Gender Differences in Adult-Infant Communication in the First Months of Life

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KEY WORDS

language, LENA, late preterm, gender, vocalizations, speech, conversation, mothers, fathers, infant

ABBREVIATIONS

AWC—adult word count
DLP—digital language processor
LENA—Language Environment Analysis
PMA—postmenstrual age

Dr Johnson conceptualized and designed the study, participated in assessments, and drafted the initial manuscript; Drs Caskey, Vohr, and Rand collaborated in designing the study and reviewing the manuscript; Mr Tucker supervised the database and analyzed and reviewed the data; and all authors approved the final manuscript.

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WHAT'S KNOWN ON THIS SUBJECT: Studies have shown that reciprocal vocalizations between mother and infant have positive effects on language development. It has been shown that girls acquire vocabulary and language skills earlier than boys.

WHAT THIS STUDY ADDS: Mothers more readily respond to their infant's vocal cues than fathers, and infants show a preferential vocal response to their mothers in the first months of life. Mothers respond preferentially to infant girls versus boys at birth and 44 weeks.

abstract

FREE

OBJECTIVES: To evaluate the verbal interactions of parents with their infants in the first months of life and to test the hypothesis that reciprocal vocalizations of mother-infant dyads would be more frequent than those of father-infant dyads.

METHODS: This prospective cohort study included 33 late preterm and term infants. Sixteen-hour language recordings during the birth hospitalization and in the home at 44 weeks' postmenstrual age (PMA) and 7 months were analyzed for adult word count, infant vocalizations, and conversational exchanges.

RESULTS: Infants were exposed to more female adult speech than male adult speech from birth through 7 months ($P < .0001$). Compared with male adults, female adults responded more frequently to their infant's vocalizations from birth through 7 months ($P < .0001$). Infants preferentially responded to female adult speech compared with male adult speech ($P = .01$ at birth, $P < .0001$ at 44 weeks PMA and 7 months). Mothers responded preferentially to girls versus boys at birth ($P = .04$) and 44 weeks PMA ($P = .0003$) with a trend at 7 months ($P = .15$), and there were trends for fathers to respond preferentially to boys at 44 weeks PMA ($P = .10$) and 7 months ($P = .15$).

CONCLUSIONS: Mothers provide the majority of language input and respond more readily to their infant's vocal cues than fathers; infants show a preferential vocal response to their mothers in the first months. Findings also suggest that parents may also respond preferentially to infants based on gender. Informing parents of the power of early talking with their young infants is recommended. *Pediatrics* 2014;134: e1603–e1610

The importance of parent talk was highlighted in Hart and Risley's[1] landmark 1995 study that showed intelligence and academic success is directly related to parents' speech with their children from birth through age 3 years. Parental speech was even more important than education or socioeconomic status to predict a child's language abilities and IQ.[1]

Infant vocalization, which is influenced by maternal verbal behavior, is an important process in language development because it mimics adult conversational exchanges.[2,3] Mothers are typically the primary caregivers with the most direct interaction with their infants, and studies have shown that reciprocal vocalizations between mother and infant have positive effects on language development.[4,5] Maternal infant-directed speech has been well described, but there is less research describing the father-infant language relationship. Language structure and speech register for maternal and paternal baby talk may be similar in the first 3 months of life.[6] However, fathers' talk is often more challenging with "what" and "where" questions encouraging toddlers to use a more diverse vocabulary and longer utterances.[7]

Gender differences have been identified in infant and child language development. Girls acquire vocabulary and language skills earlier than boys.[8,9] Girls also develop larger vocabularies, display greater grammatical complexity, spell better, and read sooner than boys,[10–12] and girls produce a higher quantity of verbal communication.[13] Data are limited for gender differences in language development of preterm infants.

The objective of our study was to evaluate an infant's language environment in the first months of life and to compare differences in verbal interactions between parents and infants based on both adult and infant gender. We hypothesized that (1) infants would be exposed to more female than male adult speech in the first months of life, (2) female caregivers (mothers) and their infants would have more reciprocal vocalizations than male caregivers (fathers) and their infants, and (3) female infants would have more vocalizations and conversational exchanges than male infants.

METHODS

Study Design

This prospective cohort study includes healthy late preterm ($34^{0/7}$–$36^{6/7}$ weeks' gestation) and term ($37^{0/7}$–$41^{6/7}$ weeks) infants recruited during their newborn hospitalization (Women & Infants' Hospital, Providence, RI).

