negative affect, sensitivity or intrusiveness, and guiding or restrictive. The Bayley Scales of Infant Development was the most commonly used measure to assess children's language and/or cognitive development as it was used in seven of the eleven studies.

Positive affect, guidance, and sensitivity, defined as the degree to which parents or caregivers responded to child's cues (gestures, expressions, signals, and vocalizations) and recognized child's needs or wants, were consistently associated with increased language and cognitive outcomes throughout infancy and early childhood (Adi-Japha & Klein, 2009; Arevalo, Kolobe, Arnold, & DeGrace, 2014; Dodici et al., 2003; Fagan et al., 2011; Fish & Pinkerman, 2003; Hirsh-Pasek & Burchinal, 2006; Karrass & Braungart-Rieker, 2005; Karrass & Braungart-Rieker, 2003; Masur, Flynn, & Eichorst, 2005; Shannon, Tamis-LeMonda, London, & Cabrera, 2002; Tamis-LeMonda, Shannon, Cabrera, & Lamb, 2004). Interestingly, the benefits of interactions characterized by positive affect, guidance, and sensitivity extended into pre-kindergarten school readiness and performance in first grade language, attention, and academic outcomes and third grade mathematics ability (Arevalo et al., 2014; Dodici et al., 2003; Fish & Pinkerman, 2003; Hirsh-Pasek & Burchinal, 2006; Karrass & Braungart-Rieker, 2003). Remarkably, maternal interactions during infancy accounted for 8-11% of the variance in auditory and language comprehension and production at pre-kindergarten entry and mediated the relationship between having a resident father and cognitive outcomes (Fagan et al., 2011; Fish & Pinkerman, 2003). Conversely, interactions characterized by negative affect, intrusiveness, restrictiveness, and limited acknowledgement of the infant's agency were consistently associated with poorer language and cognitive outcomes (Kelley, Smith, Green, Berndt, & Rogers, 1998; Masur et al., 2005; Murray, Kempton, Woolgar, & Hooper, 1993; Tamis-LeMonda et al., 2004).

While most of the studies looked at maternal affect, guidance, and sensitivity, one study looked at the responsive behaviors and affect of fathers. This study demonstrated that two year old children who scored in the normal range on the Bayley Scales of Infant Development were five times more likely to have a father who demonstrated responsive behaviors and positive affect than children who scored below the mean (Shannon et al., 2002). Because this study was cross-sectional, the directionality of this relationship remains unclear. It is possible that children who exhibit more sophisticated language and cognitive activities elicit more responsive behaviors and positive emotions from fathers. However, given results of other studies that have examined the relationship between fathers and children's development prospectively, it is likely that the behaviors of fathers during child engagement have an influential role in their children's learning and development.

Cognitive-stimulating interactions. In addition to measuring positive affect, guidance, and sensitivity, some studies looked at these measures along with parental involvement in cognitive growth and socio-emotional activities as self-reported by parents or observed in free or structured play sessions. All of these constructs were used to determine the level of cognitive stimulation present in the child's environment. As such, the role of these constructs in these studies cannot be parsed out. All seven studies consistently showed that an environment that fosters cognitive stimulation is associated with improved language and cognitive outcomes.

A commonly used measurement used to capture all these components of parent-child interactions was the Nursing Child Assessment Teaching Scale (NCATS). Higher scores on the NCATS indicate higher levels of parental engagement and were positively associated with receptive and expressive language skills, cognitive development, and literacy outcomes (Lugo-Gil & Tamis-LeMonda, 2008; Magill-Evans & Harrison, 1999; Martoccio et al., 2014). Remarkably, NCATS scores at 14 months were correlated with language and literacy outcomes on the PPVT and Woodcock Johnson Test of Achievement at five years of age, which likely have important implications regarding school readiness and future academic achievement (Martoccio et al., 2014). To add, Lugo-Gil and colleagues reported that the NCATS explained up to 40% of variance on the Bayley Scales of Infant Development at 36 months and that the association between family economic resources, including income per person, parent-living arrangement, and parent education, and the child's cognitive development was completely mediated by scores on the NCATS (Lugo-Gil & Tamis-LeMonda, 2008).

Other commonly used measurements were the StimQ and the Home Observation for the Measurement of the Environment (HOME). The cognitive environment, as measured by the StimQ or HOME, positively predicted the children's skills at kindergarten on the Woodcock Johnson Test of Achievement, Letter Word Identification Test, and the PPVT (Cates et al., 2012; Rodriguez & Tamis-LeMonda, 2011). In fact, the early cognitive environment explained 32% of the variance on the PPVT (Rodriguez & Tamis-LeMonda, 2011). Only 7% of children whose environment was low in cognitive stimulation at 15 months scored above 100 on the PPVT compared to 70% of children whose environment was high in cognitive stimulation at 15 months (Rodriguez & Tamis-LeMonda, 2011).

Activities including teaching children about new things as well as engaging in play also are other ways in which parents or caregivers enrich their child's learning environment. In one study, children whose parents reported that they do not introduce their child to new things were two times more likely to have a language delay than children whose parents did report that they introduce their child to new things (OR = 2.0; 95% CI: 1.38-2.78) (Glascoe & Leew, 2010). It is possible that this relationship was observed because introducing their children to new things may help facilitate word-object mapping and expose them to new words as well. Additionally, in a study that looked at the level of father involvement and child IQ, fathers were classified as either "high-involvement" or "low-involvement" based on maternal report of the amount of time the father-child dyad spent in play between 4-36 months (Yogman, Kindlon, & Earls, 1995).

Mean IQ, as measured by the Stanford-Binet Intelligence Scale, at 36 months was six points higher in children whose fathers were classified as “high-involvement”, after controlling for maternal involvement (Yogman et al., 1995). These findings suggest that the amount of time spent in active engagement with the father has cognitive benefits beyond those conferred from maternal engagement (Yogman et al., 1995).

Findings related to parent/caregiver book reading and child development

Frequency of book reading. Fourteen studies assessed the influence of shared book reading on children’s language and cognitive outcomes. Eight studies were prospective cohort studies; two studies were randomized control trials; two studies were cross-sectional; and two studies were reviews of primarily prospective cohort studies and randomized control trials. Three of the studies, two of which were literature reviews, discussed the shared reading benefits of the Reach Out and Read program, an intervention within low-income pediatric offices at which pediatricians and pediatric nurse practitioners and nurses provide anticipatory guidance about shared book reading as well as distribute children’s books (High, LaGasse, Becker, Ahlgren, & Gardner, 2000; Needlman & Silverstein, 2004; Willis, Kabler-Babbit & Zuckerman, 2007). Children in most samples were between 12 months and 24 months old. Samples ranged in size from 43 participants to over 2,000. The majority of these studies used parental reports of book reading activities and were correlational in nature. All studies assessed receptive and expressive language skills, most commonly with the MCDI or the PPVT; additionally, three studies also assessed cognitive outcomes with the Bayley Scales Mental Development Index.

Evidence suggests that children who are read to frequently have larger vocabularies, greater language complexity, more advanced language comprehension skills, and better cognitive outcomes than children who are not read to or are read to infrequently (High et al., 2000; Lyytinen, Laakso, & Poikkeus, 1998; Needlman & Silverstein, 2004; Raikes et al., 2006; Rodriguez et al., 2009; Schmitt, Simpson, & Friend, 2011; Willis et al., 2007). Studies have suggested that reading frequency may account for between 9-22.5% of variance in vocabulary outcomes (Deckner, Adamson, & Bakeman, 2006; High et al., 2000; Karrass & Braungart-Rieker, 2005; Rodriguez et al., 2009). As a result, high reading frequency may decrease a child's risk for early intervention services or language delays. In fact, one study investigated the association between reading frequency when children were six months and 18 months old and their eligibility for intervention services in New York at 21 months of age (Tomopoulos et al., 2006). Criteria for early intervention services in New York includes scoring two standard deviations below the mean on either the Bayley Scales Mental Developmental Index or the Preschool Language Scale, or scoring 1.5 standard deviations below the mean on both standardized assessments (Tomopoulos et al., 2006). Being read to four or more days per week was significantly associated with a decreased risk of meeting early intervention criteria (adjusted $OR = 0.16$); 75% of children who were read to less than one day a week met eligibility criteria, whereas only 36.8% of children who were read to more than four days a week met eligibility criteria (Tomopoulos et al., 2006). Similarly, children who were read to more than ten minutes per day at nine months old were 2.5 times less likely to have poor vocabulary at school-entry, or score in the bottom 20% on the PPVT, compared to children who were read to less than ten minutes per day (Farrant & Zubrick, 2013). Furthermore, shared book reading may be protective for children who have language delays. Shared-book reading improved the expressive language abilities of two year old children with language delays (Buschmann et al., 2009). By the age of three, 75% of the children whose parents were taught how to read to them had normal expressive language abilities, compared to 44% of the children whose parents were not taught how to read to their child (Buschmann et al., 2009). Together, these studies suggest that shared reading is positively associated with vocabulary development of young children.

Several studies point to the possibility that shared reading may not have the same influence on young children at every age throughout early childhood. In a study of 1046 children from the Early Head Start program, the frequency of engagement in shared book reading and storytelling accounted for 10%, 17%, and 20% variance on the MCDI at 14, 24, and 36 months respectively, controlling for earlier shared reading and storytelling (Rodriguez et al., 2009). Similarly in another study, greater frequency and duration of reading with children 18-25 months old, but not 13-17 months old, significantly improved vocabulary outcomes (High et al., 2000). These findings are also supported by another study in which the influence of book reading at both four months and eight months old was examined and only the frequency and duration of book reading at eight months old predicted expressive language skills at 12 months and 16 months (Karrass & Braungart-Rieker, 2005). These results suggest that shared reading may be more beneficial as children progress throughout their early childhood years, which may be explained by the children’s developmental progress throughout early childhood. As infants develop, their visual acuity becomes increasingly refined, which may assist in the recognition of objects and colors that a caregiver may point to during book reading, and their fine motor skills gradually increase and enable the child to hold and turn pages of the book, which may encourage active engagement in the shared reading experience. Additionally, book reading often introduces new words to a child. Children with larger receptive vocabularies may be able to take greater advantage of the presentation of these new words because the meanings of the new words are constrained by their knowledge of other words. Therefore, it is possible that shared book reading, while beneficial at earlier ages, becomes increasingly influential on children's vocabulary production and comprehension as the child grows older.

While studies support the use of shared book reading for the promotion of child development, these results should be interpreted in light of other research detailing the importance of the richness of language input and shared social experiences. Books provide a tool by which parents and caregivers can engage in conversation with their infant or toddler and introduce new words to their child. However, is shared book reading really a unique predictor of a child's language or cognitive development, or rather, are other measures of parental or caregiver linguistic input (i.e. joint attention, gestures, lexical diversity, number of words) highly correlated with shared book reading and responsible for these associations? In other words, perhaps parents and caregivers who read with their children are more likely to provide an environment that is quantitatively and qualitatively rich in language and thus the variance in language and cognitive outcomes observed in these studies could be explained by this potential correlation rather than book reading.

Few studies have controlled for other factors that promote vocabulary development and language acquisition. In a study of 17-19 month old toddlers (*N* = 1091), communication quality, which included the extent to which mothers were aware of child needs, provided encouragement, described experiences to child, and helped child give attention to things in the environment, was strongly associated with shared reading (Westerlund & Lagerberg, 2008). However, after controlling for mothers' communication quality, reading at least six times per week still added more than a 0.4 standard deviation (medium effect size) in vocabulary scores on the Swedish Communication Screening, the Swedish version of the MCDI (Westerlund & Lagerberg, 2008). In another study, the frequency of being read to accounted for 7% of the variance in expressive vocabulary at 21-27 months old, after controlling for the child's overall exposure to language (Patterson, 2002). These results suggest that there may be a unique relationship between reading and vocabulary development apart from language delivered outside of the context of shared book reading.

Quality of book reading**.** Eleven studies discussed the relationship between the quality of book reading and children's language or cognitive outcomes. Interestingly, the primary aim of five of these studies was to evaluate the efficacy of a parent-based intervention focused on teaching parents skills in dialogic book reading and improving the quality of shared book reading through a randomized control trial design. While the primary aim of these five studies was not to describe the role of the quality of book reading on children's developmental outcomes, they discussed the influence of the intervention on the quality of book reading and linked these outcomes to children's language and/or cognitive development. Like the studies that examined the frequency of book reading, most of these studies obtained a parental report about the shared reading experience; although, a few studies assessed the quality of an observed reading session by the parent-child dyad. All studies assessed the vocabulary of the children in the study sample, most commonly with the PPVT, MCDI, or Expressive One Word Picture Vocabulary Test, and five studies also assessed cognitive development or school readiness.

Quality of book reading, including level of joint attention and extra-textual talk, or talk outside of the words written in the book, may affect the relationship between book reading and language and cognitive outcomes. Nine month old infants with low levels of joint attention during shared book reading, as measured by the Communication and Symbolic Behavior Scales, had poorer vocabulary on the PPVT at 58 months than infants with high levels of joint attention, suggesting that joint attention may affect how reading affects vocabulary development (Farrant & Zubrick, 2013). Likewise, multiple studies have found that inviting children into storytelling by asking children questions, encouraging verbal responses, introducing a diversity of words, and teaching new concepts during reading improves their language comprehension, vocabulary skills, syntactical complexity, and literacy development (Cline & Edwards, 2013; Cronan, Brooks, Kilpatrick, Bigatti, & Tally, 1999; Huebner, 2000; Huebner & Meltzoff, 2005; Pancsofar & Vernon-Feagans, 2010; Valdezmenchaca & Whitehurst, 1992; Westerlund & Lagerberg, 2008). Another study also found that using prompts, praise, and recasts during book reading improved the ability to learn target vocabulary words for 22-41 month old children with expressive vocabulary delays (Tsybina & Eriks-Brophy, 2010). In this study, gains in overall vocabulary were observed but did not reach statistical significance, most likely due to a small sample size and lack of statistical power (Tsybina & Eriks-Brophy, 2010). These studies suggest that not only the frequency of book reading, but also the way in which books are shared with children, contribute to a child's language development.

In fact, quality of book reading may mediate the relationship between the frequency or duration of book reading and children's language or cognitive outcomes. Although no studies investigated this potential mediating relationship, one study found that the frequency of father book reading at 24 months was only predictive of PPVT scores at 36 months for children whose fathers had at least a high school education (Duursma, Pan, & Raikes, 2008). It is possible that a high school education mediated the relationship between book reading and receptive vocabulary outcomes based on the quality and complexity of the language provided during the book reading. However, these measures were not assessed.

Other literacy-promoting activities. Literacy-promoting activities, other than book reading, may also promote language acquisition and cognitive development. Engagement in story-telling, singing nursery rhymes or the alphabet, and participating in activities to learn numbers and letters have been shown to foster development of language and literacy skills (Bronte-Tinkew, Carrano, Horowitz, & Kinukawa, 2008; Rodriguez et al., 2009; Song, Tamis-Lemonda, Yoshikawa, Kahana-Kalman, & Wu, 2012; Topping et al., 2013). In a systematic review, studies suggested that literacy-promoting activities, including shared book reading, enhance vocabulary, language, and literacy skills by providing children with a greater diversity of vocabulary, more complex grammar, opportunities to learn phonemic skills and print concept knowledge, and by facilitating interest in literacy (Topping et al., 2013).

