Importance of Parent Talk on the Development of Preterm Infant Vocalizations

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 very preterm infants begin making vocalizations as early as 8 weeks before their projected due date and make significantly more vocalizations when a parent is present in the NICU.

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KEY WORDS
language, environment, vocalizations, very low birth weight infant, premature infant, neonatology, LENA

ABBREVIATIONS
LENA—Language Environment Analysis
SNAPPE-II—Score for Neonatal Acute Physiology-Perinatal Extension-II
PMA—postmenstrual age

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abstract

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OBJECTIVE: To determine the sound environment of preterm infants cared for in the NICU and to test the hypothesis that infants exposed to more adult language will make more vocalizations.

METHODS: This was a prospective cohort study of 36 infants who had a birth weight of ≤1250 g. Sixteen-hour recordings of the infant sound environment were made in the NICU from a digital language processor at 32 and 36 weeks' postmenstrual age. Adult word counts, infant vocalizations, and conversational turns were analyzed.

RESULTS: Infant vocalizations are present as early as 32 weeks. Both adult word counts per hour and infant vocalizations per hour increase significantly between 32 and 36 weeks. Infant exposure to language as a percentage of time was small but increased significantly. When a parent was present, infants had significantly more conversational turns per hour than when a parent was not present at both 32 and 36 weeks ($P < .0001$).

CONCLUSIONS: Preterm infants begin to make vocalizations at least 8 weeks before their projected due date and significantly increase their number of vocalizations over time. Although infant exposure to language increased over time, adult language accounted for only a small percentage of the sounds to which an infant is exposed in the NICU. Exposure to parental talk was a significantly stronger predictor of infant vocalizations at 32 weeks and conversational turns at 32 and 36 weeks than language from other adults. These findings highlight the powerful impact that parent talk has on the appearance and increment of vocalizations in preterm infants in the NICU. *Pediatrics* 2011;128: 910–916

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Speech and language development during early childhood in preterm infants is often delayed. Outcome studies of preterm infants show delayed receptive language processing, expressive language processing, deficits in phonological short-term memory, lower IQs, and lower Bayley Mental Developmental Index scores at follow-up.[1–7] The factors that may contribute to this delay include gestational age, illness severity, neonatal morbidities, duration of hospitalization, hearing status, and environment.

The sensory experiences and auditory environment of the infant born at <32 weeks of gestation in the NICU are vastly different from those of the fetus of the same gestational age. In utero, the maternal voice is a prominent stimulus during the development of the auditory system.[8] Studies of hearing in fetuses as early as 23 to 25 weeks of gestation have shown sufficient maturity of the auditory system to produce physiologic responses in the fetus to external sounds,[9] and the capacity for prenatal learning and language acquisition has also been suggested as early as 35 weeks of gestation.[10] Infants born very prematurely are cared for in the NICU at a time when they normally would be listening to and learning the prosody of their mother's speech while in utero.[10] Little is known about the amount of language infants are exposed to from parents and other care providers while in the NICU.

It is known that early language experience is necessary for the normal development of speech and language processing.[11,12] Studies in term children ages 2 months to 36 months have shown that the more parents talk to their children, the faster their vocabularies grow and the higher the children's IQ test scores at age 3.[13,14] The rate of the vocabulary growth and IQ score are more strongly related to the number of words the parent says per hour to the child than to any other variable, including parents' education level and the socioeconomic status of the family.[13] In addition, adult-child conversations are associated with healthy language development.[15] These findings combined with the knowledge that language learning is likely occurring at early gestational ages makes it crucial to better understand the language experience of very preterm infants in the NICU; their altered sensory experience may partially explain their tendency for language delay. If so, this would provide evidence of the need for early, predischarge language interventions to prevent these delays.

The objective of this study was to describe the language environment to which a preterm infant is exposed in the NICU. We hypothesized that (1) preterm infants would produce vocalizations as early as 32 weeks' gestation, and (2) preterm infants who were exposed to more adult language while in the NICU would respond with more vocalizations.

