

THE POWER OF **Talk**

2nd Edition

Impact of Adult Talk, Conversational Turns, and TV
During the Critical 0-4 Years of Child Development

LENA Foundation Technical Report ITR-01-2

By Jill Gilkerson, Ph.D. and Jeffrey A. Richards, M.A.

With Foreword by Steven F. Warren, Ph.D.

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By Steven F. Warren, Ph.D.

Professor, Department of Applied Behavior Science, University of Kansas

Measurement breakthroughs often lead to fundamental changes in science and society. Consider for example the impact of Galileo's invention of the telescope on astronomy and our conception of the universe and our place in it, or more recently the revolutions in neuroscience and medicine resulting from breakthroughs in our ability to observe and measure biological processes. In contrast, the ability to measure complex human behavior in real world contexts has been constrained by methods that have changed only incrementally over the past 50 years. That is, until now.

This second edition of *The Power of Talk* reports on what LENA – the world's first automatic system for measuring key elements of children's language learning environments – has already revealed about "meaningful differences" in these environments. None of this is trivial because of the critical foundational role that early language development plays in so much that comes later in a child's life.

LENA is in a real sense the intellectual offspring of the now famous study of Betty Hart and the late Todd Risley on meaningful differences in the everyday experiences of young American children. The Hart and Risley study was constrained by the extraordinary costs and laborious nature of collecting, transcribing and coding data by hand. These challenges limited their data to a small number of families (42) and just one hour per month of data (about 0.25% of the child's waking hours). Even so, this study was so costly and challenging that it has been thought highly improbable that other scientists would attempt to replicate and extend its results, which is normally a prerequisite for further scientific advance.

All this has changed with the invention of LENA. This breakthrough has led to the replication and refinement of the essential findings of the Hart and Risley study – and this is just the beginning. LENA has already focused its lens on many more issues. What are the effects of birth order and gender differences in the early language learning environment? What is the effect of television? What is the effect of autism?

And again this is just the beginning. As scientists, clinicians, and families begin to employ this new tool other discoveries will emerge, diagnostic and clinical practice will be improved, and, most importantly, child development will be enhanced.

Meanwhile, I'm confident that the company behind this revolutionary breakthrough will continue to improve LENA in ways that will make it more powerful, useful and appropriate for different contexts and problems. Of course, like any tool LENA has limits, some of which will eventually be resolved and others of which won't. But for now there is so much to be discovered and done so that this tool can help us achieve what we all want: enhanced language and literacy development for all children, whoever and wherever they are.

Steven F. Warren, Ph.D.

University of Kansas

August 2008

Developer's Note

Todd Risley was very excited about the development of LENA and wrote this foreword to the first edition of The Power of Talk. Unfortunately, Todd passed away on November 2, 2007 at the age of 70. Todd was a great researcher, a kind man, and a friend to many, including many here at the LENA Foundation. We miss him. We are pleased to be a part of the continuation of the research that he and Betty Hart started, and which gave impetus to all we do here at the LENA Foundation.

*Terrance D. Paul
CEO & Founder, LENA Foundation*

By Todd Risley, Ph.D. (1937–2007)

Professor Emeritus of Psychology, University of Alaska

Senior Scientist, Schiefelbusch Institute for Life Span Studies, University of Kansas

In 1995, Betty Hart and I released the findings of a longitudinal research study that we had conducted for over a decade. Our book, *Meaningful Differences in the Everyday Experience of Young American Children*, described how we learned that the most important ingredient in the recipe for a child's future academic success is the sheer volume of talk that the child's parents have with the child—from the child's birth until age three.

It was a study rooted in the history of the War on Poverty. We knew long before we conducted our study that children differed greatly in how fast they acquired language skills and subsequently developed academically. We wanted to know why.

We discovered that race and ethnicity has no bearing on a child's academic success. In fact, even disadvantages attributed to socioeconomic status can be overcome. What matters is this: The more parents talk with their child from birth to age three, the more likely their child will excel academically later in life. And that sets the stage for other successes in the child's future.

If a parent only talks a little bit, the conversation is only about business. "Stop that." "Get down from there." "Come here." But when a parent advances the conversation beyond business, the topics automatically change. The words used in conversation change, too. And that makes all the difference later in the child's intellectual life.

As is the case with most academic studies, we encountered certain limitations. The first was that we observed and recorded our 42 participants for only one hour every month. Also, the youngest children in our study were about seven months old, so we could only speculate about language development for children younger than that.

In 2006, the LENA Foundation developed LENA, which stands for Language ENvironment Analysis. This remarkable technology is unlike any other tool available—for parents or researchers. With LENA, the LENA Foundation recorded the conversations between 314 children and their parents for 12-hour periods once a month for six to 11 months. The average number of 12-hour recordings per child was five. The children's ages ranged from two months old to 36 months old.

By using LENA, the LENA Foundation verified what Betty Hart and I had uncovered—that children who hear more words from birth to age three have more sophisticated language skills than children who don't hear as many words. In other words, talk is the greatest tool parents can use to develop their child's intellectual skills. The LENA Foundation also gained insights into the patterns of talk between parents and their children, when during the day that talk occurs more often and when talk occurs less.

Of course, it is critical that parents know they are talking enough with their children. And that's where LENA comes in. LENA makes it possible for parents to know exactly how much they talk with their child.

It was professionally satisfying and exciting, as you might imagine, generating a study that educators, speech professionals, pediatricians, government officials, and parents have come to find important. And it's equally satisfying and exciting to see our study confirmed—and new findings unveiled—with the use of a revolutionary new tool such as LENA.

Todd Risley, Ph.D.
University of Kansas
December 2006

This booklet, *The Power of Talk*, provides a sample of what has been learned so far from mining the data collected using the LENA language environment analysis system. It describes the development of LENA and a natural language corpus on child and adult speech, to our knowledge the largest of its type in the world. This is the second edition of *The Power of Talk*; the first was published in January 2007. Note that numerical results have changed since the first edition due to improvements in the software processing algorithms. We plan to update this report periodically as additional data is collected and new analyses are conducted.

One objective the LENA Foundation has had from the beginning, both in the development of the LENA System and in the collection of the data on child language development, was to confirm and extend the results of the breakthrough study released in 1995 by Betty Hart, Ph.D. and Todd Risley, Ph.D. Hart and Risley asked why some children do better academically than others. They determined that a child's intellectual success later in life is directly related to the amount of talk the child hears from birth to age three. Research conducted by the LENA Foundation using the LENA System has indeed confirmed many of their important findings.

Key findings to date include:

- Parents of advanced children—children who scored consistently between the 90th and 99th percentiles on independent standard language assessments—spoke substantially more to those children than did parents of children who were not as advanced, confirming the Hart and Risley results.
- Parents estimated that they talked more with their children than they actually did.
- Most language training for children came from mothers, with mothers accounting for 75 percent of total talk in the child's environment.
- Mothers talked roughly 9 percent more to their daughters than to their sons.
- Parents talked more to their first-born than to their other children, particularly first-born males.
- Most adult talk in the child's environment occurred in the late afternoon and early evening compared to other times of day.
- Children of talkative parents were also talkative.
- Although the average daily talk for parents who graduated from college was higher than for all other parents, the average daily talk for the upper 50 percent of parents who did not complete high school was significantly higher than that of the lower 50 percent of parents who graduated from college.
- The more television time in a child's day, the lower his or her language ability scores tended to be.
- Monolingual Spanish-speaking families were similar to English-speaking families with respect to patterns of adult talk.
- Parents of children with autism tended to talk less the more severe their child's symptoms were. Conversely, the stronger their child's language abilities, the more they talked.
- Parents are quite variable in the day to day amount they talk to their children, but given the opportunity to receive feedback they are able to increase the amount of talk consistently.

*Meaningful Differences in the Everyday Experience of Young American Children*¹ describes the findings of a groundbreaking longitudinal study of parent-child talk in families in Kansas conducted over nearly a full decade by researchers Betty Hart, Ph.D., and Todd R. Risley, Ph.D. Over a three-year period, a team of researchers recorded one full hour of talk each month, including every word spoken at home between parents and children during that hour, for 42 families with children from 7 months to 36 months of age. They and their team observed and recorded parent-child talk during the late afternoon or early evening, a time when there is typically more conversation in the home. The team then spent an additional six years typing, coding, and analyzing some 30,000 pages of transcripts.

Hart and Risley categorized participants based on socioeconomic status. Their sample comprised:

- 13 families in the upper socioeconomic stratum
- 10 families in the middle socioeconomic stratum
- 13 families in the lower socioeconomic stratum
- 6 families on welfare
- 17 African American families
- 23 female and 19 male children

At the conclusion of the observation phase, Hart and Risley had 1,318 hour-long transcripts. From the recordings, their team coded interactions between the parents and children. They coded words into four categories: nouns, verbs, modifiers (adjectives and adverbs), and function words (pronouns, prepositions, demonstratives, and articles). Other sounds, such as animal and vehicle sounds, and utterances that were sentences or phrases were also coded. The process to transcribe, code, and analyze the conversations took the Hart and Risley team about six years.