Discussion

The purpose of this review was to examine available literature investigating the influence of language nutrition, or talking, reading, and interacting with a child, in the first three years of life on language and cognitive outcomes. This review highlights the importance of language nutrition for a child's developmental and educational trajectory.

A child's brain grows rapidly in the first three years of life and is dependent upon language nutrition in order to reach its intellectual capacity (National Research Council, 2000). Decades of research consistently indicate the extreme importance of an environment rich in language and social communication. Although evidence shows that the quantity of words spoken to a child dramatically improves a child's language outcomes, possibly by enhancing speech processing, the quantity of words is strongly correlated with measures of the quality of language, controlling for socioeconomic status (Hurtado, Marchman, & Fernald, 2008; Rowe, 2008; Weisleder & Fernald, 2013). In other words, the more words spoken to a child, the more varied, complex, and reciprocal the linguistic input becomes. Speech that is varied in words, grammatical complexity and syntactical structure all aid in the acquisition, comprehension, and production of language and possibly is more strongly related to children's language and cognitive learning than the actual number of words spoken to a child (Hoff-Ginsberg et al., 1998; Hoff & Naigles, 2002; Huttenlocher, et al., 2010). Remarkably, the quality of the linguistic input mediates the adverse effects of preterm birth, low levels of parent education, maternal depression, and poverty on language and cognitive outcomes (Burchinal et al., 2008;

Huttenlocher et al., 2010; Murray et al., 1993; Poelmann & Fiese, 2011). This finding suggests that parents and caregivers have the potential and the power to mitigate the influences of various circumstances that threaten to limit their child's success simply by making their child their conversational partner early and often.

The use and delivery of words in a way that children can easily recognize is a powerful component in laying a secure foundation for development. Studies indicate that the varied intonation and prosody in caregiver speech and positional salience of target vocabulary words aid in phonemic awareness, word segmentation, and an understanding of syntactic structures and grammatical rules of caregiver speech (Naigles & Hoff-Ginsberg, 1998; Read, 2014; Saint-Georges et al., 2013; Song et al., 2010). All of these components are necessary for the acquisition of language. Additionally, caregiver contingent speech, gestures, and establishing joint attention during interactions all have the potential to help children recognize and use words (Hoff, 2006; Martoccio et al., 2014; Rollins, 2003; Schmidt & Lawson, 2002). These methods of communicating with a child respond to their child's focus of attention and verbal responses and thus, help scaffold language learning, support the child's use of their existing linguistic knowledge within an interactive context, and help the child attend to their environment.

While research strongly indicates the positive impact of language input by caregivers on children's development, not all language appears to be beneficial for a child's learning. The use of imperatives and other types of directives that change the focus of child's attention were found to be negatively associated with children's language development (Cruz et al., 2013; Hoff-Ginsberg et al., 1998; Rowe, 2008; Topping et al., 2013). This type of language often has the primary goal of controlling or managing a child's behavior rather than facilitating child engagement. These directives shut down conversation and do not offer children the opportunity to contribute verbally.

Social interaction is an essential ingredient to language nutrition. The importance of social interaction paired with linguistic input was a common thread between the studies in this review. Social relationships drive the need for language—it is the basis by which we communicate with others and so it makes sense that children depend on social input for language learning. Language learning does not occur passively. Interactions between parents/caregivers and the infant and toddler, built upon responsiveness, emotional tone, guidance and encouragement of joint attention, are posited to have an positive influence on the child's language development, controlling for parent education and household income (Dodici et al., 2003; Dunphy-Lelii et al., 2014; Glascoe & Leew, 2010; Lugo-Gil & Tamis-LeMonda, 2008; Masur et al., 2005; Nicely et al., 1999; Poehlmann & Fiese, 2001; Rodriguez & Tamis-LeMonda, 2011; Rollins, 2003; Tamis-LeMonda et al., 2001). Additionally, caregiver speech and actions that encourage verbal responses all invite children to participate in conversation. Thus, caregivers who allow the child to contribute to the discourse in a developmentally expected way, first in attention to the caregiver through communication behaviors such as looks, facial expressions and utterances and later in word approximations, comments and conversation, provide children with the opportunity and modeling needed to promote the child's language development. In essence, the impact of rich and varied language nutrition delivered consistently by caregivers in the context of an engaged and trusting adult-child social relationship provides an essential component for the development of language competence that lays the foundation for academic success. Those who are academically prepared and successful are more likely to profit from education and are likely to lead lives characterized by better health (Robert Wood Johnson Foundation, 2009).

Reading and other activities such as storytelling, singing, and teaching letters or numbers offer evidence-based and concrete methods for which caregivers and children can engage in conversation. These activities introduce new and interesting vocabulary, engage the child in word and phrase play, encourage caregiver-child engagement and turn taking, and lead to greater generative language use (Topping et al., 2013). Such activities can have strong and lasting impact on the child's cognitive processes and diversity of language that result in later reading and language proficiency (Buschmann et al., 2009; Farrant & Zubrick, 2013; Tsybina & Eriks-Brophy, 2010; Westerlund & Lagerberg, 2008). Interventions have focused on counseling parents and other caregivers, such as daycare workers and teachers, on features of shared book reading that facilitate children's language learning and early literacy skills. These interventions represent a promising and potentially scalable framework for which to increase the quantity and quality of caregiver-child interactions.

In all of the studies that were reviewed, less than 10% considered the contributions of fathers to their child's early language and learning environment. While mothers were the most often studied caregiver, fathers and other caregivers are often in the position of providing a cognitively stimulating environment and are key participants in the child's learning experiences (Bronte-Tinkew et al., 2008; Yogman et al., 1995). While the findings of studies that have looked at fathers are congruent with those found in studies examining the role of maternal input, fathers may have a unique role in their child's language and cognitive development. Studies have generally assessed paternal input in the same way as maternal input, but it is possible that this results in a biased assessment of paternal input. In recognition of the diverse social networks and family constellations that comprise an infant's environment and to be consistent with Brofenbrenner's Ecological Systems Theory, future studies should take a more comprehensive approach to evaluating opportunities for children to develop linguistically and cognitively from language nutrition by fathers and other caregivers, including daycare workers, teachers, grandparents, aunts and uncles, and nannies.

There are several limitations of this review that should be considered when interpreting these findings. There is a possibility that some eligible articles were not captured by the literature search and thus are not included in this review. Although three databases were searched in a comprehensive and systematic way, there are more than three databases that could have been used to search for articles. Because six reviews were included in this study, a few studies are represented more than once. However, reviews were only cited when they contributed additional evidence that did not involve an individual study already included in this review. Additionally, only one author identified and selected articles from the search. Although the protocol for selecting articles consistently followed the guidelines set by three authors at the beginning of the review, discrepancies about the inclusion of articles at any stage of selection could have arisen if more than one author identified eligible articles. Furthermore, significant methodological differences across studies makes it more difficult to assess the strength of these findings. Sample characteristics, primary study variables, and metrics used to assess parent and child language were not consistent between studies. As such, meta-analysis was not possible. Another limitation of this review was that it looked specifically at language and cognitive development of children and did not consider the influences of language nutrition on children's socioemotional development, self-regulation, and other developmental domains. While language and cognition represent distinct domains of development, children's development does not occur in siloes. Benefits of language nutrition on children's socioemotional development or self-regulation may indirectly contribute to children's language or cognitive development.

Other limitations of this review include the individual limitations of each study. Many sample sizes were small. As a result, several studies lacked sufficient statistical power to construct predictive statistical models. However, several studies did have very large sample sizes and had adequate power to make conclusions beyond correlations. While most studies made conclusions beyond correlations, the directionality of the relationship between language nutrition and children's language and cognitive development could not be determined for every study. Children who contribute more frequent and sophisticated language responses may elicit more language input and responsive behaviors from caregivers or it is possible that the association between language nutrition and children's development is bidirectional. However, given that the majority of these studies were prospective, these findings are not likely only a reflection of variations in the child's linguistic and cognitive abilities influencing how much caregivers talk with them. To add, many studies utilized maternal reports rather than standardized instruments in assessing parental behaviors, such as talking and reading. Although maternal reports have been shown to be related to children's outcomes, there may be some reporting bias as a result of this method of assessing language nutrition.

Similarly, some of the results may be biased as mothers or other caregivers may have increased their linguistic input, positive affect, or responsivity to their child as a result of being observed. Studies that assessed language nutrition over a period of time or with objective measures, such as the LENA digital language processors, likely are subjected to less bias from a caregiver's change in behavior compared to studies that assessed parent-child dyads once for a 10 or 20 minute play session. Additionally, these assessments only offer a snapshot of the interactions between parent-child dyads. Assessments in the home compared to in an observation lab may provide a more accurate picture of these interactions.

Despite these limitations, this is one of the first integrated reviews to examine the relationship between language nutrition and a child's language and cognitive development. Data were collected systematically and over 100 articles, of which the majority were quasi-experimental or observational cohort studies, were included in this review. Study samples included in this review represented children of diverse socioeconomic backgrounds with different risk profiles for delayed development, which increases the generalizability of these findings across various populations. In addition, almost all studies controlled for known confounders, including various aspects of socioeconomic status, known to affect children's developmental outcomes. Although methodological differences existed across studies, the vast majority of the articles reported significant benefits of language nutrition, characterized by a diversity of lexical input in the context of rich social engagement, throughout early childhood on a child's language and cognitive development.

Conclusion

Given the dramatic impact that early language environment has on the developing child, those individuals who care for young children can be powerful agents of change. Families and early childhood caregivers need to be a key target for information, education, and skill building. Family engagement is integral to the success of all young children. Teaching the power and the skill of language-rich interactions that can be built into the child's life from the beginning lays the strongest possible foundation for a child's later language development and proficiency. Changing the national conversation about early childhood development and bringing easily accessible information and tools to families and caregivers is becoming the next public health challenge. Any parent and or early childcare caregiver can be coached to embed rich and varied language into their daily activities with the infant and toddler. Methodologies that not only illustrate the issues but coach parents and caregivers to develop strong habits of embedding language nutrition into their everyday lives through talking, reading, and singing are an area of emerging research and study. Programs like the Kaiser Foundation and Next Generation/Clinton Foundation's Too Small to Fail campaign, Thirty Million Word Gap, Providence Talks, and Talk With Me Baby are working to put information in the hands of parents, caregivers, and healthcare providers to encourage the rich and engaged language interactions that babies need to develop strong language proficiency.

Engaging those professionals who interact frequently with families and caregivers provides a sound strategy for ensuring access to information, tools, and skill building for families and caregivers. Elevating the importance of early brain development to include language nutrition is a necessary first step but not sufficient for change. While provision of information has merit, teaching the critical skills of language transactions to all families is the currency for true and lasting habit building and change in caregiver behavior. Coaching our early childcare and healthcare providers to be the trusted providers of information related to early language and cognitive development puts the power and influence into the hands of workforces that are trusted and are often in contact with young children and their caregivers.

Areas for continued research regarding early language development are numerous. The importance of bridging the word gap in the United States has recently gotten national prominence through a series of meetings and summits and in the funding of the Bridge the Word Gap Research Network by the Health Resources and Services Administration. We have much to discover about the variables that are involved in early language development and how to best translate these discoveries to positively influence children's developmental and educational trajectory.

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CHAPTER THREE

Determinants of preterm infants' language environment in the neonatal intensive care unit

Abstract

Background: Preterm infants spend the first months of their life in the neonatal intensive care unit (NICU) during a critical period of brain development where language exposure and parent-child interactions may be limited. However, language exposure in the NICU has not been well characterized.

Objective: This study sought to characterize infants' language environment in the NICU and identify sociodemographic, clinical, environmental, and maternal psychological factors that predict language exposure.

Methods: Using a prospective cross-sectional study design, sixty-six infants born <38 gestational weeks who were between 32-40 weeks corrected gestational age were recruited at two level III NICUs in a pediatric hospital system in the southeastern United States. The auditory environment was assessed for 48 consecutive hours using LENA language processors and independent variables were collected through surveys, medical record abstraction, and observations. Negative binomial and gamma regression analyses were performed on word count and percentage of the auditory environment composed of speech, respectively.

Results: The majority of the auditory environment was composed of silence and electronic noise, with very little language exposure (3.61 + 2.78%). Parental presence and corrected gestational age were significant predictors of adult word count and meaningful speech. Infants with high parent visitation (>37%) were exposed to an average of 184

more words per hour and 34% meaningful speech than infants with low parent visitation. Preterm infants in open bay areas and on oscillators/ventilators were exposed to 26% and 43% less meaningful speech, respectively.

Conclusion: Language represents a small percentage of the auditory stimuli in the NICU and is most strongly predicted by parent visits and corrected gestational age. Understanding the NICU language environment and factors that influence it are critical for optimizing the language environment to support preterm infants' early neurodevelopment.

Introduction

Preterm birth, defined as birth occurring at less than 37 weeks gestation, is a significant contributor to neonatal health outcomes and long term disabilities.[1] Although advances in neonatal care have led to increased survival, high rates of neurodevelopmental delays and poor educational achievement in surviving children represents a growing public health concern.[2-6] While the prevalence of poor neurodevelopmental outcomes is inversely related to gestational age, extensive evidence suggests that all children with a history of preterm birth, including those born late preterm (34-36 0/7 weeks) and early term infants (37-37 6/7 weeks) exhibit a greater risk for deficits in all domains of executive function, including language acquisition, as well as poor literacy and academic success relative to their term-born peers.[2,3,7-10] Even without a known brain injury, 34-55% of preterm infants born at less than 32 weeks gestation experience challenges with language processing, comprehension, and production, which often manifest at school entry as behavioral or attentional problems.[11,12]

Preterm birth interrupts a critical period of early auditory and brain development.[13] A significant proportion of brain growth, including that of cortical gray and white matter, as well as neuronal specialization of the auditory cortex occurs during the last trimester.[14] It has been well established that brain development is influenced by early sensory experiences and that prenatal exposure to auditory stimulation during the third trimester helps to shape neural pathways necessary for the development of language skills.[15-17] For example, in a randomized control trial with infants born <32 weeks gestation, exposure to recordings of maternal voice for three hours per day for one month resulted in greater region-specific plasticity and structural volume of the auditory cortex.[15] In addition, animal models have demonstrated that deprivation of auditory stimuli during critical periods of brain development can lead to neuropathological changes, including decreased brain volume and cortical plasticity, whereas exposure to positive auditory stimuli can improve connectivity and development of the auditory cortex.[16-20] These studies suggest that early auditory exposures profoundly influence the maturation of areas of the brain responsible for language processing and learning.

