Spring 2010

The relationship between parental language input and language outcomes in children with cochlear implants

Melinda Jean Grieb
University of Iowa

THE RELATIONSHIP BETWEEN PARENTAL LANGUAGE INPUT AND LANGUAGE OUTCOMES IN CHILDREN WITH COCHLEAR IMPLANTS

by

Melinda Jean Grieb

A thesis submitted in partial fulfillment of the
requirements for the Master of Arts degree
in Speech Pathology and Audiology
in the Graduate College of
The University of Iowa

May 2010

Thesis Supervisor: Professor Bruce Tomblin

Graduate College
The University of Iowa
Iowa City, Iowa

CERTIFICATE OF APPROVAL

____

MASTER'S THESIS

____

This is to certify that the Master's thesis of

Melinda Jean Grieb

has been approved by the Examining Committee for the thesis requirement for the Master of Arts degree in Speech Pathology and Audiology at the May 2010 graduation.

Thesis Committee: __________________________________
Bruce Tomblin, Thesis Supervisor

____
Bob McMurray

____
Sandie Bass-Ringdahl

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

Cochlear Implants

A cochlear implant (CI) is an auditory prosthesis that electrically stimulates the auditory nerve in individuals with profound sensorineural hearing loss, either children who are congenitally deaf or those who have become deafened as adults. For over 20 years these devices have been used specifically to stimulate hearing and promote language development in children who were born deaf. A cochlear implant consists of several internal and external parts, including a microphone, a speech processor, a transmitting coil and receiver, and an electrode array. The microphone is worn externally to pick up environmental sounds, including speech. The speech processor, which is programmed specifically for each individual depending on their hearing threshold, is designed to select the important aspects of the signal and transmit them to the transmitter and receiver. Once the signal reaches the transmitter coil, it is sent across the skin to the internally implanted receiver, where it is converted into an electrical signal that the auditory nerve can understand. This signal is sent to the electrode array that is placed in the cochlea. Patterns of electrical current from this electrode array stimulate the auditory nerve and thus provide acoustic information to the central nervous system.

While this system does not mimic true hearing perfectly, it has been shown that children with cochlear implants are able to learn spoken language better than deaf children without an implant or with hearing aids alone. (See for example Geers, Nicholas, & Sedey 2003; Svirsky, Robbins, Kirk, Pisoni, & Miyamoto 2000; & Tomblin, Spencer, Flock, Tyler, & Gantz 1999).

These gains in speech and language are not universal, however. Some children show substantial gains while others show much less benefit. The reasons for this variability could be due to features of the device, the child’s peripheral auditory system, or cognitive factors. All of these explanations assume that the quantity and quality of language input provided by the parents does not contribute to this variability. This study was conducted to test this assumption. Specifically, this study asked whether the language input provided by parents of children with CIs is similar to that provided to hearing children, and whether variation in the input is associated with the child's language status at this time.

Language Development in Children with Cochlear Implants

When compared to unimplanted deaf children, a large number of studies show that children with CIs do significantly better with spoken language (Geers, Nicholas, & Sedey 2003; Svirsky, Robbins, Kirk, Pisoni & Miyamoto 2000; Tomblin, Spencer, Flock, Tyler, & Gantz 1999). To name a few, Svirsky et al. (2000) measured the English language skills of 70 pre-lingually deafened children before and after implantation, and compared this information to data previously collected on language outcomes of unimplanted deaf children. They found that before implantation, the language skills of these children were similar to what would be expected of deaf children their ages. However, the rate of language development after implantation significantly exceeded that expected of deaf children and was actually similar to that of their hearing peers. Tomblin et al. (1999) also found that children with CIs had significantly better language skills on all subscales than both deaf age mates and those with hearing aids. Geers et al. (2003) reinforced this idea yet again in their study of language skills of children with CIs. While these studies and several others show that language outcomes of implanted children are significantly better than deaf or aided children, studies have also shown that these children typically do not quite reach the language levels of their hearing peers. Svirsky et al. (2000) found that the children in their study fell around 1 to 2 standard deviations below their hearing peers. Schorr, Roth, and Fox (2008) found that children with CIs fell within 1 standard deviation below their hearing peers when the scores were adjusted for nonverbal intelligence and socioeconomic status (SES). Both studies found significant variability among CI participants. This degree of individual variability is something that has been found in most studies attempting to look at outcomes of children with CIs.

Performance Variability

A problem that has puzzled researchers for years is the considerable amount of performance variability within cochlear implant users. Pisoni et al. (1999) actually calls the existence of this variability “one of the most important issues in pediatric cochlear implantation at the present time.” Some children have far better language skills than would be expected given their hearing status, and others appear to function like deaf children (Geers et al. 2003, Pisoni, Cleary, Geers, & Tobey 1999). According to Pisoni et al. (1999), these differences cannot be attributed to preimplant factors, so several other theories have been proposed to explain this diversity. The most common at this time include differences in age of implantation, educational variables such as enrollment in oral versus total communication programs at school, and home factors, including things like SES and family size. (Geers et al. 2003; James, Rajput, Brinton, & Goswami 2008; Pisoni et al. 1999). However, research has shown that none of these factors seem to account for all of the variability, or even a very large portion of it.

Children who receive CIs already have a language delay relative to their age-matched hearing peers (Schorr et al. 2008; Svirsky et al. 2000). However, the receipt of a CI helps keep this gap from getting any larger, and it has been shown that early receipt of a CI (before 3 years) leads to smaller delays (Geers et al. 2003, James et al. 2008, & Svirsky et al. 2000). In a study conducted by James and colleagues in 2008 specifically designed to determine whether age of implantation explains individual variability, the authors found that while in general early-implanted children performed better on language measures than late-implanted children, there was enough variation within each group to conclude that age of implantation does not solely explain outcome variations. Tomblin, Barker, Spencer, Zhang, and Gantz in 2004 came to a similar conclusion when they found age at initial stimulation to only account for 14.6% of the variation in individual language performance.

Educational status likewise does not seem to play a very significant role in explaining the variability between children. Connor, Heiber, and Arts (2000) found no difference in consonant production scores between children implanted before age 5 who were being educated in either an oral or total communication program. They also found that children in both groups improved on all three measures (consonant production, receptive, and expressive vocabulary) as a function of length of device use rather than educational status. Moog and Geers (1999) likewise found that neither age of implantation nor educational status could account for all of the variability they saw between children with CIs. Geers et al. in 2003 found that educational variables only accounted for 7% of the variance in total language scores in the children they studied. They found speech perception ability (presumably a measure of implant benefit) was a significant predictor of spoken language, but it still only accounted for a fraction of the variance in language skills. The most significant contributing factor Geers et al. found to explain this diversity was “child and family characteristics” such as ethnicity and socio-economic status. These characteristics accounted for 27% of the variance in total language scores.

Tomblin et al. (1999) proposed that since individual differences in language development are to be expected, it has become important to identify whether these differences in CI users are due to the same factors that contribute to differences among all language learners, or whether they can be traced to factors unique to CI users. Pisoni et al (1999) likewise suggested that the differences in CI users may simply be exaggerated forms of normal variation in language development. Since similar “child and family characteristics” have been found to be important in language outcomes of normal hearing children, it is necessary to consult typical language learning research when attempting to solve the CI conundrum.

According to a ground breaking study done by Hart and Risley in 1995, parental input is an extremely important factor influencing language development in hearing children. Children whose parents talk more to them generally have better language skills and perform better later in school than those who are exposed to less language at home. These results were confirmed by Gilkerson and Richards in 2009 in a study using the LENA recording device they developed, which will later be described in depth. Both studies also found that socio-economic status (SES), a measure based roughly on income and maternal education level, can be used as an indirect measure of parental input. In general, children of higher SES families receive more and better quality input than those in lower SES households, which then leads to better language development in the future. Huttenlocher, Vasilyeva, Waterfall, Vevea, and Hedges in 2007 also found that individual differences in caregivers related to SES may be related to children's speech and language skills. While caregivers will adjust their speech based on the characteristics of the child, individual speech patterns, which are based on educational level, are maintained over time.