Follow-up studies by Hart and Risley of those same children at age nine showed that there was a very tight link between the academic success of a child and the number of words the child's parents spoke to the child to age three.

Hart and Risley's Study of 42 Children in Kansas Uncovered Three Key Findings:

1. Variation in children's IQs and language abilities is partially predicted by the amount parents speak to their children.
2. Children's academic successes at ages nine and ten can in part be attributed to the amount of talk they heard from birth to age three.
3. Parents of advanced children talk significantly more to their children than parents of children who are not as advanced.

¹ Hart, B.S. and Risley, T.R. (1995) *Meaningful Differences in the Everyday Experience of Young American Children*. Baltimore. Paul Brookes. (1.800.638.3775)

The variability in talk among families was significant

Certainly, it came as no surprise to Hart and Risley that some families talked more than others. What surprised the researchers was the extent of the differences among families. Some parents spent more than 40 minutes in an average hour interacting with their child, while other parents spent less than 15 minutes. Some parents responded more than 250 times an hour to their child; others responded fewer than 50 times. Some parents expressed approval and encouragement of their child's actions more than 40 times an hour; others less than four times. Some parents spoke an average of more than 3,000 words per hour to their child; others spoke fewer than 500 words. By age three, the differences in each child's language experience were significant: some children had heard nearly 33 million words; others as few as 9 million.

This finding is particularly notable because the child's rate of vocabulary growth, vocabulary use, and IQ score was more strongly related to the number of words a parent said per hour than any other variable including parents' education or socioeconomic status. Figure 1 shows the differences among parents and children from the three socioeconomic strata studied.

Figure 1. Average Counts for Parents and Children (Hart and Risley, 1995)

MEASURES	PARENT COUNTS			CHILD COUNTS		
	PROFESSIONAL (N=13)	WORKING CLASS (N=23)	WELFARE (N=6)	PROFESSIONAL (N=13)	WORKING CLASS (N=23)	WELFARE (N=6)
IQ at age 3				117	107	79
Recorded Vocabulary Size	2,176	1,498	974	1,116	749	525
Average Utterances per hour	487	301	176	310	223	168
Average Different Words per hour	382	251	167	297	216	149
Average Adult Words per hour	2,153	1,251	616			
Average Adult Words per 14-hour day	30,142	17,514	8,624			

The Link Between Children's Experiences and Their Outcomes

Hart and Risley found that, "With few exceptions, the more parents talked to their children, the faster the children's vocabularies were growing and the higher the children's IQ test scores at age three and later." That is, the amount of parent talk accounted for a significant portion of the verbal and intellectual accomplishments of the children in their study. In fact, according to Hart and Risley, the measure of accomplishments at age three predicted measures of language skills at ages nine and ten. Thus, the importance of the first three years of a child's experience cannot be underestimated.

LENA is the world's first automatic natural language environment analysis system for infants and toddlers. The development of LENA was inspired by *Meaningful Differences in the Everyday Experience of Young American Children*. The LENA Foundation, the company that developed LENA, was founded on the belief that technology is best used to enhance the parent and child bond rather than become a substitute for it. It is the close daily interaction between parents and children that help children reach their full potentials. The LENA Foundation employs a world-class team of engineers, research academicians, linguists, and speech-language professionals who have spent over four years and millions of dollars researching and developing LENA. In the time since the initial LENA development, the LENA Foundation has collected over 65,000 hours of audio recordings in the natural home environment. This database forms the basis for the analyses reported here, and it will be available for researchers worldwide to draw from to facilitate independent academic studies.

The LENA System Includes:

- The LENA Digital Language Processor (DLP) that captures up to 16 hours of a child's natural audio environment.
- Specialized LENA Clothing with a technically designed pocket that holds the DLP and allows the child to play unencumbered while the DLP accurately records all day long.
- State-of-the-art vocalization and speech language environment analysis software.
- Feedback reports that provide information regarding the child's natural language environment, specifically: the number of adult words the child hears in a day, the number of conversational turns the child engages in throughout the day, and the number of speech-related sounds (or vocalizations) the child produces.²

How LENA Accurately Measures Adult Talk

The LENA DLP captures every utterance between parent, or other caregiver, and child. Then the software uses advanced algorithms and statistical modeling to analyze the conversations and estimate three primary language-related measures: Adult Word Count (AWC; the number of adult words spoken); Conversational Turns (CT; adult-child alternations per day); and Child Vocalization frequency (CV; the number of words, babbles, and "protophones" or prespeech communicative sounds produced by the child).

The accuracy of the LENA System was assessed using 70 one-hour test files from 70 different families (children two months to 36 months; two children per month of age). For Adult Word Count, LENA had a mean per-hour error rate of two percent compared to human transcribers. Accuracy for individual families may be better or worse due to variable sources of noise in the environment and confusion between non-speech noises and adult-child talk. Higher potential error rates are mitigated by the fact that, over time, errors tend to cancel out because relative values and relative change in the number of adult words and conversational turns are more important than absolute values.

² Child vocalization information may not be available in all versions of the LENA software. For more information on LENA software options, please visit our website at <http://www.lenafoundation.org>.

A unique feature of the LENA software is that LENA Foundation's engineers adapted it to work in unstructured environments. Doing so enables LENA to discern between clear and unclear or faint speech and to filter out other sounds, such as child cries and vegetative sounds, or voices from a radio or television.

In their study, Hart and Risley recorded one hour of conversation during a specific day every month—typically during the late afternoon or early evening. They counted the adult words and child vocalizations in that hour, and then extrapolated those findings across 14 waking hours to estimate the total number of adult words that their participants experienced. As a result, Hart and Risley estimated that children with advanced language skills would have heard more than 33 million words in the first three years of life, or about 30,000 words every day.

Using LENA to record an entire 12-hour day of language experience with 329 participants enabled the LENA Foundation to accurately estimate the number of adult words that children in a highly enriched language environment hear in the first three years of life: almost 22 million words, or about 20,000 words every day. With LENA we could see for the first time the pattern of talk during the entire day, revealing that talk peaks during the late afternoon and early evening (something that Hart and Risley could not have known). Considering the fact that Hart and Risley extrapolated their estimate of 33 million words based on one hour of recording at peak talk hours, the LENA estimate based on 12-hour days and the Hart and Risley estimate based on 14-hour days are strikingly similar.

LENA Software Development

To create the LENA software, LENA Foundation scientists constructed algorithms and mathematical models utilizing over 18,000 hours of recordings from 329 families. The recordings were repeatedly fed into a specially designed super computer with 148 parallel processors and 27,300 gigabytes of storage.

LENA filters out faint and unclear speech and estimates an Adult Word Count, that is, the number of words spoken by any adult—mother, father, or visitor—in the same room as the child.

LENA uses similar rules to Hart and Risley's to measure conversational turns. A conversational turn is considered to have occurred when a child vocalizes and an adult responds, or an adult speaks and a child responds. Each time that happens, one turn is counted.

One child vocalization is counted when a child's speech sound of any length is surrounded by at least 300 milliseconds of silence or non-speech.

LENA also filters out the majority of non-speech sounds a child makes. Such sounds include vegetative sounds—those that have to do with respiration or digestion—as well as cries, screams, and whining sounds.

To further augment the LENA System, the LENA Foundation developed the LENA Developmental Snapshot (LDS), a 52-question parent survey assessing both expressive and receptive language skills that provides an estimate of a child's developmental age from two months to 36 months. To evaluate the accuracy of the LDS, the LENA Foundation compared its developmental age estimate with the developmental age estimates from various standard assessments. The LDS correlated well with standard assessments (Pearson's $r = .93$, $p < .001$), as shown in Figure 2.

Figure 2. LENA Developmental Snapshot Age Correlates Well with Developmental Age from Standard Language Assessments

STANDARD ASSESSMENT	N	PEARSON CORRELATION ^a
PLS-4 Receptive Language	51	.93
PLS-4 Expressive Language	51	.92
REEL-3 Receptive Language	75	.96
REEL-3 Expressive Language	75	.96
CDI Receptive Language	143	.84
CDI Expressive Language	142	.81
CLAMS	52	.97
CAT	52	.95
Overall Average		.93

^aAll correlations are significant at the .01 level (2-tailed).

