Adult Talk in the NICU With Preterm Infants and Developmental Outcomes

WHAT'S KNOWN ON THIS SUBJECT: It is known that adult language input is important to healthy language development and that preterm infants are at risk for language delay.

WHAT THIS STUDY ADDS: This is the first study to provide evidence that preterm infants' exposure to adult words in the NICU before the mother's due date are associated with better cognitive and language outcomes at 7 and 18 months' corrected age.

abstract

OBJECTIVE: The goal of this study was to test the association of mean adult word counts at 32 and 36 weeks' postmenstrual age in the NICU with Bayley Scales of Infant and Toddler Development, 3rd Edition (Bayley-III), cognitive and language scores. It was hypothesized that preterm infants exposed to higher word counts would have higher cognitive and language scores at 7 and 18 months' corrected age.

METHODS: This prospective cohort study included 36 preterm infants with a birth weight ≤1250 g. Sixteen-hour recordings were made in the NICU by using a digital language processor at 32 and 36 weeks' postmenstrual age. Regression analyses were performed on adult word count per hour, with Bayley-III measures correcting for birth weight.

RESULTS: Adult word counts in the NICU were positively correlated with 7- and 18-month Bayley-III scores. For the 32-week recording, in regression analyses adjusting for birth weight, adult word count per hour independently accounted for 12% of the variance in language composite scores (P = .04) and 20% of the variance in expressive communication scores at 18 months (P = .008). For the 36-week recording, adult word count per hour independently accounted for 26% of the variance in cognitive composite scores at 7 months (P = .0049).

CONCLUSIONS: Increased amount of parent talk with preterm infants in the NICU was associated with higher 7- and 18-month corrected age Bayley-III language and cognitive scores. These findings offer an opportunity for language intervention starting in the NICU. *Pediatrics* 2014;133:e578–e584

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KEY WORDS

language, neonatal, outcomes, premature infant, very low birth weight infant

ABBREVIATIONS

Bayley-III—Bayley Scales of Infant and Toddler Development, 3rd Edition
LENA—Language Environment Analysis
PMA—postmenstrual age

Dr Caskey conceptualized and designed the study and drafted the initial manuscript; Dr Stephens reviewed and revised the manuscript, and suggested additional analyses; Mr Tucker performed the statistical analyses and critically reviewed the manuscript; and Dr Vohr conceptualized and designed the study, critically reviewed the manuscript, and provided suggestions for analyses. All authors approved the final manuscript as submitted.

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In utero, the maternal voice is one of the most prominent stimuli during the development of the auditory system.[1,2] In contrast, it has been shown previously that infants born very prematurely who are cared for in a modern NICU are exposed to language input for only a small percentage of the time.[3,4] Instead of language as the primary input, infants in a NICU are exposed to a variety of noises, from monitors and other equipment, as well as to prolonged periods of silence.[3] Preterm infants are at known risk for language delay,[5–11] and it is not fully understood how the altered early sensory input they receive in this relatively language-poor environment for the first months of their lives contributes to their tendency for language delay.[12,13]

It has been shown, in older children, that language development is strongly linked with language input.[14–17] Zimmerman et al[18] found that adult word counts and adult–child conversations (conversational turns) were positively associated with "healthy language development." However, it is not yet known if even very early conversations with preterm infants are associated with improved language outcomes. The objective of the present study was to test the associations of adult word counts from recordings in the NICU at 32 and 36 weeks' postmenstrual age (PMA) with Bayley Scales of Infant and Toddler Development, 3rd Edition (Bayley-III), scores at 7 and 18 months' corrected age. We hypothesized that infants who were exposed to higher adult word counts in the NICU would have higher Bayley-III cognitive composite, language composite, receptive communication, and expressive communication scores.

METHODS

This prospective cohort study was conducted at Women & Infants Hospital (Providence, RI).

Participants

Between December 2008 and August 2009, parents of infants with a birth weight ≤1250 g were approached when the child was medically stable and before 32 weeks' gestation. Infants with chromosomal or congenital anomalies or infants who were intubated or medically unstable at 32 weeks were excluded. A total of 114 infants were screened; 53 were medically stable, and their parents were approached for consent and enrollment. Of these 53 infants, 36 were enrolled (67.9%), including 8 sets of twins, for a total of 28 families. Table 1 includes maternal and infant demographic data of the cohort. The mean gestational age at birth was 27 ± 2 weeks (range: 23–30 weeks), and mean birth weight was 896 ± 195 g (range: 480–1415 g). Twenty-six families spoke English and 2 spoke Spanish as the primary language. Seven families reported a family history of language delay.