Language data were obtained from multiple language recordings of each infant over time by using the language environment analysis system (LENA Research Foundation, Boulder, CO). The LENA system includes a digital language processor (DLP) to record a child's language environment and software with advanced speech-identification algorithms to analyze and categorize audio data. LENA is the world's first automatic speech monitoring and language environment analysis system for infants and toddlers. It reliably identifies both English and Spanish vocalizations and has been validated to have a high degree of fidelity in coding when compared with human transcribers.[14]

Each infant wore the DLP in a custom-made vest for up to 16 hours of continuous recording. Recordings were performed during the newborn hospitalization and in the child's natural environment at 44 weeks' postmenstrual age (PMA) and 7 months chronologic age for term infants and corrected age for late preterm infants. During the newborn hospitalization, infant recordings took place in either the NICU or the general newborn unit. The NICU is a single-family-room unit with private rooms for each infant or twin pair. Infants in the newborn unit roomed-in with their mothers. In the home environment, parents were instructed to begin the recording when the infant awoke and continue for 16 hours on a typical day when both parents were home.

The DLP records all sounds in an infant's natural environment. Each segment of the recording is categorized as speech or nonspeech. The distinguishable audio that is used for the reportable language measures is labeled as "meaningful speech." "Distant speech" is language typically coming from at least 6 feet away from the DLP and is less clear to decipher by LENA software. The other nonspeech segments are labeled as silence or background, noise (bumps, rattles, etc), or television (audio from any electronic device).[15]

Complete recordings (>10 hours) were processed with LENA software using algorithms and statistical modeling to produce 3 primary language-related measures: infant vocalization counts, adult word counts (AWCs), and conversational turn counts.[16] Infant vocalization estimates include all speech-related child utterances that are bounded by at least 300 milliseconds of silence or nonspeech sounds. Cries, other fixed signals, and vegetative sounds from the respiratory or digestive tract are considered nonspeech sounds, which are filtered and excluded from vocalization counts. AWC estimates the number of words spoken during the recording. An AWC of 100 words per hour was our best estimate of presence of a parent with the infant. This was based on the predictive ability of 100 words per hour previously reported by using LENA.[17] Conversational turn count is a measure of adult-child interaction and estimates the number of reciprocal vocalizations between the infant and adult within 5 seconds. Human voices overlapping with another voice, noise, or electronic sound are labeled as overlap by LENA and were not included in our analysis.

Segments of the audio recording containing human vocalizations were further processed with the LENA Advanced Data Extractor and identified as vocalization activity blocks.[18] Blocks begin with

any human vocalization and end when there is at least 5 seconds of silence or nonspeech sounds. These blocks are labeled by 2 criteria: the speaker that initiated the language block and responders within the block. Any block consisting of only infant or only adult speech unreciprocated within 5 seconds is labeled as a monologue, and any block that contains both infant and adult speech is considered conversational. The block types used (Fig 1) include (1) infant monologue, (2) infant-initiated with adult response, (3) female adult monologue, (4) female adult–initiated with infant response, (5) male adult monologue, and (6) male adult–initiated with infant response.

All language-related measures were analyzed to make comparisons based on both adult gender and infant gender. Hourly infant vocalization and AWCs describe the quantity of speech, whereas conversational turns and vocalization activity blocks describe the language interactions between parents and their infants.

Demographic information was collected. Families were asked to complete logs of feeding times, sleep patterns, family members or visitors present, and other activities throughout the day of the recording.

Participants

More than 3000 hours of audio recording from 81 infants were collected between February 2010 and May 2012 as part of a language study designed to compare differences in language outcomes between late preterm and term infants. This cohort includes healthy late preterm and term infants who were medically stable without congenital anomalies, significant comorbidities, or identified hearing impairment.

Within the cohort, 33 of 81 infants met the inclusion criteria of residing in a 2-parent household with full-length recordings (>10 hours) at birth, 44 weeks' PMA, and 7 months.

During the newborn recording, 8 infants were cared for in the NICU due to gestational age <35 weeks, and 25 infants were roomed-in with their mothers in the well-baby unit. At 44 weeks' PMA and 7 months, all 33 infants were recorded at home. The length of recording time was 16 hours in the newborn hospitalization, a mean of 15.1 ± 0.64 hours (range 12–16) at 44 weeks, and 15.7 ± 0.93 hours (range 11.9–16) at 7 months. All recordings began between 8 and 10 AM.