Phase I

There were 329 participants in Phase I of the LENA Natural Language study.³ Participants recorded for at least 12 consecutive hours one day each month for six months from January through June 2006. The children in Phase I were between 2 months and 48 months of age, and there were approximately eight children in each age-month interval through age 36 months. During each month of Phase I the LENA Foundation added more two-month-old children and continued to collect data from the children who had aged beyond 36 months. The sample was recruited from the Denver, Colorado metropolitan area through newspaper ads and direct mail solicitations. Over 2,000 people expressed interest in participating, and the LENA Foundation eventually narrowed the group to match United States Census figures with respect to the attained education level of participants' mothers, as shown in Figure 3.

Figure 3. The LENA Natural Language Study Phase I Sample is Representative of the US Census With Respect to Maternal Attained Education

MOTHER'S ATTAINED EDUCATION	N	US CENSUS ^a	LENA SAMPLE ^b
Some High School	45	22%	14%
High School Diploma/GED	108	26%	33%
Some College	92	29%	28%
College Degree or Higher	84	23%	25%
Total	329	100%	100%

^a US Census Bureau (2004): Population of women 15-44 years of age.

^b Sample percentages in the two lower education groups have been adjusted since the first edition; participants who obtained GEDs moved from the 'Some High School' group to the 'High School Diploma/GED' group to more closely reflect the Census grouping.

Phase II

Eighty Phase I participants, chosen to provide a representative sample with respect to children's overall language ability and mothers' attained education, were selected to participate in an extended longitudinal study (Phase II) from July 2006 through the present and continue to record monthly. Results presented here are based on over 32,000 hours of data from 2,682 recordings collected during Phases I and II through December 2007 from participant children ages 2 months through 48 months.

³ For more information on the LENA Natural Language Study, please see LENA Foundation Technical Report ITR- 02-2 "The LENA Natural Language Study."

Percentile Norms: Adult Words, Conversational Turns, and Child Vocalizations

An important goal of the LENA Natural Language Study has been the generation of the first normative percentile estimates for Adult Word Count, Conversational Turns, and Child Vocalizations (based on 12-hour days). Figure 4 shows representative values for these measures for selected percentiles.

Figure 4. Percentile Norms for Adult Words, Conversational Turns, and Child Vocalizations per 12-Hour Day (Ages 2 Months – 48 Months)^a

PERCENTILE	ADULT WORD COUNT	CONVERSATIONAL TURNS	CHILD VOCALIZATIONS
99 th	29,428	1,163	4,406
90 th	20,824	816	3,184
80 th	17,645	688	2,728
70 th	15,516	603	2,422
60 th	13,805	535	2,174
50 th	12,297	474	1,955
40 th	10,875	418	1,747
30 th	9,451	361	1,538
20 th	7,911	300	1,310
10 th	6,003	225	1,024

^aBecause Conversational Turns and Child Vocalizations increase with age, percentile values are age-dependent and vary by month of age in the LENA software. Values shown here are representative for a 24-month-old child.

One of the most interesting details regarding adult speech that can be seen in this normative table is the degree of variation in amount of talk. Parents at the 90th percentile say over 1.5 times more words than parents at the 50th percentile and nearly 3.5 times more than parents at the 10th percentile. They engage in more conversational turns as well, at similar rates.

Comparing Hart and Risley Estimates with LENA Estimates

The LENA daily adult word count estimates are somewhat lower than those projected by Hart and Risley. The estimated mean word count for Hart and Risley's professional class parents was 30,137 words per day, and the LENA 90th percentile is 20,824 words per day. Why are these counts different?

The difference between Hart and Risley's counts and the LENA counts can be attributed to data collection procedures. The participants in Hart and Risley's study did not record all day – they recorded for one hour, and that hour was extrapolated to a 14-hour day. Importantly, Hart and Risley's participants recorded in the afternoon and evening. As it turns out, the late afternoon and evening are peak talk times as shown in Figure 9 (page 15), something that Hart and Risley could not have known without LENA. Participants in the LENA Foundation study recorded once a month for an entire 12-hour day; there was no extrapolation. The combined effect of these procedural differences means the LENA daily and hourly counts are approximately 30 percent lower than Hart and Risley's estimates.

This is actually good news. It means that each word a parent speaks to their child is 30 percent more powerful than what Hart and Risley estimated in 1995.

The assessment of language development in young children poses numerous challenges that stem in part from the difficulty of collecting a sufficient quantity of representative language data. Speech language professionals employ a variety of instruments to evaluate a child's language development.

These standard assessments incorporate both parent report and clinical observation components to varying degrees, are typically administered by a professional in a clinical setting, and can require from 30-90 minutes to complete and score. Consequently, the reliability and validity of these instruments can be affected by such factors as an unfamiliar clinical setting, heavy reliance on parent input, and limited observation time.

The LENA Foundation’s goal for the automatic vocalization assessment (AVA) is to provide parents and professionals with an automated tool that can be used to screen children for language delay and to generate an objective expressive language development estimate as part of an overall evaluation, diagnostic, and treatment process. In particular, AVA is intended to minimize the effects of confounds inherent to evaluation in a clinical setting by collecting language data in the natural home environment over an entire day in as unobtrusive a manner as possible.

AVA software uses automatic speech recognition technology to categorize and quantify the sounds present in a child’s vocalizations recorded using the LENA System. This quantitative acoustic information is analyzed statistically to generate information about the child’s expressive language development, which is reported as the AVA standard score, developmental age estimates, and an estimated mean length of utterance (EMLU). For more information on the development of AVA, please see LENA Foundation Technical Report ITR-08-1, “The LENA Automatic Vocalization Assessment.”

AVA reliability

Test-retest reliability for AVA is shown in Figure 5, which details comparisons between AVA scores from recordings two months apart for participants ages 2-48 months. For reference, test-retest reliability values for PLS-4 and REEL-3 expressive language scores from administrations two months apart during the LENA Natural Language Study are shown. As can be seen in the Correlation columns, AVA test-retest reliability is similar to that of the standard assessments. AVA scores from audio recordings collected one month apart correlated similarly well ($r=.76, p<.01$). The Mean Difference column shows that on average there were no significant differences between AVA scores from recordings made two months apart. Developmental age estimates were highly correlated ($r=.99, p<.01$). Estimates of ages one month apart, as would be expected, differed on average by approximately one month ($M=1.1, SD=1.7$).

Figure 5. Observed Expressive Language Standard Score and Developmental Age Test-Retest Reliability over Two Months: Ages 2-48 Months

MEASURE	N	PEARSON CORRELATION ^a		MEAN DIFFERENCE	
		STANDARD SCORE	DEVELOPMENTAL AGE	SS MEAN	SS SD
AVA	318	0.65	0.98	0.34	7.9
PLS-4	218	0.62	0.95	2.00	13.0
REEL-3	188	0.73	0.92	0.85	4.3

^aAll $p < .01$.

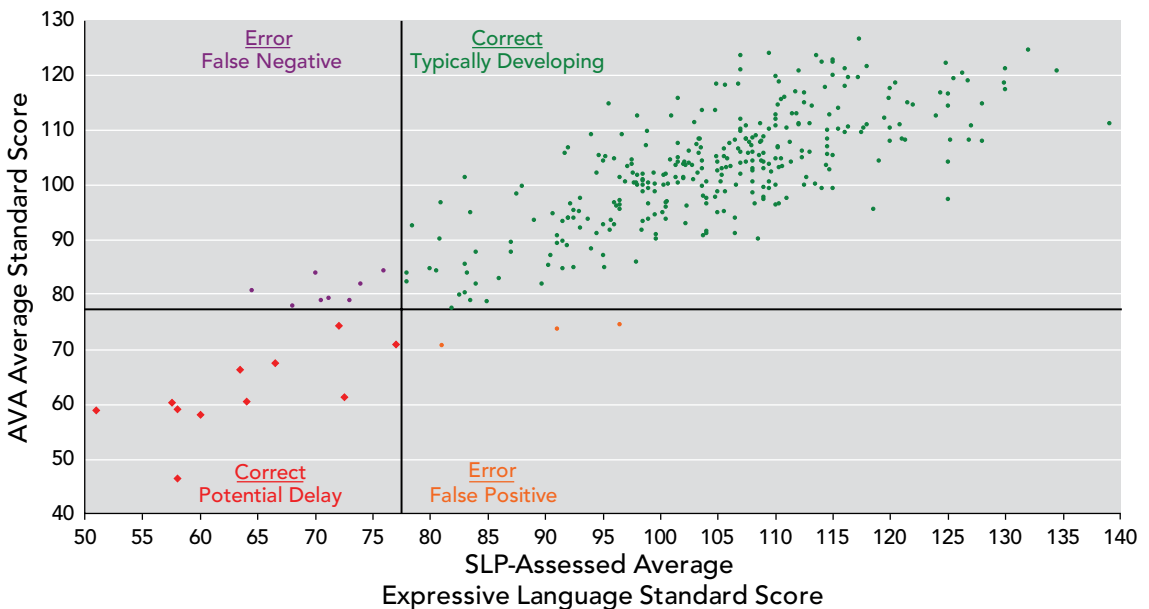
AVA Validity

The validity of AVA estimates was examined using a subset of 155 participants with six months of consecutive recordings by correlating AVA to an averaged SLP-assessed PLS-4/REEL-3 expressive language score. AVA standard scores were examined in two ways: first as single monthly scores, and then by averaging AVA scores from multiple recordings to produce a single estimate per child. Individual AVA scores for each month correlated well with the SLP-based score ($r = 0.69 - 0.76$, all $p < .01$). Averaged AVA scores from three successive months (1,2,3; 2,3,4; etc.) correlated as well or better ($r = 0.77 - 0.80$, all $p < .01$), and the average of AVA scores from every other month demonstrated ever stronger correlations (months 1,3,5: $r = 0.88$; months 2,4,6: $r = 0.86$, both $p < .01$).