TABLE 1 Maternal and Infant Characteristics

Characteristic	Value[a]
Male gender	15 (41.7)
Gestational age, wk	27 ± 2
Birth weight, g	896 ± 195
Maternal age, y	30.8 ± 7
Gravida 1	12 (42.9)
Race	
African American	6 (21.4)
Hispanic	4 (14.2)
White	18 (64.3)
Mother's education	
<High school	4 (14.3)
High school/partial college	13 (46.4)
College/graduate	10 (35.7)
Unknown	1 (3.6)
Family history of language delay	7 (19.4)
SNAPPE-II score, day 1	27.5 ± 17
SNAPPE-II score, day 3	20.7 ± 17
IVH (grade III or IV) or PVL	2 (5.6)
ROP (any)	12 (33)
Chronic lung disease (36 wk)	10 (27.8)
Hearing failed unilateral at discharge	4 (11.1)
Hearing failed bilateral at discharge	0 (0)

Data are presented as *n* (%) or mean ± SD. IVH, intraventricular hemorrhage; PVL, periventricular leukomalacia; ROP, retinopathy of prematurity; SNAPPE-II, Score for Neonatal Acute Physiology–Perinatal Extension II.

[a] Includes values for 36 infants, 28 mothers.

Study Design

Language data were collected in the NICU by using a Language Environment Analysis (LENA) digital language processor (LENA Research Foundation, Boulder, CO). LENA is a digital recording device that was placed in the pocket of a specially designed infant vest. The digital language processor recorded 16 hours, starting in the morning, of adult speech, child vocalizations, and background noise in the NICU at 32 and 36 weeks' gestational age. The audio recording was downloaded and analyzed by using LENA software. The LENA software uses speech-identification algorithms to provide word and vocalization counts for adult and child language, and to characterize the sounds in the recording. An adult word count is the number of words a child hears from an adult within a specified amount of time. The conversational turns are defined as vocal sounds from the infant followed by a response from an adult within 5 seconds or an adult word followed by a child vocalization within 5 seconds. Each time that happens, one turn is counted. A child vocalization is counted when a child's speech of any length is surrounded by >300 milliseconds of silence or other sound that is not the child's speech. LENA software does not count crying or vegetative sounds, such as sounds from the respiratory or digestive systems (ie, breath sounds, burping), in the infant vocalization counts but does include protophones such as squeals, growls, grunts, and "raspberries."[19] The vocalizations made by preterm infants usually consist of very short vowel sounds and grunts. The LENA device has previously been shown to have a high degree of fidelity in coding compared with trained human transcribers.[20]

Transcriber software (Bertin Technologies, Aix-en-Provence, France; 2008) was used by the investigator to determine how the LENA software was encoding the various sounds of the NICU

on a subset of 5 recordings. The "language" designation was given for all adult language and child vocalizations. "Television" was the designation for the monitor alarms, and "noise" was most often the designation given for noise from the motor of the isolette or from the respiratory equipment. In addition, a reliability analysis of the adult word count in the NICU environment was conducted by using 5-minute segments of 5 different recordings. The Pearson product-moment correlation between the human transcriber adult word count and LENA was $r = 0.93$, which is similar to results from the previously published reliability analysis.[20]

Demographic data and data on newborn illness severity according to Score for Neonatal Acute Physiology–Perinatal Extension II values on days of life 1 and 3 were collected; these scores include mean blood pressure, lowest temperature, lowest serum pH, urine output, presence of seizures, P_{O_2}/fraction of inspired oxygen ratio, birth weight, and Apgar scores.[21] Data were also collected on the rates of common neonatal morbidities, including bronchopulmonary dysplasia, defined according to physiologic oxygen requirement at 36 weeks' PMA; grade III or IV intraventricular hemorrhage or periventricular leukomalacia; any retinopathy of prematurity; and hearing screen results. At 7 and 18 months' corrected age, the infants were administered the Bayley-III.[22] The newest version of the Bayley-III includes scaled scores, composite scores, percentile ranks, and age equivalents (with confidence intervals) for cognition, language, and motor skills. The language and motor composite scores are further divided into receptive and expressive communication and fine and gross motor subtests, with individual age equivalents. Although there are currently no data on long-term predictive value of the Bayley-III, the predictive validity of a low mental development index on the Bayley Scales of Infant and Toddler Development, 2nd Edition, for cognitive function at school age has been shown to be low.[23] The cognitive and language composite scores, as well as the receptive communication and expressive communication scores, were included in the analysis for this report.