Development of the functional auditory system occurs primarily in the third trimester.[21-23] Although structural components of the inner ear are formed fully by 15 weeks gestation, fetuses may not hear sounds until the beginning of the third trimester.[21,23-26] Electrophysiological data demonstrates that brain stem auditory evoked potentials become recordable around 25 weeks gestation, which suggests the onset of hearing.[25] This study is consistent with other studies that have identified skeletal movement and changes in fetal heart rate in response to auditory stimulation in fetuses between 23-25 weeks gestation.[21,27] By 35 weeks gestation, fetuses develop the capacity for language acquisition.[25,28]

This process of auditory and brain maturation begins in the intrauterine environment. Although protected from extrauterine noises, the intrauterine environment is not devoid of auditory stimulation and is characterized by low-frequency (<500Hz), rhythmic, and often predictable sounds that consist primarily of maternal voice and physiological sounds, such as the mother’s heartbeat.[21] Sounds are transmitted through the uterine wall and amniotic fluid, which attenuates the decibel level and frequency of sounds.[21] These auditory exposures in utero create an optimal environment for neural and auditory development.

Given the influence of early auditory stimulation on the developing brain, it is important to understand the auditory environment in which preterm infants develop. Preterm birth dramatically changes the auditory environment in which the fetus is developing as preterm infants abruptly transition from the intrauterine environment to the neonatal intensive care unit, where the auditory environment is characterized by loud, high frequency, and unpredictable noise.[23,29-31] Multiple studies have demonstrated that sound levels in the NICU consistently exceed the American Academy of Pediatrics guidelines (<45dB) and are much higher in frequency (500-3000Hz) than sounds that fetuses are exposed to in-utero.[21,27,32,33] It is possible that the risk for language and literacy delays may be compounded by the gap in auditory exposures in the NICU and the intrauterine environment.[11]

While many studies have focused on the noise levels and noise frequency in the NICU, very little attention has been given to language exposure. To date, only two studies have examined language exposure in the NICU, which found that language only represented a small percentage of the auditory environment.[34,35] In one study, the language environment was assessed for a sample of 36 preterm infants born less than 32 weeks gestation. Language data was collected for 16 hours using Language Environment Analysis (LENA) digital language processors (DLPs) when the infants were 32 and 36 weeks corrected gestational age.[34] Language represented 2-5% of the auditory environment in a single open bay NICU and higher corrected gestational age and parental visits increased the amount of language to which infants were exposed.[34] In another study, the auditory exposure of 58 infants born <28 weeks gestation was assessed using LENA for 16 hours at birth and at 30, 34, and 40 weeks corrected gestational age.[35] This study also demonstrated that the percentage of language in the environment and number of words spoken to the infant represented a small percentage of the auditory environment, but increased across corrected gestational age.[35] In addition, electronic noises and other noises in the NICU (loud voices, people walking, changing equipment, etc.) may mask linguistic stimuli that may already be limited to the preterm infant. Taken together, these studies suggest that preterm infants may be subjected to language deprivation in the NICU. As a result, preterm infants may miss important, timed auditory exposures that enhance brain maturation and development of neural pathways, particularly those that are important for language acquisition and social communication.

Characterizing auditory exposures, particularly language exposure, in the NICU is necessary to optimize the NICU environment for the developing infant brain. In addition to understanding how much language exposure preterm infants receive, determining factors associated with language exposure may identify targets for interventions aimed at providing a developmentally-appropriate environment for preterm infants. Previous research has identified that mechanical ventilation, higher acuity, and the number of pumps present were correlated with less linguistic stimuli and greater noise exposure whereas parental presence and number of times parent held the infant were correlated with greater linguistic stimuli.[35] However, differences in word count and percentage of language for room type (open bay vs. private room) were not statistically significant.[35] Additional research with multivariate analyses investigating determinants of language exposure is warranted.

The aim of this study was to characterize the auditory environment in the NICU for preterm and early term infants and to determine sociodemographic, clinical, environmental, and maternal psychological factors that predicted language exposure in the NICU. It was hypothesized that factors that could affect parent bonding and adult-infant interactions, such as corrected gestational age, co-morbidities, bed type, room type, clinical acuity, length of hospital stay, maternal self-efficacy, maternal perceived stressfulness of the NICU, poverty level, maternal education, and parent visits, would affect the language environment in the NICU.

Methods

Sample and Setting

Seventy-one infants born at less than 38 weeks gestation and who were between 32-40 weeks corrected gestational age were recruited from two level III NICUs at two locations of a pediatric hospital in the Southeastern region of the United States between December 2016—June 2017. Infants were excluded if the mother did not have custody of the child or if the mother could not understand spoken or written English. Infants located at the study sites had been transferred from birthing hospitals due to a co-morbidity requiring specialized pediatric care, including surgical needs.

The first NICU (NICU A) is a forty-eight bed level III NICU that is divided into three sections based on medical acuity. The "A unit" is for high-risk infants who require complex, multisystem care, who are usually on high respiratory support, and consists 18 beds, of which 12 are open bay and 6 rooms are single family rooms that consist of 2 walls, a sliding glass door, and a curtain separating it from another single family room. This unit is arranged in a rectangle around the secretary's desk and provider work spaces.

The “B unit” consists of 7 single family rooms and 4 double occupancy rooms, each with three walls and a door, for a total of 15 bed spaces. Double occupancy rooms have a curtain that separated the two bed spaces. Infants in this unit are usually of low medical complexity and may be preparing for discharge within days to a few weeks. The last, or “C” unit is for infants who are in between the acuity of level of infants in the A and B unit. The C unit has 9 open bay beds, two single family rooms, and one double occupancy room. Infants were often transferred bed spaces and sections of the NICU multiple times throughout their hospitalization.

The second NICU (NICU B) is a thirty-nine bed level III NICU that has eight private rooms and thirty-one open bay beds. Infants are assigned to a bed space in either a private room or open bay upon admission based on bed availability and contact precaution status and generally remained in the same assigned room for most of their hospitalization. Four of the private rooms are reserved for infants who are preparing for discharge. The open bay is composed of two large rooms, one of which has 11 beds and the other has 20 beds, and are located on opposite sides of a hallway. The beds in the open bays are arranged in a “spindle” configuration in which sets of four infant beds are separated by headwalls. Moveable curtains are available to set up around each bed space to provide additional privacy.

All NICU nurses at NICU A had received a one- hour continuing education training, which was conducted independently from this study, about the primacy of language exposure for infants and how to educate and support parents in talking with their baby. However, no nurses at NICU B received such training. Both NICUs promote kangaroo care and breastfeeding. Additionally, both NICUs implement quiet time during

1am-3am and 1pm-3pm, which is accomplished by dimming the lights, minimizing procedures, attempting to keep voices down, and posting a sign on the NICU door indicating that it is quiet time. Volunteers are available at both NICUs to hold infants who are stable, but volunteer logs did not indicate that any of the study participants were held during the recordings. Parents are required to sign in and out of the unit when they come to visit at NICU A but not at NICU B. Parents are not viewed as visitors, but rather as "co-caregivers" and have 24/7 access to their baby. Visitation is restricted to four people at a time and children under the age of 12 were not permitted to visit during the study period as it was in the middle of flu season. Parents are allowed to room-in with their infant at both NICUs if the infant is in a single family room but are not permitted to sleep in the open bay areas. Many parents utilize available sleep rooms at night or stayed at the Ronald McDonald House (within one mile of each hospital) if they live over 50 miles from the hospital.

The study was approved by the Emory University Institutional Review Board and by the hospital's nursing research committee.

Study Design and Procedures

A cross-sectional design was used to characterize the auditory environment and identify determinants of language exposure in the NICU. Eligible participants were identified through medical record screening and study team members consulted with the nursing staff to coordinate an appropriate time to approach mothers about the study. Informed written parental consent was obtained prior to any data collection.

The auditory environment was assessed for 48 consecutive hours using Language Environmental Analysis (LENA) digital language processors. The digital language processors were placed inside of a small plastic bag for infection control and placed inside the crib or isolette at the head of the bed. Given that the memory of the digital language processors could only store 16 hours of recording, data were downloaded from the digital language processors each morning and evening. Mothers completed a demographic survey and two measures related to perceived stress and self-efficacy at the time of consent. Mothers were asked “Has a nurse in this NICU ever talked to you about talking with your baby?” to control for any effect of nurse-led education about language exposure. Medical record abstraction was detailed for pregnancy and birth outcomes, neonatal complications, and clinical factors at the time of consent. These factors included pregnancy complications, delivery method, maternal exposure to magnesium, use of prenatal steroids, gestational age, birthweight, corrected gestational age, APGAR scores at one and five minutes, age at surgery, and current comorbidities. Furthermore, current clinical factors were gathered from the medical record each time a recording was downloaded. These factors included type of respiratory support, presence and number of lines or drains (central venous line, arterial line, peripheral intravenous line, surgical drain, foley catheter, nasogastric tube, ventricular access device, mucus fistula foley, orogastric repoggle, or endotracheal tube), number of desaturations in the past 24 hours, source of nutrition, length of hospital stay to-date, number of days post-op, and infant acuity. Infant acuity was determined based on the American Academy of Pediatrics/American College of Obstetrics and Gynecology guidelines. Additionally, environmental factors during the recordings were documented. These included room type (open bay, double occupancy room, or private room), bed type (isolette or open crib), contact precautions, nurse to patient ratio, and parental presence (visitation time and number of visitors) or absence. After data collection was completed, the mother of each participant received financial compensation for her time. When the baby was discharged, hospital length of stay was abstracted from the participants' medical records.

Study Measures

LENA digital language processors capture every utterance and sound in a child's environment and uses advanced algorithms and statistical modeling to automatically process each recording to generate reports for adult word count, conversational turns, child vocalizations and the percentage of the auditory environment that is composed of silence, electronic noise, non-electronic noise, distant speech, and meaningful speech.[36] Distant speech is speech that is spoken greater than five feet from the digital language processor and is not included in the adult word count whereas meaningful speech is speech spoken with five feet of the digital language processor. It is important to note that "meaningful speech" does not necessarily indicate that the speech is child-directed; this is a term used by the LENA technology to label speech within the child's proximity. A conversational turn is defined as adult speech followed by a child vocalization within five seconds or vice versa. Reliability and validity studies have demonstrated LENA's high degree of fidelity in coding when compared to human transcribers using samples of children and parents of various socioeconomic status and language spoken. While normative data are based on children older than two months, LENA has been validated in preterm infants by comparing adult word count reported by a transcriber to adult word count detected by LENA. Results found that r=0.93, which was similar to reliability studies conducted in term-born infants.

The Parental Stressor Scale: Neonatal Intensive Care Unit was used to assess the mother's perceptions of stressors in the NICU. The PSS:NICU is a 34-item self-reported questionnaire that asks parents to rate the stressfulness of experiences in the NICU on a Likert scale from 1 (not at all stressful) to 5 (extremely stressful).[37] Items not experienced are marked as 1 to obtain the best assessment of the overall stressfulness of the NICU environment.[37] The assessment consists of three subscales: infant behavior and appearance, relationship and parental role, and sights and sounds.[37] This measure has internal consistency as evidenced by Cronbach's α=0.89 and construct validity, supported with significant correlations with the State Trait Anxiety Inventory.[37]

The Perceived Maternal Parenting Self-Efficacy Tool (PMPS-E) was used to assess parental self-efficacy in the NICU.[38] The PMPS-E is a self-administered questionnaire that consists of 20 statements which are scored on a Likert scale from 1 (strongly disagree) to 4 (strongly agree) and represent four domains of self-efficacy, including care-taking, evoking behaviors, reading behaviors, and situational beliefs.[38] This tool was developed originally for use with mothers of preterm infants in the NICU.[38] It has high internal consistency with Cronbach's α=0.91 and high test-retest reliability at r=0.96.[38]

Statistical analysis

Descriptive test statistics were used to analyze the distribution of independent variables, adult word counts, and percentage of language in the audio environment. Independent variables were assessed for multicollinearity and dependent variables were assessed for normality. The data were examined for missing values, outliers, and implausible values. Data were complete for all dependent variables, and all independent variables that were significant predictors of language exposure. Parents visits were dichotomized into “high visits” and “low visits” at a cut-off point of 37% based on optimal binning for interpretability purposes. Less than 10% of data were missing for any variable, except for poverty level. Missing data were assumed to be missing at random and were excluded in the analyses.

Data for adult word count and meaningful speech were non-normally distributed and followed a negative binomial and gamma distribution, respectively, which was determined by comparing the Anderson-Darling statistic and p-value of the data when fit to various distributions. Therefore, data for adult word count and meaningful speech were analyzed by negative binomial regression and gamma log-link regression using generalized linear modeling for multivariate analysis. Negative binomial and gamma log-link distributions use the log-link function to model the natural log of count or continuous data, respectively, and are appropriate to use for non-normally distributed data in which events are independent and the mean and variance of the outcome variable are similar in value. The natural log of the total time recorded for each infant was used as an offset variable for the multivariate modeling. Negative binomial and gamma log-link regression use the maximum likelihood estimation method to estimate regression coefficients. Scaled deviance and the likelihood ratio chi-square were used to assess goodness of fit for the model, with smaller values for scaled deviance and larger values for the likelihood ratio chi-square indicating a better model fit. Multicollinearity diagnostics were assessed for the multivariate analyses. Tolerance and variance inflation factors were greater than 0.4 and less than 1.5 for all significant predictors, respectively, and correlations between independent variables were less than 0.3. All statistical analyses were conducted using SPSS version 24 with an alpha at 0.05.

Results

Seventy-one infants were enrolled in the study; however, prior to the beginning of data collection, six infants either were transferred back to the NICU at their birthing hospital or died. As a result, data was obtained for a total of 66 infants from 66 different families.

Table 1 shows the demographics of the 66 infants who were enrolled and completed the study. Sixty percent (n=40) of infants were of minority race/ethnicity, with nearly half of the sample consisting of African American infants (n=29). Over one-third of the sample (36.8%) had an annual household income that fell under the federal poverty line while over two-thirds of the sample (68.4%) had an annual household income that fell under 185% of the federal poverty line, indicating Women, Infant, and Children (WIC) eligibility. Approximately 26% of (n=16) mothers and 20% of (n=12) fathers of infants in the sample had obtained a Bachelors degree or higher. Forty-one percent of the mothers in this sample did not have any other children (n=27) and 17.2% of the families (n=11) had a previous child in the neonatal ICU.

Gestational age of the sample ranged from 162 days (23 weeks 1 day) to 265 days (37 weeks 6 days), with a mean gestational age of 222.64 $\pm$ 34.12 days (31 weeks 5 days). The mean corrected gestational age at time of the beginning of recordings was 251.62 days $\pm$ 16.77 (35 weeks 6 days), and ranged from 224 days (32 weeks 0 days) to 279 days (39 weeks 6 days). The majority of the infants in the sample had both medical and surgical needs (n=45) and data was collected post-operation on most of these infants (n=39).

Forty (62%) infants were in an open crib and 25 (38%) infants were in an isolette, or giraffe bed, that remained closed, except during routine care requiring the top of the bed to be open or for kangaroo care with the parents if the infant was medically stable. Half of the infants (n=33) were in the traditional open bay setting whereas 40% (n=26) were in single family rooms and the remaining 12% (n=8) were in double occupancy rooms. The nurse-to-patient ratio was generally 1:2 but was occasionally a 1:3 ratio (n=15) if infants were stable and required only basic monitoring or 1:1 ratio (n=2) if infants were unstable and required complex and continuous multisystem support. The mean percentage of time in which at least one visitor was present during the recording was 32.40 ± 28.22%, or approximately 15 hours 35 minutes of the 48 hours.