The validity of AVA developmental age estimates was tested by comparing them with chronological age and with PLS-4/REEL-3 expressive language estimates assessed within six weeks of the recording from which the AVA estimate was derived. AVA developmental age correlated well with chronological age ($r = 0.97$, $p < .01$) and with age estimates from the criterion measures ($r = 0.93$, $p < .01$).

Alternately, the validity of the AVA estimate can be assessed by the accuracy with which it identifies children with potential expressive language delay. AVA scores from all available recordings were averaged to produce a single composite AVA score per child. As Figure 6 shows, using a threshold score of 77.5 (i.e., 1.5 standard deviations below the mean) AVA correctly identified 11/19 = 58% of participants similarly identified as having a potential delay by the criterion measures. Eight (42%) of the SLP-identified children with possible delay have below average AVA estimates but do not meet the threshold criteria. The false positive rate is low; 3/317 = 1% of typically developing children in the sample fall below the AVA threshold, suggesting a possible expressive language delay.

Figure 6. AVA Estimates Correctly Identify Children with Language Delays



The LENA Natural Language Study supports the conclusions that Hart and Risley drew from their study. Children's scores on language and cognitive assessments are related to the amount of adult talk in their environment and the number of conversational turns they engage in with the parent.

Correlations with Standard Assessments Confirm the Importance of Talk

The LENA Foundation retained certified SLPs who assessed the language skills of participants during independent observation sessions. These measures then were correlated to Adult Word Count (AWC), Conversational Turns (CT), Child Vocalizations (CV), and AVA. As shown in Figure 7, LENA measures correlate significantly with standard measures of language, confirming the importance of talk as reported in Hart and Risley's research.

Figure 7. LENA Measures Correlate with Standard Language Assessments

STANDARD LANGUAGE ASSESSMENTS	LENA LANGUAGE ENVIRONMENT MEASURES ^a				
	N	AWC	CT	CV	AVA
CAT/CLAMS Full DQ	118	.29	.37	.41	.64
PLS-4 Receptive	132	.32	.31	.32	.66
PLS-4 Expressive	131	.35	.38	.40	.78
PLS-4 Total	131	.35	.36	.38	.74
REEL-3 Receptive	121	.32	.35	.31	.56
REEL-3 Expressive	121	.37	.46	.43	.68
REEL-3 Total	121	.36	.42	.39	.65
PLS-4 & REEL-3 Total	87	.42	.43	.42	.74

^a All correlations $p < .01$; sample includes averaged recording data and standard assessments from children 24 months or older.

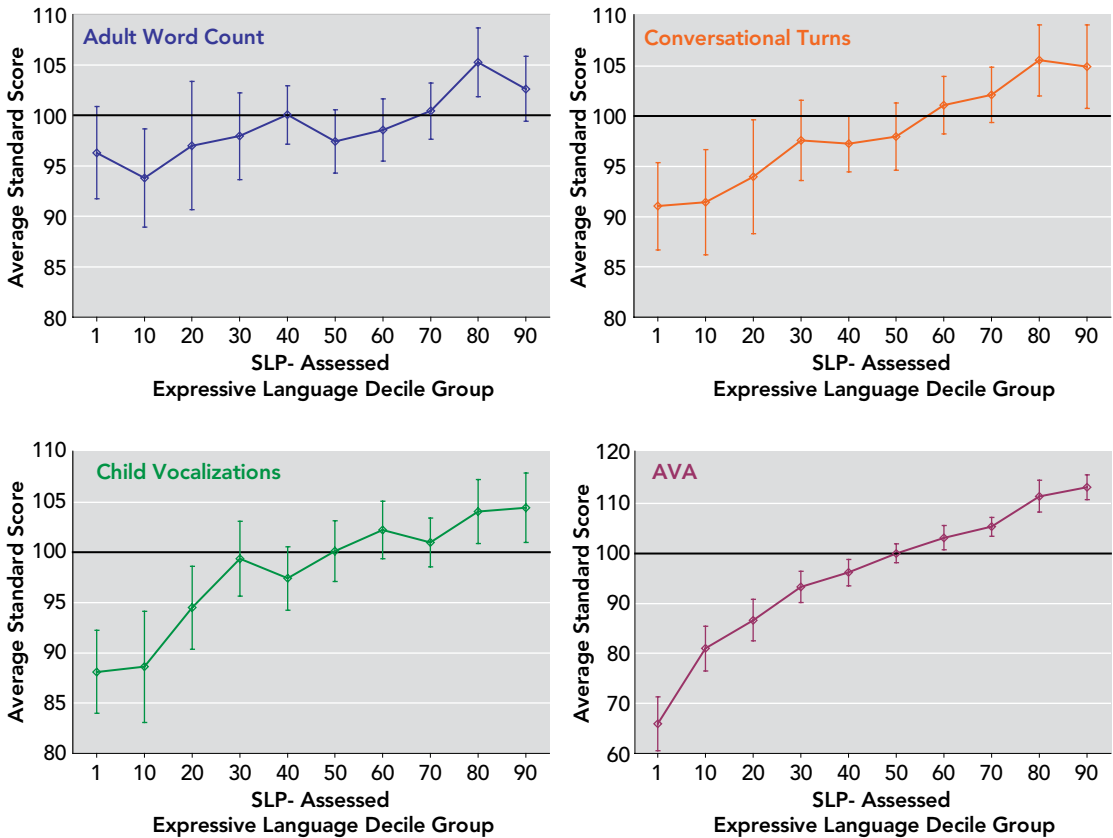
LENA ASSESSMENT	N	AWC	CT	CV	AVA
AVA	329	.28	.46	.49	—
LENA Developmental Snapshot	73	.27 ^b	.51	.49	.68

All correlations $p < .01$ except ^b $p = .02$.

In addition to the data from the 329 typically developing children collected during the LENA Natural Language Study, the LENA Foundation collected recording data using LENA from a sample of 31 children diagnosed with a language delay. The two samples were combined and split into decile groups based on each child's average PLS-4 and/or REEL-3 expressive language score as assessed by a certified SLP.

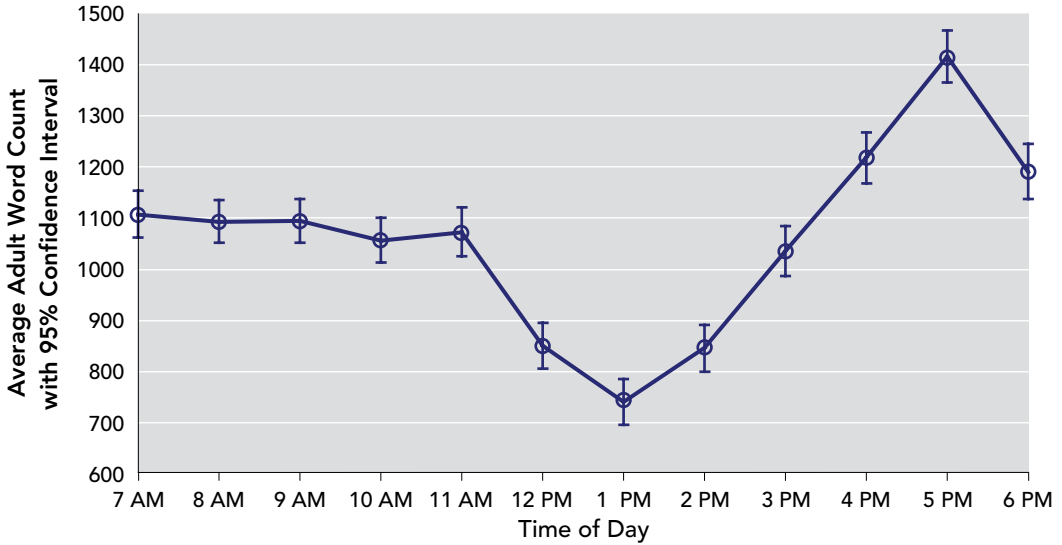
Figure 8 demonstrates the patterns of Adult Word Count, Conversational Turns, Child Vocalizations, and AVA standard scores across decile groups. To facilitate comparison and interpretation, all LENA measures are here expressed as standard scores with Mean=100 and Standard Deviation=15. As expected, compared to the children in the upper deciles children in the lower deciles are exposed to less adult talk, engage in fewer conversational turns, vocalize less frequently, and have lower expressive language skills as assessed by AVA.

