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Language Experience in the Second Year of Life Predicts Language Outcomes in Late Childhood

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Abstract

Objective—Quantity of talk and interaction in the home during early childhood correlates with socioeconomic status (SES) and predicts early language and cognitive outcomes. This study tested the effectiveness of automated early language environment estimates for children 2–36 months to predict cognitive and language skills 10 years later and examined effects for specific age periods of early development.

Methods—Daylong audio recordings for 146 infants and toddlers were completed monthly for 6 months, and the total number of adult words and adult-child conversational turns for recording days were automatically estimated with LENA software. Follow-up evaluations at 9–14 years of age included language and cognitive testing using the Wechsler Intelligence Scale for Children-Fifth Edition (WISC-V – IQ and Verbal Comprehension Index, VCI), Peabody Picture Vocabulary

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Contributors Statement Page

Dr. Gilkerson conceptualized and designed the study, coordinated and supervised data collection, participated in data interpretation, drafted the initial manuscript, and reviewed and revised the manuscript.

Mr. Richards conceptualized and designed the study, carried out statistical analyses, participated in data interpretation, and reviewed and revised the manuscript.

Drs. Warren, Oller, and Vohr conceptualized the study, participated in data interpretation, and reviewed and revised the manuscript.

Ms. Russo carried out statistical analyses and reviewed and revised the manuscript.

All authors approved the final manuscript as submitted and agree to be accountable for all aspects of the work.

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Potential Conflicts of Interest: Three of the authors (Gilkerson, Richards and Russo) are full time employees of the LENA Research Foundation, a 501(c)(3) public charity that developed and distributes the automated approach used to analyze the data described here The salaries of LRF scientists are in no way associated with data analyses or research results. The other three authors (Warren, Oller, Vohr) have no conflicts of interest to disclose.

Test (PPVT), and Expressive Vocabulary Test (EVT). Language exposure for three age groups was assessed: 2–17, 18–24 and 25+ months. Pearson correlations and multiple linear regression analyses were conducted.

Results—Conversational turn counts at 18–24 months of age accounted for 14–27% of the variance in IQ, verbal comprehension, and receptive/expressive vocabulary scores ten years later, after controlling for SES. Adult word counts between 18–24 months correlated with language outcomes but were weakened after controlling for SES.

Conclusion—These data support the hypothesis that early talk and interaction, particularly during a relatively narrow developmental window of 18–24 months, predicts school-age language and cognitive outcomes. These findings underscore the need for early intervention programs that support parents to create an optimal early language learning environment in the home.

Table of Contents Summary:

This 10-year study explores the relationship between very early child language experience and language and cognitive skills in late childhood.

Language experience in the second year of life predicts language outcomes in late childhood

In their landmark study, Hart & Risley quantified the language environments of typically developing infants and toddlers, finding that adult word exposure between 10–36 months of age predicted child IQ at age three.[1,2] Their work and subsequent research provide strong evidence that early language exposure predicts developmental outcomes.[3–6] In response, pediatric interventions have been developed to help parents and caregivers boost talk and interaction with young children; several of these incorporate LENA (Language ENvironment Analysis) software to characterize early language experience via automated analysis of daylong audio recordings.[7–10] Although these interventions reportedly have increased early talk and improved child language skills, research is needed on the long-term relationship between automated measures of early language experience and later developmental outcomes. The current study tested whether cognitive and language skills in children 9–14 years of age correlated with automated estimates of their early language experience and examined whether long-term outcomes were predicted differentially during three periods of early development. Note that we use predictiveness throughout in a statistical rather than explanatory or causative sense.

Decades of research have provided empirical evidence linking early language exposure and developmental outcomes.[1–3,5,6] In one study, 14- to 26-month-olds exposed to more adult words had higher rates of vocabulary development than those exposed to fewer words.[4] In another, high-socioeconomic status (SES) mothers of 18- to 29-month-olds spoke more often and with more varied vocabulary than mid-SES mothers, and their children demonstrated more advanced lexical development.[11] Research connecting adult word exposure with higher rates of vocabulary development generally has focused on children with spoken lexicons in the second and third years of life, when many children undergo linguistic changes that may influence interlocutors and patterns of interaction in their environment.[12,13] In fact, it has long been argued that parents adjust their speech to infants and children based on recognition of their level of development and awareness that child speech complexity changes with age.[12,13] For example, children under 18 months of age rarely engage others using word combinations.[14] Then around 18 months children commonly produce their first combinatorial speech (two-word utterances), and their spoken vocabulary increases rapidly, a phenomenon sometimes called the 'word spurt.'[15–17] The existence and nature of a literal word spurt is debatable – some researchers explain accelerated vocabulary learning and the appearance of word combinations by invoking a "naming insight," and others suggest accelerated acquisition may be a by-product of parallel word learning and variation in the time to learn new words.[18–20] Ganger & Brent argue against a word spurt but concede that "it is uncontroversial that a child's rate of word learning increases during the 2nd year of life" (p. 621).[21] Regardless of its origins, a landscape change in language use is observed around this age. Subsequently, children beyond 24 months start to produce longer utterances including grammatical morphemes and multi-clausal sentences.[14]