Considering the importance parental input has on the language of normal hearing children, it makes sense that it may be a factor in the language outcomes of children with CIs as well. It is possible this may be the main contributing factor in the "child and family characteristics" identified as being important in language outcomes by Geers et al. (2003). Unfortunately, this has not been studied directly in this population due to the time-consuming and invasive nature of such studies. Getting a glimpse into a child's home environment used to mean someone being physically present in the home (which in itself changes the environment), and hours of transcription afterwards. With the invention of the LENA Digital Language Processor (DLP), most of this work is now completed for us.

The LENA Digital Language Processor

The LENA DLP is a fairly unobtrusive recording device which weighs 2 ounces and captures up to 16 hours of audio recording. It comes with specialized clothing designed to optimize acoustic quality and yet still be comfortable and discreet enough for the child to wear all day. After a full day of recording, the LENA is plugged into a software program adapted from cutting-edge speech recognition software designed specifically to work in unstructured environments. It uses advanced algorithms and statistical modeling to automatically analyze and segment the audio data to provide several reports, including a measure of child vocalizations, adult words, conversational turns, and audio environment. The software is able to differentiate between adult and child speech, clear and unclear or faint speech, and even tv, environmental, and vegetative sounds (such as crying) versus meaningful speech to give researchers an insight into how much language the child is being exposed to at home. When comparing the LENA software's analysis of a sample to human transcription of the same samples, Gilkerson and Richards (2009) found a mean per hour error rate of only two percent.

The LENA DLP gives us our first real glimpse into the child's home language environment, making it much easier to compare across children with cochlear implants, and to compare their environment with that of normal hearing children. With the invention of this device, we may just learn that this performance variability in children with CIs is more related to the same characteristics of the home environment that affect the language of normal hearing children than anything directly related to the device.

The primary research questions this study addressed were as follows:

1. Are individual differences in language ability associated with quantitative aspects of parental input?
2. Is parental language input to children with cochlear implants similar to that of hearing children?

CHAPTER II

METHODS

Participants

A total of 14 participants and their parents were selected based on their association with an ongoing longitudinal study through the University of Iowa Hospitals and Clinics. Each child had a profound bilateral sensorineural hearing loss, was between the ages of 2 and 6, and had been implanted for at least 18 months prior to participating in the study. Of these fourteen, four families were not interested in participating and one was unable to be contacted. Nine families agreed to participate, but one did not return the device in time to be analyzed. Thus, data from eight children and their parents were included in the study.

Table 1 Age, gender, and implantation history of participants.

Child	Age	Gender	Length of CI use (months)	Age at implantation (months)
P1	4:7	F	41	16
P2	3:2	M	24	14
P3	3:3	F	30	12
P4	3:5	M	31	13
P5	5:6	F	55	14
P6	3:4	M	25	15
P7	4:2	M	34	15
P8	2:7	F	18	13

Procedures

Initial contact with the parents was made by letter, which was followed up with a phone call. During the initial phone call the study was described, and the parents were asked to return the consent form by mail if they were interested in participating. The procedures were either described in detail during this call, or a second phone appointment was set up at a more convenient time. Once the signed consent form was returned, a package was mailed to the family including a LENA DLP, specialized clothing designed to hold the DLP, paperwork, a packet of instructions, and a 10 dollar gift card. The family was asked to record for at least 12 hours on a typical day in their child's life. They were instructed to leave the DLP on all day, even while the child was napping. A daily log was provided for the parents to indicate the times during which the LENA was turned on, the type of environment the child was in throughout the day, and whether the child's CI was on or off. Several of the children attended preschool during the week, so these families were asked to record on a weekend when the child was at home with his parents since parental talk was the primary area of interest. Once the recording was finished, the family mailed back the device and it was analyzed by the LENA software to attain word counts and number of conversational turns. A few of the families, particularly those with younger children, were unable to obtain a full twelve hours of recording. However, the LENA software was designed to estimate 12-hour word counts based on any recording of at least 10 hours so this was not problematic.

Through their association with the larger longitudinal study, each child had recent *Preschool Language Scales 3rd Edition (PLS-3)* scores on file. These scores were compared to the word count and conversational turn data collected by the LENA, as well as with SES information collected on a parent questionnaire. The data collected by the LENA were also compared to norms collected in a nationwide "pilot" study of normal hearing children using the LENAs (Gilkerson & Richards 2008). Since the norms collected in this study only included children up to age 4, some extrapolation was required to compare the subjects over age 4 to the collected norms. The main percentile ranks (10, 25, 50, 75, and 90) were extrapolated from the original normative figures provided with the LENA, and then specific percentiles were interpolated from these graphs. The normative table for adult words was unchanging over time. Thus it was possible to use the 50^{th} percentile as a representative of the mean of the distribution and the 25^{th} percentile to represent -.674 standard deviations. These values were then used to compute z-scores for the adult word counts without interpolating from the graphic.

CHAPTER III

RESULTS

The data obtained from each participant was analyzed by the LENA software described previously for number of adult words (AW), child vocalizations (CV), and conversational turns (CT). These data were compared to the national LENA norms described in the *methods* section.

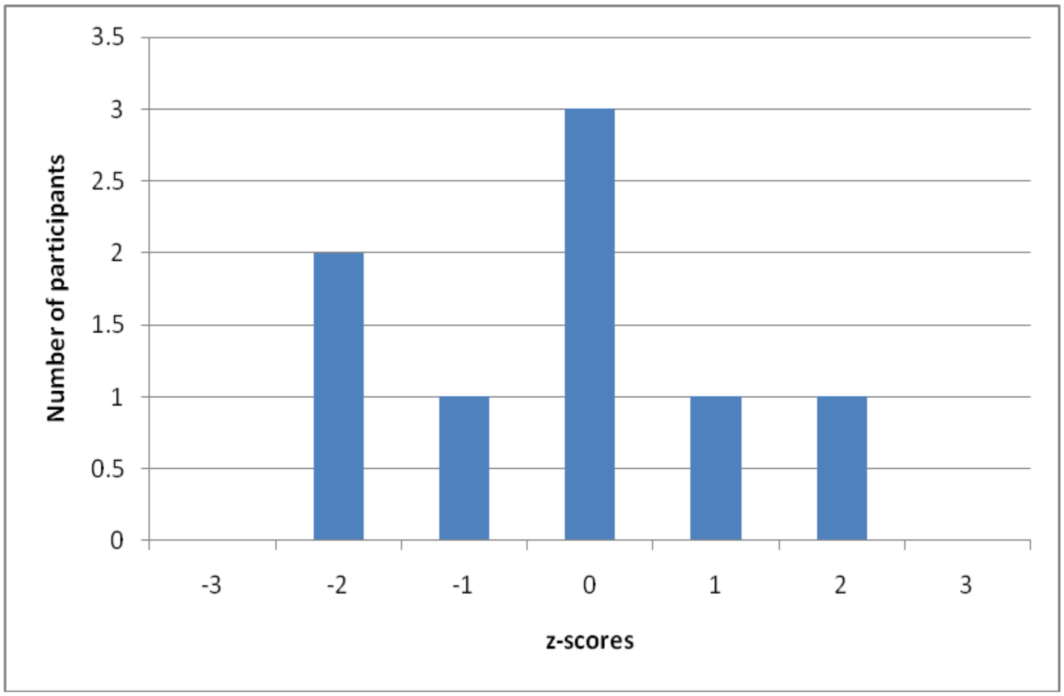
In order to answer the primary research questions, the data collected by the LENA was also compared to the child's most recent *Preschool Language Scales - 3rd Edition (PLS-3)* scores. The Total Language (TL) standard scores from the PLS-3 were used primarily, since they are a sum of the child's overall receptive and expressive language performance.

Due to the relatively small sample size, the inferential statistics performed were limited in power compared to what they could have been with a larger sample. Therefore, the data will be presented descriptively with inferential statistics provided as appropriate.

