Quality versus Quantity: An Investigation of the Impact of Home Language and Maternal Education Level on Young Children's Vocabulary Size

by

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ABSTRACT

Research in child language development has consistently observed that a child's vocabulary size is shaped in part by language input in the home. While a focus of several recent large-scale intervention programs have been on increasing quantity of input, the quality of the input is also important. The purpose of this study was to examine how quantitative and qualitative aspects of linguistic input in the home, with level of maternal education considered, are related to the size of young children's (28-38 months) vocabulary. Families from a larger longitudinal study (n = 176) participated in standardized vocabulary testing in a research setting and completed audio recordings in the home with the Language Environment Analysis (LENA) system. These recordings were analyzed to obtain quantitative measures using the LENA software. A subset of language samples (n = 18) were also transcribed and coded to obtain qualitative measures. Results for the larger group indicated that the quantitative measures of percentage of meaningful speech and percentage of TV predicted 13% of the variability in a child's expressive vocabulary, while 9% of the variability receptive vocabulary size was predicted by percentage of meaningful speech. There were stronger relationships between vocabulary size and percentage of meaningful speech for the low maternal education level group relative to the other two groups. A number of correlations were observed between qualitative and quantitative measure of input and between both types of input measures and vocabulary size in the smaller group of children. However, information on qualitative aspects of input from more children is needed in order to better understand the relationships among qualitative and quantitative aspects of input and vocabulary size.

SPECIFIC AIMS

It is well-documented that children of mothers with lower levels of education are at an increased risk for difficulties related to language development. One environmental factor that has received increased attention since Hart and Risley's (1995) seminal publication is the quantity of linguistic input children receive in their formative years. Hart and Risley found that families with higher maternal education levels expose their children to three times as many words compared to families with lower levels of maternal education. Providing children with more linguistic input results in larger vocabularies and a steeper rate of vocabulary growth (Hart & Risley, 1995; Hoff, 2006). A number of intervention programs, such as the 30 Million Words project (Suskind, 2010) and Providence Talks (Riquetti, 2013), have recently been developed to try to increase linguistic input in the household, as measures of language input are stronger predictors of child outcomes than SES alone.

One factor that has led to an increased interest in linguistic input in recent years is the development of the Language Environment Analysis (LENA) system. Developed within the past decade, the LENA system is comprised of a digital language processor (DLP) to record audio in the child's home environment and computer software to analyze the recording. Much like a language pedometer, the system reports the number of words spoken by adults and the child in the household as well as the composition of the listening environment. While quantity of linguistic input is now a relatively easy variable to measure (compared to Hart and Risley's manual coding and analysis of language samples), this variable presumably interacts with other aspects of the child's environment, such as the quality of the input and the composition of background noise, such as TV. Differences in the quality of the input have also been shown to be related to socioeconomic status (Hart & Risley, 1995; Hoff, 2006) and, unlike quantity, change

with the child's age (Rowe, 2012). Furthermore, television and other forms of electronic noise that are part of a child's audio environment, while not equivalent to meaningful language input, may also influence language development (Naigles et al., 1995; Naigles & Mayeaux, 2001). The challenge, therefore, lies in understanding how quantity and quality of linguistic input interact with each other and with other features of the home environment.

Mahr, Law, and Edwards (2014) found a strong relationship between quantity of linguistic input, measured as the number of words spoken to a child in a 12 hour period, and expressive vocabulary size, as measured via standardized assessments, for children from families with low maternal education levels. However, this relationship was not observed for children from families with levels of high maternal education. Mahr and colleagues posited that the input from mothers with higher levels of education was of a higher quality, regardless of quantity, while linguistic quantity and quality of the input from mothers with low maternal education levels were more tightly linked. The current study was designed, in part, to evaluate this claim.

The lack of information regarding home language quality in relation to children's vocabulary size stands as a significant gap in the research and warrants additional study. To bridge this gap in knowledge, I plan to examine the relationship between *quantity* of linguistic input, as defined by the number of words spoken by adults in the child's immediate listening environment, and the *quality* of linguistic input, as defined by relationships between parts of speech. I also plan to examine the relationship among vocabulary size, maternal education level, and various input measures reported from the LENA system. These measures include conversational turn count, the percentage of electronic noise in the child's auditory environment, the percentage of meaningful speech as measured by distance from the speaker, and the adult word count (AWC) or amount of linguistic input provided by adults.

CHAPTER ONE

Literature Review

A number of studies have explored the interaction between maternal education, quantity of linguistic input, and size of children's vocabulary. This interaction received increased attention in the 1970s when the interdisciplinary focus in child development was shifted heavily towards fighting the War on Poverty. Hart and Risley (1995) noticed a discrepancy during this time between the vocabulary sizes of children from different socioeconomic backgrounds by the time they entered school, and wondered whether the amount of linguistic input received at home affected vocabulary differences. The authors grouped level of maternal education, occupation, and family income under the umbrella term "SES", classifying families as welfare, working class, or professional based on these highly-associated factors. The researchers observed 42 young children, beginning when the children were 10-months-old and continuing once a month for three years, recording and transcribing by hand the hour-long interactions between the children and family members at home. The number of words and interactions were calculated for each hour observed, and different quality markers (e.g., affirmations, number of different words, modifiers) were reliably coded within each recording. The vast quantity of data collected and analyzed by Hart and Risley for over two decades described the rate of children's vocabulary growth, suggesting that children from higher SES backgrounds learn words more quickly than children from lower SES backgrounds. The authors hypothesized that this discrepancy was related to increased amounts of linguistic input at home during the first three years of life. The difference in amount of linguistic input received by the age of four for a child from a family with high levels of maternal education and income compared to a child from a family with low levels of maternal education and income could be as much as 32 million words. This seminal result

showed that the achievement gap begins much earlier than previously thought. Hart and Risley proposed that providing children with more communication opportunities and richer linguistic input would positively impact the rate of vocabulary growth. In subsequent research, both Huttenlocher et al. (2010) and Hoff (2006) also found that the amount of linguistic input interacts with maternal education and children's vocabulary size, further supporting the claims of Hart and Risley that vocabulary size is influenced by social experience. From Hart and Risley's longitudinal study spanning 20 years to the most recent publications, researchers have provided the field with important information regarding the relationship between level of maternal education, vocabulary size, and quantity of linguistic input, informing interventionists and parents of the importance of early language learning environments.