Although follow-up with Hart & Risley's original sample showed that child word complexity and length of utterances between 10–36 months of age predicted academic outcomes in third grade (e.g., expressive/receptive language, spelling, reading), analyses were presented in aggregate and did not examine effects for specific age groups.[22] Little is known regarding whether language experience during different developmental periods may uniquely impact long-term outcomes. This study addresses the question longitudinally using LENA language experience metrics extracted from automatically-analyzed, full-day audio recordings collected from infants and toddlers to predict their language and cognitive skills in middle school. These relationships are examined across the full span of recording ages as well as within subgroups of children 2–17, 18–24, and 25+ months of age. Analyses within these age groups address the possibility that the long-term impact of a child's parent-generated language environment may depend in part on developments in child utterance complexity.

Methods

Phase I

Study Design.—The initial 2006 phase of this research has been reported in detail.[23] Briefly, 329 children predominantly between 2–36 months of age (nine between 38–47 months) were recruited from the Denver-metro area, matching the US census on an SES proxy (mother's attained education). Families completed daylong (12-hour) audio recordings monthly for 6 months.

Apparatus.—LENA software automatically processed audio recordings to quantify adult word exposure, child vocalization, and turn-taking interactions throughout the day based on algorithmic analysis.[7] The adult word count (AWC) algorithm does not recognize words directly but analyzes acoustic information, e.g., related to syllable counts and consonant distributions, to estimate counts. The recording device registers all speech near the child, thus AWC includes both overheard and child-directed speech. Child vocalizations (CVs) quantify speech-related vocalizing by the child. The conversational turn count (CTC) quantifies adult-child alternations (vocal initiations with responses that occur within 5 seconds). Both intentional vocal responses and accidental vocal contiguity can be included in the CTC measure.[24]

Reliability of LENA's automated speaker segmentation has been extensively reported, with accuracy of identification of adult and child segments between 68–82 percent.[25–28] Reliability for LENA measures was based on 5,000 minutes of transcribed recording data from 94 children ages 2–48 months, 30–70 minutes each (mean = 53.2, SD = 12.7 minutes). AWC, CV, and CTC correlated highly with human transcription counts, $r = .95$, .82, and .83 respectively, all $P < .001$. Differences between transcribed counts and LENA estimates were uncorrelated with age for AWC, $r = -.12$, $P = .27$, CV, $r = .16$, $P = .11$, or CTC, $r = .06$, $P = .57$. Concurrent validity of LENA measures in the Phase I sample was demonstrated by significant correlations with language assessments administered by a certified Speech-Language Pathologist (SLP).[23]

Measures.—Participant children were evaluated by a certified SLP on a battery of assessments. A composite child language skills score (mean = 100, SD = 15) was generated by averaging total (expressive and receptive) language standard scores from the Preschool Language Scale-Fourth Edition and the Receptive Expressive Emergent Language Test-Third Edition.[29,30] Parents completed an age-appropriate version of the MacArthur-Bates Communicative Development Inventory, from which the child's vocabulary size was included.[31] Figure 1 illustrates growth in vocabulary across age for 90 participants for whom it was available concurrently with recordings and indicates that sample children demonstrated accelerating vocabularies around 18 months.

Phase II

Study Design.—In Phase II, letters sent to Phase I families invited the now early school age children (9–13 years old) to complete follow-up language and cognitive assessments with a clinical psychologist, during which time the parent completed a demographic questionnaire. Upon completion, children were given a $50 gift card. Participants were not provided with assessment results, and the evaluator was blind to Phase I data and results.

Participants.—Participant addresses were updated via phone calls and email correspondences between phases. Figure 2 shows the derivation of the study sample in a simplified flow diagram. Ultimately, 146 Denver-area families provided informed consent approved by Heartland Institutional Review Board and participated in Phase II (see Table 1). Over 95% of Phase II children were 36 months of age or younger at Phase I onset. No differences were found between Phase II participant and non-participant families (n = 183) on child gender or age at recording, but more Phase II mothers had attended college (64.4% versus 44.8%), $\chi^2 = 12.51$, $P < .001$.

Measures.—Participant children were administered the *Wechsler Intelligence Scale for Children-Fifth Edition* (WISC-V), the *Peabody Picture Vocabulary Test* (PPVT), and the *Expressive Vocabulary Test* (EVT).[32–34] The WISC-V, for children 6–16 years of age, comprises five Primary Index Scales (Verbal Comprehension, Visual-Spatial, Fluid Reasoning, Working Memory, Processing Speed) which produce the Full-Scale Intelligence Quotient (IQ); of these, Full-Scale IQ and Verbal Comprehension Index (VCI) were included in this study. The PPVT is a widely used measure of receptive vocabulary for ages 2–90+ years in which respondents indicate which of four pictures matches a given word. The EVT, an expressive counterpart to the PPVT for the same ages, provides pictures that participants are asked to name. WISC-V administration generally takes 60 minutes, and the PPVT and EVT each take ~15 minutes. All assessment scores were standardized (mean = 100, SD = 15) against the general population.