METHODS

Study Design

This prospective cohort study was conducted in the Women and Infants' Hospital (Providence, RI). Data were collected in the NICU using a Language Environment Analysis (LENA) digital language processor. LENA is a 2-oz digital recording device that was placed in the pocket of a specially designed infant vest. The digital language processor recorded 16 hours of adult speech, child vocalizations, and background noise in the NICU starting in the morning at 32 and 36 weeks' gestational age. The audio recording was downloaded and analyzed using LENA software. The LENA software uses speech-identification algorithms to give word and vocalization counts for adult and child language, and to characterize the sounds in the recording. LENA software does not count crying or vegetative sounds, such as sounds from the respiratory or digestive systems (ie, breath sounds or burping), in the infant vocalization counts. LENA also categorizes the audio data in the recording environment into language, noise, silence, electronic noise, overlapping language, and uncertain segments. This device has previously been shown to have a high degree of fidelity in coding when compared with trained human transcribers.[16]

Transcriber software (Bertin Technologies, Aix-en-Provence, France; 2008) was used to determine how the LENA software was encoding the various sounds of the NICU on a subset of recordings. The "language" designation was given for all adult language and child vocalizations. The vocalizations made by the infants usually consisted of very short vowel sounds. "Television" was the designation for the monitor alarms, and "noise" was noise from the motor of the isolette or from the respiratory equipment. The "conversational turns" are defined as vocal sounds from the infant such as a coo or squeal followed by a response from an adult within 5 seconds or an adult word followed by a child vocalization within 5 seconds.

Demographic data and data on newborn illness severity by Score for Neonatal Acute Physiology-Perinatal Extension-II (SNAPPE-II) scores on days of life 1 and 3 were collected. The SNAPPE-II score included mean blood pressure, lowest temperature, lowest serum pH, urine output, presence of seizures and P_{O_2}/F_{IO_2} ratio, birth weight, and Apgar scores. Data were also collected on the rates of common neonatal morbidities including bronchopulmonary dysplasia, defined by physiologic oxygen requirement at 36 weeks' postmenstrual age (PMA),

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grade 3 or 4 intraventricular hemorrhage or periventricular leukomalacia, and hearing screen results. Data regarding the environment during the recording were collected including type of respiratory support, type of isolette, feeding times, type of feeding (oral or gavage), parent visiting times, and apnea/bradycardia/desaturation episodes.

Participants

Between December 2008 and August 2009, parents of infants who weighed <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, and 53 were medically stable and were approached for consent and enrollment. Of these, 36 infants were enrolled (67.9%), including 8 sets of twins. Table 1 includes demographic data of the cohort. The mean gestational age of these infants was 27 ± 2 weeks (range: 23–30 weeks), and mean birth weight was 896 ± 195 g (range: 480–1415 g).

A total of 26 families spoke English, and 2 spoke Spanish as the primary language. There were 7 families who reported a family history of language delay. All recordings were completed at Women and Infants in an open-bay NICU. The first recording was done at 32 ± 2 weeks, 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, a total of 35 infants had a recording at 32 to 34 weeks (mean: 33.1 weeks), and 33 infants had a recording at 35 to 38 weeks (mean: 36.3 weeks) PMA while in the NICU. One infant was intubated at 32 weeks so was not recorded; however, per mother's request, infant was enrolled after extubation at 36 weeks.

TABLE 1 Characteristics of Study Infants ($N = 36$)

Male, *n* (%)	15 (42)
Average gestational age, wk	27 ± 2
Average birth weight, g	896 ± 195
Maternal age, y	30.8 ± 7
Gravida 1, %	44
Race, %	
Black	16.7
Hispanic	13.9
White	69.4
Mother's education, %	
<High school	11.1
High school/partial college	41.7
College/graduate	44.4
Unknown	2.8
Father's education, %	
<High school	16.7
High school/partial college	50
College/graduate	22.2
Unknown	11.1
Family history of language delay, *n* (%)	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, *n* (%)	2 (5.6)
Chronic lung disease (36 wk), *n* (%)	10 (27.8)
Hearing failed unilateral at discharge, *n* (%)	4 (11.1)
Hearing failed bilateral at discharge, *n* (%)	0 (0)

IVH indicates intraventricular hemorrhage; PVL, periventricular leukomalacia.