Historically, the effective measurement of the quantity of linguistic input in any setting has posed a significant challenge. Researchers have struggled with financial and time constraints, underestimating the personnel required to accurately attain and transcribe recordings by hand. The decision to measure input in the home environment has further compounded these challenges, necessitating an approach to lessen the impact of an unfamiliar observer and maintain respect for family schedules. The Language Environment Analysis (LENA) system, developed within the past decade, facilitates these goals. LENA is comprised of two main components: a digital language processor (DLP) which serves as a specialized audio recorder, and a computer software system that analyzes the content of the recording. Greenwood, Thiemann-Bourque, Walker, Buzhardt and Gilkerson (2011) used the LENA system to obtain the same information about quantity of linguistic input in the home that Hart and Risley strived to collect years prior. Based on weekly 12-hour recordings, Greenwood et al. (2011) found a similar pattern relating higher amounts of linguistic input, or adult word count (AWC), with higher levels of maternal

education. Not only does LENA allow for the collection of longer language samples, but the system analyzes data more quickly while maintaining 98% accuracy compared to manual transcription of the same audio files (Gilkerson & Richards, 2009). Using the LENA system to collect and analyze data provided almost immediate results in the Greenwood et al. (2011) study, a substantial upgrade compared to the time-intensive process experienced by Hart and Risley's team. Beyond the time-saving benefits, LENA also may encourage more authentic measures of language input in the home. For example, families may be more inclined to interact in a typical manner in the absence of the presence of a researcher taking notes in the room during a linguistic interaction. The incorporation of LENA into research on language acquisition has been beneficial in circumventing previous challenges of obtaining environmental linguistic input while maintaining the reliability associated with manual collection. Another benefit of the LENA system is that it provides a wide range of information on the quantity of linguistic input. It provides information on the number of words spoken to the child (adult word count or AWC) as well as the conversational turn count (CTC) between the child and his/her caregivers. It also outputs information on the auditory environment more generally, by providing percentage of meaningful speech (%MS), the percentage of distant speech (%DS), the percentage of electronic noise (%TV), the percentage of other noise (%ON), and the percentage of silence (%S) for any given time period.

The development of the LENA system has led to a resurgence of interest in not only increasing the amount of linguistic input in the home, but also providing feedback to change parental behaviors and achieve the goal of shaping parental speaking patterns. In 2010, the 30 Million Words project was pioneered to respond to Hart and Risley's 1995 findings that children from lower SES backgrounds are exposed to approximately 30 million fewer words by age three

than children from higher SES backgrounds. The 30 Million Words project is a parent-directed approach that educates families on the importance of parent talk in the home environment (Suskind, 2010). The project aims to use LENA to provide parents with feedback regarding the amount of language use at home, encouraging ways to modify input and thereby preemptively close the achievement gap among school-aged children. A 31% increase in AWC and 24% increase in conversational turn count (CTC) was observed after eight weeks of randomized, controlled intervention through the project using the LENA system (Suskind, 2013). These findings suggest that structured education and feedback for parents can have a significant impact on changing the quantity of linguistic input in a child's home environment and perhaps thereby the child's vocabulary size. Providence Talks, a similar intervention program launched in 2013, incorporates the LENA system in the mission to close the word gap. Families receive biweekly education about appropriate language input, as well as LENA reports and subsequent, personalized coaching. Results thus far have showed an average increase in adult word count (AWC) of 55% (Riquetti, 2013). Through this program, founders hope to provide parents with the necessary information to augment the quantity of linguistic input in the home as early as possible, leading to a narrowing of the achievement gap once children enter school. Using LENA in a clinical setting may produce similar results and benefits. Educating parents from all SES backgrounds about how to improve the linguistic input in their child's immediate environment before the age of four may lead to larger vocabularies and, subsequently, greater success in school.

Not only is the "word gap" believed to have a significant impact on the evolution of children's vocabularies due to decreased quantity of input, but discrepancies in quality of linguistic input in different home environments are also thought to play a role in subsequent

vocabulary size (Suskind, 2010). Quality of linguistic input, like quantity of linguistic input, is related to maternal education level (Hoff, 2006; Huttenlocher et al., 2010). In Hoff's 2006 study, families with higher levels of maternal education tended to talk more, provide more responses contingent to their child's actions, and use their language to elicit conversation from children in the household. Families with lower levels of maternal education tended to use their language more to direct their child's behavior, providing shorter utterances and less diverse input. Vocabulary size was shown to be linked to the differences in both total number of words (quantity) and number of different words (quality), supporting the critical interaction between quantity and quality of linguistic input. While quantity of input has been deemed an important factor in shaping language development, the quality of the linguistic input may play an equally crucial role. Hart and Risley (1995) coded and analyzed various quality markers in their study's audio recordings to gain an improved understanding of the aspects of language input that had the greatest impact on language development. The researchers paid specific attention to factors related to: discourse (e.g., declaratives, imperatives, auxiliary-fronted yes/no questions); adjacency conditions between the parent and child (e.g., initiations, responses); and valence or emotional weight of the utterance (e.g., prohibitions, affirmations), all of which were found to influence the rate of children's vocabulary growth. After controlling for SES, quantity of input, and receptive vocabulary size of the child (as measured by the PPVT-4), Rowe (2012) also found that quality measures in the input were closely related to rate of vocabulary growth. These factors included: vocabulary diversity (i.e., number of different word types), vocabulary sophistication (i.e., rare words), and decontextualized utterances associated with narratives or explanations. While these quality factors were important across all formative language years, they were most important at ages three and four; vocabulary growth at age two instead benefited

most from quantity rather than quality of input. While quantity of linguistic input remains relatively stable across the first few years of a child's life (2-48 months), the quality of input children receive changes as their language skills develop (Rowe, 2012). Both variables serve as valuable informants of not only level of maternal education but also children's vocabulary size, and should therefore be investigated in tandem to understand all facets of the equation.

The purpose of this study is to continue to investigate the relationships among quantity and quality of linguistic input in a diverse group of young children. This study will address three specific questions. First, what is the relationship among various measures of linguistic quantity, maternal education level, and receptive and expressive vocabulary size (standard scores on the *Expressive Vocabulary Test* [EVT-2] and *Peabody Picture Vocabulary Test* [PPVT-4]) in a large group of 2- to 3-year-old children (n = 176). Second, what is the relationship between measures of linguistic quantity and quality in a subset of this larger group (n = 18). Finally, do measures of quantity or measures of quality better predict vocabulary size in this smaller group?

The ability to pinpoint specific targets of intervention to support subsequent language growth in children from families with lower levels of maternal education is of the utmost importance in the mission to close the achievement gap. While maternal education is closely linked with the amount of linguistic input a child receives and serves as a predictor of overall vocabulary size, the relationship between quantity and quality is not well understood. Similarly, the influence of background noise (in particular, electronic noise) on a child's language development is also not well-understood. With knowledge about these specific features that have the potential to influence the language-learning process, professionals will be better equipped to appropriately identify, counsel, and provide interventions for at-risk children. Professionals

cannot simply instruct parents to talk more to their children—they must also teach parents what to talk about and how to improve the quality of input they already provide their children.

CHAPTER TWO

Methods

PARTICIPANTS:

The LENA language samples were from recorded by the families of 176 children, who were participating in a larger longitudinal study at the Learning to Talk Lab at UW-Madison. All children had normal hearing, spoke English as their first and only language, and had typical speech and language development per parent report. Children with IEPs were excluded from the current study, as were children referred by the research team's speech-language pathologist for additional speech and language testing. Table 1 provides the descriptive information on this group of children.

Table 1. Age and mean test scores (standard deviations in parentheses) for the larger group of children.

Maternal education level[1]	Number of participants	Age	EVT-2 standard score	PPVT-4 standard score
Low	12	33.5 (3.72)	109 (19)[2]	98 (25)
Middle	29	31.8 (3.3)	102 (20) [3]	105 (13)
High	135	32.1 (3.4)	119 (16) [4]	116 (15)[5]

[1]High = college or graduate degree; Middle = some college, associate degree, or technical school degree; Low = high school diploma, GED, or less than high school diploma.

[2]Missing test scores for 3 children; [3]missing test scores for 1 child; [4]missing test scores for 2 children; [5]missing test scores for 3 children.