Analysis

All valid recordings contributed by families over the six-month Phase I study were included for the full sample. LENA metrics were age-standardized (mean = 100, SD = 15) against a LENA Foundation corpus of 3,384 recordings from 378 families of typically developing children (including current participants) collected during Phase I and subsequent studies. These values were then averaged within family across recordings to produce one representative value and to minimize random variation in monthly scores. For this study, the early child language experience is characterized by AWC and CTC; CV is included only as a measure of child volubility.

Pearson correlations were calculated for AWC and CTC with outcome measures and then recalculated adjusted for SES and repeated by age subgroups. For analyses within age groups, only age-appropriate recordings were used, and each family was represented in only one age group, the one for which they contributed the maximum number of recordings (with preference given to the 18–24 months group to improve sample balance). That is, one set of LENA values that covered the full six-month period and one set restricted to an age subgroup (e.g., 18–24 months) were analyzed. Mean full sample and age-restricted values were highly correlated for AWC, CV, and CTC ($r = .98$, .96, and .97, respectively, all $P < .001$). Additional analyses examined the impact of a single recording per family and corrected for inequality of variance in age subgroups. Finally, to examine the possibility that CTC might not only reflect meaningful caregiver/child interaction but could act as a proxy for other child language characteristics (e.g., volubility), we conducted a multiple linear regression analysis that controlled for children's Phase I CV, language skills, and vocabulary size. See Table 2 for more detail.

Results

Full sample

Table 3 summarizes Phase II assessment scores for the full sample and age subgroups. Pearson correlations with LENA measures are shown in Table 4. CTC was associated with VCI, PPVT, and EVT but did not significantly predict IQ. AWC predicted only VCI. CTC and AWC demonstrated a strong concurrent relationship with each other, $r = .74$ [95% confidence interval (CI): .66 – .81], $P < .001$, $R^2 = .55$.

Age groups and SES

Subsequent analyses examined possible systematic variation related to child age. To generate a smoothed representation of the relationship between early language experience and later outcomes, a moving average age window was defined such that recording values were averaged within-family for each target age month +/− 3 months. For example, language values for age 18 months were computed as the average of available values from 15–21 months. Figure 3 displays the relationships between CTC/AWC and primary outcome measures for the resulting seven-month age window. The strongest relationships (solid lines indicate statistical significance) occurred in a middle period starting at ~18 months.

The sample was split into three exploratory age groupings (2–17, 18–24, and 25+ months). Pearson correlations between language experience predictors and outcomes within each age group are provided in Table 4. Essentially no significant relationships were observed for the 2–17 and 25+ age groups. However, both CTC and AWC strongly predicted outcomes in the 18–24 months group. Repeating these analyses controlling for maternal attained education as a marker for SES (Table 5) demonstrated that correlations in this group remained significant for CTC with IQ, VCI, PPVT, and EVT, but the predictive power of AWC was weakened considerably.

Assessment of Sampling Issues

LENA metrics generally derived from multiple recordings per family (Table 2). To test whether similar results held using a single recording, we randomly selected one recording per family within each age group. Overall correlation patterns were similar; magnitudes were reduced somewhat but remained significant. For example, the multiple recordings 18–24 months CTC/VCI correlation was $r = .57$, $P < .001$; correlations computed from two random draws of one recording for this group were $r = .43$ and .47, both $P < .01$.

CTC distributions were further examined to investigate whether increased predictiveness for the 18–24 months age group could have resulted from greater variance in the language environment compared to younger or older children. The Levene test statistic W was computed to compare the homogeneity of variance among age groups. CTC variance in the 18–24 months group (SD = 15.5) was significantly larger than that in the younger group (SD = 10.1), $W(1, 93) = 11.09$, $P = .001$, and marginally so compared to the older group (SD = 12.6), $W(1, 93) = 3.68$, $P = .06$. Nine cases with the highest squared errors (compared to the group mean) were excluded from this group to achieve homogeneity of variance with the other age groups, $W(2,134) = 1.16$, $P = .32$. Recomputed correlations (controlled for SES) between CTC and language outcomes (Table 5) were higher than with the cases included, supporting the interpretation that the predictive strength for this group did not derive solely from increased CTC variance.

The CTC/VCI relationship in the 18–24 months group was the strongest observed. To evaluate whether this correlation could be accounted for by other child characteristics, we added three contemporaneously collected, potentially related measures of child language development.[23] CTC correlated significantly with CV, language skills, and vocabulary size, $r = .84$, .57, and .63 respectively (all $P < .001$). However, results from multiple linear regression analyses predicting VCI from CTC controlling for these factors demonstrated that their addition to the model did not significantly alter the predictive power of CTC. Table 6 displays regression metrics for three models: Model 1 – turns only; Model 2 – turns plus vocalization and language skills; Model 3 – turns plus vocalization, language skills, and vocabulary size.