Adult Words

A central question in this study was whether the language provided by caregivers to children with cochlear implants was comparable in amount to that provided to hearing children of a similar age. The LENA software provides an estimate of the total number of words produced by adults in close proximity to the child. Figure 3.1 provides a frequency histogram of the adult word use provided to each of the participants in the study. These data represent z-score values based on the LENA sample. In general, the adult word counts across participants in this study spanned the range expected of parents with hearing children (mean=12689, SD=7658). Figure 3.1 shows that most of the parents fell within one standard deviation on either side of the normal hearing mean. However, slightly more of the adult participants fell below the mean than would be expected in a normal distribution. A single sample t test, however, revealed that these parents were not significantly different from the expected mean of 0 t=0.183(df=7) SEM=0.534, p=0.86. Due to the small sample size it was difficult to determine whether the differences seen were due to factors unique to the CI parenting community as a whole or simply reflective of individual parenting styles of those studied.

Figure 3.1 Distribution of adult words used with children with cochlear implants



Child Language

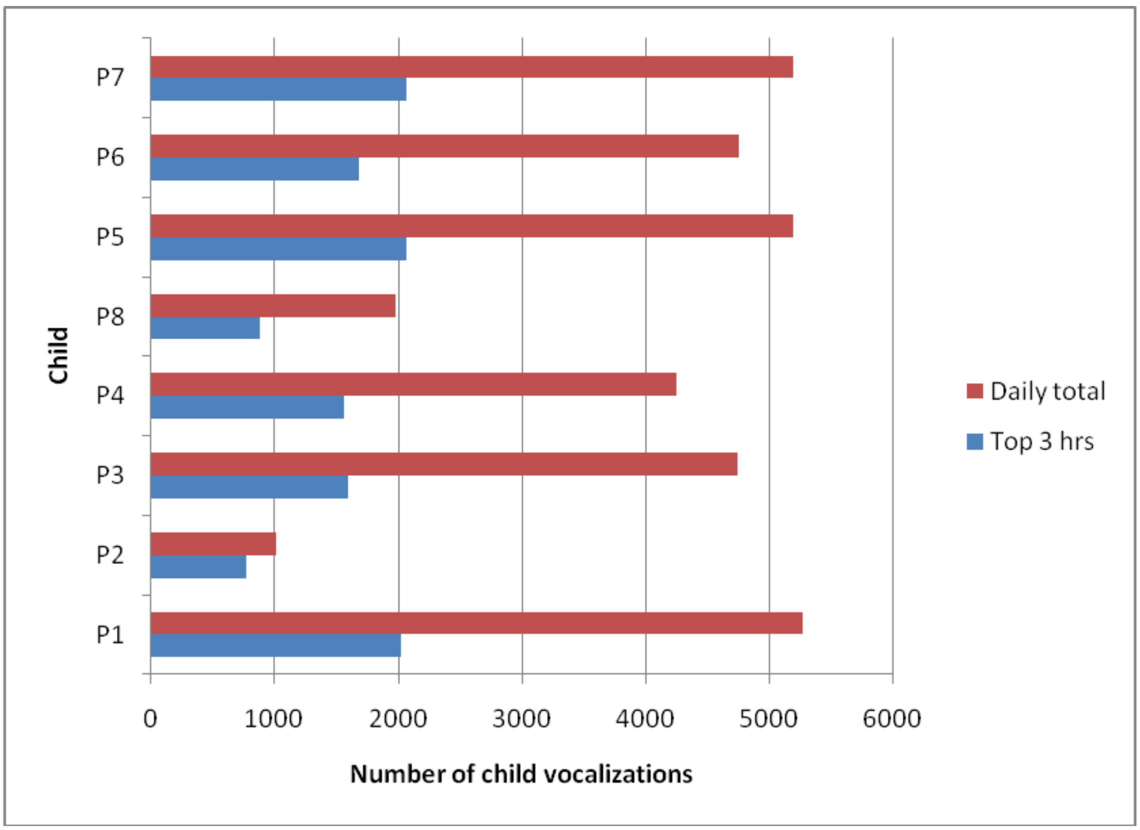
The features of the children's language in this study were measured in two ways. The LENA software provided an estimate of the total number of words the child produced during the day the sample was obtained. Additionally, a measure of the child's language development had been obtained previously using the PLS-3. The total number of words produced by each child is provided in Table 2, along with their PLS-3 total language scores.

Table 2 Language scores for child vocalizations derived from the LENA and scores obtained for each child from the PLS-3

Child	P1	P2	P3	P4	P5	P6	P7	P8	Mean	SD
CV score	5268	1011	4746	4252	5188	4748	3888	1977	3885	1564
CV Percentile	99	8	97	93	95	96	85	42	77	34
PLS TL Standard Score	76	81	86	50	107	85	52	73	76	18
PLS TL Percentile	5	10	18	1	68	16	1	4	15	22

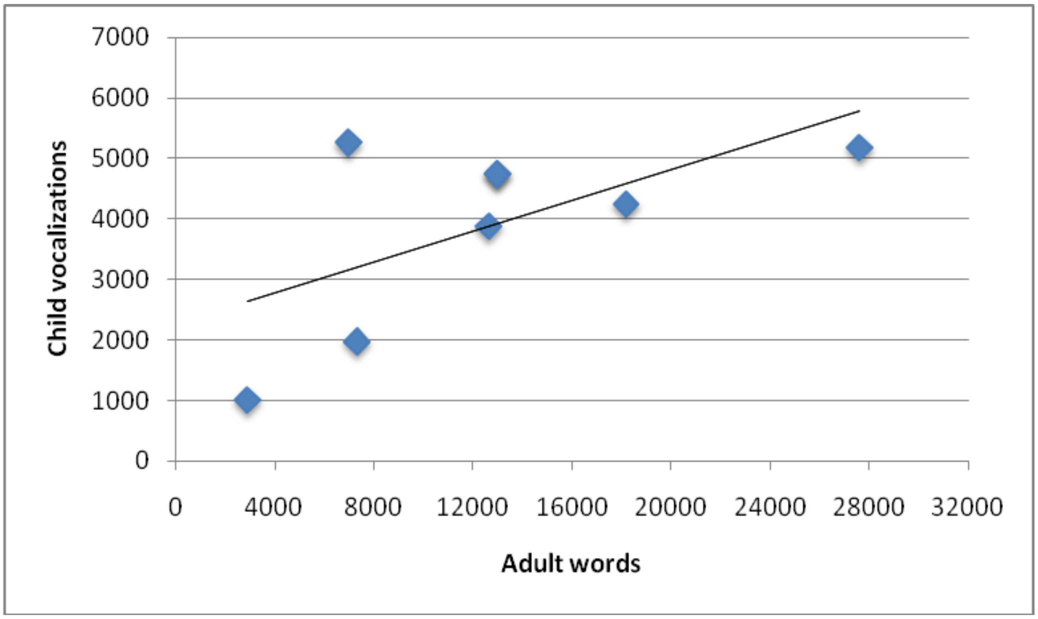
The LENA software provides a means of examining the number of words produced during specified time periods throughout the day. When these profiles of word production were examined for each child, it became clear that some children spent at least one or two hours with little to no words produced whereas other children maintained a fairly steady rate of talk throughout the day. It is likely that these "silent" periods were the result of naps, as they were more common in the younger children. This variability in the kind of activities the children engaged in may have influenced the measure of total words obtained such that the total words may not have been reflective of the child's language when engaged in communication. Upon examination of the profiles of word production across the children, it became clear that in each case there were at least three "peak" hours in which the children were actively talking. Thus, the number of total vocalizations in a day was compared to the number of words produced by the child during these three top hours of vocalization. This comparison can be seen in Figure 3.2. Typically, 30-40% of the child's total vocalizations came from the top three "talking" hours, which is roughly what would be expected from a 12 hour sample given the typical talking patterns throughout the day described in Gilkerson and Richards (2009). However, the children with less overall speech had a greater proportion of it come from those top three hours. In the child with the smallest amount of speech overall, 76% of it come from the three peak hours. The correlation between the top three hours and daily total of CV for all of the children was r=0.965, which was statistically significant at p=0.001. Thus, the number of words produced throughout the day largely mirrors the maximum rates of production, giving greater support for the validity of the total words measure as a reflection of the child's word productivity throughout the day.