Table 2 quantifies the auditory exposure in the neonatal intensive care unit across all recordings for all 66 infants. The majority of the auditory environment in the NICU was composed of silence (52.19 ± 19.61%) and electronic noise (22.01 ± 17.41%), whereas language spoken near the infant (within five feet) represented a small percentage of the auditory environment (3.61 ± 2.78%). Mean adult word count was 304.68 ± 245.63 words per hour and mean number of conversational turns was 1.25 ± 1.31 per hour.

The NICU site in which the infant was located did not appear to affect the results of the study as there were no significant differences in adult word count or meaningful speech based on NICU site (p=0.106). Additionally, there were no significant differences in adult word count or meaningful observed based on whether or not parents reported that a nurse had talked to them about talking with their baby (p=0.468).

Adult Word Count

Adult word count was significantly associated with corrected gestational age and parent visits. The standardized β coefficients with the corresponding incidence rate ratios (IRR) for this model are shown in Table 4. The hourly adult word count increased 12.6% for every one week increase in corrected gestational age, adjusting for parent visits ($p<0.001$). Additionally, infants whose parents had a high visitation rate (≥37%) were exposed to 1.84 times the number of adult words than infants whose parents had a low visitation rate (<37%) (IRR: 1.84 [1.08, 3.13], $p<0.001$), adjusting for corrected gestational age. The estimated marginal means for adult word count by parent visits are given in Figure 1. The likelihood χ^2 for the model was 34.004 ($p<0.001$). There was no significant interaction effect between parent visits and corrected gestational age.

Meaningful speech

Meaningful speech was significantly associated with type of NICU room, corrected gestational age, oscillator/ventilator respiratory support, and parent visits. Table 5 shows the standardized β coefficients and odds ratios (OR) for this model. Like adult word count, higher amount of parent visits (OR: 1.34, 95% CI: 1.03. 1.75, $p=0.032$) and a higher corrected gestational age (OR: 1.12, 95% CI: 1.05, 1.19, $p<0.001$) were both associated with increased exposure to meaningful speech, controlling for the other significant predictors in the model. Both the open bay area design (OR: 0.73, 95% CI: 0.56, 0.96, $p=0.023$) and oscillator/ventilator respiratory support (OR: 0.57, 95% CI: 0.41, 0.78, $p=0.001$) were associated with decreased exposure to meaningful speech, adjusting for the other significant predictors in the model. Estimated marginal means for all independent variables included in the model are shown in Figure 2. The likelihood χ^2

for the model was 56.237 ($p<0.001$). There were no significant interactions between any of the independent variables.

Discussion

This study is the first study to examine social, environmental, clinical, and maternal psychological determinants of the language environment of preterm infants across all gestational ages and the first study to characterize the auditory environment across all times of the day in the NICU. This study adds to the literature characterizing the language environment of the NICU and highlights the significant influence of parental presence on preterm infants' early language exposure in the NICU. After considering the large influence of parent visits, no other factors considered for inclusion in the multivariate analysis for adult word count were significant except corrected gestational age. While preterm infants at all corrected gestational ages were exposed to a rather low number of words and very little meaningful speech, both measures of language exposure were directly related to the preterm infants' corrected gestational age. In the multivariate analyses for meaningful speech, differences were observed across room type and for oscillator/ventilator respiratory support. Although previous studies have suggested that sociodemographic factors and maternal psychological well-being influence the language environment of term-born children, neither sociodemographic factors nor measures of maternal psychological well-being (perceived stressfulness of the NICU or self-efficacy) significantly affected the language environment in the multivariate analyses.

Preterm infants spend the first weeks to months of their lives developing in the NICU. Previous research has suggested that language exposure during the third trimester of pregnancy promotes brain development and positively influences neurodevelopmental outcomes.[21,22,39,40] As such, language exposure for preterm infants in the NICU during this time is crucial. In the present study, language represented less than 4% of the auditory environment, with silence and electronic noise comprising the majority of auditory exposures. These results are consistent with two previous studies that demonstrated that language represented only a small percentage of the auditory environment in the NICU.[34,35] Although no parameters for optimal language exposure for preterm infants have been established, it is likely that age-equivalent fetuses receive greater language exposure as they are developing in an environment where maternal voice is the most prominent auditory stimulus.[21] This reduced language exposure for preterm infants may have developmental consequences. While very little research has been conducted examining the effect of language exposure on preterm infants' development, one study demonstrated that greater language exposure in the NICU was associated with higher scores on measures of language and cognitive function at 7 and 18 months, controlling for birthweight.[41] Additional studies investigating the effect of language exposure on preterm infants' outcomes are needed.

Parent visitation had a significant influence on the quantity of language to which preterm infants were exposed. Even after controlling for sociodemographic characteristics and clinical acuity, the strongest determinant of adult word count was the amount of time in which a parent was present in the NICU. Consistent with other studies, this study demonstrated significant variability in parent visitation.[42-45] Lack of consistent parental presence in the NICU is a common challenge reported by many NICUs across the country. Increasing parent visitation requires innovative strategies that target not just parents at the individual level, but also policies and regulations at the institutional level concerning NICU design and provision of sleep rooms, parent access to the NICU, and encouraging parental involvement in care.

In addition to parent visits, corrected gestational age was predictive of adult word count and meaningful speech. Both of the two existing studies that characterized language exposure in the NICU also previously identified that higher corrected gestational age was significantly associated with higher adult word count and meaningful speech.[34,35] The number of infant vocalizations per hour increases as corrected gestational age increases ($r=0.429$, $p<0.001$), suggesting that infants at a lower corrected gestational age may initiate less communication and may respond less overtly to language exposure compared to infants of higher corrected gestational age.[34,35] Given that infant vocalizations and adult word count are highly correlated ($r=0.514$, $p<0.001$), the data suggest that adults may talk and engage less with infants who are less responsive.

Additionally, some of the influence of corrected gestational age on language exposure may be partially explained by bed type and clinical acuity. While these variables were not significant predictors of either adult word count or meaningful speech in the multivariate analyses, these variables were highly correlated with corrected gestational age ($r=-0.73$, $p<0.001$; $r=-0.53$, $p<0.001$) as well as with adult word count ($r=-0.33$, $p=0.006$; $r=0.59$, $p<0.001$) and meaningful speech ($r=-0.43$, $p<0.001$, $r=-0.40$, $p=0.001$). Lower gestational age is associated with being in an isolette, which provides a barrier to auditory stimuli, and is also associated with higher clinical acuity, which may present challenges for parent-infant interactions. While optimal language exposure may vary based on corrected gestational age, infants of lower corrected gestational age may be at a higher risk of missing important language exposure.

Significant differences in meaningful speech were also observed between open bay areas and single family or double occupancy rooms. Infants in open bay areas were exposed to 27% less meaningful speech compared to infants in non-open bay areas. Single family and double occupancy rooms provide additional privacy and accommodations that encourage rooming-in with the infant and decrease exposure to toxic noise.[46-50] Studies have suggested that single family rooms are associated with decreased parental stress, increased parental satisfaction, improved breastfeeding rates, and longer and more frequent visits.[46,48-51] It is possible that the benefits afforded by a more private room facilitate parent-infant attachment and greater parental involvement in care, which in turn could result in greater exposure to meaningful speech. However, the effect of room type on parental behavior cannot fully explain the predictive relationship observed between room type and meaningful speech as there was no interaction effect between parent visits and type of NICU room. The absence of such an interaction may assuage concerns about the potential for language isolation in private rooms for infants whose parents rarely visit.[11] This finding supports efforts to modify the architectural design to include single family and double occupancy rooms as a way to improve the NICU environment and provide family-centered care.[48-50].

Respiratory support via an oscillator or ventilator significantly decreased exposure to meaningful speech. Mechanical ventilation has previously been found to be negatively correlated with meaningful speech and adult word count.[35] Like infants of lower corrected gestational age, preterm infants who are intubated for respiratory support may be less likely to elicit communication from adults due to less production of vocalizations and non-verbal cues compared to non-intubated infants. Indeed, infants who were not on oscillators or ventilators vocalized nearly six times more than infants on oscillators or ventilators ($t=4.30$, $p<0.001$). However, an alternative explanation could be that the LENA detects and labels only the most prevalent sound and is not capable of labeling multiple sounds at any given time.[36] Oscillators and ventilators were associated with greater non-electronic noise in the NICU ($r=0.439$, $p<0.001$). Therefore, if an adult talked softly to the infant, LENA may have labelled this overlap in auditory exposures as "noise" as opposed to "meaningful speech." However, the way in which the auditory stimuli were labeled could be reflective of the infant's experience.

Other limitations include assessment of only forty-eight hours in the NICU, the possibility that data was collected on a non-typical day for the infant, potential Hawthorne effect from the presence of the DLP in the crib or isolette, unknown hearing status of the infant, and the inability of the LENA technology to determine if words were child-directed. Furthermore, parents did not sign in and out of one of the NICUs in the study and therefore, data collection for parent visits relied on nurse charting.

Future research should be conducted to evaluate the influence of language exposure in the NICU on preterm infants' outcomes, including short-term outcomes such as length of hospital stay and infant bonding as well as long-term developmental outcomes. Research aimed at establishing parameters for the optimal exposure of language in the NICU auditory environment, considering corrected gestational age, would further advance this area of research.

Conclusion

Preterm infants are exposed to a very small amount of language during a critical period of brain development, which may contribute to disparities in their developmental trajectory compared to term-born infants. Importantly, the language environment in the NICU is modifiable. Understanding the NICU language environment and the factors that influence it are critical for optimizing the language environment in a way that supports preterm infants' early neurodevelopment. This study found that the corrected gestational age and the amount of parental visitation time most strongly predicted language exposure in the NICU, controlling for clinical acuity and sociodemographic factors. This result highlights the impact all parents, regardless of socioeconomic status, can have on their infant's environment in the NICU, which in turn could positively influence the child's long-term developmental outcomes. Additional research is needed to explore the influence of NICU design and protocols (such as promotion and facilitation of parent and family visitation) on the language environment, and to identify the optimal amount of language exposure across corrected gestational age for social, cognitive, and language development.

Table 1: Demographics of sample

Child's Gender	
Male	63.6% (n=42)
Female	26.4% (n=24)
Child's race	
Black	43.9% (n=29)
White	39.4% (n=26)
Hispanic	3.0% (n=2)
Asian	13.6% (n=9)
Maternal age	29.20 ± 6.66
Maternal college degree	37.7% (n=23)
Parents living together/Married	74.9% (n=50)
Maternal full-time employment	33.9% (n=21)
Other children at home	58.5%(n=39)
Under Federal Poverty Line	36.8% (n=21)
WIC Eligible (under 185% federal poverty line)	68.4% (n=39)
Previous experience with a child in the NICU	17.2% (n=11)

Table 2: Descriptive statistics for clinical variables

Gestational age at birth		31.81 ± 4.87
Corrected gestational age at data collection		35.94 ± 2.39
Birth Weight (g)		1880.76 ± 932.46
Days in hospital at time of data collection		15.55 ± 18.39
Maternal complications		
	Hypertension/Pre-Eclampsia	16.7% (n=11)
	Gestational Diabetes	10.6% (n=7)
	Infection	24.2% (n=16)
	Group B Strep Positive	15.2% (n=10)
	Placental Abruption	7.6% (n=5)
	Oligohydramnios	7.6% (n=5)
	Polyhydramnois	7.8% (n=5)
	Intrauterine Growth Restriction	18.2% (n=12)
	Drug/alcohol use	7.6% (n=5)
	Tobacco use	9.1% (n=6)
	Prolonged Rupture of membranes	16.7% (n=11)
	Multiples birth, with infant death	3.0% (n=2)
Mode of Delivery, Vaginal		47.0% (n=31)
History of intubation		64.6% (n=42)
History of surgery		59.1% (n=39)
Gastrointestinal complications		51.5% (n=34)
	Necrotizing enterocolitis	16.7% (n=11)
	Intestinal perforation	18.2% (n=12)
	Abdominal wall defect	7.5% (n=5)
	Duodenal/jejunal atresia	7.6% (n=5)
Neurological complications		51.5% (n=34)
	Intraventricular hemorrhage	24.2% (n=16)
	Hypoxic ischemic encephalopathy	6.1% (n=4)
	Hydrocephalus	7.5% (n=5)
	Neural tube defect	3.0% (n=2)
	Seizures	4.5% (n=3)
Cardiac complications		51.5% (n=34)
	Noncyanotic heart defect	12.1% (n=8)
	Cyanotic heart defect	3.0% (n=2)
	Patent Ductus Arteriosus	31.8% (n=21)
	Patent Foramen Ovale	22.7% (n=15)
Pulmonary complications		66.7% (n=44)
	Acute Respiratory Failure	34.8% (n=23)
	Chronic lung disease	27.3% (n=18)
	Apnea of Prematurity	30.3% (n=20)
	Pulmonary hypertension	12.1% (n=8)
	Lung structural abnormality	6.0% (n=4)

Renal complications		24.2% (n=16)
Endocrine complications		17.2% (n=11)
Musculoskeletal complications		12.1% (n=8)
	Cleft palate	10.8% (n=7)
	Club foot	4.5% (n=3)
Genetic/chromosomal disorder		10.6% (n=7)
Infection		22.7% (n=15)
Intubated for respiratory support		24.2% (n=16)
Number of lines/drains		2.51± 1.53
Central line		47.0% (n=31)
Sedated		32.3% (n=22)
Nutrition		
	Breastmilk-fed	66.7% (n=44)
	Formula	24.2% (n=16)
	Total Parenteral Nutrition	36.5% (n=24)
Infant acuity		
	Continuing/Intermediate Care	54.5% (n=36)
	Intensive Care	25.8% (n=17)
	Multisystem/Complex Care	19.7% (n=13)

Table 3: Descriptive statistics for environmental and maternal psychological factors

Hospital		
	A	56.1% (n=37)
	B	43.9% (n=29)
Nurse to patient ratio		
	1:1	3.0% (n=2)
	1:2	72.7% (n=48)
	1:3	24.2% (n=16)
Contact precautions		12.3% (n=8)
Isolette		37.9% (n=25)
Room type		
	Open bay	48.5% (n=32)
	Double occupancy room	13.6% (n=9)
	Single family room	37.9% (n=25)
Kangaroo care		68.4% (n=39)
Parent educated by nurse about language exposure		58.3% (n=35)
Parent visits (%)		32.40 $\pm$ 28.22
	Low visits (<37%)	66.7% (n=44)
	High Visits ($\geq$37%)	33.3% (n=22)
Visits with >1 visitor (%)		44.94 $\pm$ 43.52
Parental Stressor Scale: NICU (33-170)		101.15 $\pm$ 26.97
Perceived Maternal Parenting Self-Efficacy Scale (0-80)		70.93 $\pm$ 7.40

Table 4: Auditory Exposures in the NICU

	Mean $\pm$ Std. Deviation
Silence (%)	52.19 $\pm$ 19.61
Noise (%)	17.04 $\pm$ 12.27
Electronic sounds (%)	22.01 $\pm$ 17.41
Distant speech (%)	5.16 $\pm$ 3.46
Meaningful speech (%)	3.61 $\pm$ 2.78
Adult Word Count per hour	304.68 $\pm$ 245.63
Conversational turns per hour	1.25 $\pm$ 1.31
Child vocalizations per hour	6.49 $\pm$ 6.15