Discussion

These results support the hypothesized relationship between early language experience and school age developmental and language outcomes using an objective, automated method to estimate conversational turns and adult words in the language environment. But, the strength of the association based on automated counts was age-dependent; in subgroup analyses the mean number of CTCs for young children specifically between 18–24 months of age predicted IQ, verbal comprehension, and expressive and receptive language skills at 9–13 years. Importantly, these correlations remained significant after adjustments for SES or child language development, suggesting that the impact of increased early interaction on long-term developmental outcomes extends beyond the influence of socioeconomic factors and child skills.

It is possible that the automated procedure is not yet sensitive enough to capture significant relationships outside the 18–24 months range, and that improvement in automatic detection will make it possible to observe significant correlations across all early ages. It is also possible that, although not indicated in our transcriptional analysis, the automated procedure is particularly well suited to accurate counts of conversational turns during the 18–24 months range. In short, though these findings show strong predictiveness of outcome measures by conversational turns in the 18–24 months range, they do not rule out possible relationships at earlier or later ages.

Assuming, however, that a most sensitive period for prediction of language outcomes by early language experience really does begin around 18 months (with individual variation expected), these findings might be explained by a newly emergent cognitive process such as a naming insight or with a more mechanistic proposal not necessitating cognitive insights. But whatever the cause for the increased vocabulary growth and onset of combinatorial speech observed during this period, the data presented here support the possibility that developmental changes associated with complexity in child vocalizing are concurrent with a particularly sensitive period for adult-child interaction.[14] If specialized cognitive processes contribute to the onset of more frequent word usage based on symbolic reference to external entities, then perhaps during this period children increasingly engage in especially impactful, referentially meaningful exchanges. These turn-taking exchanges may prepare the child's cognitive and linguistic capacities for enhanced growth as indicated by the correlational patterns depicted in Figure 3.[19] Empirical evaluation of this possibility requires further investigation. Although little is known about the neuronal mechanisms underlying accelerated vocabulary acquisition after 18 months, sensitive periods for language acquisition suggest that brain architecture may be differentially receptive to environmental input at different periods in early childhood.[35–37] Numerous studies have explored such sensitive periods and the long-term effects that can result when normal patterns of experience are disturbed during development.[38] The present work supports research that suggests exposure to tailored experience during specific periods of early development may have important effects on later development.[35–37]

The current study expands on previous research by addressing certain limitations in Hart & Risley's work. First, they reported a correlation between early word exposure and IQ at age three but did not report results controlled for SES. Second, although their adult word counts correlated with 36-month IQ scores, turn-taking quantity did not, which is surprising given what is now known about the relationship between parent-child interactions and cognitive development.[1,39] However, Hart & Risley's "parent behavioral turns" differed from LENA's conversational turns metric and included both verbal and nonverbal responses. Third, although additional research on a subset of the original Hart & Risley sample found measures of child language production (e.g., MLU and child vocabulary use) correlated with developmental outcomes in elementary school, analyses on early adult word and turn counts were not reported.[22] This study fills these gaps, demonstrating significant correlations between turn-taking interactions early in life and cognitive and speech/language skills at 9–13 years of age.

There are several possible reasons CTC is better correlated with long term developmental outcomes than AWC. AWC does not measure alternation and so is more likely to contain overheard speech, whereas CTC requires alternation between vocalizations of the child and adult speakers and so is more likely to include child-directed speech. Further, unlike AWC, CTC *incorporates* child speech which may be predictive of later developmental outcomes.[40] This finding is supported by other reports showing that adult-child turn-taking is more important to early development than is simple word exposure.[26,41] Romeo et al. specifically identified a possible neural mechanism, reporting that LENA conversational turns predicted fMRI activation in language areas of the brain for 4- to 6-year-olds, whereas AWC did not.[42] Their study represents the first empirical research linking a direct measure of neural functioning to early language environment and supports the current finding that turns are more strongly related to long term outcomes than is simple exposure to adults words. Consequently, we suggest that the long term predictiveness of turn-taking reported here coupled with empirical evidence for its relationship to neural functioning provides strong support for the pivotal roles of the early language environment in healthy cognitive development.

Hart & Risley showed that the early language environment is important in predicting developmental outcomes. But their laborious transcription methods severely limited most clinical applications. Automated analyses from daylong recordings are unquestionably easier to obtain than labor-intensive transcriptions, and the ability to predict long-term IQ and language skills even from a single recording has implications for developmental intervention and prevention programs. Potential issues in a child's language experience may be identified early; if one or two recordings are completed before the 18-month well-baby visit and impoverished language environments are identified, families could be supported through appropriate intervention.

One limitation to these results is their correlational nature – although we refer to statistical predictiveness, we cannot infer causality. For example, other developmental changes occurring during the 18–24 months period may primarily account for cognitive and language skills later. Another limitation is that although the sample spanned a relatively large range of mother's education levels, only 10 children were from the lowest SES group. In addition, the sample is not ethnically diverse and includes only monolingual English-speakers, so the generalizability of results to other languages and cultures is unknown.