All 16-hour recordings were completed at Women & Infants Hospital in an open-bay NICU. The first recording was performed at 32 ± 2 weeks' PMA and the second recording was done 4 weeks after the first recording (at 36 ± 2 weeks' PMA) for all infants. Of the 36 infants enrolled, 35 (97%) had a recording at 32 to 34 weeks' PMA (mean: 33.1 weeks), and 33 (92%) had a recording at 35 to 38 weeks' PMA (mean: 36.3 weeks) while in the NICU. One infant was intubated at 32 weeks and was not recorded; however, per the mother's request, the infant was enrolled after extubation at 36 weeks. At 32 weeks, 80% of infants were recorded in a regular isolette, 17% in a Giraffe OmniBed incubator (GE Healthcare, Waukesha, WI), and 3% (1 infant) in an open crib. For the 36-week recordings, 80% of infants were in an open crib and 20% were in an isolette. Two infants were transferred to another nursery before the 36-week recording, and 1 infant was discharged from the hospital before 36 weeks. Some infants also received recordings in the home setting after discharge at 44 weeks', 7 months', and 18 months' corrected age. Thirty-two (89%) of the 36 infants were administered the Bayley-III at 7 months' corrected age; 30 had both 32- and 36-week recordings in the NICU, and 1 infant had only a recording at 36 weeks. Thirty-one (86%) of 36 infants were administered the Bayley-III at 18 months' corrected age; all of these infants had both 32- and 36-week recordings in the NICU. The Women & Infants Hospital institutional review board reviewed and approved the study, and informed consent was obtained.

Statistical Analyses

Descriptive statistics for demographic and other subject characteristics were calculated. Pearson correlations were used to measure the simple (zero-order) relationship of LENA measures and Bayley-III scores. Multiple linear regression was used to model the independent effects of the LENA adult word count at 32 and 36 weeks on the dependent variables (Bayley-III scores) while adjusting for birth weight. Parameter estimates (partial r^2) were calculated to measure the percentage of variance in the Bayley-III scores attributable to the LENA counts. The effect of each LENA measure was included in a separate model, which also included birth weight. To examine the cumulative effect of language exposure on Bayley-III scores, the infants who had complete recordings up to the time of administration of the Bayley-III were analyzed, relating the sum of LENA measures (sum of adult word counts, sum of conversational turn counts) across all recordings within child to their Bayley-III scores by using partial correlation, adjusting for birth weight. Analysis of the maternal education level and the Bayley-III outcomes were also analyzed. All statistical analyses were conducted by using SAS version 9.1 (SAS Institute, Inc, Cary, NC).

RESULTS

The mean adult word counts, conversational turns, and child vocalizations for each of the recordings have been presented previously[3] and are shown in Table 2. There was a significant increase in the median total adult word counts from 1289 to 8255 ($P = .0001$), an increase in the median conversational turns from 15 to 36 ($P = .0009$), and an increase in the median child vocalization count from 77 to 153 ($P = .0003$) between the 32- and 36-week recordings.

The Bayley-III scores at 7 and 18 months' corrected age are displayed in Table 3.

TABLE 2 Increase in Adult Words, Child Vocalizations, and Conversational Turns Over Time

Vocalization Counts	32 Weeks (n = 35)	36 Weeks (n = 33)	Percent Change (95% CI)
Total adult words			
Mean ± SD	3306 ± 4274	8556 ± 6407	160
Median	1289	8255	74–287
Range	144–16 549	374–26 145	
Total conversational turns			
Mean ± SD	25 ± 29	48 ± 45	96
Median	15	36	32–192
Range	0–105	3–188	
Total child vocalizations			
Mean ± SD	113 ± 101	195 ± 156	76
Median	77	153	30–138
Range	10–374	21–705	

Analysis for change over time estimated by using negative binomial regression with generalized estimating equations.

TABLE 3 Mean Bayley-III Measures for Study Patients

Bayley-III Measure	7 Months (n = 32)	18 Months (n = 31)
Cognitive composite score	94 ± 8 (80–110)	91 ± 10 (65–105)
Language composite score	78 ± 9 (65–103)	85 ± 15 (59–127)
Receptive communication scaled score	6 ± 2 (3–11)	7 ± 3 (3–14)
Expressive communication scaled score	7 ± 2 (3–11)	8 ± 3 (3–15)

Data are presented as mean ± SD (range).