Figure 8. LENA Measures Across Expressive Language Decile



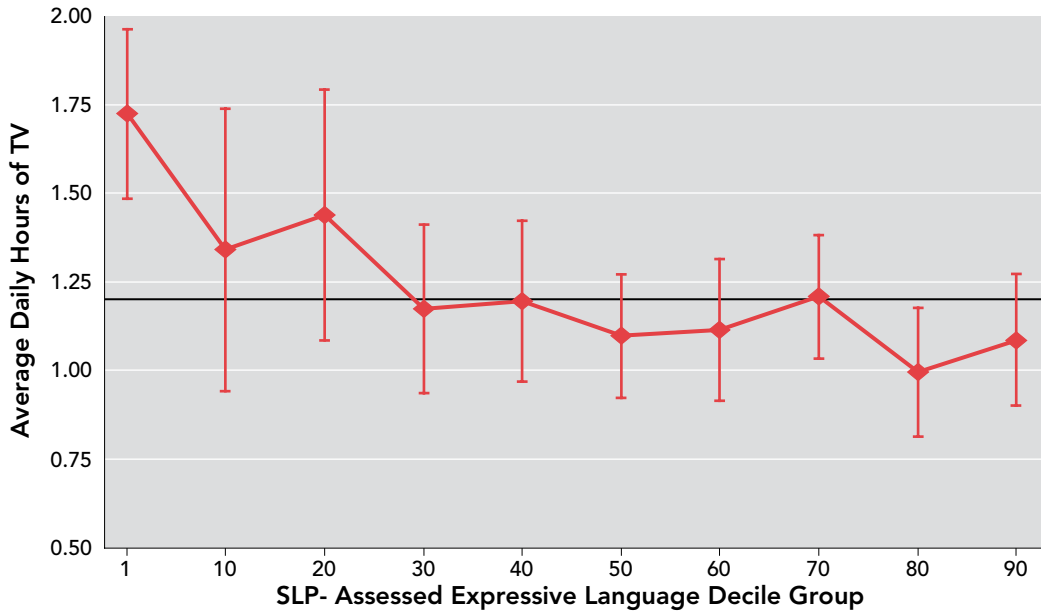
Most talk between parents and children aged 2 months to 48 months typically occurred at the end of the day. As can be seen in Figure 9, the amount of talk throughout the morning was relatively flat. The biggest surprise from the timeline analysis was that there was not much talk in the early afternoon, presumably because children were eating or napping, and then rose until dinnertime.

Figure 9. Adult Talk Varies Throughout the Day



Studies have suggested that overexposure to television has a detrimental impact on young children's language development (Christakis and Zimmerman, 2006). Data from the LENA Natural Language Study provide support for this claim. Figure 10 demonstrates the negative correlation between hours of television and other electronic media detected in recordings and a child's average SLP-assessed language ability.

Figure 10. TV Exposure Across Expressive Language Decile



This negative association with TV can also be seen for LENA measures. For example, in a sample of 165 2-year-olds, average detected TV time was negatively correlated with Adult Word Count ($r=-.34$, $p<.01$), with Conversational Turns ($r=-.45$, $p<.01$), with Child Vocalizations ($r=-.41$, $p<.01$), and with the child's AVA expressive language score ($r=-.29$, $p<.01$).

Researchers who are experts on the effect of television on child development, Frederick J. Zimmerman, Ph.D. and Dimitri A. Christakis, M.D., M.P.H. conducted independent analyses of the impact of television time on parent-child interactions using data from the LENA Natural Language Study. They confirmed the negative impact of TV, importantly discovering that adult-child conversations (i.e., Conversational Turns) are a crucial aspect of a child's language learning environment, more powerful than the quantity of adult words. In addition, they showed that at least one measurable effect television viewing may have is to reduce the number of such parent-child interactions.

Parents Overestimate the Amount They Talk with Their Child

The LENA Foundation asked study participants to rate the amount they talked to their children; 239 parents responded. Virtually all parents—99 percent—thought they talked an average amount (3 on a 5-point scale) or an above-average amount (4 or 5 on a 5-point scale). In fact, 74 percent of the parents thought they talked “more than average” (4 on a 5-point scale) or “much more than average” (5 on a 5-point scale). Of these parents who thought they talked more than average or much more than average, 40 percent were actually below the 50th percentile for adult word count. Only 20 percent of those who thought they talked much more than average were in the 80th percentile or higher.

Children with Advanced Language Skills Have Parents Who Talk More

The LENA Foundation confirmed that parents of advanced children—children who scored consistently between the 90th and 99th percentile on independent standard language assessments—talked significantly more to their children than parents of less advanced children.⁴ The parents of advanced children also engaged in significantly more conversational turns with their children.⁵ Figure 11 displays estimated mean values for these two groups.

Figure 11. Adult Word Count and Conversational Turns for Children with Advanced vs. Non-Advanced Language Skills

	N	ADULT WORD COUNT ^a	CONVERSATIONAL TURNS ^b
ADVANCED 90 th -99 th Percentile	62	14,690	578
NON-ADVANCED 1 st -89 th Percentile	243	12,395	364

^aAdvanced vs. Non-Advanced $t(303)=3.85$, $p<.01$.

^bAdvanced vs. Non-Advanced $t(303)=5.21$, $p<.01$.

The difference in the mean number of adult words spoken to advanced children compared to all other children is 2,295 words. In a 12-hour day, that is a difference of 191 words per hour.

The mean difference in conversational turns between advanced children and their parents compared to all other children is 214 turns in a 12-hour day, or almost 18 additional turn-taking events an hour.

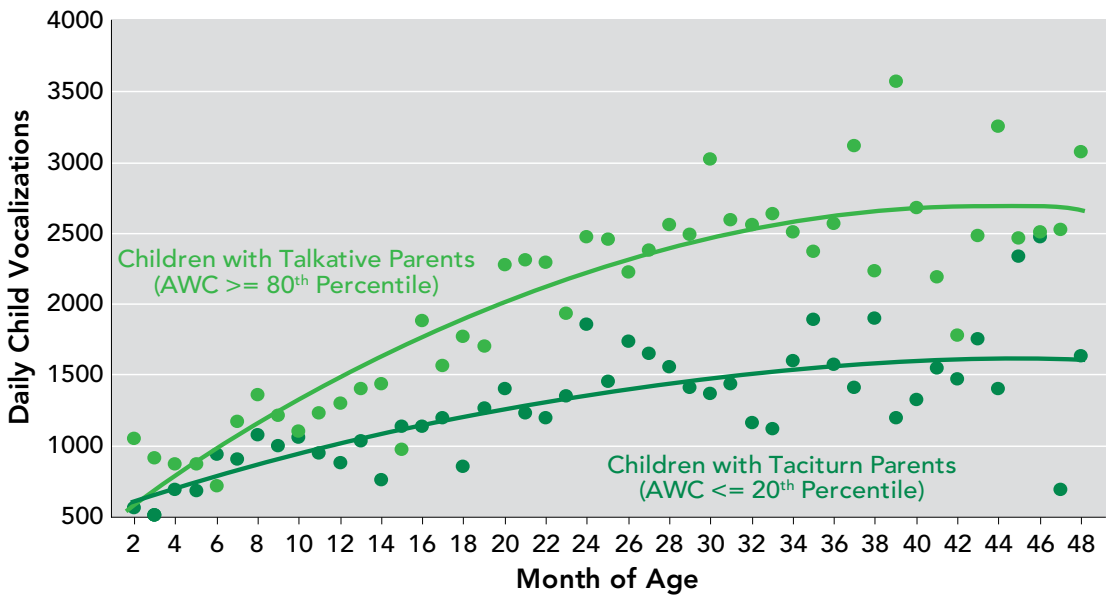
⁴ Children’s language skills group designation was assigned based on the greater of each child’s average PLS-4 or REEL-3 overall language ability scores.

⁵ Conversational turns for Advanced vs. Non-Advanced children were compared after first standardizing values by age. Displayed values reflect turn counts using each child’s average age.

Talkative Parents Have Talkative Children

Confirming results from Hart and Risley's research, the LENA Natural Language Study found that as children of talkative parents grow older, they vocalize more frequently than children of taciturn parents. Figure 12 displays the difference in average daily child vocalizations for children of parents in the highest versus lowest 20th percentile with respect to Adult Word Count.