Conclusion

Our findings support the concept that a child's early language experience may predict developmental outcomes years later. This study expands on previous research by using an automated system to estimate language experience. Conversational turn-taking between the ages of 18–24 months was highly correlated with later language and cognitive skills. The use of automated recordings in the home language environment provides an objective and relatively non-invasive method for assessing the strengths and weaknesses of a child's language environment and an opportunity to design individualized family feedback and offer education and support to enhance child development, potentially altering developmental trajectories especially of children living in impoverished language environments.

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Abbreviations

SES	Socioeconomic status
SLP	Speech-Language Pathologist
WISC-V	Wechsler Intelligence Scale for Children-Fifth Edition
IQ	Intelligence Quotient
VCI	Verbal Comprehension Index
PPVT	Peabody Picture Vocabulary Test
EVT	Expressive Vocabulary Test
LENA	Language ENvironment Analysis
AWC	Adult Word Count
CTC	Conversational Turn Count
CV	Child Vocalizations

CI	Confidence Interval

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What's Known on This Subject:

Previous studies using transcriptions of short recordings have shown that quantity of talk and interaction experienced by infants and toddlers is correlated with early language and cognitive abilities.

What This Study Adds:

Automated estimates of turn-taking interaction with children 18–24 months of age predict their IQ and language skills ten years later, suggesting that a child's language experience during this relatively narrow early age window may predict later language and cognitive development

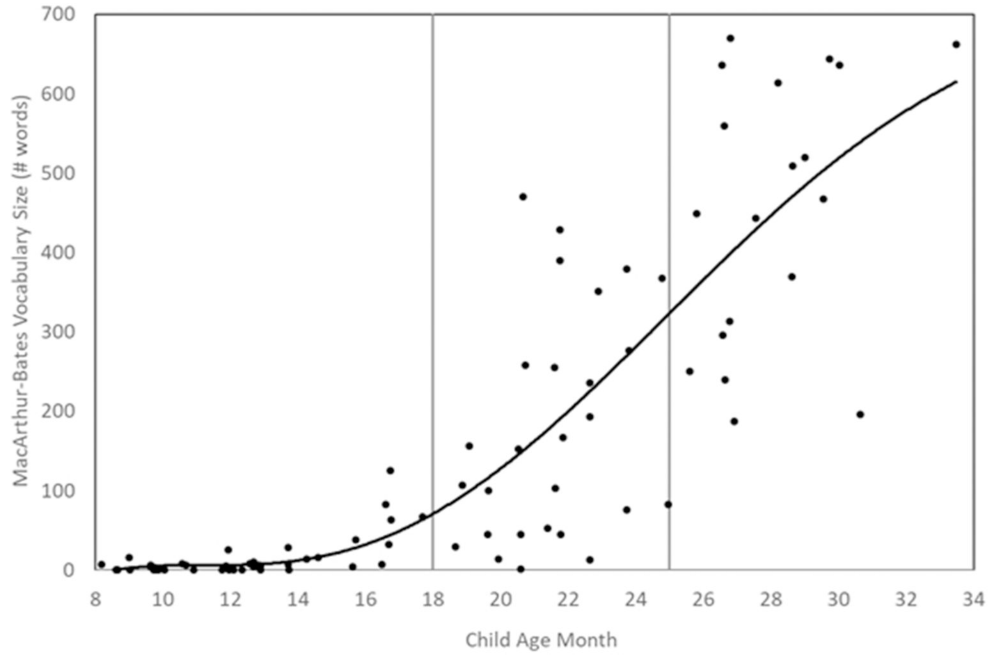


Figure 1.

Phase I Vocabulary Size by Child Age Month

Note. Each marker represents one child.