The mean cognitive composite score was within the normal range (85–115) for both 7 and 18 months. The language composite score was delayed at 7 months and low–average at 18 months. The mean expressive and receptive communication scores (normal: 7–13) were borderline-delayed at 7 months and low–average at 18 months.

The results of the correlation analyses of the LENA recording measures and the Bayley-III scores are shown in Table 4. Regression analyses of the adult word counts with Bayley-III scores are displayed in Table 5. After adjustment for birth weight, adult word count per hour during the 32-week recording alone accounted for 14% of the variance in receptive communication score at 7 months (P = .04), 12% of the variance in language composite scores at 18 months (P = .04), and 20% of the variance in expressive communication scores at 18 months (P = .008). Adult word count per hour during the 36-week recording independently accounted for 26% of the variance in cognitive composite score at 7 months (P = .0049) after adjustment for birth weight. Every increase by 100 adult words per hour during the 32-week recording was associated with a 2-point increase in language composite score (P = .04) at 18 months and a 0.5-point increase in expressive communication score (P = .008). The associations of the LENA variables with Bayley-III scores remained significant after excluding the 7 infants with a family history of language delay. When we covaried the maternal level of education with our Bayley-III results for our cohort, there was no association between education level and the outcomes studied.

When the smaller cohort of infants who had recordings at 32 and 36 weeks in the NICU as well as 44 weeks' and 7 months' corrected age at home (n = 12) and the infants who had all the previous recordings plus 1 recording at 18 months' corrected age (n = 9) were analyzed, positive correlations (adjusted for birth weight) between cumulative LENA counts for all recordings and the 7- and 18-month Bayley-III outcomes were identified (data not shown). The cumulative adult word count for all recordings was associated with higher cognitive composite scores at 7 months (r = 0.69, P = .02), language composite scores at 7 months (r = 0.88, P = .001), and receptive communication scores at 7 months (r = 0.59, P = .05). For the 18-month outcomes, cumulative adult word counts for all recordings (r = 0.73, P = .04) were associated with higher expressive communication scores when adjusting for birth weight.

DISCUSSION

It is known that early language experience is necessary for the normal development of speech and language processing,[14,17] and that there is an association between the amount parents talk to their children between birth and age 3 years and subsequent vocabulary growth and IQ scores at age 3 years.[16,24] Studies in older children have shown an association between adult word counts, adult–child conversations, and improved child language outcomes.[18] To our knowledge, this is the first study showing that early exposure in the NICU of preterm infants to higher numbers of adult words is positively correlated with cognitive and language outcomes after discharge. We have included data on the conversational turns per hour and child vocalizations per hour, which also positively correlated with a number of the Bayley-III outcome measures; however, the reliability analysis of these measures in young infants are in the process of being completed, and we did not include them in our prediction models.

There are a number of possible interpretations of these data. It could be that parents and caregivers have more opportunity to talk to infants who are less sick, and the improved outcomes therefore reflect less severe illness in the NICU. We did, however, adjust for birth weight in our regression models. Because the study group was selected from the most stable infants at 32

TABLE 4 Correlations of LENA Variables at 32 and 36 Weeks' Corrected Age Recordings With 7- and 18-Month Bayley-III Scores

32-week recordings	CC		LC		RC		EC	
	7 Months (n = 32)	18 Months (n = 31)	7 Months (n = 28)	18 Months (n = 31)	7 Months (n = 32)	18 Months (n = 31)	7 Months (n = 28)	18 Months (n = 31)
Adult words/h	0.24	0.27	0.27	0.45*	0.35**	0.32*	0.08	0.53*
Conversational turns/h	0.36*	0.18	0.37*	0.41*	0.36*	0.23	0.24	0.54*
Child vocalizations/h	0.23	0.20	0.24	0.22	0.27	0.06	0.11	0.35**
36-week recordings	CC		LC		RC		EC	
	7 Months	18 Months	7 Months	18 Months	7 Months	18 Months	7 Months	18 Months
	(n = 30)	(n = 29)	(n = 26)	(n = 29)	(n = 30)	(n = 29)	(n = 26)	(n = 29)
Adult words/h	0.48*	0.08	0.18	0.30	0.13	0.13	0.12	0.44*
Conversational turns/h	0.50*	−0.02	0.34	0.06	0.23	−0.06	0.31	0.19
Child vocalizations/h	0.44*	−0.17	0.36	−0.05	0.25	−0.09	0.31	0.01

Zero-order Pearson correlations for 32- and 36-week recordings and 7- and 18-month Bayley-III scores. *$P < .05$; **$P = .05$. CC, cognitive composite score; LC, language composite score; RC, receptive communication score; EC, expressive communication score.

weeks, they had a low incidence of severe morbidities.