Demographic information is shown in Table 1. The mean gestational age was 37 ± 2 weeks. Fifty-five percent were late preterm, and 45% were term. Thirty-two mothers and fathers were included because there was 1 set of twins. Thirty families spoke English as the primary language, but nearly one-third of families identified their households as bilingual.

The study infants differed from those not included for the following characteristics: mean gestation (37.7 vs 36.5 weeks, $P = .01$), public insurance (24% vs 71%, $P < .0001$), maternal age (30 vs 27 years, $P = .04$), and education beyond high school for both mothers (97% vs 60%, $P = .0001$) and fathers (72% vs 30%, $P = .01$).

Statistical Analysis

Analysis of AWC data was done by negative binomial regression because of the highly dispersed and nonnormally distributed nature of the counts. Logistic regression was used to analyze the probability of infant-adult responses during conversational blocks. Adjustment for multiple measures (blocks) within each individual child was done by generalized estimating equations. All statistical analyses were calculated using SAS 9.1 (SAS Institute, Inc, Cary, NC).

RESULTS

The language environment findings are shown in Table 2. Infants in the NICU were exposed to significantly less speech than those infants rooming-in with their mothers. Meaningful speech exposure increased after discharge for NICU infants, whereas it decreased for normal newborn infants. Overall language exposure (combined distant and meaningful speech) increased over time for all infants as they matured. Additional longitudinal analysis of the language

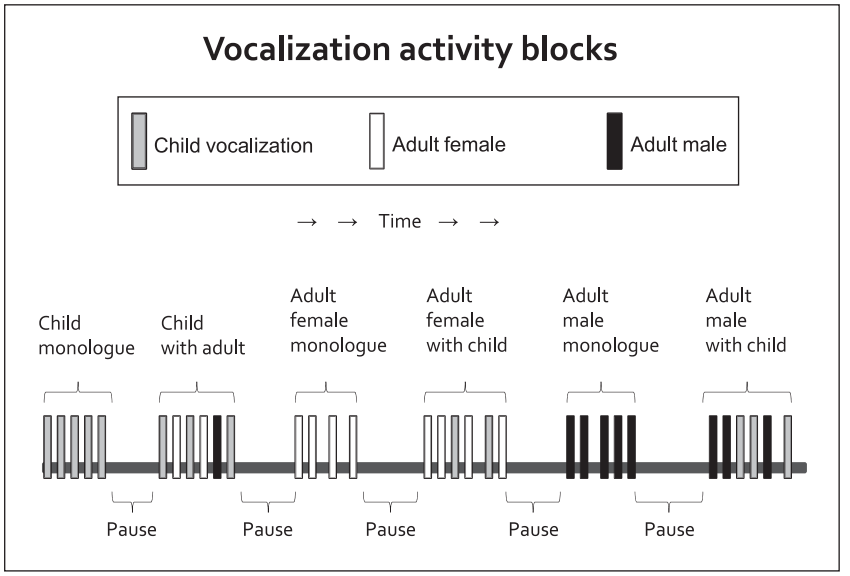

FIGURE 1
Schematic figure to demonstrate study definitions: vocalization activity blocks.

TABLE 1 Characteristics of Study Infants ($N = 33$[a])

		Infant Girls	Infant Boys	*P*
n		17	16	
Mean gestational age, wk	37 ± 2	37 ± 2	37 ± 2	.6216
Late preterm, %	55	53	56	.8787
Male, %	48			
Twins, %	6	6	6	.9647
NICU stay, %	24	24	25	.9215
Infant race, %				
White non-Hispanic	67	59	75	.4279
Black non-Hispanic	3	6	0	
Hispanic	9	6	13	
Multiracial/other	21	25	13	
Maternal age, y	30 ± 5	29 ± 4	31 ± 5	.1810
Gravida 1, %	50	47	31	.3530
Mother's education, %				
Less than high school	0	0	0	.1834
High school/partial college	28	35	14	
College/graduate degree	66	65	86	
Unknown, *n*	2	0	2	
Father's education, %				
Less than high school	3	6	0	.2214
High school, partial college	31	47	23	
College/graduate degree	56	47	77	
Unknown, *n*	3	0	3	
Bilingual household, %	31	35	25	.5202
English as primary language spoken, %	94	94	94	.9647

[a] Thirty-three infants from 32 households (1 set of twins).