LENA language samples for 18 children from the larger group were selected for the quality analysis. Six recordings from families with high maternal education, six families with a moderate level of maternal education, and six recordings from families with low maternal education were chosen; within each group, three recordings were chosen with high CTCs and three recordings were chosen with low CTCs. Table 2 provides descriptive information for this smaller group of children.

Table 2. Age, CTC per hour, AWC per hour, and mean test scores (standard deviations in parentheses) for the smaller group of children.

Maternal education level[1]	Conversational turn count (per hour)	Adult word count (per hour)	Age (in months)	EVT-2 standard score	PPVT-4 standard score
Low	27 (24), range 3-51	702 (440), range 113-1097	35 (2), range 31-37	109 (15)	110 (18) [1]
Middle	38 (38), range 2-75	830 (616), range 102-1640	32 (4), range 28-38	102 (15)	97 (8)
High	53 (50), range 2-107	1141 (598), range 224-1850	32 (3), range 28-36	111 (10)	107 (20)

[1]Missing test score for 1 child.

PROCEDURE:

As part of the larger longitudinal study, children received a hearing screening and two norm-referenced measures of vocabulary, *the Expressive Vocabulary Test, second edition* (EVT-2, Williams, 2007) to measure expressive vocabulary and the *Peabody Picture Vocabulary Test, fourth edition* (PPVT-4, Dunn & Dunn, 2007) to measure receptive vocabulary. Parents were asked to fill out a demographic background survey. Each family received an oral and/or written introduction to the LENA system with pictorial support (see Appendix A) and were asked to complete the 16-hour recording in the home environment before the time of the child's next visit, which was typically within one to three weeks.

ANALYSIS:

Measures of linguistic quantity. Adult word count (AWC) is defined through the LENA software analysis system as a measure of the number of words adults say directly to the child. This was divided by the number of hours of the recording, as not all of the recordings were of equal length. Conversational turn count (CTC) refers to the number of conversational exchanges between the child and another speaker. This was also divided by the number of hours of the recording. Auditory environment reflects the breakdown of meaningful and distant speech, TV/electronics, other background noise, and silence per recording. The LENA output gives information on the general auditory environment by providing percentage of meaningful speech (%MS), the percentage of distant speech (%DS), the percentage of electronic noise (%TV), the percentage of other noise (%ON), and the percentage of silence (%S) for any given time period. The definition of meaningful speech (%MS) is inconsistent in the literature, but the Language Environment Analysis (LENA) system defines meaningful input as speech directed toward the

child at a distance under six feet (Gilkerson & Richards, 2009). The LENA computer software was used to analyze the recordings and generate individualized reports for the 10-16 hour AWC, CTC, %MS, and %TV values (see Appendix B). As noted above, both the AWC and the CTC were divided by the number of hours of the recording because the recordings were not all equal in length.

Measures of linguistic quality. Thirty minutes from the hour with the highest CTC for each of the 18 selected participants was transcribed orthographically in Praat (Boersma & Weenik, 2013). The transcriptions were then input into SALT (Miller & Iglesias, 2012) and coded for a subset of quality markers described in Hart and Risley (1995). The quality measures analyzed were the following: language diversity (number of nouns and modifiers per hour), symbolic emphasis (sum of nouns, modifiers, and past-tense verbs vs. all utterances per hour), mean length of utterance (MLU), and number of different words (NDW).

Other measures (maternal education level and vocabulary size). In the demographic background survey, mothers were asked to note their highest level of education achieved, using a multiple-choice format. Eight choices were provided: GED, less than high school, high school diploma, trade school, technical/associate's degree, some college, college degree, and graduate degree. These choices were reduced to three levels: low (less than high school, GED, high school diploma), mid (trade school, technical/associate's degree, some college), and high (college degree, graduate degree). Standard score was also calculated for both the EVT-2 and PPVT-4.

Statistical analysis. Three separate analyses were run, one for each experimental question. Regression analysis was used for the first question because of the large number of subjects (n = 176) and correlational analysis were used for the second and third questions because of the much

smaller number of subjects (n = 18). The first experimental question examined the relationship among measures of the quantity of linguistic input, maternal education level, and vocabulary size. For this analysis, two sets of step-wise multiple regression analyses were run. The dependent variable for one set was receptive vocabulary size (PPVT-4 standard score) and the dependent variable for the other set was expressive vocabulary size (EVT-2) standard score. The first analysis in each set included all LENA measures (AWC, CTC, %MS, %TV) as the independent variables. The second analysis in each set also added maternal education to the model, after the significant LENA measures had been included.

The second question examined the relationship between linguistic quantity and linguistic quality for the 18 LENA language samples that were coded for quality. All measures of linguistic quantity (AWC, CTC, % MS, and %TV) were correlated with all measures of linguistic quality (MLU, NDW, symbolic emphasis, and language diversity).

The third and final question examined whether measures of linguistic quantity or quality better predicted vocabulary size. Two sets of correlations were run. One set of correlations examined the relationship between expressive vocabulary size and all measures of linguistic quantity and quality (AWC, CTC, %MS, %TV, MLU, NDW, symbolic emphasis, language diversity). The second set examined the relationship between receptive vocabulary size and all measures of linguistic quantity and quality.

CHAPTER THREE

Results

The first experimental question was whether linguistic aspects of the home environment, as measured quantitatively by the LENA system, and maternal education level predict vocabulary size in young children.

The first examination of the LENA data for the large set of 176 language samples was descriptive. Figure 1 provides box plots for the four LENA measures (AWC, CTC, %MS, and %TV) as well as EVT-2 and PPVT-4 standard scores by level of maternal education. It can be observed that there is much variability within each maternal education level both for the linguistic input measures and for vocabulary size. A series of one-way ANOVAs were run with the linguistic input measures as the dependent variables and maternal education level for the families (n = 166) as the independent variable. All of these ANOVAs were significant (AWC: $F[2, 172] = 7.48$, $p = .001$; CTC: $F[2, 172] = 8.07$, $p < .001$; percentage of meaningful speech: $F[2, 170] = 9.14$, $p < .001$; percentage of TV: $F[2, 170] = 4.87$, $p = .009$). Post-hoc tests were run to examine the differences among the three maternal educational levels (low n = 9; middle n = 26; high n = 131). With one exception (percentage of TV), the low and middle maternal education level groups did not differ from each other, but both had significantly lower scores than the high maternal education level group. For percentage of TV, the low maternal education level group had significantly more TV than the other two groups, which did not differ from each other.