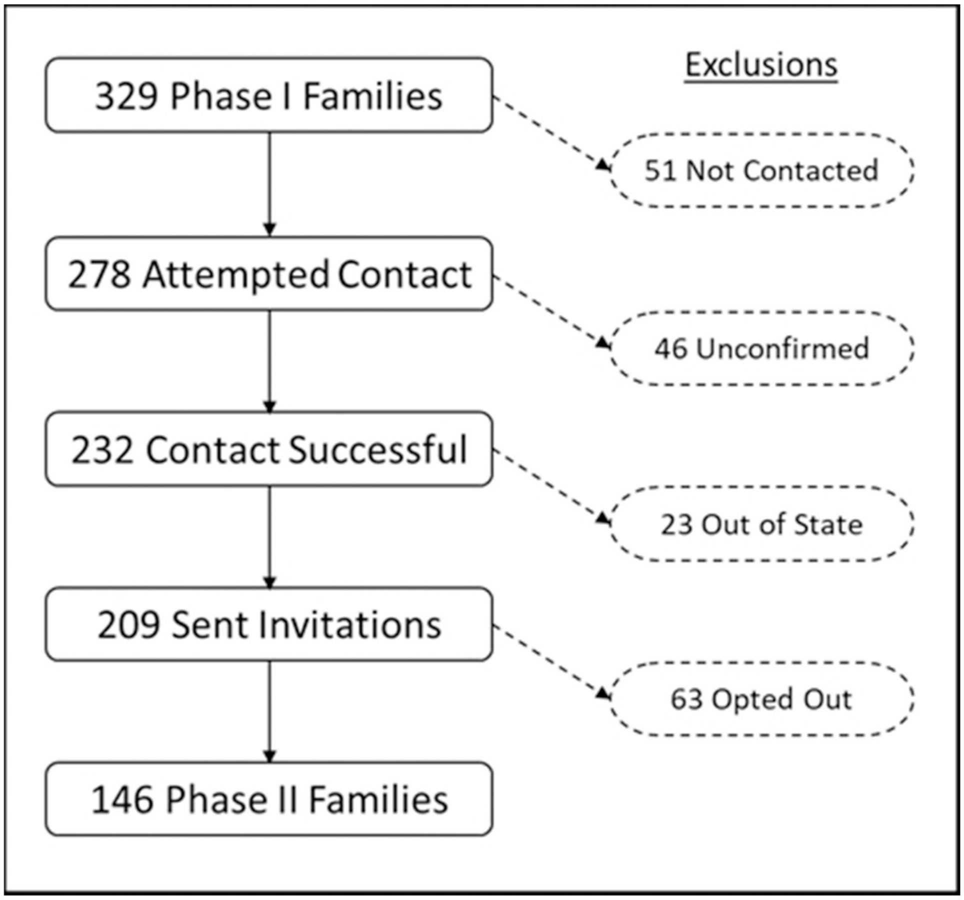
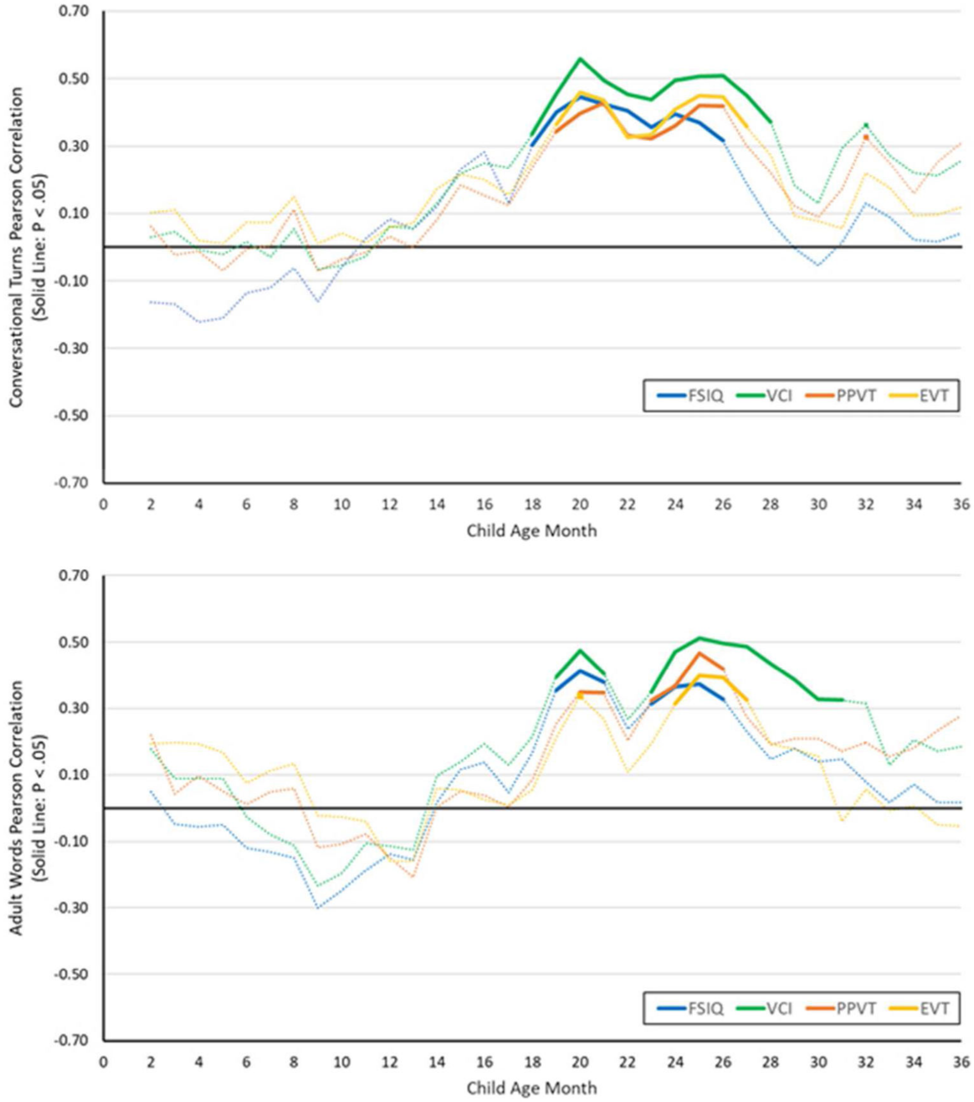


Figure 2.
Phase II Participant Recruitment Flow



Note. LENA values at each age month are the average of counts for that month +/- 3 months. FSIQ = Wechsler Adult Intelligence Scale Full Scale Intelligence Quotient; VCI = Verbal Comprehension Index; PPVT = Peabody Picture Vocabulary Test; EVT = Expressive Vocabulary Test. Solid lines reflect correlations with p < .05.