Two infants were transferred to another nursery before the 36-week recording, and 1 infant was discharged from the hospital before 36 weeks. The Women and 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. Nonnormally distributed and highly dispersed hourly count data (word counts, conversational turn counts, and vocalizations counts) were analyzed by negative binomial regression using the generalized estimating equation method to adjust for multiple measures on the same individual. Negative binomial regression was also used for analysis of the sound environment. Regressions were done looking at a variety of variables including adult word counts and infant vocalizations and conversational turns, gestational age, chronological age, mother's age, and parity of the mother. All statistical analyses were conducted by using SAS 9.1 (SAS Institute, Inc, Cary, NC).

RESULTS

The breakdown of the sound environment in the NICU into language, monitor noise, silence, and other noise (ventilators, isolettes, etc) is shown in Table 2. The majority of the sound environment at each time period is composed of monitor sounds and back-

TABLE 2 Sound Breakdown for Recordings at 32 and 36 Weeks' PMA

Breakdown of Sounds	32 wk ($n = 35$)	36 wk ($n = 33$)	Percent Change	Significance
Language			+142	.0001
% of recording ± SD	2 ± 2	5 ± 3		
Median %	1	5		
% range	0.2–8.6	0.5–13		
Monitor			+48	.015
% of recording ± SD	26 ± 21	38 ± 22		
Median %	19	33		
% range	0–71	1–81		
Silence			−31	.008
% of recording ± SD	39 ± 23	27 ± 18		
Median %	39	27		
% range	0–75	1–72		
Noise			−10	.47
% of recording ± SD	33 ± 22	30 ± 14		
Median %	25	27		
% range	7–91	8–70		

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ground noise. Language, either adult or infant, comprises a small percentage of the sounds to which infants are exposed in the NICU, but does increase significantly over time. The language category includes ~85% adult language and 15% infant vocalizations. A majority of the language infants are exposed to in the NICU is from female voices (88% of adult language) compared with male voices (12% of adult language) as determined by the LENA analysis.

The environment of the infants varied during the recordings. At 32 weeks, 80% of infants were recorded in a regular isolette, 17% in a Giraffe Omnibed, and 3% (1 infant) was in an open crib. For respiratory support at 32 weeks, 17% required a low flow nasal cannula, 31% were in a high flow nasal cannula, 17% were on nasal continuous positive airway pressure, and 34% were in room air. For the 36-week recordings, 80% of infants were in an open crib and 20% were in an isolette, with 67% in room air, 12% in low flow nasal cannula, 12% in high flow nasal cannula, and 6% in nasal continuous positive airway pressure. At 36 weeks, there was a significant decrease in adult word count and conversational turns if the infant was still in an isolette compared with an open crib ($P = .0001$) or on a high level of respiratory support, either continuous positive airway pressure or high flow nasal cannula at the time of the recording as compared with room air ($P = .0001$).

In Table 3, the increase in adult word counts, conversational turns, and infant vocalizations over the recordings are shown. The total number of adult words for the 16 hours recordings in the NICU at 32 and 36 weeks varied from as low as 144 words to more than 26 000 words. Preterm infant vocalizations were recorded as early as 32 weeks (8 weeks before the due date) and 36 weeks (4 weeks before the due date); the number of vocalizations increased significantly over the study period. Infants vocalized a median of 5 times per hour (mean: 7 ± 6 times per hour) at 32 weeks and 10 times per hour (mean: 12 ± 10 times per hour) at 36 weeks while in the NICU.