Insert Figure 1 about here

To examine whether linguistic input measures from LENA predicted expressive vocabulary size, a stepwise multiple regression was performed. The dependent variable was standard score on the EVT-2. All of the linguistic input measures from LENA (AWC, CTC, %MS, AE) were included as independent variables. Two linguistic input measures were significant predictors; together, they predicted 13% ($p < .001$) of the variability in expressive vocabulary size. These were percentage of meaningful speech (β= 92.57, *S.E.* = 24.27, $t = 3.81$, $p < .001$) and percentage of electronic noise ($\beta = -44.67$, *S.E.* = 22.44, $t = -1.99$, $p = .048$). A larger vocabulary was associated with relatively more meaningful speech and relatively less electronic noise, as can be observed in Figure 2. In a second analysis, maternal education level was added as a predictor after percentage of meaningful speech and percentage of TV had been included in the model. Maternal education level explained an additional 2 percent of the variability in expressive vocabulary size ($r^2 = .15$, $p < .001$ for both models) over and above percentage of meaningful speech. The percentage of TV was no longer a significant predictor, once maternal education level was included (percentage of meaningful speech: β= 85.42, *S.E.* = 24.23, $t = 3.53$, $p = .001$ and maternal education level: $\beta = 7.0$, *S.E.* = 2.45, $t =$. 2.06, $p = .005$). Figure 2 shows separate regression lines for the three levels of maternal education. For the relationship between expressive vocabulary size and percentage of meaningful speech, it can be observed that there is a much larger effect of maternal education level on expressive vocabulary size for children from low maternal education level families. This is illustrated by the steeper slope for this group. The slopes of the regression lines for the other two groups were similar, although the values of the EVT-2 standard scores for any given value of percentage of meaningful speech were higher for the high maternal education level group than for the middle maternal education level group.

Insert Figure 2 about here

Similar results were observed for the relationship between linguistic input measures from LENA and receptive vocabulary size. Another stepwise multiple regression was performed for all samples in which the dependent variable was standard score on the PPVT-4. All of the linguistic input measures from LENA (AWC, CTC, %MS, AE) were again included as independent variables. For the entire data set (n = 172), percentage of meaningful speech was the sole linguistic input measure that significantly predicted 9% ($p < .001$) of the variability in receptive vocabulary size ($\beta = 91.20$, $S.E. = 22.25$, $t = 4.10$, $p < .001$). Similar to the results for EVT-2 model, a larger receptive vocabulary was associated with relatively more meaningful speech (see Figure 3).

Insert Figure 3 about here

In order to determine if maternal education level was a significant predictor of receptive vocabulary size for the larger sample, after measures of linguistic input have been accounted for, the regression analysis was rerun with maternal education level added to the models as a predictor after percentage of meaningful speech had already been included. Maternal education level explained an additional 7 percent of the variability in receptive vocabulary size ($r^2 = .16$, $p < .001$ for both models) over and above the percentage of meaningful speech. Figure 3 shows separate regression lines for the three maternal education levels. Similar to the findings for the model with expressive vocabulary size, there was a stronger relationship between receptive vocabulary size and percentage of meaningful speech for the low maternal education level group relative to the other two groups.

The second experimental question focused on the relationship between the quantity and quality of linguistic input.

The analyses for this question used data from the smaller group of 18 LENA samples. Again, the first analyses were descriptive. As shown in the box plots in Figure 4, there was much variability within each group and overlap between the groups. A series of one-way ANOVAs were run, but there were no significant differences in any of these quantity or quality measures as a function of maternal education level. This was likely due to the small number of participants and the large amount of variability for each measure, as can be observed in the box plots.

Insert Figure 4 about here

Correlations between the quantitative linguistic input measures from LENA (AWC, CTC, %MS, %TV) and the quality measures (number of different words, mean length of utterance, language diversity, and symbolic emphasis) were calculated. Adult word count was correlated with one measure of quality, number of different words ($r^2 = .72$, $p < .001$). Similarly, conversational turn count was correlated with number of different words ($r^2 = .47$, $p = .002$). These relationships are shown in Figure 5.

Insert Figure 5 about here

Percentage of meaningful speech was also correlated with a number of qualitative measures: number of different words (r^2 = .63, p < .001), mean length of utterance (r^2 = .27, p = .026), and symbolic emphasis (r^2 = .28, p = .023). These relationships can be seen in Figure 6.

Insert Figure 6 about here

The final question focused on whether quality or quantity of linguistic input better predicts vocabulary size in young children.

Two correlation analyses were run to examine whether quantitative or qualitative measures of linguistic input best predicted vocabulary size. For the first analysis, EVT-2 standard score was correlated with both the quantity measures from LENA (AWC, CTC, %MS, %TV) and the quality measures from the language sample analysis (MLU, NDW, linguistic diversity, symbolic emphasis) were the independent variables. For the second analysis, PPVT-4 standard score was correlated with the same measures of linguistic input. In this smaller set, adult word count, a quantitative measure, was the only measure that was correlated with expressive vocabulary size. (r^2 = .25, p = .036). The PPVT-4 standard score was significantly correlated with two measures of linguistic quality: symbolic emphasis (r^2 = .39, p = .007) and mean length of utterance (r^2 = .32, p = .017). All of these relationships are shown in Figure 7. It can be observed that as vocabulary size increases, as all of these input measures increase.

Insert Figure 7 about here

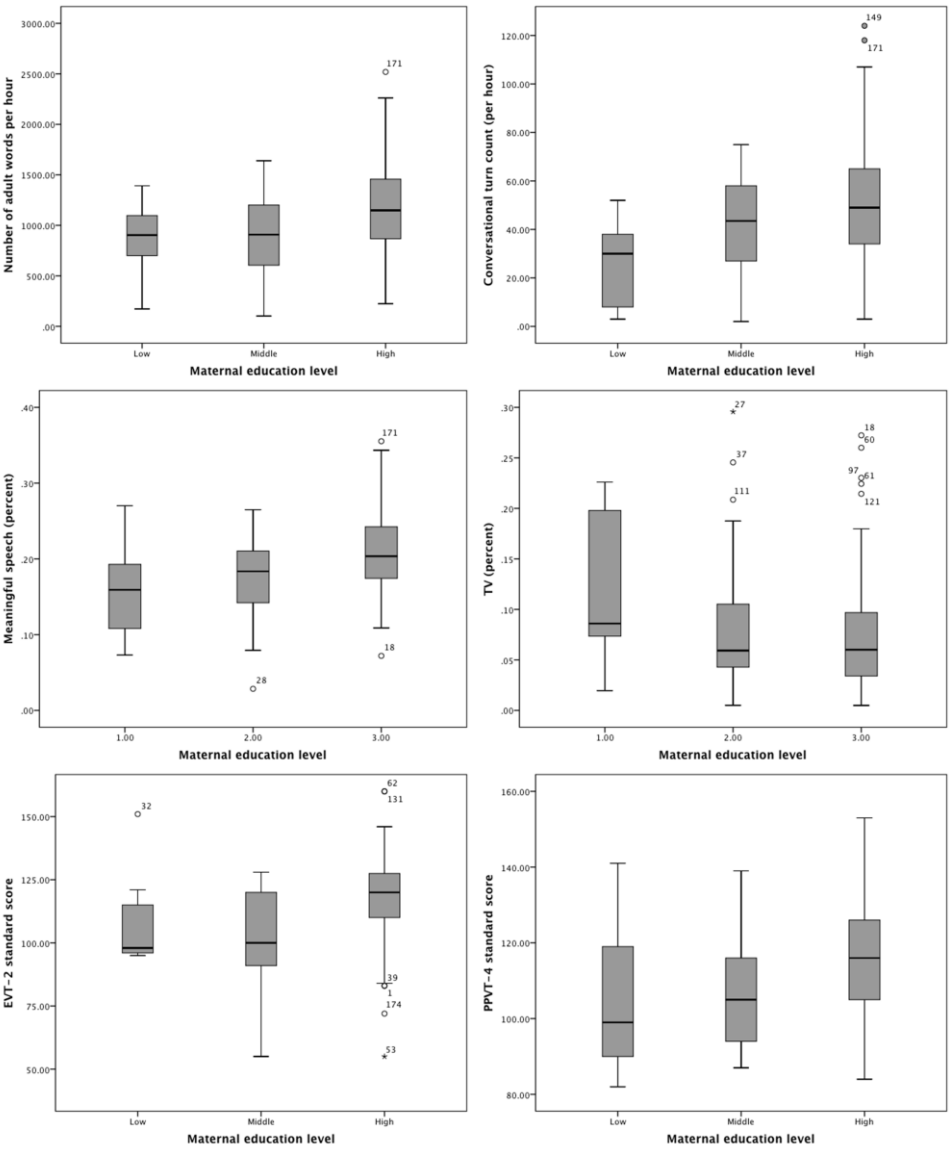


Figure 1: Box plots for the linguistic input measures from LENA and expressive and receptive vocabulary size as a function of maternal education level (low n = 9; middle n = 26; high n = 131). Top of box shows the third quartile, bottom of box show the first quartile, and the line in the box shows the median. The top and bottom whiskers show plus/minus 1.5 x the inter-quartile range.