TABLE 2 Comparison of Language Environment by Location

	NICU	Newborn Nursery	Home 44 wk	Home 7 mo
Background/silence, %	71.9[a,b,c]	52.3	52.0	46.2
Noise, %	4.2[a,b]	1.1[c]	1.8[c]	4.6
Television, %	7.4[a,b]	16.8[c]	16.0[c]	10.0
Distant speech, %	9.9[b,c]	10.8[b,c]	15.3[c]	25.5
Meaningful speech, %	7.6[a,b,c]	18.8[b,c]	15.4	13.7

$P < .05$[a]: versus newborn nursery[b] versus home 44 weeks[c] versus home 7 mo. % represents percentage of duration of entire recording.

environment data revealed no differences between the NICU and newborn nursery groups for percent distant speech at 44 weeks (17.4% vs 14.7%; $P = .23$) and 7 months (24.1% vs 25.9%; $P = .56$) and percent meaningful speech at 44 weeks (15.8% vs 15.2%; $P = .77$) and 7 months (13.8% and 13.7%; $P = .94$), respectively.

Female adults had significantly higher mean hourly AWCs than male adults during all recordings (Fig 2). Although there is variance in the number of adult words spoken per hour, infants, on average, received nearly 3 times as much language input from their mothers than their fathers from birth through 7 months of age. To make a best estimate of a parent's overall presence with the infant during the recording, hourly AWCs for male versus female adults were compared. Analyses of AWC >100 words/hour to reflect parents' presence with the infant identified an overall average of 74% for mothers versus 47% for fathers for all recordings.

The language interactions between mothers and infants compared with fathers and infants were further explored by analyzing language block data. Infant response to adult language was measured by including all language activity blocks initiated by female and male adults. The percentage infant response was determined by counting the number of adult-initiated blocks with an infant response compared with adult monologue blocks. Figure 3 shows that of all adult-initiated language blocks, infants vocally responded preferentially to mothers compared with fathers during all 3 recording periods. With increasing age, infant response to both parents increased ($P < .0001$).

Of all infant-initiated language blocks, the percentage of blocks with any adult responder ranged from 28% during the newborn recording to 23% by 7 months (data not shown). Only the language blocks initiated by the infant with an adult response (female adult only, male adult only, or both) were analyzed. Figure 4 shows that mothers were the primary responders to an infant's verbal cues. During each recording period, infants had relatively few vocal interactions with their fathers independent of their mothers. Any male adult response occurred in 27% to 30% of the blocks compared with any female adult response, which occurred in 88% to 94% of infant-initiated language blocks ($P < .0001$).

Table 3 shows infant vocalizations and verbal interactions by infant gender. Vocalization counts did not differ significantly at any recording period. At 44 weeks' PMA, infant boys had higher hourly conversation turn counts than infant girls (24 vs 18, $P = .05$). There were no significant differences for AWC based on infant gender.

Figure 5 shows adult response rates to infant vocalizations by adult gender. Female adults had a higher response rate to language blocks initiated by infant girls than boys during the newborn period and at 44 weeks' PMA. At 7 months, the response rate remained higher but did not reach statistical significance. Male adults responded more frequently to infant boys than infant girls, but the difference did not reach statistical significance.

Analysis of child response by adult gender showed few differences. Infant boys

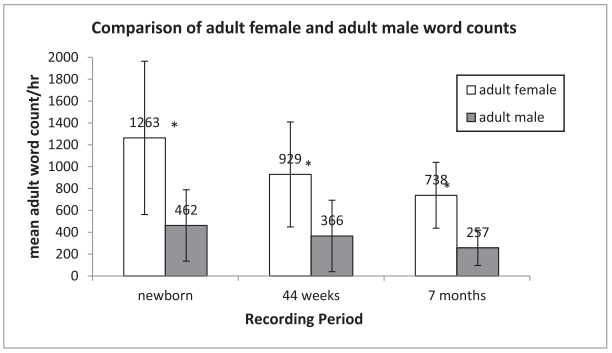

FIGURE 2
Comparison of female versus male AWC per hour. *$P < .0001$ comparing female to male adults. Error bars represent SD.

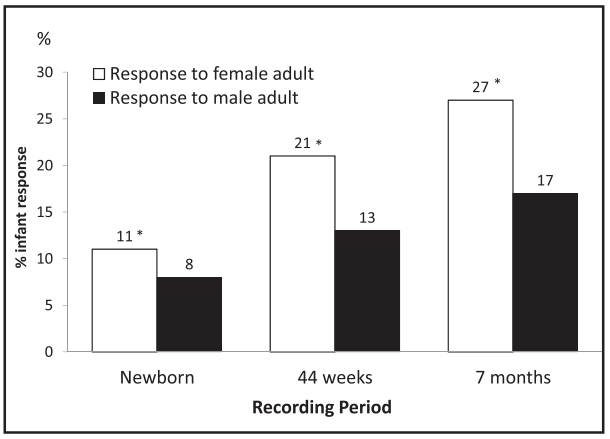

FIGURE 3
Infant response to female and male adult–initiated language blocks. *$P < .01$ comparing infant response to female versus male adult.