Figure 12. Child Vocalizations for Talkative Versus Taciturn Parents

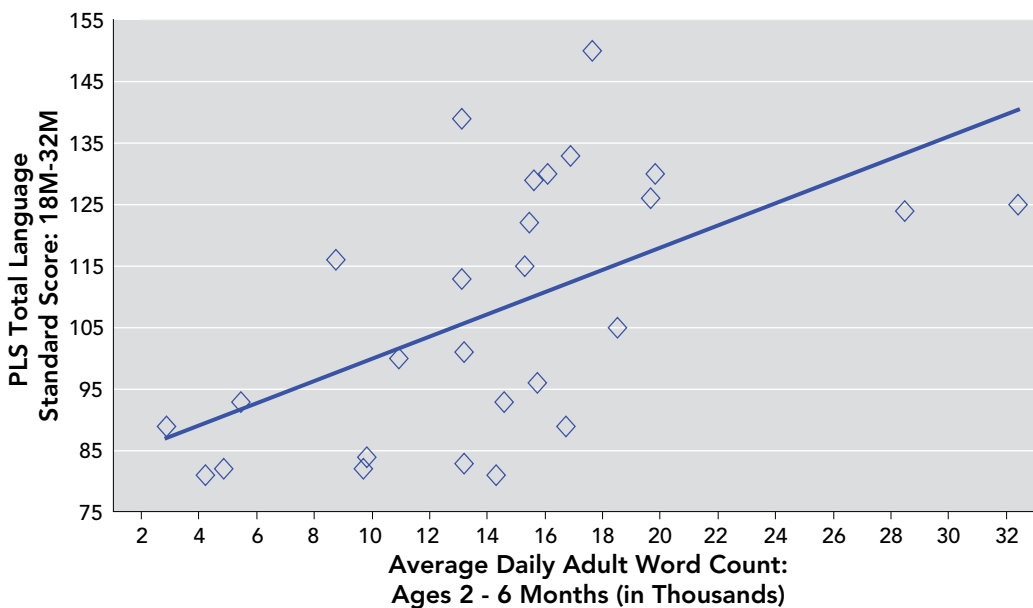


Whether parents were taciturn or talkative, the study showed that children had similar vocalization levels at an early age. With time and as the language environment started to have an effect, children's vocalization rates grow significantly different, emphasizing the important role parents may play as language teachers for their children. Overall, children of talkative parents had average vocalization counts near the 67th percentile, whereas children of taciturn parents averaged below the 36th percentile ($t(326) = 5.33, p < .01$).

Early Parent Talk Predicts Later Language Ability

The LENA Foundation examined the power of adult talk during the first six months to predict later language ability in a sample of 27 children from the Phase II longitudinal sample. Average adult word counts from recordings completed when each child was between two months to six months of age were compared to average PLS-4 Total Language standard scores from evaluations completed on average at 24 months of age (range 18 months – 32 months). As Figure 13 demonstrates, the more adult talk children were exposed to in the first six months, the higher their language ability scores were a year or more later ($r=0.59$, $p<.01$). A similar pattern was observed for conversational turns ($r=0.51$, $p<.01$). These results reinforce the importance of adult talk during the first few months to a child's language development.

Figure 13. Early Adult Word Counts Correlate with Later Language Ability



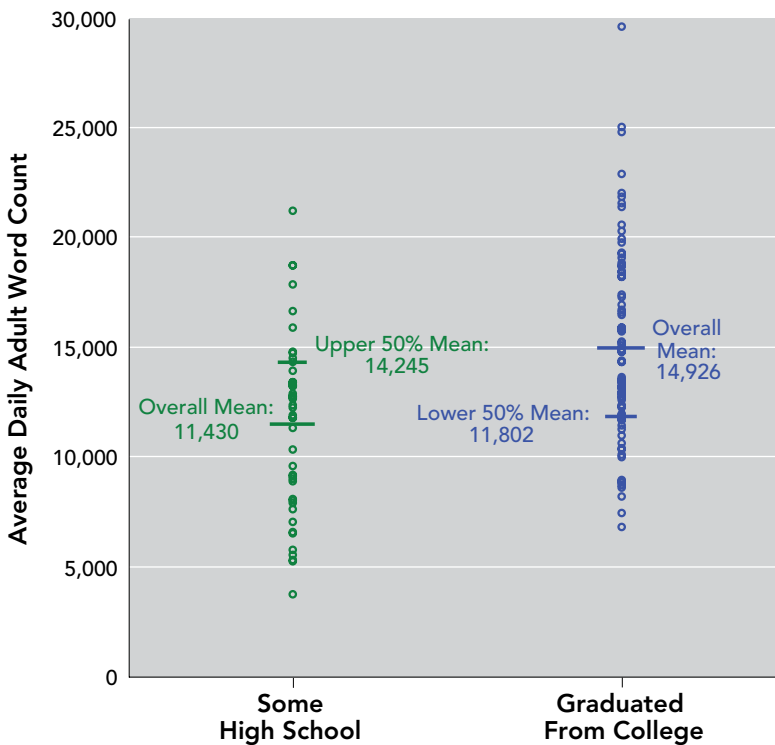
Effect of Attained Education

The Variation in Talk Among College-educated Parents is Substantial

The average daily adult word count for professional parents—parents who earned at least a bachelor’s degree—was significantly higher (Mean=14,926) than the average daily adult word count (Mean=12,024) for other parents ($t(327)=5.53$, $p<.01$).

However, there was substantial variation in adult word count within all groups. In fact, as can be seen in Figure 14, the upper 50 percent of parents who did not complete high school had a significantly higher average daily word count (Mean=14,245) than the lower 50 percent of parents who graduated from college (Mean=11,802; $t(71) = 4.55$, $p<.01$).

Figure 14. Daily Adult Word Count Varies Within Education Groups



Effect of Child Gender

The LENA Foundation also looked at the differences between genders: Is there a difference between the amount of language input that girls receive from their parents compared to boys? It is often suggested that girls are generally more advanced than boys in the early school years. As Hart and Risley learned and the LENA Foundation confirmed, there are distinct academic advantages for children whose parents talk more to them. Do girls hear more words in the crucial development years?

As can be seen in Figure 15, there is evidence that girls do hear more words. Mothers tended to talk with their daughters more than with their sons. Up through age 30 months, mothers talked with their daughters nearly 9 percent more than mothers talked with their sons.

Figure 15. Adult Female and Male Word Counts for Girls Versus Boys For Ages 2 Months – 30 Months

	GIRLS (N=132)	BOYS (N=120)	OVERALL (N=252)	PERCENT DIFFERENCE
ALL ADULT WORD COUNT	13,160	12,436	12,815	Overall girls hear 5.8% more words than boys
ADULT FEMALE WORD COUNT	10,023	9,200	9,631	Mothers talk 8.9% more to their daughters ^a
ADULT MALE WORD COUNT	3,137	3,236	3,184	Fathers talk 3.2% more to their sons

^a $t(250) = 1.96, p=.05$.

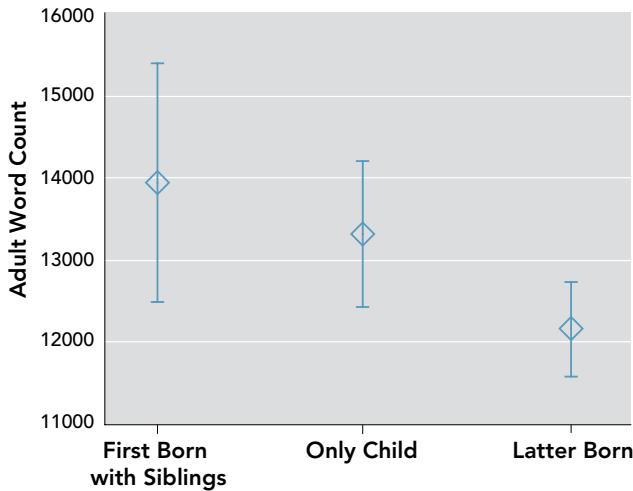
Fathers spoke substantially fewer words to their children than mothers did. Mothers spoke an average of 6,447 more words per day to their children, a difference that was more pronounced with daughters than with sons. Mothers contributed approximately 75 percent of the total adult words spoken, compared with the fathers' 25 percent.⁶

⁶ Although the LENA software does distinguish male from female word counts, these measurements are combined and reported as one aggregate number (Adult Word Count). Adult male and female word counts can be obtained using the LENA Advanced Data Extractor (ADEX).