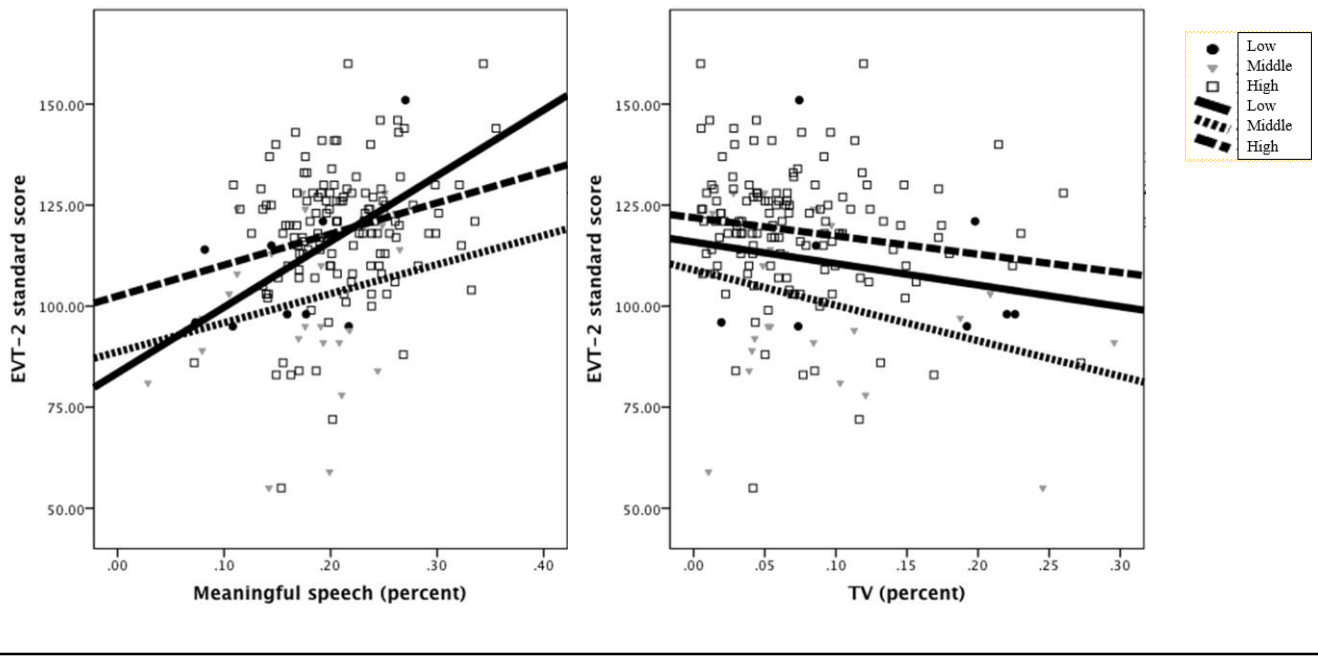


Figure 2: Percentage of meaningful speech (left) and percentage of TV (right) plotted against expressive vocabulary size for the three levels of maternal education. (Separate regressions by group were significant for the high and low maternal education level groups, but not for the middle maternal education level group.)

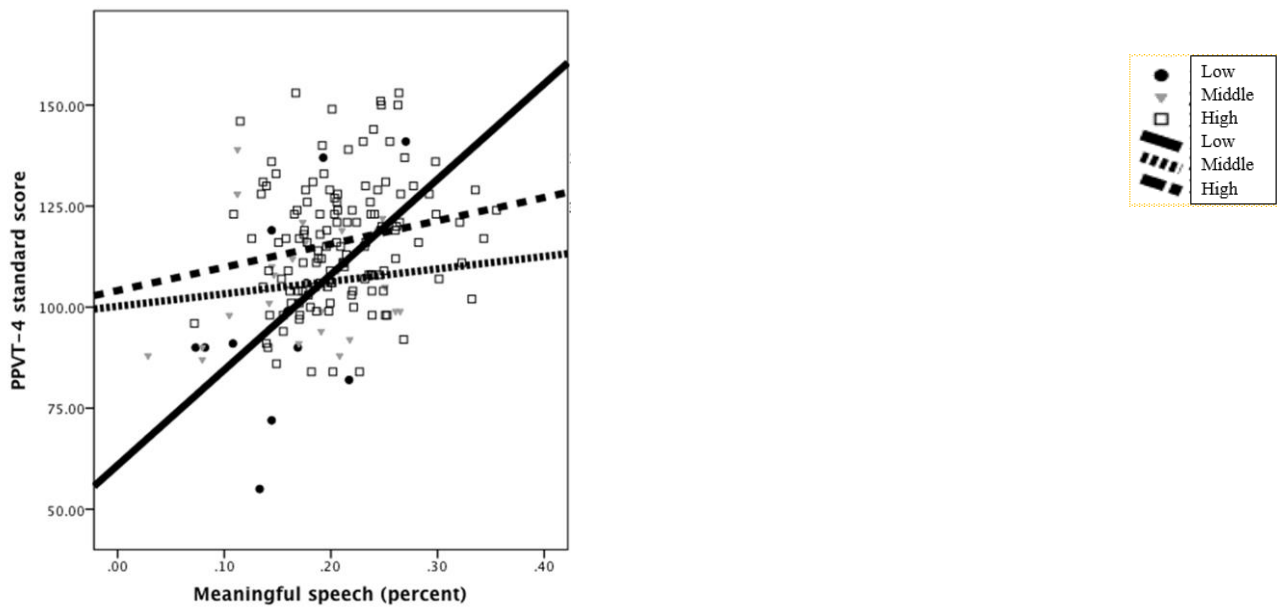


Figure 3: Percentage of meaningful speech plotted against receptive vocabulary size for the three levels of maternal education. (Separate regressions by group were significant for the high and low maternal education level groups, but not for the middle maternal education level group.)