This association may also indicate that talking with preterm infants in the NICU improves their subsequent language development. The time interval between 32 weeks and term is a period of critical brain development and may provide a window of opportunity for parents and caregivers to expose the infant to early language enrichment. Fetuses of the same gestational age as infants cared for in the NICU have the maternal voice as the primary auditory stimulus,[1] and NICU infants are deprived of this developmentally appropriate stimulus during this critical time. Language exposure provided in the NICU from caregivers may help to improve outcomes for these vulnerable infants. A recent article by Pena et al[25] found that the increased exposure to language experienced by preterm infants compared with term controls did not give them an advantage in detecting nonnative phonemes. However, in that study, they compared preterm infants with term infants, and the current study had no term control group for comparison. Furthermore, the outcome studied in the article by Pena et al was receptive language, whereas our primary outcome of significance was expressive speech. We found that in this group of preterm infants, all of whom were at-risk for language delay, the infants who received more exposure to adult words had better outcomes, particularly expressive language skills, compared with those who received less exposure. These differing findings highlight how little is truly understood about preterm infant language acquisition and that further studies are needed.

Two infants in the study had Spanish as the primary language in the home, and previous studies using LENA and testing English- versus Spanish-speaking families have demonstrated that the average adult word count between the 2 groups is similar overall.[20] Education level has also been shown to be associated with higher adult word counts. One study previously found that for parents who earned at least a bachelor's degree, the mean daily adult word count was significantly higher (14 926) than the mean daily adult word count (12 024) for other parents. However, as in our sample, there was substantial variability in word count at all levels of education. We speculate that there may be a number of reasons for the high variability in the amount of language input seen among recordings. First, some parents tend to talk more to their infants while they are visiting in the NICU, while others prefer to sit quietly and read or do other activities but do not talk. In addition, some nurses talk to the infant during care times and feedings while others do not. Furthermore, parents who have other children or problems with transportation to the NICU visit less frequently, and these circumstances will affect the amount of time the infant is exposed to parent talk. Our previous report[3] identified that language input as reflected by adult word count is significantly higher for preterm infants in the NICU during the times when the parent is visiting. Overall, this variability offers the opportunity for parent language

TABLE 5 Regression Analysis of LENA Measures at 32- and 36 Weeks and Bayley-III Scores, Adjusted for Birth Weight

LENA Measure/Bayley-III	b[a]	P	Model R^2	LENA Partial r^2
32 weeks, adult word count/h				
Receptive communication, 7 mo	0.3	.0413	0.14	0.14
Language composite, 18 mo	2.0	.0404	0.25	0.12
Expressive communication, 18 mo	0.5	.0081	0.30	0.20
36 weeks, adult word count/h				
Cognitive composite, 7 mo	1.2	.0049	0.26	0.26
Expressive communication, 18 mo	0.3	.0701	0.24	0.10

[a] Unstandardized regression coefficient adjusted for birth weight (units: per 100 adult words/hour).

intervention in the NICU. The analyses conducted on the infants in our cohort who had home recordings in addition to NICU recordings showed even stronger associations between the cumulative adult word counts and subsequent outcomes, which further supports intervention with parents beginning in the NICU.

Limitations of the study are that we did not have access to the language content of the recording and knowledge of whether adult language was child directed, which may be important because it has been shown in older children that child-directed speech predicts later vocabulary skills.[26] In addition, we had a small sample size, and some of the analyses showed trends that did not reach statistical significance. Because the LENA recording device has not been previously tested fully in preterm infants, there is no normative data set for this group. Furthermore, although the findings in this article suggest a positive association between adult talk to preterm infants and subsequent cognitive and language development, additional aspects of the auditory environment seem to have clinical relevance. Other researchers have described adverse physiologic changes in preterm infants associated with high noise levels and concerns for overstimulation in the NICU.[27–29] We suggest that importance should be placed on teaching caregivers to recognize the readiness and stress cues of the preterm infant and to tailor their interactions to the infant's individual tolerance for stimulation.[30–33] Overall, more research is needed to identify the ideal sensory environment to provide for very preterm infants in the NICU to maximize their developmental outcomes.

CONCLUSIONS

Increased parent talk with preterm infants in the NICU was associated with higher 7- and 18-month corrected age Bayley-III cognitive and language scores.

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