Figure 3.2 Relationship between the daily total and top three hours of child vocalizations



The primary research question in this study was concerned with the association between amount of adult speech and the amount of child vocalizations. As would be expected, there was a positive correlation (r=0.625) between adult words and child vocalizations. In general, the more loquacious children had parents who talked more to them. However, the correlation was not significant for this sample (p=0.097). It is likely this correlation would be significant if the sample was larger, and it is possible that the correlation would be even stronger if the families had been recorded for more than one day. Gilkerson and Richards in 2009 found that typical families varied by more than 50 percent in their amount of talk from one day to the next. Therefore, it is difficult to draw strong conclusions about the relationship between child and parental talk based on only one day of recording.

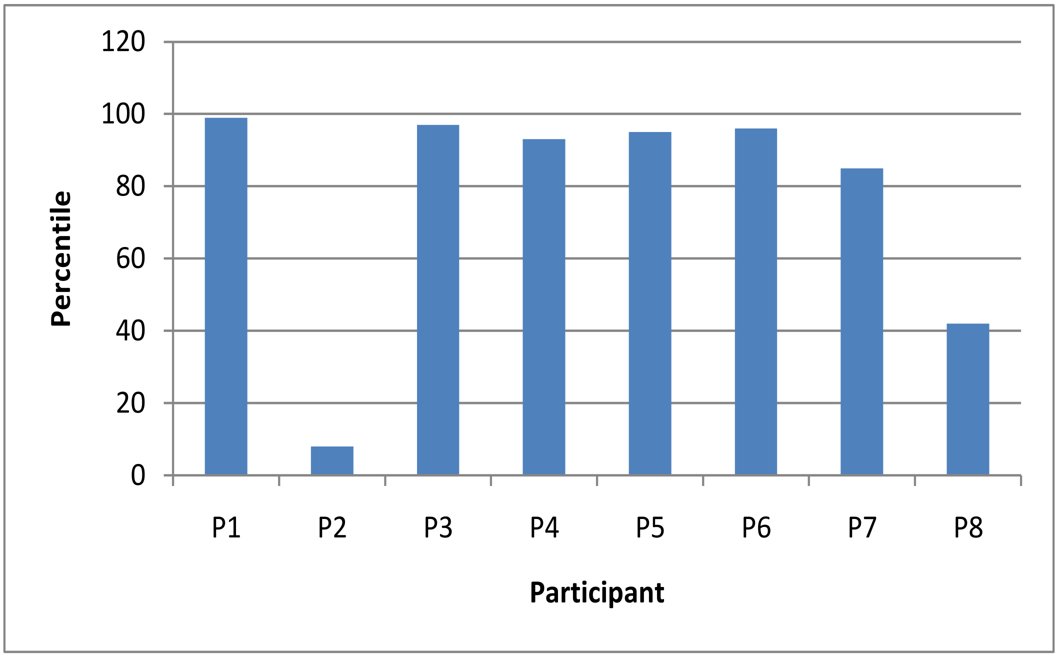
Figure 3.3 The correlation between child vocalizations and adult words



As described in the *methods* section, each child's total vocalization score (CV) was converted into norm referenced percentile scores using norms provided by Gilkerson and Richards (2008). Table 3.1 provides these scores for each child. The mean percentile for this group of children was 77 (SD=34), while the expected mean for hearing children is 50 with a standard deviation of 34. Thus, as a group these children were above the expectations for their age with respect to their hearing age mates. In fact,

Figure 3.4 shows that 5 out of 8 of these children fell in the range between the 90th and 99th percentile for amount of talking. The difference between this group of children and the normative expectations was significant t=2.246(df=7) SEM=12.02, p=.05.

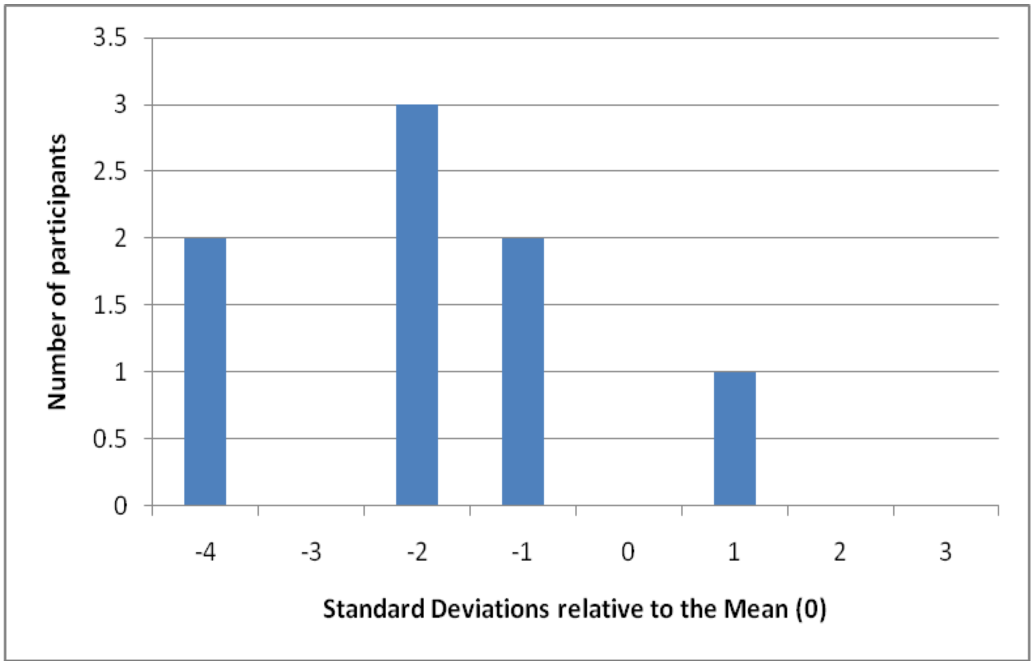
Figure 3.4 Child vocalization percentiles compared to normal hearing age mates



These data from the total number of words produced suggest that at least in this aspect of language, these children are well above the levels of their hearing age mates. The standardized language scores on the PLS-3, however, provide a different perspective.

Table 3.1 provides the total language standard and percentile scores of each child on the PLS-3. In this case the percentile scores ranged from the 1st to the 68th percentile and their mean percentile score was 15 (SD=22). Figure 3.5 shows their distribution relative to the mean.

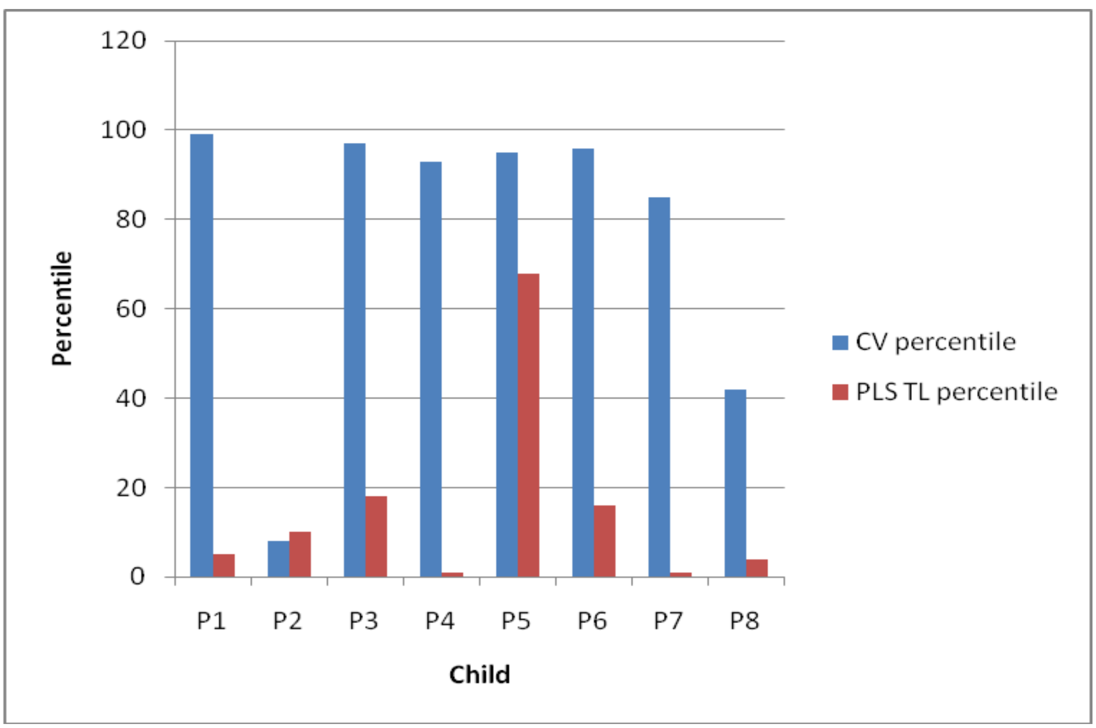
Figure 3.5 Distribution of Preschool Language Scales-3 total language norm referenced scores (z-scores)