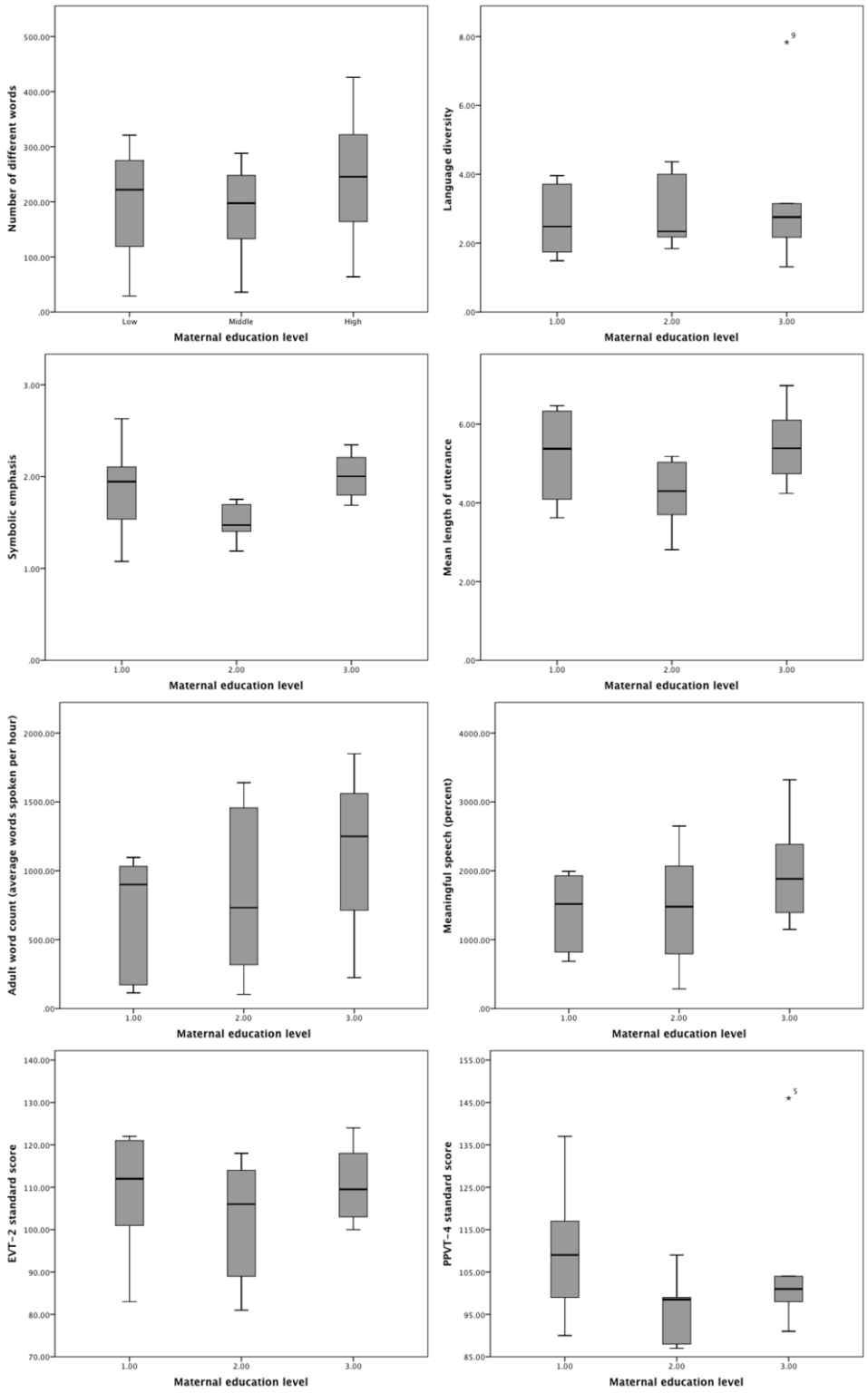


Figure 4: Box plots for quantitative and qualitative measures of linguistic input, and expressive and receptive vocabulary size as a function of maternal education level for the families (low n = 6; middle n = 6; high n = 6).

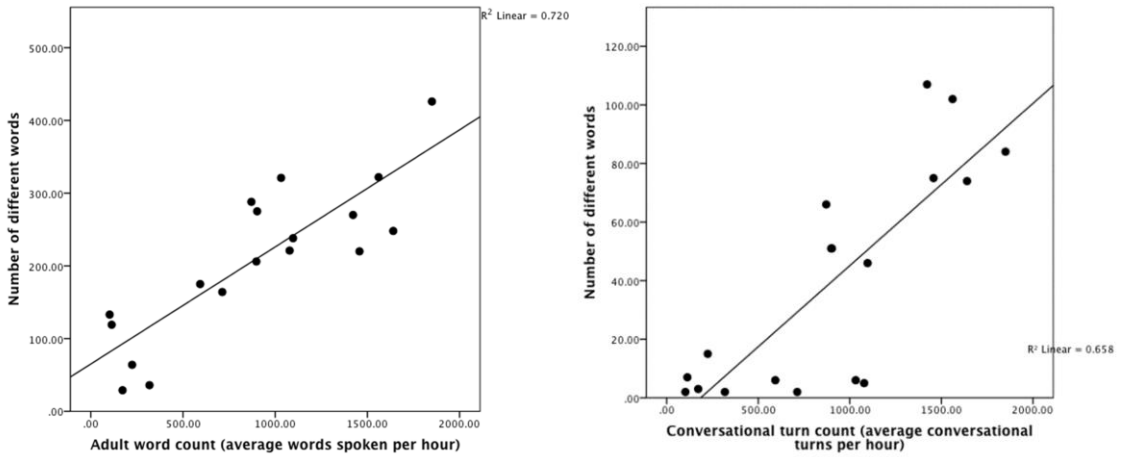


Figure 5: Adult word count plotted against number of different words (left) and conversational turn count plotted against number of different words (right).