Table 5: Predictors of Adult Word Count

Parameter	β	Standard error	Exp (β) (95% CI)	Wald χ^2	p-value
(intercept)	0.55	1.93			0.550
High parent visits	0.61	0.27	1.84 (1.08-3.13)	5.00	0.025
Corrected gestational age	0.12	0.05	1.13 (1.01-1.25)	4.81	0.028

Dependent variable: Total Adult Word Count;
Offset variable: LN total time recorded
Model: Deviance: 22.046, deviance/df=0.350, χ^2=34.004, p<0.001

Table 6: Predictors of Meaningful Speech

Parameter	β	Standard error	Exp (β) (95% CI)	Wald χ^2	p-value
(intercept)	-2.77	1.11		8.05	0.005
Open bay area	-0.32	0.14	0.73 (0.56, 0.96)	5.15	0.023
Corrected gestational age	0.11	0.03	1.12 (1.06, 1.19)	14.13	<0.001
Ventilator	-0.57	0.16	0.57 (0.41, 0.78)	11.95	0.001
High Parent visits	0.29	0.14	1.34 (1.03, 1.75)	4.60	0.032

Dependent variable: Total meaningful speech;
Offset variable: LN total time recorded
Model: Deviance 16.463, deviance/df=0.270, χ^2 =56.237, p<0.001

Figure 1: Estimated Marginal Means of Word Count by Parent Visits

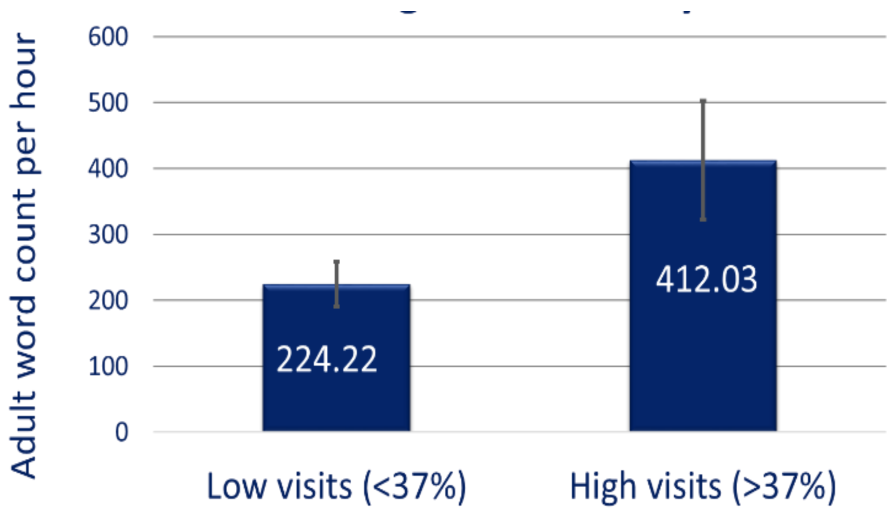
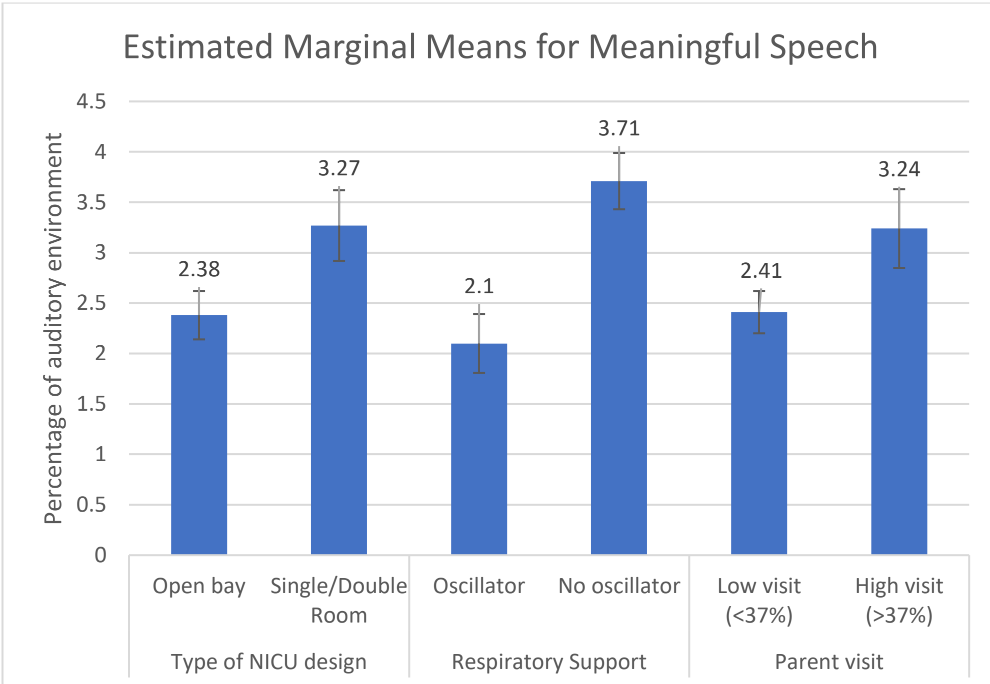


Figure 2: Estimated Marginal Means for Meaningful Speech



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CHAPTER FOUR

Predictors of parental visitation for preterm infants in the neonatal intensive care unit

Abstract

Background: Preterm infants spend the first several weeks to months of their lives developing in the neonatal intensive care unit (NICU), where they are often separated from their parents. Parent visitation in the NICU has been shown to result in better short-term as well as long-term developmental outcomes for preterm infants. However, little research has been conducted to identify predictors of parent visitation in the NICU.

Objective: The goal of this study was to identify sociodemographic, clinical, environmental, and maternal psychological factors that predicted parent visitation in the NICU. It was hypothesized that factors that could contribute to impaired parent-infant attachment as well as sociodemographic factors that may interfere with frequent or long visitation would be predictive of lower parent visits.

Methods: Using a prospective cohort design, sixty-six preterm infants <38 weeks gestation who were between 32-40 weeks corrected gestational age were recruited at two level III NICUs within a pediatric hospital system in the United States. Length of parent visits were collected for 48 consecutive hours from daily visitation logs and medical records. Independent variables were assessed through medical record abstraction, and maternal completion of a demographic survey and self-reported measures of perceived stressfulness of the NICU and self-efficacy. A general linear model was estimated to identify significant predictors of parent visits.

Results: Parent visitation varied considerably with a mean percentage of visitation time of 32.40%. The number of children at home (p=0.003), presence of neurological co-

morbidity ($p<0.001$), room type ($p<0.001$), surgical history ($p<0.001$), and perceived stressfulness of the NICU ($p=0.034$) each had large main effects on parent visitation. A large interaction effect existed between room type and surgical history ($p=0.004$). Together, these predictors accounted for 65.8% of the variance in percentage of time in which parents visited during the study period.

Discussion: Future research aimed at understanding factors that predict parent visitation can help providers and researchers develop interventions and design NICUs that support parental presence, and thus, improve preterm infants' outcomes.

Introduction

Advances in medical care have led to a remarkable improvement in the survival of preterm infants over the past few decades.[1,2] Surviving preterm infants are admitted to the neonatal intensive care unit (NICU), where they often have lengthy hospital stays, in which they are physically separated from their parents. This separation along with the medical condition of the preterm infant limit early parent-infant interactions, which places preterm infants at risk for social isolation and impaired attachment.[3] Extensive evidence from animal models demonstrate that delayed attachment due to early, prolonged maternal separation has lasting effects on neurodevelopment, self-regulation, and emotional and behavioral health.[4-7] Absent or reduced early parent-infant interactions in the NICU may contribute to the known disparities in the socioemotional and neurodevelopmental outcomes between preterm and term-born children.[8-10]

Preterm birth confers both biological and environmental risks on an infants' developmental trajectory. [11-13] While biological risks cannot be modified, parent involvement in the NICU, which is modifiable, is thought to be a significant mediating factor between the infant's perinatal risk and developmental outcomes.[3,14] Evidence supports the benefits of parental involvement through breastfeeding, kangaroo care, touch and massage, and maternal voice on the clinical status of preterm infants.[15-21] These modalities have been demonstrated to lessen physical responses to painful procedures, decrease levels of cortisol, improve sleep, provide exposure to positive sensory stimuli, and increase the concentration of hormones, namely oxytocin and brain growth promoting factor, that promote bonding and synaptic plasticity, respectively.[16] It is possible that, through these mechanisms, parent involvement enhances the neurobehavioral and neurodevelopmental outcomes of preterm infants.

Involvement in the NICU necessitates the presence of a parent. However, previous studies have suggested that parent visitation patterns vary significantly, with some parents visiting every day for almost the entire day while other parents rarely visit.[22-26] While few studies have examined the relationship between the frequency or duration of parent visits and infant outcomes, higher visitation frequency has been associated with shorter NICU length of stay, lower rates of behavioral problems at school entry, and decreased levels of parental stress and depression.[14,26] With a growing consensus that parental presence and involvement have the potential to improve outcomes, recent efforts to encourage parental visitation and to support parents as caregivers of their infant have been implemented in many NICUs throughout the country. While visitation has historically been restricted to certain hours, many NICUs have revised visitation protocols to allow 24-hour unrestricted access to parents and have encouraged a culture in which parents are viewed not as "visitors" but rather as partners in taking care of the hospitalized infant. Furthermore, many NICUs have been transitioning from traditional open bay units to single-family rooms, which offer a more private and less noisy environment with recliners or beds for parents to sleep in overnight.[13,27]

Few studies have described predictors of parental presence in the NICU. Most of the studies conducted were published over a decade ago and focused primarily on the frequency of parent visits rather than the duration of time in which a parent was present. These studies consistently found that infants with siblings were visited less frequently compared to infants who were their parents' first child.[22-25,28,29] Additionally, increased length of hospitalization was associated with decreased visitation frequency but the infant's medical condition or co-morbidities as well as maternal health had no effect on parent visitation.[3,22,23,25,28,29] Findings from these studies are inconsistent for the effect of gestational age, birthweight, maternal marital status, and maternal age on visitation frequency.[23-25,28,30] While several studies from over a decade ago have suggested that longer commutes affect visitation, a recent study suggested that transportation issues, such as access to a car and finding parking at the hospital, rather than length of commute, affected visitation.[28] Furthermore, two recent studies found that measures of maternal psychological stress were predictive of visitation practices. Mothers who had lower maternal anxiety and mothers who scored higher on the Infant Appearance and Behavior subscale of the Perceived Stress Scale: NICU visited less often. [24,28] Understanding factors that contribute to parental visits may help identify infants who are at risk for low parental visitation, and thus, at a higher risk for delayed attachment and poor outcomes.

The purpose of this study was to identify sociodemographic, environmental, clinical, and psychological predictors of the duration of parental visitation in a sample of infants born <38 weeks hospitalized in a neonatal intensive care unit.

Methods

Sample and Setting

Infants born at less than 38 weeks gestation who were between 32-40 weeks corrected gestational age were recruited from two level III NICUs at two locations in a pediatric hospital system in the southeastern region of the United States between December 2016—June 2017. Infants at the study sites had been transferred from their birthing hospitals due to co-morbidities requiring specialized pediatric care, including surgical needs. Exclusion criteria were if the infant was a ward of the state or if the mother could not understand written or spoken English.

One of the NICUs (NICU A) is a 45 bed NICU that is divided into three sections based on medical acuity and consists of 21 open bay beds, 15 single family rooms, and 5 double occupancy rooms. Infants at NICU A were moved around to different sections of the unit throughout their NICU stay based on medical acuity. All three sections of the unit have single family rooms but the lowest acuity section does not have an open bay area and the highest acuity section does not have any double occupancy rooms. The other NICU (NICU B) is thirty-nine bed NICU with 8 single family rooms and 31 open bay beds that is divided into two sections separated by a hallway. Infants in this NICU were assigned a bed space at admission and generally remained in the same bed space throughout their hospitalization. The beds in the open bays are arranged in a “spindle” configuration in which sets of four infant beds are separated by headwalls. Movable curtains are available to set up around each bed space to provide additional privacy.

Both NICUs allowed for parent access at all hours of the day except if a surgical procedure was taking place at the bedside. Parents were not viewed as visitors, but rather as co-caregivers along with the medical staff. Visitation was restricted to four people at a time and children under the age of 12 were not permitted to visit during the study period as the study took place during the flu season. Both NICUs required that the parents call the unit secretary to obtain entry into the NICU and were required to sign in and out at NICU A but not at NICU B. Parents were allowed to room-in with their infant at both NICUs if the infant was in a single family room or double occupancy room but were not allowed to sleep in the open bay areas in NICU A. Many parents utilized available sleep rooms at the hospital or stayed at Ronald McDonald House (within one mile of each hospital), a non-profit that provides near-by housing for families of hospitalized children, if they live over 50 miles from the hospital.

The study was approved by the Emory University Institutional Review Board and by the hospital's nursing research committee.

Study Design and Procedures

A cross-sectional design was used to quantify parent visits and to identify determinants of parent visits in the NICU. Eligible participants were identified through medical record screening and study team members consulted with the nursing staff to coordinate an appropriate time to approach mothers about the study. Informed written parental consent was obtained prior to any data collection.

This study was conducted as part of a larger study that recorded the audio environment of the NICU for a total of 48 hours. As part of the larger study, parent visits were assessed during the audio recordings in the NICU. As a result, parent visits were collected for 48 consecutive hours. The time in which parents visited was collected using visitation logs from NICU A and using medical record abstraction from NICU B. Medical record abstraction was also used in NICU A as an additional verification source for the visitation logs and study team members checked with nurses to verify visitation times recorded in the medical record at NICU B. Total time in which an infant had at least one visitor was added and divided by the total time in which audio recordings took place to obtain a percentage of time in which parents visited. This percentage is referred to as "parent visits" throughout this paper.

At the time of consent, mothers completed a demographic survey and two surveys that assessed perceived stressfulness of the NICU and self-efficacy. Medical record abstraction was detailed for clinical factors at the time of consent, which included pregnancy complications, delivery method, gestational age, birthweight, postmenstrual age, surgical need, co-morbidities, type of respiratory support, number of lines/drains, length of hospital stay-to-date, and infant acuity, based on the American Academy of Pediatrics/American College of Obstetrics and Gynecology guidelines. Additionally, environmental factors in the NICU, including room type (open bay, double occupancy room, or private room), bed type (isolette or open crib), and contact precautions were documented. All independent variables considered as predictors in this study are defined in Table 1. After data collection was complete, the mother of each participant received a $25 gift card.