A single sample t test revealed that this was significantly different from the expected mean of 50 t=4.499(df=7) SEM=7.78, p=.0028. Thus, on this measure of language these children do not appear to be as capable with language as they appeared with respect to words produced. It is possible that this difference can be accounted for by differences in the norms used. If the normative populations had different average ability levels, then the distributions on these two measures would simply be shifted, but the relative standing of the children in each case would be preserved. If this were the case, then we should see that the two measures are correlated.

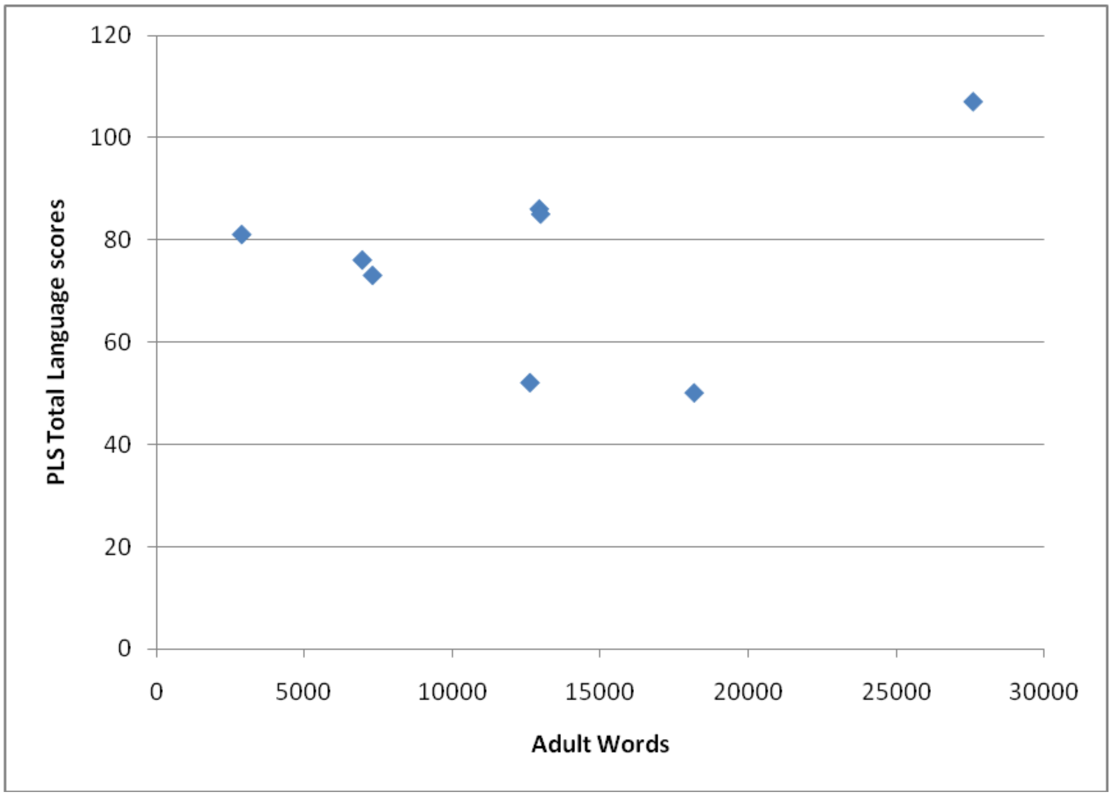
The simplest way to compare the PLS-3 total language (TL) scores and the LENA CV count was to look at the percentile scores for each, as in Figure 3.6. However, percentile distributions are not normally distributed and thus, in order to perform the correlation that assumes bivariate normality, the percentile values on each measure were transformed to z-scores. The correlation between the LENA CV z-scores and the PLS-3 TL z-scores was low (r=0.156 p=0.71). Although this correlation is very small and is not significant in this sample, in fact the correlation between the PLS and CV count was only 0.38 in the LENA study and was significant in their sample (Gilkerson & Richards 2009). In both this study and the LENA study, it would appear that the CV measure reflects features of language behavior that are not reflected on the PLS-3. One possible explanation for this low correlation is that the LENA is designed to pick up real words as well as babbling, squealing, and growling, therefore it measures the amount of vocalizations regardless of the developmental qualities of that speech while the PLS is primarily testing higher level language regardless of how much the child talks.

Figure 3.6 The relationship between Child Vocalization percentile rank and PLS TL percentile rank



Since the amount of child speech collected by the LENA was not strongly correlated with their PLS-3 scores, it is reasonable to assume that the amount of parental input will also not correlate significantly with the PLS-3. Figure 3.7 depicts this association. Statistically, they were not strongly associated (r=0.294, p=0.48) in this sample. However, the LENA study by Gilkerson and Richards (2009) found the correlation between AW and PLS scores to be only 0.35, which was significant in their large sample. It is possible there would have been a *slightly* stronger and more significant correlation in this study if the sample size had been similar to their study.

Figure 3.7 PLS Total Language scores compared to number of adult words



Maternal Education Level

Surprisingly, maternal education level (a measure of SES) was negatively correlated with adult words at -0.399, and to child vocalizations at -0.416 (see Figures 3.8 and 3.9). Both were not significant (p>.05), however were still opposite of what would be expected given previous reports from parents of hearing children. Both Gilkerson and

Richards in 2009 in the LENA study and Hart and Risley in 1995 showed SES to be positively correlated with amount of both adult and child talk, meaning families at higher SES levels typically provided more and higher quality input to their children, which led to higher child vocalization counts. While the quality of input cannot be measured by the LENA, the current data showed parents with higher levels of education talking less to their children. Gilkerson and Richards (2009) did, however, mention that there was significant variability in adult language counts related to maternal education. They found that the upper 50% of those who did not graduate from high school had significantly higher average word counts than the lower 50% of parents who graduated from college. Therefore, the negative correlation found in this study may simply be an effect of sample size.