The relationships of SNAPPE-II scores with adult word counts, conversational turns, and infant vocalizations were explored. There was a 1.84% decrease in adult word count at 36 weeks for every 1 SNAPPE-II point at 3 days; otherwise there were no significant relationships between SNAPPE-II scores at 1 day and adult word count, child vocalizations, or conversational turns at 32 weeks or 36 weeks, or with SNAPPE-II scores at 3 days and adult word count, conversational turns, or child vocalizations at 32 weeks and with conversational turns and child vocalizations at 36 weeks.

In addition, infants vocalized significantly more in the hour surrounding a feeding with 6 ± 11 vs 10 ± 13 infant vocalizations per hour at 32 weeks and 10 ± 18 vs 16 ± 18 infant vocalizations per hour at 36 weeks ($P < .0001$), and were exposed to higher adult word counts in the hour surrounding a feeding with 156 ± 499 vs 388 ± 748 adult words per hour at 32 weeks and 375 ± 649 vs 986 ± 1266 at 36 weeks ($P < .0001$) (data not shown).

In Table 4 the mean hourly counts of adult and child vocalizations during parent visits are shown compared with the hourly counts when parents were not visiting. The hourly adult word counts increased by more than 380% at 32 weeks and by 220% at 36 weeks in the hours when a parent was visiting, and conversational turns increased by 520% at 32 weeks and by 160% at 36 weeks in the hours when a parent was visiting ($P < .0001$). Child vocalizations per hour were significantly increased at 32 weeks when a parent was visiting ($P = .0001$), and were increased by 36% but did not achieve significance at 36 weeks ($P = .08$). There were no differences in the analyses of adult word count, conversational turns, or

TABLE 3 Increase in Adult Words, Child Vocalizations, and Conversational Turns Over Time

Vocalization Counts	32 wk ($n = 35$)	36 wk ($n = 33$)	Percent Change	Significance
Total adult words			+160	.0001
Mean ± SD	3306 ± 4274	8556 ± 6407		
Median	1289	8255		
Range	144–16549	374–26145		
Hourly adult words			+160	.0001
Mean ± SD	207 ± 267	535 ± 400		
Median	81	153		
Range	9–1034	23–1634		
Total conversational turns			+96	.0009
Mean ± SD	25 ± 29	48 ± 45		
Median	15	36		
Range	0–105	3–188		
Hourly conversational turns			+95	.0012
Mean ± SD	2 ± 2	3 ± 3		
Median	1	2		
Range	0–7	0–12		
Total child vocalizations			+76	.0003
Mean ± SD	113 ± 101	195 ± 156		
Median	77	153		
Range	10–374	21–705		
Hourly child vocalizations			+81	.0002
Mean ± SD	7 ± 6	12 ± 10		
Median	5	10		
Range	1–23	1–44		

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TABLE 4 Combined Analysis of 32- and 36-Week Data With Parent Visitation

Hourly Counts	No Parent Visiting	Parent Visiting	% Change With Parent Present	Significance
Hourly adult words				
32 wk			+383	.0001
Mean ± SD	139 ± 450	871 ± 1052		
Median	12	567		
Range	0–4342	6–3742		
36 wk			+220	.0001
Mean ± SD	415 ± 701	1427 ± 1504		
Median	164	953		
Range	0–5460	14–7894		
Hourly conversational turns				
32 wk			+524	.0001
Mean ± SD	1 ± 3	7 ± 11		
Median	0	2		
Range	0–19	0–46		
36 wk			+162	.0001
Mean ± SD	2 ± 5	7 ± 9		
Median	0	4		
Range	0–59	0–43		
Hourly child vocalizations				
32 wk			+173%	.0001
Mean ± SD	6 ± 10	15 ± 20		
Median	1	8		
Range	0–97	0–87		
36 wk			+36%	.08
Mean ± SD	11 ± 18	16 ± 19		
Median	5	9		
Range	0–213	0–107		