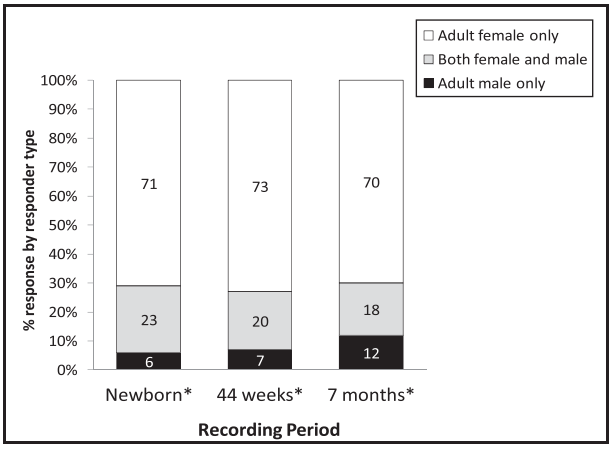

FIGURE 4
Adult response to infant-initiated language blocks. *$P < .0001$ comparison among 3 categories.

and girls had similar response rates to female adult-initiated language blocks for all recordings. Infant boys displayed a higher response rate than girls to male adult–initiated blocks at 7 months (19% vs 15%, $P = .02$).

DISCUSSION

More than 1500 hours of language recordings were analyzed to provide a comprehensive description of language input and interactions between infants and their caregivers in the first months of life. It is known that early language exposure is important for language development,[19] and children with a rich language environment, specifically infant- or child-directed speech,[20] have better language and cognitive outcomes.[1,21,22] A recent study of preterm infants in the NICU using the same LENA technology showed that parental talk in the NICU was a significant predictor of infant vocalizations and conversational turns, and the AWC in the NICU also correlated with improved cognitive and language outcomes through 18 months of age.[17,23] Our study is among the first to assess language environment and language interactions longitudinally beginning in the first days after birth.

The AWC data support our hypothesis that infants are exposed to more female than male adult speech in the first months of life. It also confirms the LENA Natural Language Study that the majority of the total talk environment comes from mothers.[22] The infants' total language exposure increased from birth to 7 months as they became more mature and engaging. The finding that the hourly AWCs from mothers and fathers actually decreased over time is explained by the fact that the "meaningful speech" category, from which AWC estimates are generated, decreased over time, whereas "distant speech" increased. The physical proximity between parent and infant is 1 component in a complex Gaussian mixture model that determines if the audio data are categorized as distant versus meaningful speech. Parents are more likely to be in closer proximity during early infancy with more frequent feeding and holding.

The finding that reciprocal vocalizations between mothers and infants were

TABLE 3 Infant Vocalizations, Conversational Turns, and AWC per Hour by Infant Gender

	Overall (n = 33)	Infant boy (n = 16)	Infant girl (n = 17)	P Boy Versus Girl
Infant vocalizations/h				
Newborn	36	31	39	.39
44 wk	72	85	59	.07
7 mo	86	95	77	.12
Conversational turns/h				
Newborn	12	11	13	.67
44 wk	21	24	18	.05
7 mo	23	24	21	.46
AWC/h				
Newborn	1724	1643	1800	.64
44 wk	1295	1391	1204	.37
7 mo	994	1050	942	.46