Study Measures

The Parental Stressor Scale: Neonatal Intensive Care Unit was used to assess the mother's perceptions of stressors in the NICU. The PSS:NICU is a 34-item self-reported questionnaire that asks parents to rate the stressfulness of experiences in the NICU on a Likert scale from 1 (not at all stressful) to 5 (extremely stressful).[31] Items not experienced are marked as 1 to obtain the best assessment of the overall stressfulness of the NICU environment.[31] The assessment consists of three subscales: infant behavior and appearance, relationship and parental role, and sights and sounds.[31] This measure has internal consistency as evidenced by Cronbach's $\alpha=0.89$ and construct validity, supported with significant correlations with the State Trait Anxiety Inventory.[31] The subscales are correlated with the total score (49-82% of variance).[31]

The Perceived Maternal Parenting Self-Efficacy Tool (PMPS-E) was used to assess parental self-efficacy in the NICU.[32] The PMPS-E is a self-administered questionnaire that consists of 20 statements which are scored on a Likert scale from 1 (strongly disagree) to 4 (strongly agree) and represent four domains of self-efficacy, including care-taking, evoking behaviors, reading behaviors, and situational beliefs.[32] This tool was developed originally for use with mothers of preterm infants in the NICU.[32] It has high internal consistency with Cronbach's $\alpha=0.91$ and high test-retest reliability at $r=0.96$.[32]

Statistical analysis

Descriptive statistics were analyzed for all study variables. Distribution for the variables of interest were assessed for normality and parent visits met the criteria for normal distribution. A general linear model was estimated to identify predictors between parent visits and sociodemographic, clinical, environmental and maternal psychological factors. All possible two-way interactions between each independent variable and the dependent variable were assessed. All statistically significant two-way interaction effects were added to the resulting model. Multicollinearity in the model was assessed and highly correlated independent variables were not included in the model. Model fit was assessed by using the F-statistic and the lack of fit test. All significant effects were interpreted using Cohen's d for effect sizes. The results of the general linear model were summarized using the estimated marginal means. All data were reviewed for data entry errors, outliers, and missing data. Data for parent visits (dependent variable) were complete and less than 10% of the data for the independent variables were missing. Missing data were assumed to be missing at random and were not included in the analyses. All statistical analyses were conducted using SPSS version 24 with alpha set at 0.05 and two tailed.

Results

A total of 71 infants were enrolled in the study; however, six infants were either transferred back to the NICU at the birthing hospital or died prior to the beginning of data collection. As a result, data was collected for 66 infants, all from different families.

Demographics and clinical characteristics of the sample are given in Table 2 and 3. More infants were recruited from NICU A (n=37) than NICU B (n=29) but differences in the sample characteristics, except for corrected gestational age and surgical history, were not statistically significant between hospitals. The mean corrected gestational age for NICU A was 1.54 weeks higher than the mean corrected gestational age for NICU B (95% CI: 0.41, 2.68; p=0.008) and a greater percentage of babies at NICU A had a surgical history compared to NICU B (χ^2= 7.87; p=0.005). The sample had a higher number of males (63.6%, n=42) compared to females (26.4%, n=24) and was diverse in racial composition, with over half of the sample representing a minority race (56.1%, n=40). The mean gestational age at birth was 31.80 $\pm$ 4.87 weeks and the mean corrected gestational age at time of data collection was 35.95 $\pm$ 2.40 weeks. Most infants in the sample had both medical and surgical needs (n=45) and data was collected post-operation on most of these infants (n=39). Nearly half (n=31) of the infants had a neurological complication, which included intraventricular hemorrhage, hypoxic-ischemic encephalopathy, hydrocephalus, seizures, and neural tube defect. Half of the infants (n=32) were in the traditional open bay setting whereas 37.88% (n=25) were in single family rooms and the remaining 13.63% (n=9) were in double occupancy rooms. The mean percentage of time in which parents visited during the 48 hours of data collection was 32.40%, or 15.55 hours. Visitation ranged from 0% to 100%, while the median was 27.69% and the 25-75% IQR ranged from 10.01-44.92%, or 4.8 to 21.56 hours.

The general linear model (GLM) yielded evidence that NICU room type, surgical history, presence of a neurological co-morbidity, number of children in the family, and total score on the PSS:NICU were significant predictors of parent visits (F=20.23, p<0.001). Additionally, an interaction between type of NICU room and surgery had a significant effect on parent visits. The standard B coefficients and standard errors for each predictor are given in Table 4 and the estimated marginal means are given in Table 5. Together, the model accounted for 65.8% (Adjusted R^2=0.658) of the variance in parent visits.

Sociodemographics

There was a significant main effect, with a large effect size, for the number of children in the family on percentage of time in which parents visited (F=9.98, p=0.003, *d*= 6.32, r=0.953). Parents who had more than one other child at home visited on average 60% less time (27.56 ± 4.46%) than parents with either zero or one other child at home (43.67 ± 2.69%).

Clinical and NICU-Environmental Factors

There was a significant main effect of neurological co-morbidity on percentage of time in which parents visited (F=24.60, p<0.001, *d*=4.92, r=0.98). The mean percentage of time in which parents visited was 1.9 times higher in infants without a neurological co-morbidity (46.71 ± 3.17%) compared to infants with a neurological co-morbidity (24.51

± 3.74%). Effect size for neurological co-morbidity was large based on Cohen's d (*d*=4.92, r=0.98).

Room type and surgical history both had significant main effects on the percentage of time in which parents visited (F=37.71, p<0.001, *d*=-5.54, r=0.94; F=24.45, p<0.001, *d*=10.54, r=0.98). However, there was also a significant interaction effect between room type and surgical history (F=9.188, p=0.004). For the main effects, infants with a surgical history were visited for less time than infants without a surgical history, while infants in single family room were visited for more time than infants in a non-single family room. The effect of room type on parent visits differed based on surgical history as shown in Figure 1. Infants in a single room were visited 2.18 times longer if they did not have surgery, and infants not in a single room were visited 1.56 times longer if they did not have surgery. Likewise, the effect of surgical history differed based on room type. Infants who had surgery were visited for twice the amount of time if they were in single room compared to an open bay or double occupancy room. Furthermore, infants who did not have surgery but were in a single family room were visited 2.78 times more than infants without a surgical history who were not in a single family room. Cohen's effect size value (*d*= -6.06; r=0.950) suggested this interaction had a large effect on parent visits.

Maternal well-being

There was a significant main effect for perceived stressfulness of the NICU on parent visits (F=4.74, p=0.034, d=r=0.908). Mothers who reported higher perceived NICU-related stress (40.61 ± 3.71) visited their infants for approximately 33% more time than mothers who reported lower perceived NICU-related stress (30.62 ± 3.29). The effect size for perceived NICU-related stress was large (*d*=-4.35, r=0.909).

Discussion

This cross-sectional study evaluated sociodemographic, clinical, environmental, and maternal psychological variables as predictors of parent visits in the NICU. Like previous studies, the amount of time in which parents visited their hospitalized infant varied considerably. [23-26,28] Results of this study suggest that the presence of a neurological co-morbidity, surgical history, type of room, perceived NICU-related stress, and number of children in the family accounted for a significant amount of variance in parent visits. Importantly, each of the significant predictors had large effect sizes on parent visits (r>0.8). These findings contribute to the limited body of literature that have examined predictors of parent visits.

Like previous studies, this study demonstrated that the number of children in the family was a significant negative predictor of parent visits.[28] Parents who have a higher number of children at home have the responsibility of taking care of their other children and thus, may be limited in their ability to visit their hospitalized infant. Staying overnight in the NICU or in accommodations close to the NICU may not be an option for parents who have other children, particularly those who are school age. While the NICUs in this study did not permit visitation by any child under 12 years old at the time this study was conducted, it is possible that the effect of this predictor may be diminished if visitation policies allowed child visitors. The restricted visitation policy poses both logistical and financial challenges to families with other children, especially those who are socioeconomically disadvantaged. It is possible that families may benefit from hospital-provided childcare for siblings during parent visits.

In addition to number of children in the family, the present study also investigated the relationship between other sociodemographic factors, including infant gender, infant race/ethnicity, maternal age, maternal education, maternal employment, partner status, and poverty level. It seems plausible that parents of lower socioeconomic status may visit their infant less frequently than parents of higher socioeconomic status and that single parents or parents employed full-time would have less time to visit their infants. While education level (bachelor's degree vs. no bachelor's degree), partner status (living with partner/married vs single), and race had significant associations with parent visits at the univariate level, they did not have significant effects on parent visits in the multivariate analysis. There were no associations with infant gender, maternal age, maternal employment, or partner status and parent visits at either the univariate or multivariate level. Previous studies have documented inconsistent results regarding the predictive effect of socioeconomic factors on parent visits.[24,28,29] While two studies identified younger maternal age as a predictor of less visitation, two other studies found that maternal age had no association with parent visits.[23-25,28] Similar inconsistencies have been reported for maternal education, marital status, and household income.[23-25,28,33]

Self-reported measures of maternal well-being were collected as potential predictors of parent visits. This study is the first study to investigate whether self-reported self-efficacy influenced parent visits. The mothers in this sample reported unusually high levels of self-efficacy without considerable variation. Although mothers were informed of the confidentiality of the questionnaire and completed them in privacy away from the study team, it is possible that the high levels of self-efficacy may reflect social desirability bias. While no significant association was found between self-reported maternal self-efficacy and parent visits, the lack of variation in the scores limited the ability to identify an association. This study also examined perceived NICU-specific stress and found that higher perceived NICU-related stress was associated with greater parent visits. An association between less frequent visitation and higher NICU-specific parenting stress related to the infant's appearance and behavior (subscale of the PSS:NICU)) has previously been documented.[24] As such, the direction of the association in this study was contrary to what was expected. However, another study demonstrated that higher maternal anxiety, as measured by the State-Trait Anxiety Inventory, was predictive of higher visitation.[28] The PSS:NICU, while NICU-specific, is highly correlated with the State-Trait Anxiety Inventory.[31] A possible explanation is that higher NICU-related stress compels parents to visit their infant. Furthermore, maternal visitation to the NICU may also help to decrease anxiety by allowing mothers to be involved in caring for their infant and by promoting parent-infant attachment.

NICU room type was another strong predictor of parent visits. To date, studies have not considered whether double occupancy rooms affected parent visitation. Interestingly, parents did not visit more frequently in a double occupancy room but did visit more in single family rooms compared to the open bay design. In fact, the mean percentage of time in which parents visited in the single room (50.47 $\pm$ 30.85) was over double the percentage of time in which parents visited in either the double occupancy rooms (15.56 $\pm$ 12.77) or open bay areas (23.01$\pm$ 21.32) ($p<0.001$). While double occupancy rooms provide more privacy and a quieter environment compared to open bay areas, it is possible that parents do not perceive these differences to be meaningful to them. Future research exploring parental satisfaction, involvement in care, and visitation in double occupancy rooms is important for NICU design considerations.

In contrast to double-occupancy rooms, the single family room design significantly predicted greater parent visits. These findings are similar to a previously published study comparing parent visitation between single patient rooms and open bay areas.[27] In that study, parents visited 1.5 times more in single patient rooms, or 8.64 hours more per week, compared to open bay areas from birth until hospital discharge, controlling for gestational age, length of intubation, medical acuity, brain injury, socioeconomic status, and maternal age.[27] While very little literature exists concerning the influence of NICU design on parent visits, several studies have documented higher parental satisfaction afforded by single family rooms compared to open bay areas.[34] Single family rooms offer families more privacy, protection from lights and noise in the NICU environment, and may increase involvement in the infant's care, skin-to-skin contact, and breastfeeding, all of which promote infant growth and parent-infant attachment.[13,34,35] This study adds to the literature supporting the benefits of the single-family room design and offers evidence suggesting double-occupancy rooms may not provide similar benefits.

Interestingly, the effect of the single family room was significantly different based on whether or not the infant had a surgical history. It may be important to note that surgical history was highly correlated with the medical acuity (r=0.282, p=0.022), gestational age (r=-0.313, p=0.010), and number of days in the NICU at the time of data collection (r=0.314, p=0.011), which were correlated with parent visits (r=-0.434, r=0.397, r=-0.394, p<0.001 respectively). While previous studies have conflicting results about whether medical acuity and gestational age influences parent visits, previous studies have consistently suggested that greater length of stay in the NICU is associated with less frequent parent visits and that visitation decreases throughout hospital stay.[23,29] However, the number of days in the NICU at the time of data collection was not predictive of parent visits in this study after including surgical history in the model. It is possible that parent involvement in the baby's care is reduced in surgical infants due to the complexity of the infant's medical condition and the need for rest. Decreased parental involvement may lead to less visitation. Another explanation is that parents of preterm infants who are admitted to the NICU for a surgical need may have higher psychological distress compared to parents of preterm infants who do not need surgery. Although no studies have been conducted examining differences in psychological distress based on surgical history, parents of surgical infants may have experienced their infant undergoing a greater number of painful medical and surgical procedures, which is known to cause distress in parents.[36-38] High psychological distress may result in avoidance of situations that contribute to the distress, such as visiting their infant. If parents fear death of their infant, they may also distance themselves from their infant as a protective mechanism, which could affect visitation practices.

Similarly, the presence of a neurological co-morbidity significantly predicted lower parental visitation. Like surgical history, neurological co-morbidity was highly correlated with the number of days in the NICU at the time of data collection (r=0.284, p=0.021), gestational age (r=-0.290, p=0.018), and medical acuity (r=-0.587, p<0.001). These correlations may contribute to the effect of neurological co-morbidity observed in this study. Another explanation, like surgical history, is that parents may be more reserved in their interactions if their infant has a neurological co-morbidity. Parents may experience more difficulty establishing a positive parent-infant relationship as infants with neurological complications may not respond as overtly to parent engagement as an infant without a neurological co-morbidity. However, no studies have examined parent-infant interactions and attachment in preterm infants with neurological insults. This novel finding has important implications as preterm infants with known brain injuries or neurological complications may benefit the most from parental presence and engagement in the NICU, as they are more vulnerable to a poor neurobehavioral and neurodevelopmental trajectory.[39-41]

The present study is not without limitations. First, this study was nested within a parent audio-recording study. As such, parent visitation data was collected for only the 48 hour time period that audio-recording data were being collected. The average length of stay in the NICU for our sample was 60.52 days. Therefore, data about parent visitation was not collected on the vast majority of days in which the infant was hospitalized. These 48 hours may or may not be representative of the parents' visitation patterns throughout the entire length of stay. Although a paired t-test showed no statistical differences in the mean parent visits on weekdays versus weekends ($p=0.146$), the data were not collected systematically on both a weekday and a weekend. This study also only looked at duration of the visits, rather than frequency. Most of the other studies that have looked at predictors of parent visits have examined frequency of visits over a longer period of time. Therefore, the ability to compare results of the present study with previous studies is limited.

Furthermore, data about maternal depression were not able to be collected. The study hospital's IRB advised against using depression screening instruments due to the hospital's inability to treat the mother should she indicate high depressive symptomology or thoughts of harming herself. Postpartum depression is known to be higher in mothers whose infants have complex medical needs and greatly influences parent-infant interactions.[37,42] Therefore, postpartum depression may be an unaccounted variable that may have changed the results of the model in this study.