Figure 3.

Correlations between Phase I LENA Values and Phase II Outcome Measures

Table 1.

Number of Phase II Participants by Phase I Child Age Group

Age Sample:	2–17 Months n = 51	18–24 Months n = 44	25+ Months n = 51	Full Sample N = 146
Child Gender				
Female	26	21	25	72
Male	25	23	26	74
Mother's Education[a]				
Some High School	3	6	1	10
High School Diploma	9	17	16	42
Some College	21	10	15	46
Bachelor's Degree +	18	11	19	48

[a]Mother's highest attained education level includes: Some high school without a diploma; high school diploma or equivalent (e.g., GED); some college but less than bachelor's degree; bachelor's or more advanced degree.

Table 2.

Phase I Language Measures by Child Age Group

Age Sample:	2–17 months n = 51 Mean (SD) Range	18–24 months n = 44 Mean (SD) Range	25+ months n = 51 Mean (SD) Range	Full Sample N=146 Mean (SD) Range
Age (mos) at Recording	8.97 (4.08) 2.66–16.24	21.43(1.72) 19.14–24.43	34.22(5.42) 26.66–48.21	21.48(11.41) 2.66–48.21
Recordings per Family	4.82(1.73) 1–7	3.77(1.55) 1–6	5.14(1.13) 2–7	5.17(1.35) 1–7
Conversational Turns SS	99.93(10.13) 82.11–127.35	97.76(15.5) 61.30–131.02	100.82(12.59) 77.59–131.06	99.99(12.64) 61.30–135.42
Adult Word Count SS	105.52(20.69) 62.55–152.74	96.72(16.12) 57.41 – 129.03	101.01(15.74) 68.75–141.42	101.56(18.05) 57.41–152.74
Child Vocal-ization SS	101.26(9.85) 81.34–130.71	97.32(14.41) 60.27–122.77	99.87(10.88) 71.65–124.69	99.94(11.30) 60.27–130.71
Conversational Turns Count	285 (120) 118–750	440(221) 59 – 967	548 (232) 212–1166	428 (224) 59–1,166
Adult Word Count	14,484(6,022) 4,256–30,794	11,768(4,159) 3,372–21,069	12,928(4,342) 5,305–25,810	13,218(5,079) 3,372–30,794
Child Vocal-ization Count	1,110(396) 449 – 2,227	1,736 (716) 321–3,439	2,316(728) 711–4,176	1,730 (786) 321–4,176
[a]Language Skills	100.70(8.81) 80.5–122.5	104.06(13.2) 76.00–130.00	112.21(15.74) 56.00–139.00	105.69(13.70) 56.00–139.00
[b]Vocabulary	13.95(25.38) 0–125 n = 44	177.48(143.86) 1–470 n = 27	455.79(168.96) 187–670 n=19	156.29(203.55) 0–670 N = 90

Note: LENA SS (standard scores) age-normalized to mean=100, SD=15. LENA Counts reflect totals across a 12-hour recording day.

[a]Language Skills score was unavailable for one child in the 25+ months age group.

[b]MacArthur-Bates Vocabulary scores were unavailable for some participants outside the assessment age range.

Table 3.

Phase II Language Standard Scores by Phase I Child Age Group

Age Sample:	2–17 months n = 51	18–24 months n = 44	25+ months n = 51	Full Sample N = 146
	Mean (SD) Range	**Mean (SD) Range**	**Mean (SD) Range**	**Mean (SD) Range**
Age (yrs) at Assessment	10.69 (0.57) 9.74 – 12.24	11.79 (0.53) 10.99 – 12.99	12.74 (0.64) 11.70 – 14.59	11.74 (1.04) 9.74 – 14.59
IQ	103.78 (17.04) 73 – 137	104.82 (13.36) 71 – 132	102.69 (12.65) 73 – 131	103.71 (14.46) 71 – 137
VCI	105.10 (15.06) 68 – 133	105.36 (14.04) 68 – 127	101.84 (10.63) 76 – 124	104.04 (13.35) 68 – 133
PPVT	112.12 (16.16) 76 – 146	113.57 (14.85) 76 – 137	111.02 (11.41) 76 – 134	112.17 (14.19) 76 – 146
EVT	106.61 (14.06) 75 – 143	109.93 (14.12) 78 – 143	106.75 (9.87) 77 – 124	107.66 (12.78) 75 – 143

Note: All scores age-normalized to mean=100, SD=15. IQ = Wechsler Adult Intelligence Scale Full Scale Intelligence Quotient; VCI = Verbal Comprehension Index; PPVT = Peabody Picture Vocabulary Test; EVT = Expressive Vocabulary Test.