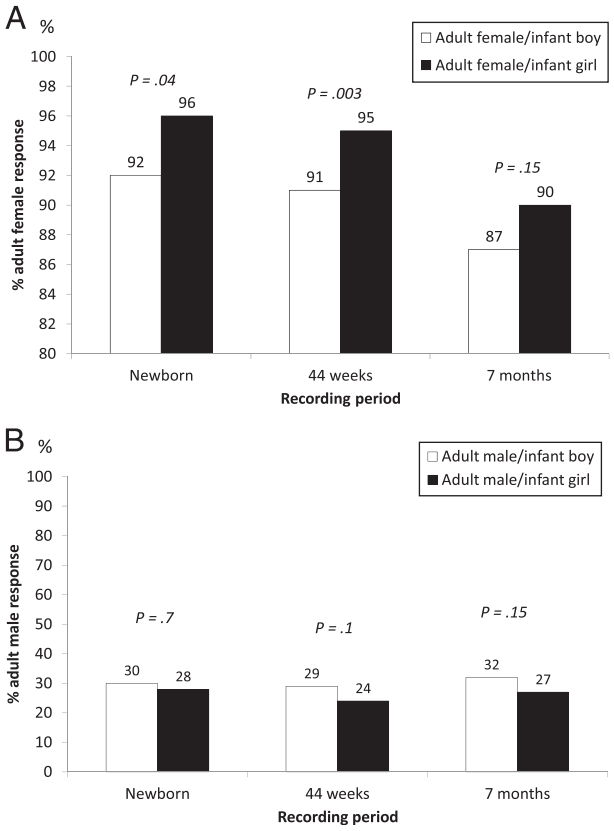

FIGURE 5
A, Female adult response to infant-initiated language blocks by infant gender. B, Male adult response to infant-initiated language blocks by infant gender.

more frequent than those between fathers and infants supports our second hypothesis. What is striking is not simply that mothers speak more and have more vocal interaction with their infants, but rather by how much more they speak compared with fathers. Functional magnetic resonance imaging has shown that mothers, but not fathers, have increased brain cortical activation in specific language processing areas when listening to infant-directed speech, suggesting that mothers have an intent to communicate and the difference in neural processing is experience-dependent.[24] The mothers spoke more to infant girls than boys in early infancy. Girls have been shown to have earlier brain maturation, eye contact, and joint attention, which may in turn influence greater maternal responsiveness.[12,25,26] A significant gap in language input from fathers may have long-term implications. Recent studies have shown that fathers' language input and vocabulary spoken to infants and young children may also be a predictor of child language outcomes.[27–29]

Our study adds to the literature by describing the relationships between adult and infant gender relative to early parent-infant communication to better describe the infant early linguistic experience. Early language delays are of clinical importance, and our study findings, which suggest unique gender effects on early communicative interactions between parents and their infants, support a need to explore novel approaches to early gender-specific intervention.

Much of the literature examining interactions of parents with their sons and daughters has provided inconsistent results. Some investigators have reported that parents converse more and speak longer to their girls than boys.[30,31] Others found that parents of infants and toddlers used more explanations and descriptive statements when talking to their sons than daughters.[21,32] Mothers tended to give more instructions,[30] teach problem-solving skills, and be more directive with their sons,[33] and they asked more questions and made more statements about feelings or needs with their daughters.[30,34] These variations in communication with children illustrate differences in both amount and type of language parents are using. For our study, we did not analyze the actual words but rather the estimated count of adult words spoken.

Infant gender differences in vocalizations and conversational exchanges and the relationship with language skills deserve further investigation. The gender differences described in the literature showing that girls acquire language skills earlier than boys was not reflected in our

early vocalization and conversational turn counts. Our findings suggest infant boys are more vocal with more conversational turns at 44 weeks' PMA with a trend for more vocalizations and conversational turns at 7 months. This may reflect a difference in emotional expressiveness with infant boys having an immature nervous system and greater irritability and need for soothing compared with girls.[12,35] The prelinguistic vocalizations analyzed in this study, however, may be different from the extensively studied meaningful speech that develops beyond the first year of life.

Strengths of this study are that (1) it is among the first longitudinal studies to evaluate an infant's language environment from the first days of life, (2) it uses a novel research device with analysis of thousands of hours of natural language environment data, (3) it analyzes both the mother's and the father's role in early language exposure, and (4) it analyzes the role of infant gender in language interactions.

A limitation of the study is small subgroup sample size. In addition, LENA has been used to document language environment and vocalization activity of preterm infants, but there is no normative LENA data set for infants <2 months of age.[23] The findings of female and male adult speech reflecting the actual mothers' and fathers' speech was based on logs the families kept for each recording and not by any method of direct visualization. The actual presence of an individual is confirmed only if there are words spoken and included in the data set. Only infants residing in 2-parent households exposed to both female and male adult speech were analyzed, and the findings may not be representative of all home environments.

CONCLUSIONS

Language interactions between female caregivers and their infants surpass those of male caregivers. Mothers provide the majority of language input and are the primary responders to their infant's vocal cues, and infants show a preferential vocal response to their mothers. In addition, the data suggest that mothers may respond preferentially to infant girls. On the basis of these findings, both mothers and fathers should be informed about the important benefits of parent talk and a rich language environment on their infant's language development and later academic success.

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