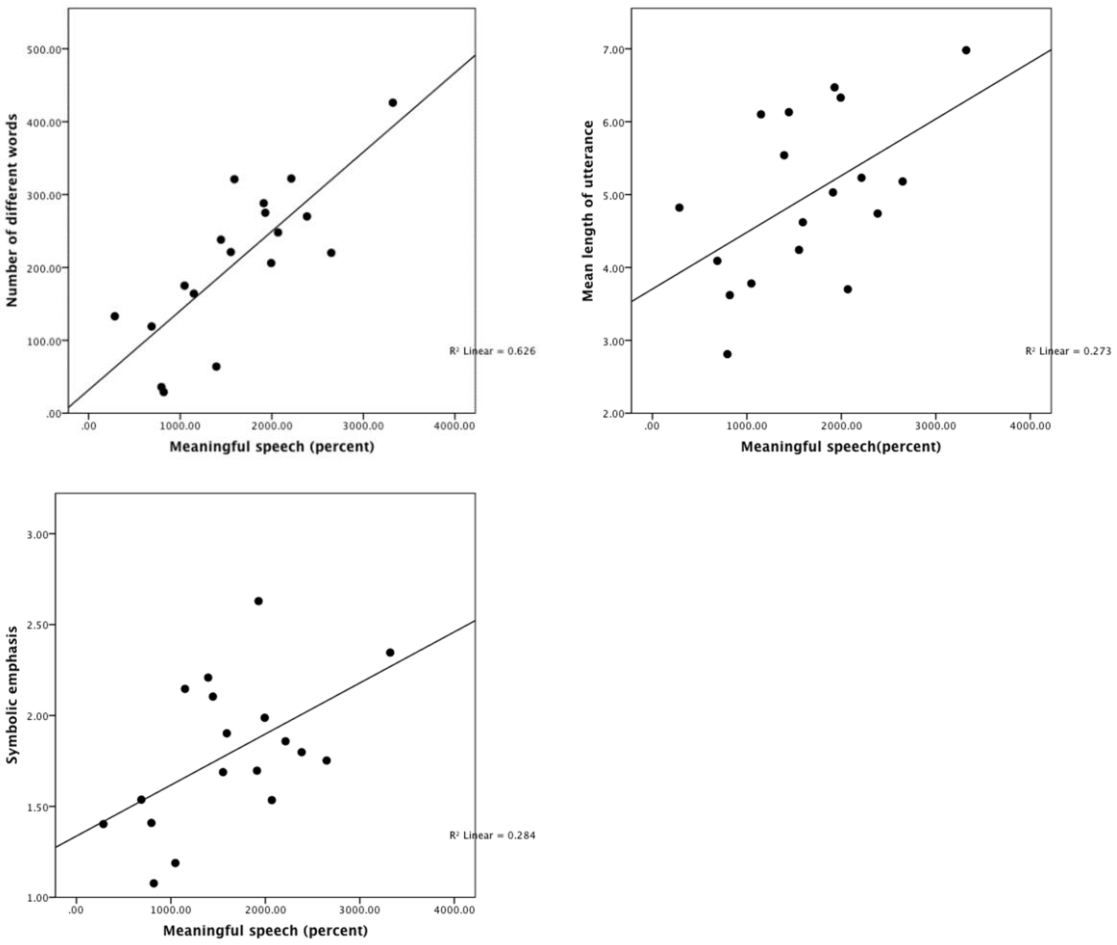


Figure 6: Percentage of meaningful speech plotted against number of different words (top left), mean length of utterance (top right), and symbolic emphasis (bottom left).

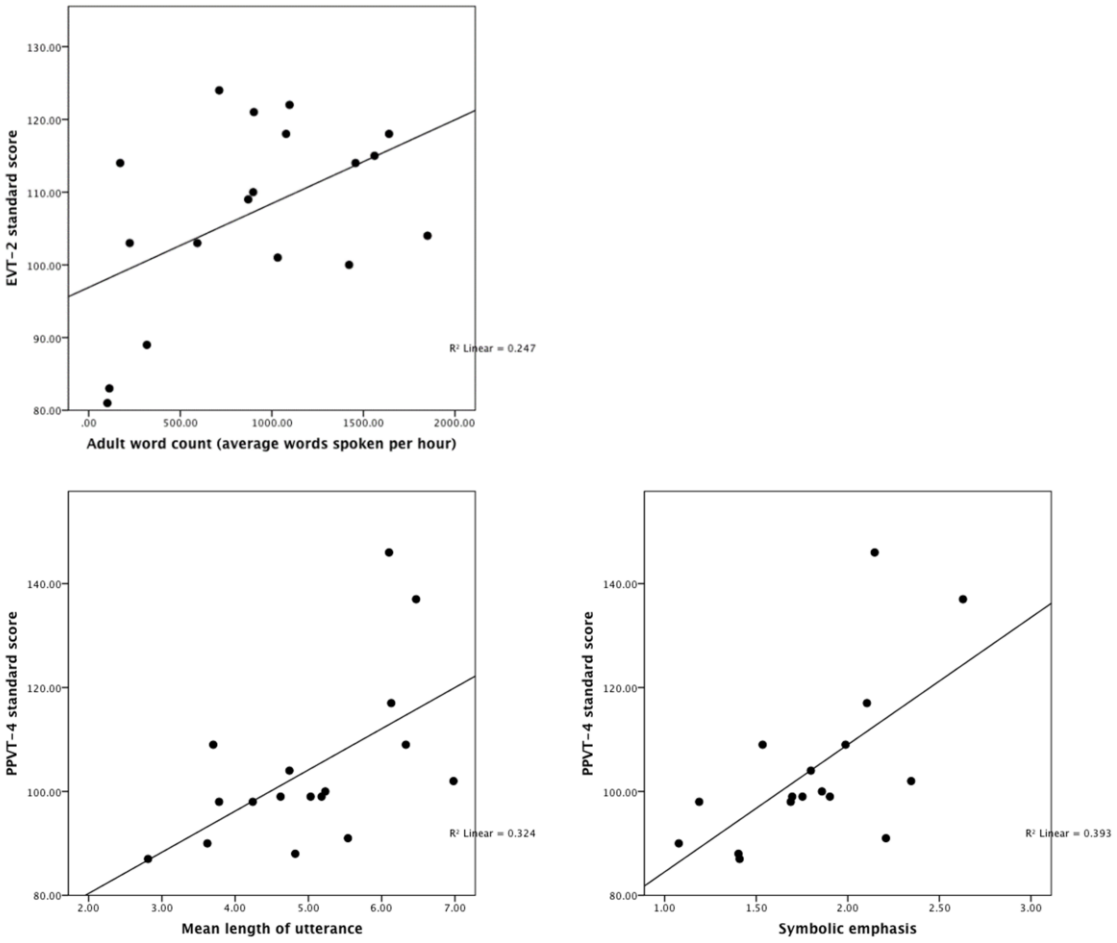


Figure 7: Expressive vocabulary size plotted against adult word count (top left); receptive vocabulary size plotted against mean length of utterance (bottom left) and against symbolic emphasis (bottom right).

DISCUSSION

Three questions were addressed in this paper. The first focused on the relationship between different measures of linguistic input and vocabulary size in a relatively large sample of 176 children. In this study, quantitative measures of linguistic input from LENA explained about 10% of the variability in vocabulary size. This is somewhat smaller than has been found in previous studies. For example, Greenwood et. al (2011) found that around 25% of children's receptive vocabulary and 18% of expressive vocabulary could be explained by quantitative measures of linguistic input from LENA. One explanation for the discrepancy between the results in the current study and the results of Greenwood et al. is that the children in the Greenwood study were younger (12 to 20 months), while the children in the current study were older (28 to 38 months). There may be a more direct relationship between linguistic input and vocabulary size in younger as compared to older children. It is also important to highlight the importance of maternal education level's impact on a child's vocabulary growth trajectory. The relationship between percentage of meaningful speech and both expressive and receptive vocabulary size was stronger for children from low maternal education level families, relative to children from middle and high maternal education level families. In other words, children from families with low levels of maternal education ($n = 9$ for expressive vocabulary size and $n = 12$ for receptive vocabulary size) were more influenced by linguistic input than children from families with middle ($n = 26$) and high ($n = 131$) levels of maternal education. These results may have been more robust if this study had included more families with low levels of maternal education. Due to challenges with the administration of standardized assessment including inability to complete the assessment in full, several children were retroactively removed from this study. Of the six children who did not receive a score for the EVT-2, three were from low maternal education families, one was from a family with a middle level of maternal education,

and two were from high maternal education families. Of the three children who did not receive a score for the PPVT-4, two were from families with high maternal education levels and one was due to an administration error. Given the small number of children in the low maternal education group, drawing hard and fast conclusions is not possible. Understanding that more research should be conducted on this topic, the overarching idea that linguistic input remains a crucial factor in predicting vocabulary size, especially in children from families with low levels of maternal education, remains evident.