Table 4.

Correlations between Phase I LENA Measures and Phase II Outcomes

		Conversational Turns			Adult Words		
	N	*r* (95% CI)	*P*	R^2	*r* (95% CI)	*P*	R^2
All Ages							
IQ	146	.14 [−.02 – .30]	.08	.02	.08 [−.09 – .24]	.35	.01
VCI	146	.27 [.11 – .42]	.001	.07	.20 [.04 – .35]	.02	.04
PPVT	146	.21 [.04 – .36]	.01	.04	.14 [−.03 – .29]	.10	.02
EVT	146	.21 [.04 – .36]	.01	.04	.10 [−.07 – .25]	.25	.01
2–17 mos							
IQ	51	−.05 [−.32 – .23]	.73	.00	−.11 [−.37 – .17]	.45	.01
VCI	51	.05 [−.23 – .32]	.74	.00	.02 [−.26 – .29]	.90	.00
PPVT	51	.02 [−.26 – .29]	.92	.00	−.01 [−.28 – .27]	.95	.00
EVT	51	.10 [−.18 – .37]	.48	.01	.09 [−.19 – .35]	.54	.01
18–24 mos							
IQ	44	.44 [.16 – .65]	.003	.19	.37 [.08 – .60]	.01	.14
VCI	44	.57 [.32 – .74]	<.001	.32	.42 [.14 – .64]	.005	.18
PPVT	44	.43 [.16 – .65]	.003	.19	.33 [.04 – .57]	.03	.11
EVT	44	.45 [.17 – .66]	.002	.20	.27 [−.03 – .52]	.08	.07
25+ mos							
IQ	51	.08 [−.20 – .35]	.58	.01	.08 [−.20 – .34]	.60	.01
VCI	51	.25 [−.03 – .49]	.07	.06	.22 [−.06 – .47]	.12	.05
PPVT	51	.19 [−.09 – .44]	.07	.04	.18 [−.10 – .43]	.21	.03
EVT	51	.02 [−.25 – .30]	.87	.00	−.10 [−.37 – .18]	.49	.01

Note: IQ = Wechsler Adult Intelligence Scale Full Scale Intelligence Quotient; VCI = Verbal Comprehension Index; PPVT = Peabody Picture Vocabulary Test; EVT = Expressive Vocabulary Test.

Table 5.

Correlations between LENA Metrics at 18–24 Months and Phase II Outcomes Adjusted for SES and for Equal Age Group Variance

		Conversational Turns			Adult Words		
	n	*r* (95% CI)	*P*	R^2	*r* (95% CI)	*P*	R^2
SES Adjusted							
IQ	44	.37 [.08 – .60]	.01	.14	.24 [−.06 – .50]	.12	.06
VCI	44	.52 [.26 – .71]	<.001	.27	.30 [.00 – .55]	.05	.09
PPVT	44	.37 [.08 – .60]	.01	.14	.21 [−.09 – .48]	.18	.04
EVT	44	.38 [.10 – .61]	.01	.15	.12 [−.19 – .40]	.46	.01
Equal Variance							
IQ	35	.48 [.17 – .70]	.004	.23	.34 [.00 – .60]	.05	.11
VCI	35	.61 [.34 – .78]	<.001	.37	.36 [.03 – .62]	.04	.13
PPVT	35	.58 [.31 – .77]	<.001	.34	.38 [.05 – .63]	.03	.14
EVT	35	.54 [.25 – .74]	.001	.29	.18 [−.16 – .49]	.30	.03

Note: IQ = Wechsler Adult Intelligence Scale Full Scale Intelligence Quotient; VCI = Verbal Comprehension Index; PPVT = Peabody Picture Vocabulary Test; EVT = Expressive Vocabulary Test.

Table 6.

Multiple Linear Regression Predicting Verbal Comprehension (VCI) in Phase II from Phase I Measures at 18–24 Months

Regression Model	n	Standardized Coefficient	Unstandardized Coefficient	*t*-test Value	*P*	Model R^2	Model Adj. R^2
Model 1							
Conversational Turns	44	.51	.57	4.43	<.001	.32	.30
Model 2							
Conversational Turns	44	.67	.74	3.06	.004	.33	.28
Child Vocalizations	44	−.19	−.20	−0.78	.44		
Language Skills	44	−.01	−.01	−0.05	.96		
Model 3							
Conversational Turns	44	.75	.88	2.52	.02	.28	.28
Child Vocalizations	44	−.28	−.29	−0.86	.40		
Language Skills	44	.04	.04	0.13	.90		
Vocabulary Size	44	−.01	−.09	−0.33	.74		

Note: The Child Vocalizations and Language Skills scores in Models 2 and 3 were available for all participants in the 18–24 months subgroup; MacArthur-Bates Vocabulary Size in Model 3 was available for 27/44 participants in this group. The Language Skills score was computed by averaging total language standard scores from the Preschool Language Scale – Fourth Edition and the Receptive Expressive Emergent Language Test – Third Edition.