Effect of Birth Order

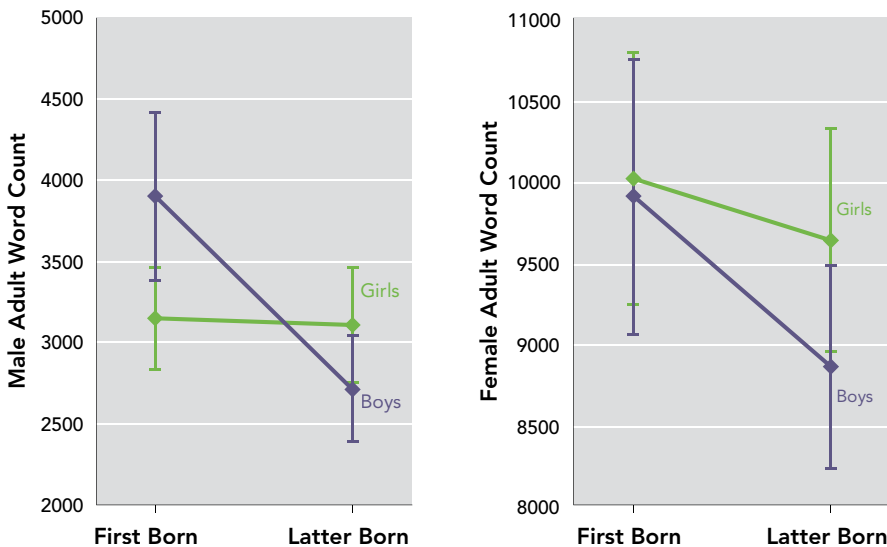
As Figure 16 demonstrates, average daily adult word counts were somewhat higher for first-born compared to latter-born children, whether or not the child had siblings. Overall, first-born children were exposed to an average of 1,338 more words per day ($t(327)=2.81, p<.01$).

Figure 16. Adult Word Counts are Higher for First-Born Children



There were interesting gender effects as well, both for the parents and for the children, as seen in Figure 17. Both male and female adults spoke significantly more to their first-born boys than their latter-born boys, but spoke similarly to their girls regardless of birth order.⁷

Figure 17. Gender Differences for First-Born and Latter-Born Children



⁷ First-Born vs. Latter-Born Boys – Male Adult Talk: $t(165) = 3.93, p < .01$; Female Adult Talk: $t(165) = 2.00, p < .05$.

High Variability Demonstrates Opportunity for LENA Users

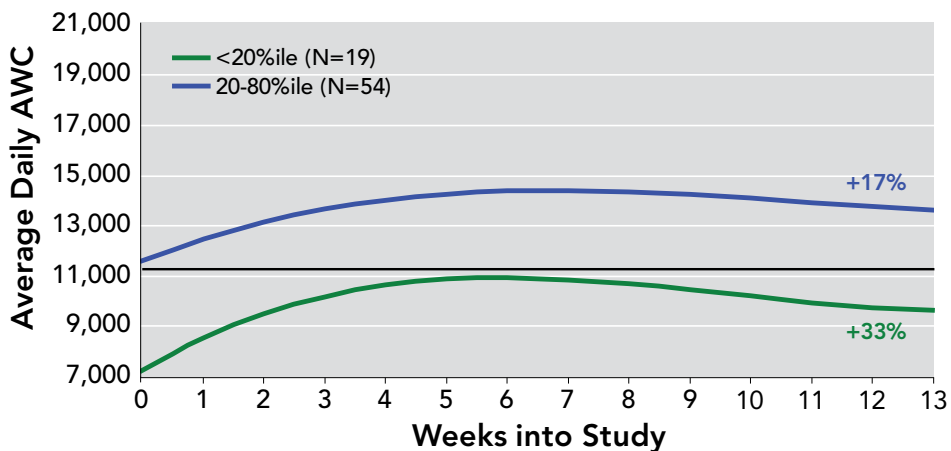
One of the most important findings of the LENA Natural Language Study is the high degree of variability in adult words and conversational turns between families and within families. Figure 14 (p. 20) illustrates this variability with respect to adult speech and maternal attained education. But there aren't only differences between families; families themselves differ from day to day.

One method to characterize within-family variation for adult talk is to calculate the coefficient of variation based on the ratio of the variability in word counts to the average word count. In our normative sample, the coefficient of variation is 52.5 percent, meaning that any given day the typical family in our sample could vary in their total adult talk by over 50 percent of the average amount. That is, they might speak as little as 6,000 words or as many as 19,000 words on any particular day. Families are similarly variable when it comes to conversational turns. For a typical family with a 24 month-old the coefficient of variation is 53 percent, with an average of 520 turns per day. So for this family, turn counts could range from as few as 250 to as many as 800 on any given day. Thus, day to day both the amount of adult words a child hears and the number of conversational turns a child engages in varies substantially in the average family.

Both the high within family and between family variation in the child language environment demonstrate that there is an opportunity for parents using LENA to improve significantly. Many parents on some days are already providing outstanding language environments for their children. Receiving feedback using the LENA software could help parents consistently provide more high word count and fewer low word count days and engage in more conversational turns, which in turn could help to improve their child's cumulative language experience and accelerate their overall language development.

The LENA Foundation provided LENA systems to 102 families in the US and UK and asked them to record weekly and to try to improve the amount they talked to their children. As can be seen in Figure 18, parents who started out at or below the 20th percentile with respect to adult talk were able to increase their daily counts substantially using the feedback provided by the LENA software. Parents who started out at average levels were able to increase their counts as well. It is worth noting that both groups experience initial gains followed by slight declines, illustrating that behavioral change needs both feedback and reinforcement.

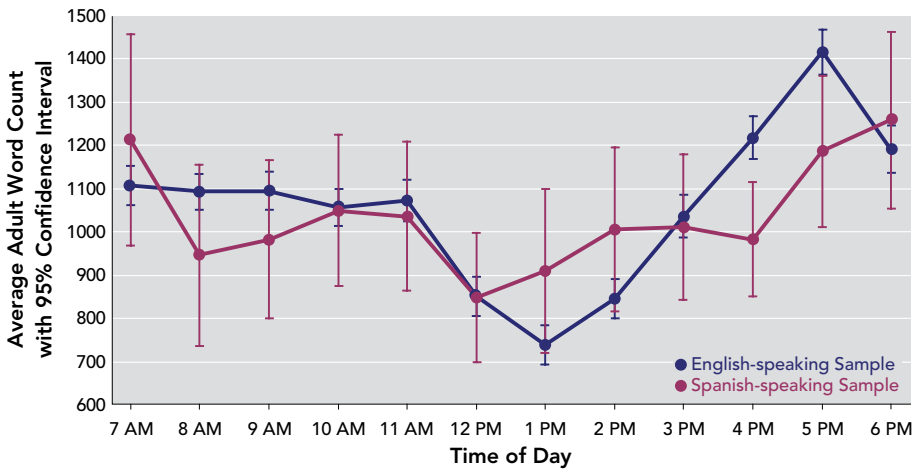
Figure 18. Parents Using LENA Increase the Amount They Talk to Their Children



Monolingual Spanish-Speaking Families

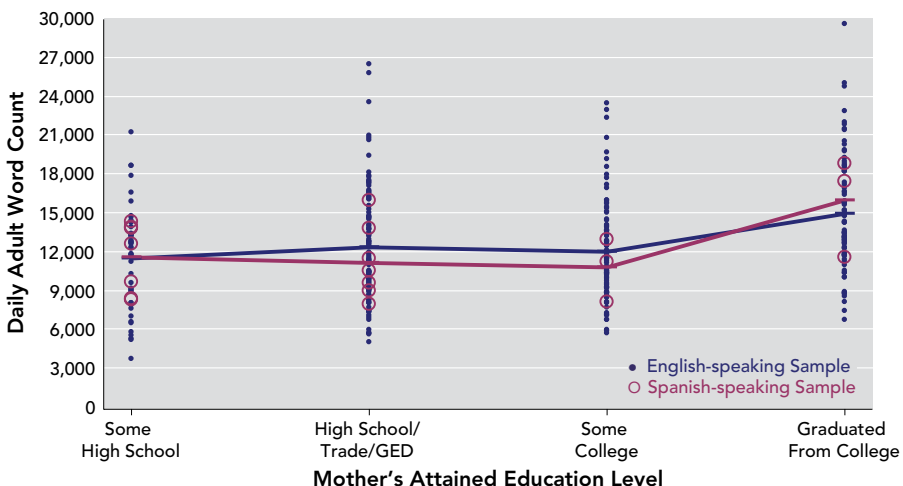
The LENA Foundation collected monthly recording data over a six month period from a sample of 20 children 2 months to 34 months of age from monolingual Spanish-speaking families. Figure 19 demonstrates that despite the small sample size relative to the normative sample, the pattern of adult talk over the course of a day is quite similar. Talk time is relatively high in the morning hours, drops toward lunch and nap times, then rises again until dinner time.