Figure 3.8 Number of adult words by maternal education level

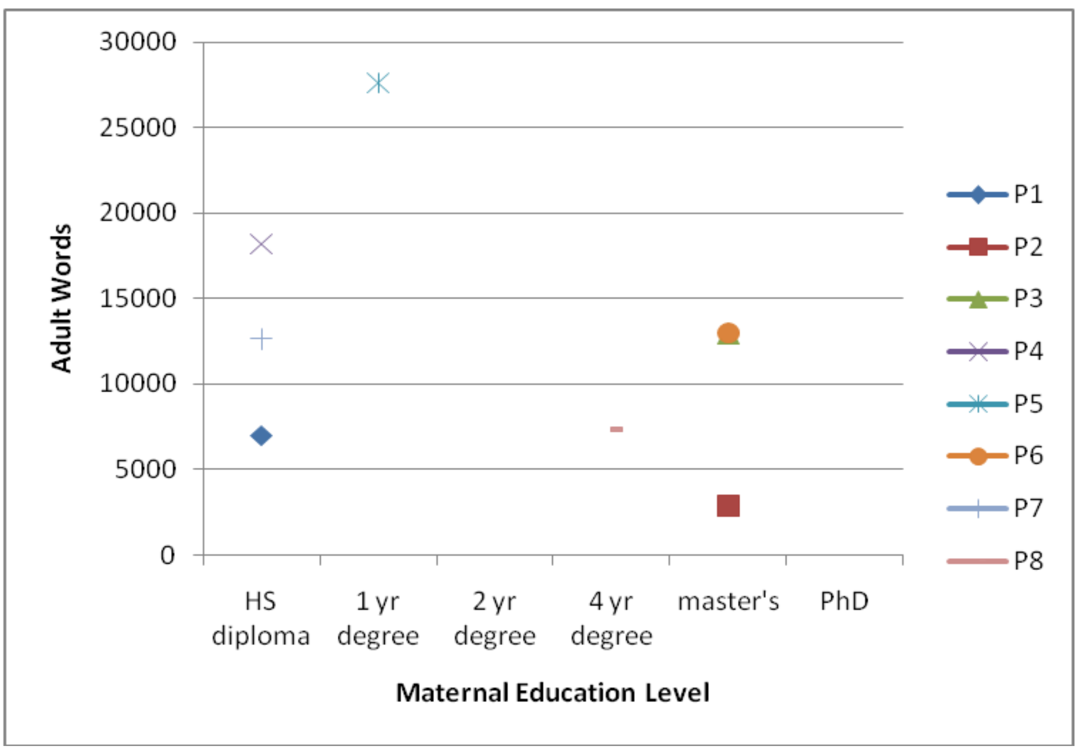
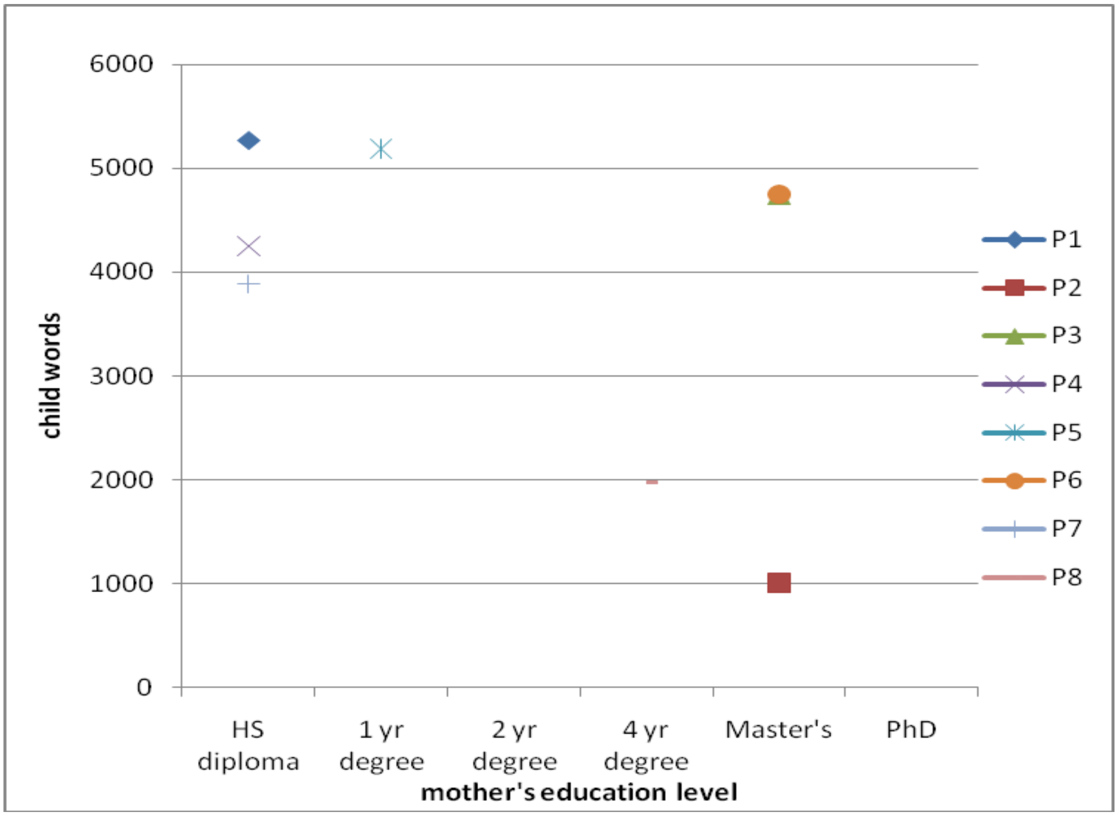


Figure 3.9 Relationship between child vocalizations and maternal education level

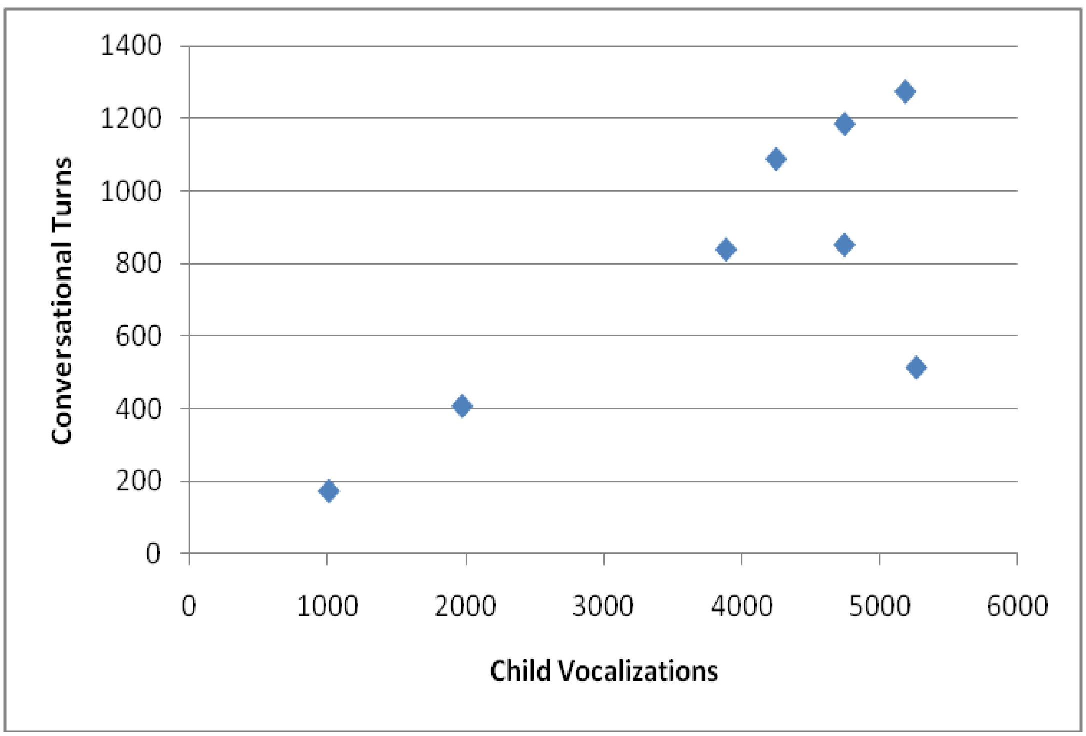


While maternal education level was not correlated with child talk in the way expected, it was slightly (though non-significantly) correlated with other measures. There was a correlation of r=0.447 between amount of child talk and whether the mother stayed at home during the day or had a full time job outside the home. Of the four mothers who identified themselves as homemakers, three of the children were above the 90th percentile on CV, and the fourth was in the 83rd. There was also a positive correlation of 0.588 between maternal education level and PLS TL scores. Mothers with higher levels of education typically had children who did better on the PLS, regardless of occupation. Since PLS scores are based more on quality of language rather than quantity, it makes sense that this would be affected by SES.

Conversational Turns

As seen in Figure 3.10, the number of conversational turns (CT) was significantly correlated with the amount of child vocalizations (r=0.754 p=0.03), suggesting that most of the children were not simply talking to themselves all day. Those children with higher vocalization scores also had higher numbers of conversational turns. The conversational turns were not, however, strongly correlated with the child's PLS TL scores (r=0.162 p>.05), so the exact relationship between language and conversational turns is unclear.