Constructing a response to the second question regarding the relationship between quality and quantity of linguistic input remains more of a puzzle. In part, this is because of the small sample size for these analyses (n = 18). Few strong relationships were found among quantitative and qualitative measures. Not surprisingly, the qualitative measure of number of different words (which is, in part, a quantitative measure) was the quality measure that was most consistently correlated with the quantitative measures of AWC, CTC, and %MS. While future research should include a larger sample size and other measures of linguistic quality, these results suggest that there is some independence between measures of quantity and quality. That is, a higher AWC or a higher percentage of meaningful speech does not automatically mean that the linguistic input is of higher quality, in terms of linguistic complexity.

The final question focused on whether measures of linguistic quantity or quality were more related to vocabulary size. Again, it was difficult to draw conclusions, given the small sample size for this analysis and the fact that only a few lexical and syntactic measures of linguistic quality were included in the analysis. Results from this study found that AWC average was a significant quantitative predictor of expressive vocabulary size, predicting 25% of the variability in expressive language. In regard to receptive language, the qualitative measures of

symbolic emphasis and mean length of utterance were shown to predict about 30 to 40% of the variability in receptive vocabulary. Perhaps certain quantitative measures are the best predictors of expressive vocabulary size while qualitative measures serve as the best predictors of receptive vocabulary size. However, additional research with a larger sample size and the inclusion of other measures of linguistic quality needs to be conducted before providing such a blanket statement to families. Investigating the impact of pragmatic aspects of language quality, such as responsiveness, for example, was beyond the scope of this study, and should therefore not be ruled out as contributing influences on vocabulary development.

This study set out to investigate which aspects of linguistic input in the home are most influential in shaping children's vocabulary size; by knowing these factors, professionals could ideally educate families on ways to modify home language to more directly target vocabulary growth. It appears that this overarching question does not have a panacea response, but rather a series of specific yet plausible answers. Results seem to suggest that for children with expressive language concerns, measuring the amount of adult words spoken in the child's environment using the LENA system could be a helpful way for interventionists to collect baseline information on home language while also gauging progress at certain intervals. Children with receptive language challenges may benefit more from interventionists suggesting parents increase the number of different words used in the home. While not measured and progress monitored as easily as with the LENA system, families of children with extreme receptive language delays may benefit from this knowledge should this idea be replicated in subsequent studies. A feasible language support for all families lies in reducing the amount of TV time at home. Because increased television time reduces the opportunity for meaningful speech in a child's environment, an inverse relationship on vocabulary size is observed. Therefore, families

from all levels of maternal education who do not have the time or means by which to increase the number of adult words or different words at home can support their child's vocabulary growth simply by limiting television time.

Results from the current study support researchers' past findings to encourage families to talk more with their children; however, reasonable evidence exists that children can also benefit from being spoken to in different ways and with different words. Whether families work alone or intimately with interventionists, and whether qualitative assessment, quantitative assessment, or a combination of the two is implemented, the main message is simple: to support children's holistic vocabulary growth, keep families talking.

REFERENCES

Boersma, P. & Weenink, D. (2013). Praat: doing phonetics by computer [Computer program]. Version 5.4.08. Retrieved from http://www.praat.org/.

Dunn, L. M., Dunn, D. M. (2007). *Manual: Peabody Picture Vocabulary Test, fourth edition*. Bloomington, MN: Pearson Assessments.

Gilkerson J., Richards J. A. (2009). The power of talk: Impact of adult talk, conversational turns, and TV during the critical 0-4 years of child development (Technical Report LTR-01-2). Retrieved from: http://www.lenababy.com/pdf/The_Power_of_Talk.pdf.

Greenwood, C. et al. (2011). Assessing children's home language environments using automatic speech recognition technology. *Communication Disorders Quarterly, 32,* 83-92.

Hart, B. & Risley, T, (1995). *Meaningful differences in the everyday experience of young American children*. Baltimore, MD: Paul H Brookes Publishing.

Hoff, E, (2006). How social contexts support and shape language development. *Developmental Review, 26,* 55-88.

Huttenlocher, J. et al. (2010). Sources of variability in children's language growth. *Cognitive Psychology, 61 (4),* 343-365.

Gilkerson J., Richards J. A. (2008b). The LENA foundation natural language study (Technical Report LTR-02-2). Retrieved from:http://www.lenafoundation.org/TechReport.aspx/Natural_Language_Study/LTR-02-2.

Mahr, T. et al. (2014). The influence of home language input and lexical processing efficiency on vocabulary size in 3-year-olds. *Symposium for Research in Child Language Disorders*.

Miller, J. & Iglesias, A. (2012). Systematic Analysis of Language Transcripts (SALT), Research Version 2012 [Computer Software]. Middleton, WI: SALT Software, LLC.

Naigles, L. and Hoff-Ginsberg, E. (1995) Input to verb learning: Evidence for the plausibility of syntactic bootstrapping. Developmental Psychology 31, 827-837.

Naigles, L. & Mayeux, L. (2001). Television as incidental language teacher. In D. Singer & J. Singer (Eds.) Handbook of Children and the Media (pp. 135-153).

Riquetti, A. (2013). *Providence Talks*. Providence, RI: Bloomberg Philanthropies. Retrieved from http://www.providencetalks.org/.

Rowe, M. et al. (2012). The pace of vocabulary growth helps predict later vocabulary skill. *Child Development, 83 (2),* 508-525.

Senechal, M., LeFevre, J., Hudson, E., & Lawson, P. (1996). Knowledge of storybooks as a predictor of young children's vocabulary. Journal of Educational Psychology, 88, 520-536.

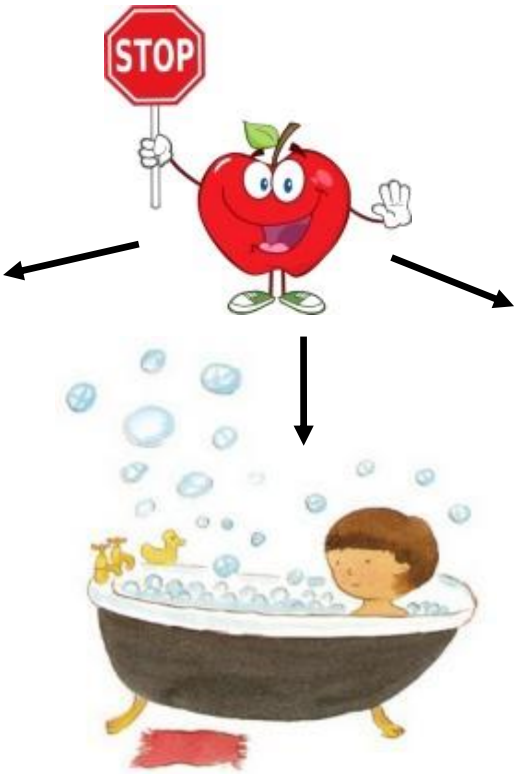
Suskind, D. (2010). *Thirty Million Words Initiative*. Chicago, IL. Retrieved from http://thirtymillionwords.org/.

Suskind, D. et. al (2013). An Exploratory Study of "Quantitative Linguistic Feedback": Effect of LENA Feedback on Adult Language Production. *Communication Disorders Quarterly, 34 (4)*, 199-209.

Williams, K. (2007). *Manual: Expressive Vocabulary Test, second edition*. Bloomington, MN: Pearson Assessments.

Appendix A: Introduction to the LENA system with pictorial support

LENA: Language Environment Analysis



Appendix B: Example of individualized LENA reports for 10-16 hour recordings