Other potential limitations of this study relate to the data collection of parent visits. While parents were required to sign in and out of the NICU at NICU A, it is possible that parents did not record accurate times in the visitation logs or inadvertently did not sign in. Furthermore, we had to rely on medical records to obtain parental visitation times at NICU B. While we verified the times with the nurses, the timing of the parent visits at NICU B were likely estimates. However, results of this study do not conflict with the results of previous studies that examined parent visitation over a long period of time. Additionally, the percentage of time in which parents visited in this sample is greater than other studies that examined parent visitation time. There are two possible reasons why a higher percentage of visitation time was observed in this study. First, the parents of the infants enrolled in this study may have been more likely to visit compared to the general population of NICU parents. Because participants were recruited by meeting with parents when they came to the NICU, study team members had less opportunities to approach parents who rarely came to the NICU and thus, selection bias may have occurred. Secondly, data collection started at the time of recruitment for most participants unless study materials for the larger study were unavailable at time of recruitment. As a result, almost all parents were visiting at the time when data collection began. While this alone could have resulted in a higher percentage of visitation time during the data collection period compared to the entire NICU hospitalization, it should be noted that 70% of the infants in the sample were visited on both days of data collection. Also, parent visits were still normally distributed and several parents did not visit during the data collection time period.

Conclusion

Parent visitation in the NICU is multi-faceted and is undoubtedly affected by a combination of sociodemographic, clinical, environmental, and maternal psychological factors. The present study identified number of children, perceived parenting stress, type of NICU room, surgical history, and neurological co-morbidity as predictors of parent visitation, with an interaction effect between NICU room and surgical history.

Observational studies have shown that greater parental visits and involvement in the care of their preterm infant results in better short term as well as long-term outcomes.[14,26] Parental involvement has significant implications for the establishment of a healthy parent-infant attachment, which strongly influences the infant's socioemotional and developmental trajectory.[43] Remarkably, parent visitation in the NICU has been shown to be a stronger determinant of behavioral and emotional outcomes than medical complications and birth weight.[14] As such, parent visits are necessary to optimize the health and developmental trajectory of hospitalized preterm infants.

Given that neonatal intensive care units have recently begun to implement policies to encourage greater parental visitation, this research is timely. Additional studies are needed to investigate the relationship between the predictors identified in this study and parent visits. Documenting parent visits over a longer period of time, including both frequency and duration of visits, would help advance this area of research. Identifying and understanding factors that underlie differences in parental visitation practice can help providers and researchers develop interventions and design NICUs that support parental presence and involvement, and ultimately, improve attachment and outcomes among preterm infants.

Table 1: Independent Variables Considered as Predictors of Parent Visits

Independent Variables Considered as Predictors	Definitions/Categories
Sociodemographic Variables	
Infant Gender	Male , Female
Infant Race/Ethnicity	White, Black, Asian, Hispanic, Other
Maternal age	Continuous
Maternal education	Bachelors degree, No Bachelors degree
Maternal/paternal employment	Full time, Part time/unemployed
Partner status	Living with partner/married , Single/divorced
Number of children	Two or less, Three or more (based on 50^{th} percentile)
Poverty level	Under federal poverty line, Above federal poverty line
Insurance	Private, Medicaid/None
Clinical Variables	
Gestational age	Continuous
Corrected gestational age	Continuous
Mode of delivery	Vaginal, Caesarean section
Medical acuity	Continuous (Median acuity over 48 hours based on ACOG guidelines)
Days in the NICU at time of data collection	Continuous
Surgery	Had surgery/will have surgery during NICU stay, No surgical need
Neurological Co-morbidity	Yes (IVH, HIE, Seizures, Neural Tube Defect, Hydrocephlaus), No
Gastrointestinal co-morbidity	Yes (NEC, intestinal perforation, gastroschisis, omphalocele, duodenal/jejunal atresia, imperforate anus, CDH, TEF, cholestasis, ascites), No
Pulmonary co-morbidity	Yes (ARF, Chronic Lung Disease/BPD, Apnea of Prematurity, pulmonary hypertension, lung structure abnormality), No
Cardiac co-morbidity	Yes (PFO, PDA, ASD, VSD), No
Genetic abnormality	Yes (Trisomy 18, Trisomy 21), No
Infection	Yes, No
Oxygen support	Not ventilated, ventilator
Sedated	Yes, No
Number of lines/drains	Continuous
Environmental Variables	
Bed type	Isolette, crib

Type of NICU room	Single family room, open bay, double occupancy room
Kangaroo care	Yes, No
Hospital	Hospital A, Hospital B
Contact precautions	Yes, No
Maternal Psychological Variables	
Perceived Maternal Self-Efficacy Scale	Continuous
Parent Stressor Scale: NICU	Scores $\leq$98, Scores >98 (based on 50th percentile)

ACOG=American College of Obstetrics and Gynecology; IVH=intraventricular hemorrhage, HIE: hypoxic ischemic encephalopathy, NEC: Necrotizing enterocolitis, CDH: congenital diaphragmatic hernia; TEF: tracheoesophageal fistula; ARF: acute respiratory failure; BPD: bronchopulmonary dysplasia; PDA: patent ductus arteriosus; PFO: patent foramen ovale; VSD: ventricular septal defect; ASD: atrial septal defect

Table 2: Demographics of sample

Child's Gender	
Male	63.6% (n=42)
Female	36.4% (n=24)
Maternal age	29.20 $\pm$ 6.66
Child's race	
Black	43.9% (n=29)
White	39.4% (n=26)
Hispanic	3.0% (n=2)
Asian	13.6% (n=9)
Maternal college degree	37.7% (n=23)
Living with partner/Married	74.2% (n=49)
Maternal full-time employment	33.9% (n=21)
Number of children in household (not including patient)	
One	70.8% (n=46)
Two or more	28.2% (n=20)
Under Federal Poverty Line	36.8% (n=21)
WIC Eligible (under 185% federal poverty line)	68.4% (n=39)
Previous experience with a child in the NICU	17.2% (n=11)

Table 3: Clinical characteristics of sample

Gestational age at birth	222.64 ± 34.12
Corrected gestational age at time of data collection	251.62 ± 16.77
Birth weight (g)	1880.76 ± 932.46
Hospital A	56.1% (n=37)
Days in NICU at time of data collection	27.26 ± 25.76
Bed type (isolette)	36.4% (n=24)
Single family room	37.88% (n=25)
Vaginal delivery	47.0% (n=31)
Surgery	66.7% (n=44)
Gastrointestinal co-morbidity	51.5% (n=34)
Pulmonary co-morbidity	66.7% (n=44)
Neurological co-morbidity	47.0% (n=31)
Intraventricular hemorrhage	24.2% (n=16)
Hypoxic ischemic encephalopathy	6.1% (n=4)
Hydrocephalus	7.5% (n=5)
Neural tube defect	3.0% (n=2)
Seizures	4.5% (n=3)
High acuity	42.4% (n=28)
PSS:NICU <98	45.5% (n=30)
Percentage of time in which parents visited (%)	32.40 ± 28.22
Percentage of parent visit with only one visitor (%)	55.06 ± 43.53

Table 4: Parameter Estimates for General Linear Model

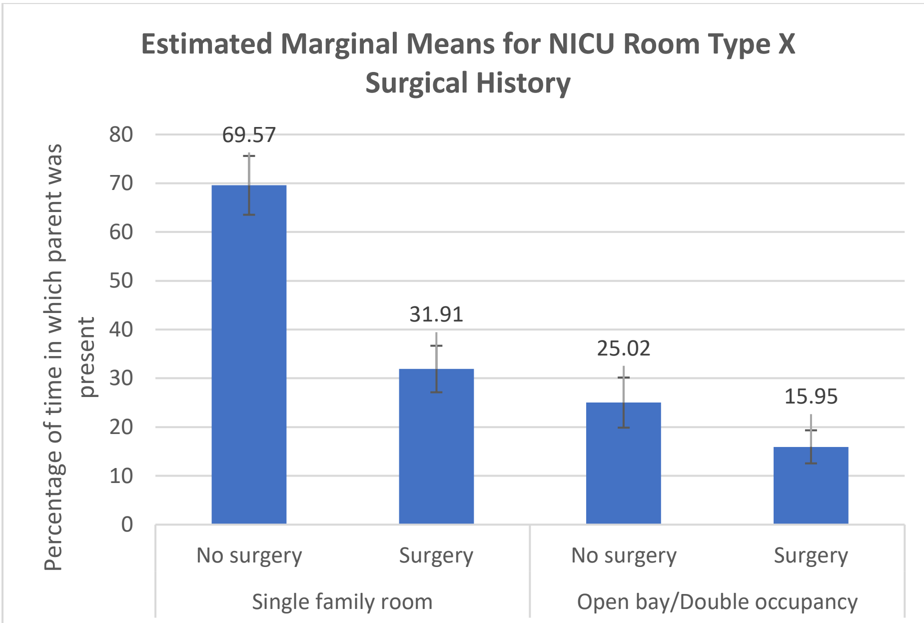
Parameter	β (95% CI)	Standard Error
(intercept)	17.75 (2.81, 32.68)	7.45
Neurological co-morbidity	-22.19 (-31.16, -13.22)	4.47
Number of children (≤2)	16.12 (5.89, 26.34)	5.10
Parenting Stress Scale :NICU (≤98)	-9.98 (-19.18, -0.79)	4.59
Single family room	15.96 (4.42, 27.50)	5.76
Surgery	-37.66 (-32.53, -10.66)	7.14
Single family room*Surgery	-28.593 (-47.50, -9.68)	9.43

Model statistics: Adjusted R square=0.658; F statistic=20.23, $p<0.001$;
Lack of Fit: F=0.814, p=0.668

Table 5. Estimated marginal means of parent visits by predictor

Predictor		Mean (%)	Std. error	95% CI (%)	Pairwise comparison
Number of children	Two or less	43.67	2.69	38.28, 49.06	F=9.98,
	Three or more	27.56	4.46	18.62, 36.49	p=0.003
Neurological co-morbidity	Yes	24.52	3.74	17.01, 32.02	F=24.60,
	No	46.71	3.17	40.35, 53.07	p<0.001
Parental Stressor Scale: NICU	≤98	30.62	3.29	24.03, 37.21	F=4.74,
	>98	40.61	3.71	33.16, 48.05	p=0.034
Single family room (SFR) * Surgery	SFR*Surgery	31.91	4.77	22.35, 41.47	
	SFR*No surgery	69.57	6.03	57.48, 81.66	
	No SFR*Surgery	15.95	3.39	9.15, 22.76	
	No SFR*No surgery	25.02	5.14	14.72, 35.32	

Figure 1. Estimated Marginal Means for Interaction Effect between Room Type and Surgical History



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CHAPTER FIVE

The purpose of this dissertation study was to characterize the language environment of preterm infants and identify determinants of the language environment and parental presence in the NICU. Sociodemographic factors, birth history, clinical status, NICU environmental factors, and maternal perceived stress and self-efficacy were considered as predictors of the language environment and parental presence in the NICU.

A cross-sectional design was used to examine the relationship between the independent variables and language exposure (adult word count and meaningful speech) and the independent variables and parental presence in the NICU (percentage of time in which parents were present during 48 hours of data collection). A convenience sample of preterm and early term infants (born at <38 gestational weeks) was recruited from two NICUs within a pediatric hospital system located in the southeastern United States. A LENA digital language processor was placed in the infants' crib or isolette for 48 consecutive hours that captured all the sounds in the environment and provided a report for number of words spoken around the infant and the percentage of the auditory environment composed of silence, electronic sounds, noise, and speech. Mothers completed a demographic survey, the Parent Stressor Scale: NICU, and the Perceived Maternal Self-Efficacy Scale at the time of consent. Clinical data were collected via medical chart review. Time of parent visits were collected via visitation logs and medical chart review. The three manuscripts included in this dissertation research document the results from the specific aims of this study as well as provide a comprehensive and detailed literature review on the influence of early language exposure on children's language and cognitive outcomes.

The first manuscript (Chapter 2) addresses a gap in the literature by providing a detailed, integrated review of the effect of talking, reading, and interacting with a child in the first three years of life on their subsequent language and cognitive outcomes. While there have been a few reviews on this topic, this review represents the largest and most comprehensive review on the impact of early language exposure on a child's developmental outcomes. The review examined various features of linguistic input, including quantity of words, lexical diversity, grammatical complexity, syntactical diversity, intonation and prosody, use of gestures, joint attention, contingent responses, and shared book reading. A total of 103 articles were included, most of which were cross-sectional or prospective cohort studies.

Findings from this review highlight the importance of early language exposure and positive parent-child interactions on a child's neurodevelopmental and educational trajectory.[1] Speech that is varied in words, grammatical complexity, syntactical structure, and prosody all contribute to the acquisition, comprehension, and production of language.[2,3] Greater language exposure provides children with the opportunity to learn new words, interpret language, and develop and refine skills necessary for language learning. Benefits of early language exposure and positive parent-child interactions mediated the adverse effects of various conditions (such as preterm birth, poverty, parent depression and low education) on children's development.[3-6] These benefits extended past early childhood into measures of school readiness and third grade academic outcomes, but were limited to language that is child-directed.[7-11] Overheard speech and media exposure were not positively associated with children's language outcomes, suggesting that language that is not delivered in the context of an engaged parent-child interaction is not supportive of early neurodevelopment.[12-16] This finding emphasizes the importance of parent-child interactions for a child's development.

This review identified a significant gap in the literature for examining the influence of language exposure for preterm infants and infants less than 6 months old. Only 7.7% (n=8) of the studies in this review had samples that included children who were born preterm and less than 10% (n=9) had samples that included children who were less than 6 months old. Neural networks for language learning are present prior to birth and infants' brains are primed to learn language.[17,18] As such, it is postulated that language exposure starting even before birth is critical for a child's development. Additional studies evaluating the influence of language exposure in the first few months of life on a child's developmental trajectory, as well as in samples of children born preterm, are needed to understand the effect of language exposure on preterm infants' and young infants' (<6 months) developmental and academic outcomes.

The second manuscript (Chapter 3) described the findings of the first and second specific aims of the dissertation study, which were to characterize the language environment of the NICU and identify predictors of preterm infants' language environment in the NICU. In this study, meaningful speech (percentage of the auditory environment composed of speech) only represented 3.61$\pm$ 2.78% of all auditory exposures in the NICU. Silence and electronic noise were the predominant exposures, each representing 52.19 $\pm$ 19.61% and 22.01 $\pm$ 17.41%, respectively. Average adult word count was 304.68 $\pm$ 245.63 words per hour. Although there are no normal parameter estimates for adult word count or meaningful speech for infants born preterm, a recent study conducted with typically developing children reported that two-month old children were exposed on average to 15,439 words over a 12 hour period, or 1,287 words per hour.[19] While the children in this sample were not in the NICU and were a different corrected gestational age, this study suggests that 2 month old children are exposed to 423% more words than preterm infants.[19] The same study, which had a data set with 3,213 12-hour LENA recordings, found that word count actually significantly decreased as age of the child increased.[19] This decrease may be related to more close face-to-face interactions with infants, for instance through feedings, and the lack of mobility by young infants.