Figure 19. The Pattern of Adult Talk Throughout the Day is Similar for Spanish-Speaking and English-Speaking Families



Average daily Adult Word Count for the 329 English-speaking and 20 Spanish-speaking families are shown in Figure 20, grouped by mother's attained education. Again, despite the much smaller sample size it is evident that the increase in counts for the college-educated families holds for both samples. There are no differences among the first three education groups, but the AWC for the most educated group is significantly higher than that for the other three groups.

Figure 20. Adult Word Count Varies Similarly By Education Group



Childhood Autism Study

The LENA Foundation collected weekly recording data using LENA over a 7-week period from a sample of 27 children diagnosed with autism and correlated LENA measures with a variety of assessments of symptom severity and language ability. Figure 21 shows negative correlations were found between M-CHAT and CBCL symptom severity scores and both AWC and Conversational Turns, meaning that the parents who talked more with their children also reported fewer symptoms. Note that we are not implying causation here, these correlations are simply telling us that there is a relationship between questionnaire scores and the LENA variables. It is likely that the more severe children are less vocal, which would naturally result in fewer turns and fewer adult words.

Figure 21 also details positive correlations between a child’s language and ability skills and both AWC and Conversational Turns. For example, the higher the child’s vocabulary size reported on the MacArthur, the higher the Adult Word Count and Conversational Turns. Overall results are stronger for Conversational Turns than for Adult Word Count.

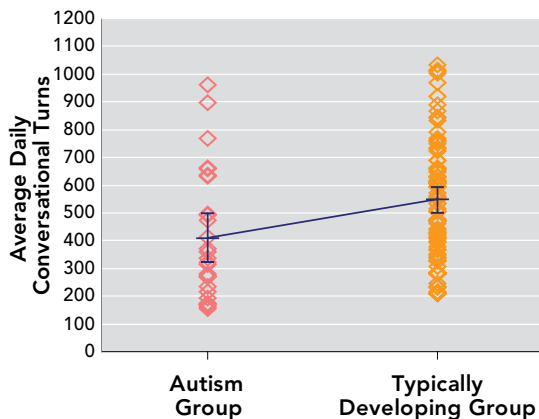
Figure 21. Correlations Between LENA Measures and Symptom Severity and Language Ability Assessments

SYMPTOM ASSESSMENT	AWC	URNS	ABILITY ASSESSMENT	AWC	URNS
M-CHAT TOTAL SCORE	-.61**	-.49*	LENA SNAPSHOT	.40*	.61**
CBCL TOTAL SCORE	-.46*	-.49*	CSBS TOTAL SCORE	.51**	.74**
			CDI GENERAL SCORE	.65**	.74**
			MACARTHUR VERBAL PRODUCTION SCORE	.49*	.70**

* p<.05; ** p<.01

The LENA Foundation compared the sample of children with autism to a demographically matched typically developing sample with respect to the number of conversational turns between parent and child. Figure 22 illustrates that the typically developing children were engaged in approximately 140 more conversational turns per day than the children with autism (t(106)=2.81, p<.01). The effect of that difference for children with autism can be seen over time, adding up to roughly 1,000 fewer turns per week or 50,000 fewer turns per year.

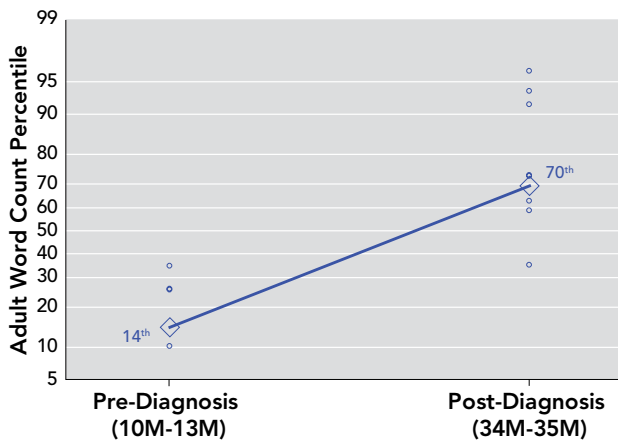
Figure 22. Children With Autism Engage In Fewer Conversational Turns With Adults



Childhood Autism Study: Case Studies

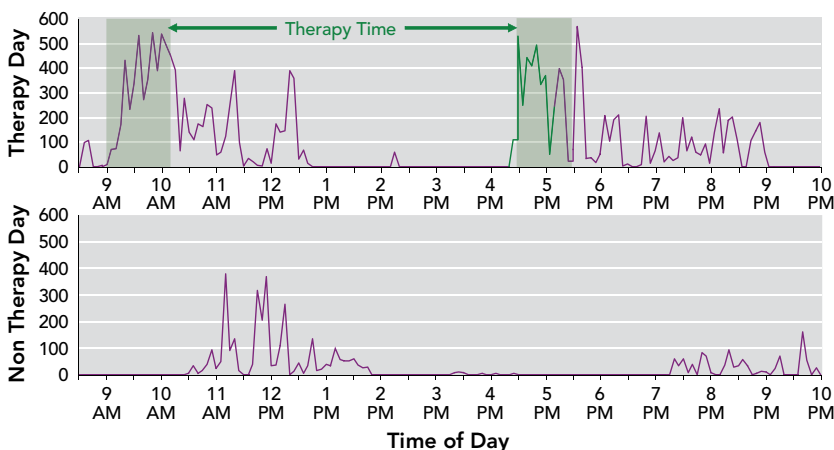
Data for two case studies of children with autism are presented below and demonstrate the use of LENA as a clinical tool to examine the effect of treatment interventions. Figure 23 profiles adult word counts from individual recordings for a family whose child was a participant in the LENA Natural Language Study between the ages of 10-13 months. Approximately one year later this child was diagnosed with autism and a few months after that participated in the Childhood Autism Study described previously. Prior to the child's diagnosis, the adult word counts averaged at the 14th percentile, never reaching as high as the 40th percentile. Based on recordings completed a few months after starting treatment, these parents had raised their average word counts to the 70th percentile, on some days exceeding the 95th percentile.

Figure 23. Parent Talk Before and After a Diagnosis of Autism



Next, Figure 24 demonstrates the use of LENA to examine a child's language environment at the micro level, in this case adult word counts during therapy and outside of therapy for a participant from the Childhood Autism Study. Adult word counts displayed at 5-minute intervals over the course of an entire day clearly show the impact of treatment. In fact, roughly half of the total adult speech in the child's environment on the therapy day occurred during the two hours or so of treatment.

Figure 24. Parent Talk on Therapy and Non Therapy Days



The original study conducted by Hart and Risley—recording one hour of conversation between parents and young children in 42 homes each month for three years—was truly groundbreaking in that it led educators, government officials, teachers, linguists, and parents to rethink language development for children from birth to three years of age. Hart and Risley learned there was a direct correlation between adult words and a child's IQ, adult words and a child's academic success, and adult words and a child's vocabulary learning trajectory. They also learned that families in the high socioeconomic status category talk more than families in other categories, but that the amount of talk between families varies tremendously—even among families in the high socioeconomic status category.

The LENA Natural Language Study, which used LENA to record conversations between parents and children in 329 homes over a 12-hour day for six months or more, was equally groundbreaking. The LENA Foundation confirmed the key finding of the Hart and Risley study—the best thing parents can do for their children is talk with them. Consistent with Hart and Risley's research, the children most advanced with respect to language development had parents who spoke significantly more than parents of less advanced children. The LENA technology allowed the LENA Foundation to build on Hart and Risley's seminal work, creating the first-ever percentile norms for daily adult word counts, conversational turns, and child vocalizations.

Additional interesting findings from the LENA Natural Language Study reflect the impact of gender and birth order on adult talk. Children heard more talk from their mothers than their fathers, and mothers talked more to their daughters than to their sons. Analyses also showed that both parents talked more to first-born children, particularly boys, than to latter-born children.

Not surprisingly, children of talkative parents were equally talkative, and children of taciturn parents were just as taciturn. This finding reflects the important role parents play in their children's language development. Parents tend to overestimate the amount they talk to their children, and they can be highly variable from day to day. However, given the opportunity to receive feedback on how much they are talking, parents are able to increase that amount consistently.

The LENA System permits a detailed look into the audio environment of the child. For example, the ability to track adult words on an hourly basis enabled the LENA Foundation to learn that most talk between parents and their children occurred in the late afternoon and early evening. Examination of television detected in the home revealed that the more television that was detected, the lower a child's language abilities were.

Moving beyond the LENA Natural Language Study, the LENA System has been utilized to study the language environment of children from other populations. This research has found, for example, that monolingual Spanish-speaking families demonstrated similar patterns of talk to English-speaking families, and that parents of children with autism talked less the more severe their children's symptoms were.

Although many questions remain and there is much more research to be done, it is more and more clear that for the parents who want to give their child the best chance of succeeding academically, one key is to talk to and with their child as much as possible.

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