Figure 3.10 The relationship between number of child vocalizations and number of conversational turns



The percentile scores for these conversational turns were slightly higher than those of hearing children, ranging from the 5th to the 99th percentile with a mean of 68.75 and a standard deviation of 34.83. A single sample t test revealed no significant difference from the expected mean of 50 $t=1.523(df=7)$ $SEM=12.314$, $p=.172$. However, these scores, when considered along with the high CV scores and low AW counts, may give some insight into the types of interaction happening between parents and their children.

CHAPTER IV

DISCUSSION

This study sought to gain a new perspective on a long standing issue in cochlear implantation. This issue concerns the substantial amount of variation in speech and language developmental outcomes in children who receive cochlear implants. To date, the majority of the research on this topic has considered factors having to do with the contribution of the device, the peripheral auditory system, or central cognitive factors. This study examined the child's language environment in the home as a new and potentially potent factor that could account for some of these individual differences.

The present study had two main objectives. First, it examined similarities between parents of children with cochlear implants and parents of hearing children, specifically in terms of amount of language input. Second, it sought to compare the relationship between amount of parental talk and the child's current language status, both in terms of reciprocal talk and formal language measures. Both of these objectives were designed to attempt to explain some of the significant language variability among children with cochlear implants.

Parental Input

It seems that parents of children with cochlear implants talk to their children in a similar fashion to parents of normal hearing (NH) children. That is, there is a fairly large distribution among and even within both parents of NH children and parents of children with CIs in regards to amount of talk. Hart and Risley (1995) found the parents in their study to vary by over 2,500 words in an hour, meaning the talkative parents might talk 2,500 more words per hour than the quiet ones. This study found that parents varied by over 24,000 words in a day. Since their samples were 12 hours this could be converted to roughly 2,000 in an hour. Conversational turn data was slightly higher, though non-significantly, than that of hearing parents, suggesting these parents are engaging their children in conversation rather than talking "at" them.

What was difficult to determine from this study, however, was the specific nature of that parent/child interaction. Research has shown that parental interaction techniques that follow the child's lead are more successful at increasing expressive language skills than those where the parent directs the conversation. Specifically, responsive interaction, where the mother uses imitation and expansion of the child's utterance, has proven to lead to better child language than simply slowing down and using simpler language (Girolametto, Weitzman, Wiggs, & Pearce, 1999). Further information about the specific interaction styles of each parent may further explain the interaction between parental talk and the child's language skills.

The amount of parental talk during the day was positively associated with amount of child vocalizations and, to a much lesser extent, the child's PLS-3 scores. The talkative children typically came from parents who talked more to them, which also mirrors the results of the LENA study (Gilkerson & Richards, 2009), as well as Hart and Risley in 1995 and Huttenlocher et al. in 2007. Hart and Risley (1995) actually found that a child's language skills were more associated with amount of parental talk than any other factor, including parents' education level and SES. The fact that these children were so similar to the results of other studies looking at amount of parental input confirms the general belief that parental input matters, at least with respect to the amount the child talks, and proves it is a potentially important factor in variations in at least some aspects of children's language development and use. At the very least, it is certainly a factor that warrants further exploration.

The high correlation between conversational turns and child vocalizations, as well as the higher than average number of conversational turns, give us important information about family interaction styles. It shows that these children were most likely conversing with their parents, rather than talking to themselves all day. It also shows that a great deal of the parent talk was most likely directed towards the child. In a very directive interaction style, it is unlikely there will be high levels of turn taking, as the child will most likely lose interest in the adult's chosen subject matter quickly. However, if the adult is following the child's lead in regards to the subject of discussion, as in the responsive interaction style (Girolametto et al., 1999), the child's interest is stimulated and the conversation may last longer, leading to more adult and child talk, as well as higher numbers of conversational turns. Since the responsive interaction style produces higher levels of child language according to Girolametto et al. (1999), it makes sense that conversational turns are also correlated with amount of child and adult speech. The LENA study also showed a correlation between conversational turns and parent and child word counts, further emphasizing that families of children with CIs are similar to those with hearing children. Children who talk more typically engage in more conversational turn taking than those who talk less, whether or not they have a CI.

Several studies (Gilkerson & Richards, 2009; Hart & Risley, 1995; Huttenlocher et al., 2007) have shown that the amount of language used in the home is associated with the socioeconomic status (SES) of parents. Gilkerson and Richards (2009) and Hart and Risley (1995) both found that amount of parental input is associated with SES, specifically that parents and children of low SES talk less. The parents talk significantly less to their children, which leads to lower levels of child language. Huttenlocher et al. (2007) likewise found low SES to be associated with poorer language skills in children. In the present study however, variation in *amounts* of adult (and child) language was not associated with SES in the way it is with parents of hearing children. Rather than low SES being a predictor of low levels of parental input and likewise the amount of child speech, there was a slight negative correlation. Parents with higher levels of education actually talked less to their children, and their children had lower word counts as well. Although SES was negatively correlated, albeit non-significantly, with amount of parent speech, it was positively associated with the child's PLS scores, an effect that was also seen by Geers et al. in 2003. This association suggests that maternal education is affecting the child's overall quality of language skills if not amount of speech.

The small sample size in the present study makes it difficult to determine whether this difference in the effects of SES is a phenomenon unique to parents of children with CIs, or simply an idiosyncrasy of this particular group of parents. However, these parents had several things in common that are unique to the CI population that may have affected the results. It may be that language intervention in the form of clinical services is affecting the way these families relate to each other, specifically the way the parents talk to their children. These parents were most likely encouraged to use a responsive interaction style with their children to promote language development. Almost all of the children in this study attended preschool during the week, and many preschool intervention programs also emphasize parental language input and responsive interaction styles. Children with cochlear implants are often placed in special language-oriented preschools, which could further change family dynamics, possibly rendering SES useless as a predicting factor of language. Furthermore, through their association with an ongoing longitudinal study that utilizes frequent language testing, and even by the act of getting their child implanted, these parents have shown more concern for their child's communication skills than a typical family might for their hearing child. The parents may even have felt they were being "tested" to see if they were implementing strategies learned during other visits with doctors and speech pathologists associated with the longitudinal study. Therefore, it is highly possible that multiple factors are affecting the typical SES effect in these families.

Child Talk

As expected from previous CI research, the children in this study in general scored significantly worse than the normative sample on the PLS-3. Svirsky et al. in 2000 and Schorr et al. in 2008 both found that children with CIs typically score one to two standard deviations below the mean on language tests, so these results were not unexpected. These children illustrated typical performance very clearly, with most of them scoring between one and two standard deviations below the mean, with a couple scattered above and farther below. Surprisingly, however, as a group they talked significantly more throughout the day than normal hearing age mates from the LENA normative study (Gilkerson & Richards, 2008). This might have been expected if the parental talk levels were similarly higher than the normative population, but in general they were not. Again, intervention and factors unique to families with CI children may be responsible for this difference. It is easy to imagine that parents of a deaf child would encourage that child to talk as much as possible once the child is able. If the parents are using responsive interaction styles and following the child's lead, it could cause the child to talk even more while the amount of adult talk remains fairly steady. Furthermore, many programs for children with CIs (such as preschools) encourage them to talk more than they would NH children, since development of language is arguably the reason they received an implant.

The finding that the standardized language scores are poorer than the NH average, but the amount of talking by these children is above average suggests there are factors at play affecting language besides simply parental input. The PLS-3 primarily looks at quality of speech while the LENA looks at quantity. This study found virtually no relationship between the two, while the national LENA study did find a small but significant relationship between them. It is possible that within normal hearing children, the quality and quantity of language tend to parallel each other, but begin to come apart in the CI population. One possible explanation for the discrepancy in this population is that these children may be very chatty, but the types of things they're saying or the syntax and morphology they're using to say them are not developmentally appropriate.