Determinants of adult word count were identified through multivariate analysis using negative binomial regression. The percentage of time in which parents were present in the NICU during the 48 hour data collection (referred to as “parent visits”) was the strongest predictor of adult word count. As a continuous variable, a one percent increase in parent visits (increased visitation of 28.8 minutes) resulted in a 13% increase in adult word count. However, parent visits were dichotomized into high vs. low parent visits at the cut-off point of 37% using optimal binning for interpretability purposes. As a dichotomous variable, infants whose parents had a high visitation rate were exposed to 184% more words than infants whose parents had a low visitation rate ($p<0.001$). Difference in estimated marginal means for adult word count by parent visits was 188 words per hour, or 4,512 words per day. When parents were present, infants were exposed on average to 170% more words compared to the times when parents were not present. After controlling for parent visits, no other factors considered for inclusion in the model were predictive of adult word count except for corrected gestational age. Each week increase in corrected gestational age increased adult word count by 12.6% ($p<0.001$).

Multivariate analysis using gamma log-link regression was used to determine predictors of meaningful speech in the NICU. Like adult word count, parent visits and corrected gestational age were significant predictors of meaningful speech. Infants of parents with high visitation rate were exposed to 34% more meaningful speech than infants whose parents had a low visitation rate and each week increase in corrected gestational age increased meaningful speech by 12%. Infants in single family or double occupancy rooms were exposed to a 27% more meaningful speech compared to infants in open bay areas. Infants on oscillators or ventilators were exposed to 43% less meaningful speech compared to infants not on oscillators or ventilators.

Infants were exposed to significantly more language exposure the greater amount of time parents were present in the NICU. Findings from this dissertation suggest that parental presence in the NICU significantly enriched the language environment regardless of the socioeconomic, educational, or racial/ethnic background of the parents. While it is not clear whether the language was specifically directed towards the infant or rather conversations between adults, (either between two or more visitors in the room, or between a parent and a nurse or healthcare provider), the data clearly demonstrate a large effect of parent visits on language exposure. The increase in language exposure may be a beneficial result of having an engaged adult present to focus their attention on spending time with and interacting with their child.

Given the strong influence of parents on the language environment in the NICU, developing interventions specifically targeted at increasing parental presence in the NICU is a logical strategy to improve the language environment in the NICU. Parent visitation practices are widely varied, as some parents visit rarely while other parents are present for the entire hospital stay. As such, understanding factors that affect parent visitation is an important first step to influence parental presence in the NICU.

The third manuscript (chapter four) describes the findings of the third dissertation aim, which was to identify predictors of parent visits in the NICU. The mean percentage of time in which parents visited was 32.40%, or 15.55 hours, and the 25-75% IQR was 10.01-44.92%. In the multivariate regression, surgical history, neurological co-morbidity, greater number of children at home, lower perceived stressfulness of the NICU as self-reported by the mother, and non-single family rooms (open bay/double occupancy rooms) were identified as significant negative predictors of parental presence in the NICU. An interaction effect was observed between surgical history and room type. Each of these predictors had a large effect size on parent visits and together accounted for 65.8% of the variance in parent visits ($p<0.001$).

Of the five predictors of parent visits, none were significant predictors of adult word count and only room type predicted meaningful speech as well, controlling for parent visits. The presence of a neurological co-morbidity (Spearman's rho= -0.269, $p=0.029$), open bay areas (Spearman's rho= -0.426, $p<0.001$), and oscillator/ventilator support (Spearman's rho= -0.356, $p=0.003$) were negatively correlated with adult word count, and oscillator/ventilator support (Spearman's rho= -0.553, $p<0.001$) was negatively correlated with meaningful speech. Neither surgical history nor number of children were correlated with either measure of language exposure. Mediation models were not constructed in this dissertation study because it was not an original aim of the study and the sample size was relatively small for such analysis. However, investigating whether parent visits mediate the relationship between predictors of parent visits and measures of language exposure is a next step to further understand relationships observed in this data.

Strengths and Limitations

This dissertation makes several significant contributions to a limited area of research. The comprehensive integrated review provides one of the first reviews examining the relationship between early language exposure and parent-child interactions on children's language and cognitive outcomes. Additionally, this dissertation study is the first study to examine the language environment of preterm infants across all gestational ages with a variety of co-morbidities, as the samples in the two previous studies examining the language environment in the NICU were restricted to infants born less than 28 or 32 weeks gestation without any co-morbidities. Furthermore, this is the first study to investigate social, environmental, clinical, and maternal psychological determinants of the language environment of preterm infants and the first study to identify room type a significant predictor of meaningful speech. Likewise, this is one of the few studies to identify predictors of parental presence in the NICU and supports previous studies that suggest that a greater number of children at home is associated with decreased parent visits. This study was the first study to identify the presence of a neurological co-morbidity (including intraventricular hemorrhage grade II-IV, hypoxic ischemic encephalopathy, hydrocephalus, neural tube defect, or seizures) and a surgical history as negative predictors of parent visits. Results of this study support transitioning from an open bay design to single family rooms, as single family rooms were associated with greater language exposure as well as greater parent visits. This study provides potential targets for optimizing the early experiences of preterm infants in the NICU.

Additional strengths of the integrative review include that data were collected systematically for over 100 articles, of which most employed a quasi-experimental or prospective cohort design. The sample across all studies was diverse in socioeconomic backgrounds, race/ethnicity, and developmental abilities, which increases the generalizability of the review findings. Limitations of the integrative review include the fact that several studies included lacked the statistical power to construct predictive statistical models. Also, methodological differences across the studies makes it more difficult to assess the strength of the findings, although most studies arrived at the conclusion that a higher quality and greater quantity of language exposure and parent-child interactions were beneficial for a child's development.

There are many additional strengths of this dissertation. First, this study is the largest study to date examining the language environment in the NICU and the only study that has assessed the language environment for 48 consecutive hours rather than only 16 hours at a time. By assessing the language environment for 48 consecutive hours, the language environment was assessed at every hour of the day. Also, the data were analyzed through multivariate statistical tests that were appropriate for the distribution of the data. Previous research has relied on bivariate analyses that did not control for potential confounders. Additionally, given that meaningful speech is a continuous variable and not discrete data, gamma log-link regression is a better fit for meaningful speech data compared to negative binomial regression, which has been used in a prior study. Furthermore, this study considered many potential factors that could influence parent visits and the language environment in the NICU. These factors included a long list of clinical factors, sociodemographics, NICU environmental factors, and maternal psychological factors.

Results of this study must be interpreted considering several limitations. First, data was collected for only forty-eight hours. This forty-eight hour period may not have been representative of parental presence or the language environment for the entire NICU stay. It is possible that various procedures or care tasks that were not performed daily, such as returning from surgery, placement of a central line, or discharge teaching, were performed during a day in which the data were being collected and may have affected results. Moreover, parents did not sign in and out of one of the NICUs in the study and thus, data collection for parent visitation relied on the nurse charting parental presence. Parents may have also incorrectly recorded time of arrival and leaving time on the visitation log at the NICU that kept visitation logs. Although study personnel attempted to verify parent visit times with the nurse, it likely that there is some error in the data collection of parent visits.

Several limitations of the study relate to the use of the LENA digital language processor (DLP). It is possible that the presence of the DLP may have affected adult interactions with the preterm infants. Previous studies using LENA have demonstrated a small Hawthorne effect in the first two to three hours of use before observing stabilization of language exposure; for this reason, the LENA Research Foundation recommends that at least 16 hours are recorded at a time.[20] Independent t-tests for this study demonstrated that significant differences did not exist between the language exposure during the first set of 24 hours compared to the language exposure during the second set of 24 hours, suggesting that the Hawthorne effect was minimal and not statistically significant (p=0.922). Additionally, while the DLP stayed in the infants' beds, it was sometimes moved around in the bed by nurses or other allied health staff as they provided care to the infant. While this theoretically should not affect the results as speech variables are detected up to five feet away, the placement of the LENA was not always uniform. Likewise, infants were often taken out of their bed to be held or for kangaroo care while the parents were visiting and the LENA remained in the bed. Although most parents were within five feet of the LENA while holding their baby, it is possible that some parents held their baby further than five feet away. As a result, child vocalizations and adult word count may not be picked up by the recorder and any meaningful speech would be recorded as distant speech.

The LENA automated analysis is not able to determine if words are child-directed. Research demonstrates that the social interaction involved in conversation is a crucial aspect of early language development and thus, not knowing to whom the words were directed would have important developmental implications.[21] Likewise, the content of the words and the tone of voice were not investigated, but previous research suggests that not only the quantity but also the quality of the words spoken to an infant influences their language development.[1,3,15,16,22] Furthermore, the LENA automated analysis is only able to label one point in time with the primary auditory stimulus. Therefore, if an adult is talking to an infant at the same time that an oscillator or ventilator is making noise or a television is on, the LENA is unable to generate a report that shows simultaneous auditory exposures.

Other limitations include that responses to the questionnaires were self-reported and only were completed at one time in the NICU. Responses to the questionnaires may have subjected to social desirability bias as not much variation was seen on the Perceived Maternal Self-Efficacy Scale. Responses on questionnaires may also have been different depending on the status of the infant at the time the questionnaires were given. Furthermore, this study was not able to administer a questionnaire to assess for post-partum depression. Original study plans included the Edinburgh Postpartum Depression Scale as a questionnaire, as evidence suggests that post-partum depression affects maternal interactions with her child.[23,24] However, the study hospital's IRB advised against using depression screening instruments due to the hospital's inability to treat the mother should she indicate high depressive symptomatology. As a result, this study was not able to control for post-partum depression.

Lastly, this study may have been subjected to selection bias. Mother-infant dyads were recruited into the sample in the NICU when the mother was present visiting her infant. As a result, it is possible that infants in this study had mothers who were more engaged and visited more often compared to the eligible infants who were not recruited into the study.

The generalizability of this study is limited by the characteristics of the sample and the NICU design. The majority of the sample had surgical needs in addition to medical needs, and thus, is likely a more medically complex and medically fragile population compared to the majority of infants in neonatal ICUs across the country. This study also was conducted in a pediatric hospital, whereas the majority of NICUs are in birthing hospitals. Generally, birthing hospitals are selected by families based on the hospital's proximity to their home. However, infants were often transported over 50 miles to receive specialized pediatric care at the NICUs in this study, possibly creating a barrier to parental involvement. In addition to increased distance from home, many of the families in this study had socioeconomic challenges that may have limited the ability of parents to engage in meaningful interactions with their child. As a result, settings in which parents have adequate resources to be involved in the care of their child in the NICU may yield different results. Additionally, the layout of the NICU may have a profound influence on the auditory environment. As shown in this study, the auditory environment was significantly different in single family and double occupancy rooms compared to open bay areas. Open bay areas vary considerably between NICUs in regard to the number and arrangement of the beds, and space and dividers between beds. Attention to parent involvement, hospital characteristics, and NICU layout are all essential contextual factors to consider when generalizing these study results.

Implications for research, practice, and policy

This dissertation has made significant contributions to the area of research concerning early language exposure and parent visits in the NICU, but this field of research is in its early stages. Future research is needed to further characterize the language environment in a variety of NICU settings and to develop normative parameters for language exposure in preterm infants. Additional studies are needed to confirm or disconfirm the findings in this study and to investigate other potential contributors to the language environment and parental presence in the NICU. Larger studies as well as collecting language exposure data and duration/frequency of parent visits over a longer period of time would help to further characterize the language exposure and to better understand the relationships between predictors and language exposure and parent visits. In addition, no study has investigated the quality of language exposure in the NICU. To date, only the quantity of language exposure has been studied. As the integrated review from this dissertation suggests, the quality of the language exposure may be more influential on a child's developmental outcomes than the actual quantity of language exposure. As a result, research looking at the quality of language exposure in the NICU is important to advance this field of research. Future studies that evaluate the effect of the level of parent involvement in care and about the specific type of interactions parents have during parent visits may also help unpack the contribution of parent visits on language exposure. Furthermore, it is essential that cohort studies be conducted to investigate the influence of language exposure in the NICU on preterm infants' short term outcomes, such as length of stay or number of days until full feeds, and long term outcomes, including measures of school readiness and educational achievement. Until a clear, positive relationship between the language environment and infant outcomes can be established, there is a lack of evidence to support interventions developed to increase language exposure in the NICU.

Findings from this research study may be used to influence clinical practice. This study can provide clinicians with a better understanding of the auditory stimuli in the NICU to which preterm infants are exposed. Understanding the auditory environment in the NICU is a first step to making the NICU environment more developmentally appropriate for infants. Furthermore, results from this study support interventions aimed at increasing parental presence in the NICU and interventions targeted towards parents, who can dramatically modify the auditory exposures experienced by their child.

Healthcare providers can educate parents about the important role they have in shaping the early experiences of their infant and about the importance of their presence for their infants' social, language, and neurological development while hospitals can decrease barriers to visitation. The use of volunteers, or "baby buddies", especially for infants at risk of low parent visits or low language exposure, may help improve the language environment in the NICU. Results from this study could provide the foundation for quality improvement projects to foster a language-promoting culture within the NICU and enhance parental engagement in the NICU. It is important that researchers and clinicians work together to move knowledge to the bedside.

This dissertation study has important policy implications. Given the large effect of parental presence in the NICU on the language environment in the NICU, this study supports hospital policies that encourage parental presence and involvement in the NICU. For example, granting unrestricted parental access to the NICU, offering sleep rooms, and encouraging parental involvement in care may be measures that encourage parent visitation. Additionally, results of this study suggest that parent visits and language exposure are significantly higher in single family rooms compared to open bay areas. While language exposure was also higher in double occupancy rooms compared to open bay areas, parent visits were not higher in the double occupancy rooms. Results of this study support transitioning from the traditional open bay area to single family rooms. Single family rooms appear to provide infants with an environment that is richer in social interactions and opportunities for language learning and parent-infant bonding. In NICUs where such a design change is not possible, providing privacy for families, such as by providing curtains, may also help encourage parent visitation and facilitate parent-infant interactions. Furthermore, while the American Academy of Pediatrics has guidelines concerning the noise levels in the NICU, no evidence-based guidelines exist for language exposure in the NICU. Establishing such guidelines should be a policy initiative as having guidelines will allow for researchers to better evaluate the language environment in the NICU and develop interventions surrounding language exposures to best meet the physiological and neurodevelopmental needs of these vulnerable infants.

Summary

Preterm birth predisposes infants to poor neurodevelopmental and academic outcomes relative to term-born infants. Brain development is shaped by early sensory experiences, including exposure to language and parent-infant interactions. Not much is known about the language environment in the NICU or about factors that influence parental presence in the NICU.

This study demonstrated that preterm infants are exposed to a small amount of language during a critical period of brain development. However, the language environment in the NICU is modifiable. While several determinants of the language environment in the NICU are nonmodifiable, including corrected gestational age and oscillator/ventilator support, these factors can be used to help identify infants at risk for low language exposure. Results of this study suggest that single family rooms encourage parental visitation and are associated with greater language exposure, adding to the literature supporting the transition from open bay areas to single family rooms. Additionally, parental presence, which was significantly influenced by the number of children at home, surgical history, neurological co-morbidity, perceived stressfulness of the NICU, and room type, was a stronger determinant of language exposure in the NICU than clinical acuity, medical complications, and sociodemographic factors. This result highlights the critical role that parents have in shaping the early environment of their infant in the NICU, which could help to optimize the infants' health and developmental outcomes. This study is a first step in examining and understanding the language environment in the NICU, and ultimately, improving the NICU environment in such a way that supports and facilitates the neurodevelopmental trajectory and educational achievement of all infants born preterm.

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