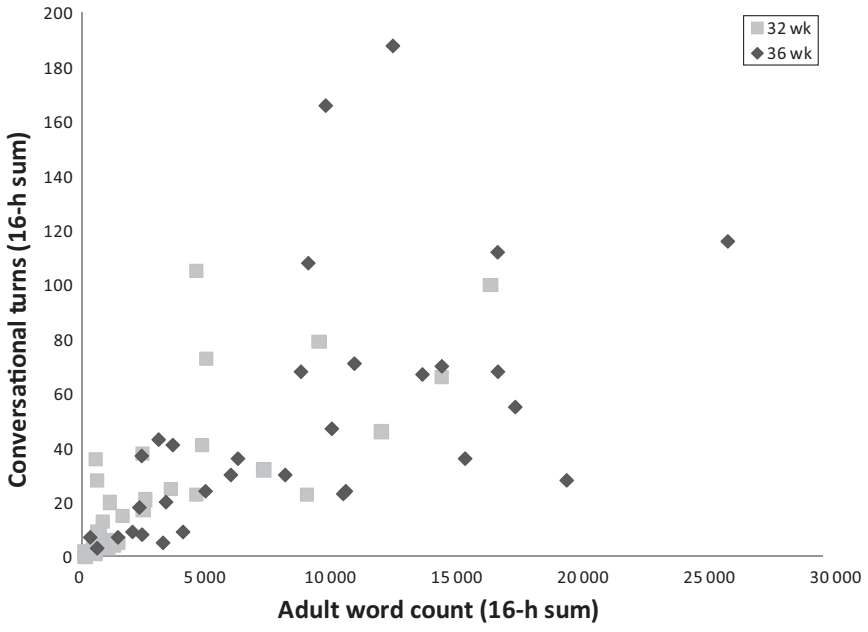

FIGURE 1
Regression of total adult words and conversational turns at 32 and 36 weeks. Negative binomial regressions identified an estimated 20% increase in turn-taking for every 1000 adult words (P = .0001) at 32 weeks and an estimated 10% increase in turn-taking for every 1000 adult words (P = .0001) at 36 weeks.

child vocalizations if the infants with a history of language delay were excluded.

In Fig 1 regressions of all adult vocalizations are shown versus conversational turns at 32 and 36 weeks. Negative binomial regressions identified an estimated 20% increase in turn-taking for every 1000 adult words (P = .0001) at 32 weeks and an estimated 10% increase in turn-taking for every 1000 adult words (P = .0001) at 36 weeks.

In Table 5 feedings with a parent present are compared versus feedings given by the nurse. At 32 and 36 weeks, parents spoke significantly more than nurses during a feeding time (P < .02). There was also a significant increase in the number of conversational turns at 32 weeks when a parent was giving the feeding compared with a staff nurse (P = .02). There were no differences in infant vocalizations or conversational turns during the hour of a feeding between a parent feeding and a nurse feeding at 36 weeks.

DISCUSSION

Studies in which the sound levels in NICUs are examined reveal high levels of noise in most nurseries.[17–19] However, this is the first study to break down the types of sounds to which preterm infants are exposed while being cared for in the NICU. These data reveal the dearth of language that very preterm infants are exposed to during a critical time in their early development. This is in contrast to a fetus of the same gestational age, which is in an environment where the maternal voice is the most prominent stimulus.[20] The increase in percentage of time that infants are exposed to language between 32 and 36 weeks is partially explained by the fact that at 32 weeks the infants were often still in an isolette, where it has been shown that little language is audible unless it is directed into the hole of the isolette.[21] By 36 weeks, the infants are often in an open crib and may be preparing for discharge, with parents visiting more often and holding infants for feeds which were more often given by mouth as opposed to by gavage tube. The increase

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TABLE 5 Combined Analysis of 32- and 36-Week Count During Feedings With Parent Versus With Nurse