Since the quantity of parental input these children are receiving is similar to that of hearing children, it may be possible to attribute the differences between quantity and quality of the child's speech to factors related to the device itself. One of these factors is simply when the child receives the device. There is a large body of research already showing that the reduction of length of deafness by earlier implantation does improve language development outcomes. Another factor remains whether children with cochlear implants vary with respect to the amount or type of speech information provided by their device. These talkative children may be receptively "missing out" on key pieces of the auditory signal that could significantly change PLS scores without affecting conversation at home, such as the plural /s/ marker for example. This is not to say that parental input does not play a role in the variability in these children. It more than likely does, since there was a relationship between parent and child talk. However, due to the complexity of their hearing and language situation, more research is needed to further explore this relationship.

The families in this study were similar to those in the national LENA study in terms of amount of parental talk. However, the LENA study utilized a much larger sample as well as recordings of the same families more than once. They found substantial variation within and between families, which presents two potential issues for the present study. First, it reduces the strength of any conclusions drawn since the families in this study were recorded only once. Recording multiple times would have lessened the "newness" of the device, and most likely the tendency to interact as though someone were listening. Also, since parental talk can range by up to 50% on any given day according to the LENA study, multiple recordings would have provided a more stable baseline for each family. Second, the results of the LENA study suggest that, since a wide degree of variability is normal in typical families, it should also be expected in families of children with CIs. Further, since we know parental language affects child language and is highly variable across families with CIs as well, the conclusion can be drawn that language skills across children will be highly variable. The question becomes whether children with CIs vary excessively in language skills compared to the normal variation seen in their hearing peers. A substantial amount of research has shown that children with CIs have significant language variation and has tried and explain this variation. However, very little if any has been conducted to determine whether these children are varying by a normal amount, that is, by the same amounts as their NH peers, or if this variation is greater than should be expected. In much the same way one would not expect a random group of NH children to all perform the same on a standardized language measure, we should not expect children with CIs to all perform in a uniform manner when the only similarity they share is their implant. Therefore it is important to further compare this variation to that in normal language learning to see if it really is excessive before any more time is spent attempting to explain the variation.

Insights Gained Regarding the LENA as a Research Tool

The LENA provides a whole new array of exciting possibilities for the field of research in child language development. However, this study, serving as the LENA "guinea pig," has also uncovered several things to keep in mind for future research studies. Both pros and cons of using the LENA as a research tool will be outlined in the hopes that future researchers can receive a head start.

The LENA provides an almost effortless way to look into a child's home language environment. A small recording device that the child wears is much less invasive (and easier to forget about) than a human transcriptionist. In theory this will lead to a natural sample that is a more accurate representation of a typical day. However, it is still recommended that future studies record on multiple days to allow the family to adjust to the device. Several of the families in this study seemed afraid of it at first, particularly of what the research team would think if they listened to the recording. Multiple notes were sent back, describing how their child was "unusually naughty" that day, or how they usually have more patience with the children but it was a rough day, or explaining the circumstances around particular meltdowns. If the families had a chance to see that none of this mattered, they might stop worrying and begin to interact in a more natural way around the device. It is also necessary to explain very clearly that they should try to engage in a typical day. Some of the families seemed to approach it as a test which may have skewed their word count data.

Another important (an unexpected) issue this study unearthed was the issue with the clothing. Several of the girls did *not* like the LENA vests and adamantly refused to wear them. Stickers were provided to decorate the vests, which helped to some extent. However, the best solution was discontinuing use of the vests in favor of t-shirts. The shirts resembled normal clothing more so than the vests, and none of the parents reported problems with them.

If future research is done with children with CIs, it is recommended that a few of the samples be transcribed manually. This was not done in the present study due to time constraints and lack of sufficient manpower, however would allow for deeper investigation into specific interaction styles as well as to see if the LENA is as accurate coding the speech of implanted children as it is with NH children.

Future Research

The LENA normative study utilized several formal language measures, including the *Receptive-Expressive Emergent Language Test-3 (REEL-3)* and the *Bayley Scales of Infant and Toddler Development* to assess the language skills of children as young as 2 months. They found that children had similar language skills early on, and that amount of parental input did not really start making a difference until around age one. From there, the gap became wider and wider as the children with talkative parents surged ahead in language abilities. It is possible a similar effect may be seen for length of spoken language exposure (or device use) in children with CIs. Children with earlier implantation and thus a longer period of spoken language development would be expected to show a greater effect of parental language input than those who have had less of an opportunity for the parental input to take effect. Due to the nature of this study and the small sample size it was impossible to look at the length of use or age of implantation.

However, it would be interesting to see in a longitudinal study based on “hearing age” whether a similar gap is present that can be attributed to amount of parental input.

Another potential use for the LENA in this population would be to track changes in parental input pre and post-implant. It would be interesting to see whether there is a significant change in amount of parental talk from pre to post-implantation, and whether this is associated with the child’s future language skills. Since the LENA gives us our first real glimpse into the home environment of these children, it is a wonderful tool to help us understand more about the complex interactions between parental and child language, and the effects these interactions have on language variability.

REFERENCES

Connor, C.M., Hieber, S., & Arts, H.A. (2000) Speech, vocabulary, and the education of children using cochlear implants: Oral or total communication? *Journal of Speech, Language, and Hearing Research*, 43, 1185-204.

Geers, A.E., & Brenner, C. (2003). Background and educational characteristics of prelingually deaf children implanted by five years of age. *Ear & Hearing*, 24, 2S-14S.

Geers, A.E., Nicholas, J.G., & Sedey, A.L. (2003). Language skills of children with early cochlear implantation. *Ear & Hearing*, 24, 46S-58S.

Gilkerson, J. & Richards, J.A. (2008). The LENA natural language study (LTR-02-2). Boulder, Colorado: LENA Foundation.

Gilkerson, J. & Richards, J.A. (2009). The power of talk 2nd edition: Impact of adult talk, conversational turns, and tv during the critical 0-4 years of child development (ITR-01-2). Boulder, Colorado: LENA Foundation.

Girolametto, L., Weitzman, E., Wiigs, M., & Pearce, P.S. (1999). The relationship between maternal language measures and language development in toddlers with expressive vocabulary delays. *American Journal of Speech-Language Pathology*, 8, 364-374.

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

Huttenlocher, J., Vasilyeva, M., Waterfall, H.R., Vevea, J.L., Hedges, L.V. (2007). The varieties of speech to young children. *Developmental Psychology*, 43, 1062-1083.

James, D., Rajput, K., Brinton, J, & Goswami, U. (2008) Phonological awareness, vocabulary, and word reading in children who use cochlear implants: Does age of implantation explain individual variability in performance outcomes and growth? *Journal of Deaf Studies and Deaf Education*, 13, 117-137.

Moog, J.S., & Geers, A.E. (1999). Speech and language acquisition in young children after cochlear implantation. *Otolaryngologic Clinics of North America*, 32, 1127-1141.

Pisoni, D.B., Cleary, M., Geers, A.E., & Tobey, E.A. (1999). Individual differences in effectiveness of cochlear implants in children who are prelingually deaf: New process measure of performance. *Volta Review*, 101, 111-165.

Ruben, R.J. & Schwartz, R. (1999). Necessity versus sufficiency: the role of input in language acquisition. *International Journal of Pediatric Otolaryngology*, 47, 137-140.

Schorr, E.A., Roth, F.P., & Fox, N.A. (2008). A comparison of the speech and language skills of children with cochlear implants and children with normal hearing. *Communication Disorders Quarterly*, 29, 195-210.

Svirsky, M. A., Robbins, A. M., Kirk, K. I., Pisoni, D. B., & Miyamoto, R. T. (2000). Language development in profoundly deaf children with cochlear implants. *Psychological Science*, 11, 153-158.

Tomblin, J.B., Barker, B.A., Spencer, L.J., Zhang, X, & Gantz, B.J. (2004). The effect of age at cochlear implant initial stimulation on expressive language growth in infants and toddlers. *Journal of Speech, Language, and Hearing Research,* 48, 853-867.

Tomblin, J. B., Spencer, L., Flock, S., Tyler, R., & Gantz, B. (1999). A comparison of language achievement in children with cochlear implants and children using hearing aids. *Journal of Speech, Language, and Hearing Research*, 42, 497-511.