Counts per Hour	32 wk		Percent Change With Parent Present	*P*	36 wk		Percent Change With Parent Present	*P*
	Feeding With Nurse	Feeding With Parent			Feeding With Nurse	Feeding With Parent		
Adult words			+175	.01			+63	.02
Mean ± SD	274 ± 600	754 ± 1031			797 ± 1002	1423 ± 1666		
Median	44	220			403	927		
Range	0–3359	6–3742			0–5460	65–7894		
Conversational turns			+240	.02			NS	
Mean ± SD	2 ± 4	6 ± 13			5 ± 6	6 ± 7		
Median	0	2			3	4		
Range	0–19	0–46			0–28	0–30		
Child vocalizations			NS				NS	
Mean ± SD	9 ± 9	15 ± 21			17 ± 20	13 ± 12		
Median	4	9			10	11		
Range	0–37	0–87			0–93	0–49		

NS indicates not significant.

in monitor noise at 36 weeks is also explained by the move to the open crib, because infants are then exposed to not only their own monitor noise, but also those of nearby infants. What is left unanswered is the question of what is a developmentally appropriate sound environment to provide for very preterm infants. Although there is emerging evidence that recorded music or mother's voice has many benefits for the premature infant, there seems to be little evidence that providing tape recordings of the mother's voice provides any long-term language benefits for sick preterm infants.[22,23] There is some evidence that infants may benefit from reducing overall noise levels in the nursery[24] and from encouraging individualized caregiver and parental involvement sensitive to the infant, including talking to infants while in the NICU.[25,26]

This is the first study in which it is documented that preterm infants begin to make primitive vocalizations as early as 8 weeks before their expected due date, which supports our first hypothesis. In addition, there was an increase in the number of vocalizations over time. The number of conversational turns between infant and parent also increased over time, which is significant because adult-child conversations have been shown in older children to be associated with improved child language outcomes.[15] The regressions clearly demonstrate at both 32 and 36 weeks that the more adult language the preterm infant is exposed to in the NICU, the greater the number of reciprocal vocalizations, which represent a more meaningful early conversation. In addition, preterm infants vocalize more when their parents are visiting, with increases in the number of vocalizations by as much as 129% when a parent is present, which was particularly evident at 32 weeks. These data highlight the early interaction through language that is occurring with preterm infants and their parents. An unexpected finding was that conversational turns and infant vocalizations were higher during feeds provided by parents than nurses at 32 but not 36 weeks. This could reveal that there is a relationship formed with nurses by 36 weeks, as many are primary nurses. Nurses often give the evening feedings and sometimes this is the time when infants are more awake. Another explanation from research of mother-infant interactions suggests there may be overstimulation by some mothers. Reissland and Stephenson[27] and Field[28] both showed that mothers of preterm infants tend to be more active in their interactions with their infants and preterm infants respond less. Field showed that when preterm mothers were instructed to be less active in their interactions with their infants, the infants became more attentive. It may also be related to the comfort of the family with the infant because feedings with nurses are sometimes more successful and less stressful when parents are still learning. Perhaps infants vocalize more when they are under less stress.

Strengths of this study are that (1) it is the first comprehensive assessment of the sound and language environment of very preterm infants in a NICU at 32 and 36 weeks of age, (2) it is the first longitudinal assessment of very preterm infants' vocalizations and reciprocal vocalizations in the NICU, and (3) it is the first study to demonstrate the importance of parent and caregiver conversations with their infants in the NICU.

A limitation of the study is that the LENA recording device has not been tested in preterm infants previously, so there is no normative data set. Additional study of the fidelity of this device for analysis of these very young and preterm infant vocalizations would be beneficial.

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CONCLUSIONS

In this study we provide new evidence that very preterm infants are cared for in an environment with very little adult language. Very preterm infants begin to make vocalizations before their expected due dates and increase the number over time. In addition, infants vocalize significantly more when a parent is visiting. These findings support the powerful effects of parent visiting in the NICU on the emergence of early vocalizations among preterm infants and provide the rationale for intervention studies with both parents and nurses in the NICU.

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Importance of Parent Talk on the Development of Preterm Infant Vocalizations

Melinda Caskey, Bonnie Stephens, Richard Tucker and Betty Vohr

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