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Linguistic Input, Electronic Media, and Communication Outcomes of Toddlers with Hearing Loss

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Abstract

Objectives—The objectives of this study were to examine the quantity of adult words, adult-child conversational turns, and electronic media in the auditory environments of toddlers who are hard of hearing (HH) and to examine whether these variables contributed to variability in children's communication outcomes.

Design—Participants were 28 children with mild to severe hearing loss. Full-day recordings of children's auditory environments were collected within 6 months of their 2nd birthdays by utilizing LENA (Language ENvironment Analysis) technology. The system analyzes full-day acoustic recordings, yielding estimates of the quantity of adult words, conversational turns, and electronic media exposure in the recordings. Children's communication outcomes were assessed via the receptive and expressive scales of the Mullen Scales of Early Learning at 2 years of age and the Comprehensive Assessment of Spoken Language at 3 years of age.

Results—On average, the HH toddlers were exposed to approximately 1400 adult words per hour and participated in approximately 60 conversational turns per hour. An average of 8% of each recording was classified as electronic media. However, there was considerable within-group variability on all three measures. Frequency of conversational turns, but not adult words, was positively associated with children's communication outcomes at 2 and 3 years of age. Amount of electronic media exposure was negatively associated with 2-year-old receptive language abilities; however, regression results indicate that the relationship was fully mediated by the quantity of conversational turns.

Conclusions—HH toddlers who were engaged in more conversational turns demonstrated stronger linguistic outcomes than HH toddlers who were engaged in fewer conversational turns. The frequency of these interactions was found to be decreased in households with high rates of electronic media exposure. Optimal language-learning environments for HH toddlers include frequent linguistic interactions between parents and children. To support this goal, parents should be encouraged to reduce their children's exposure to electronic media.

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There is extensive evidence that children's early language development is shaped by the linguistic input to which they are exposed. For children with normal hearing (NH), simply being exposed to high rates of linguistic input is associated with positive linguistic outcomes (Huttenlocher et al. 1991; Hart & Risley 1995; Hoff & Naigles 2002; Hurtado et al. 2008). When children have a hearing loss (HL), however, the sensory deficit may negatively impact their ability to consistently access the auditory-linguistic information necessary for successful spoken language development. This may be true not only for children who are deaf, but also for children who are hard of hearing (HH; mild to severe HL). Although the fitting of hearing aids and other assistive listening devices (e.g., FM systems) can improve access to the auditory signal, these devices cannot fully normalize the auditory experiences of these children or their ability to access auditory-linguistic information. An inability to consistently access auditory-linguistic input may lead to language delays, which are commonly reported for these children (Davis et al. 1986; Elfenbein et al. 1994; Wake & Poulakis 2004; Fitzpatrick et al. 2011; see Moeller et al. 2007 for a review).

The auditory experiences of children who are HH differ most notably from those of children with NH during periods in which they do not have access to amplification. This includes the period before initial fitting of hearing aids and periods without amplification due to equipment issues (e.g., broken technology), situations in which hearing aid use is not feasible (e.g., bathtime), and a variety of other device-use challenges (e.g., uncooperative child behavior). Although wearing hearing aids provides children who are HH with increased access to auditory information, these devices are limited in the benefit they can provide. For children with greater degrees or specific configurations of HL, hearing aids simply may not be capable of rendering the speech spectrum fully audible (Bagatto et al. 2011; Stiles et al. 2012). Additionally, bandwidth limitations prevent hearing aids from providing many HH children with access to speech sounds produced with high spectral energy, especially when produced by females and children (Stelmachowicz et al. 2001). Furthermore, hearing aids may be limited in effectiveness when faced with the physiological limits imposed by the sensory deficit. Similarly, they may not render speech fully intelligible when used in auditory environments that are less than ideal, including those with background noise, reverberation, or substantial distance between the listener and speaker. These factors may contribute to HH children experiencing inconsistent auditory access to meaningful linguistic information. As a result, even when HH children are exposed to high rates of linguistic input, there may be constraints in the amount of input that is actually accessed by these children. Harris (1992) referred to this as a limitation in uptake, which is the "part of the input that is actually attended to by the child" (p. 44).

Contributions of Quantity of Linguistic Input to Communication Outcomes

The limitations in accessing linguistic input experienced by HH children are concerning given the substantial research literature establishing strong relationships between early language exposure and later language outcomes for children with NH. In their study of children's everyday experiences, Hart and Risley (1995) found that quantity of caregiver talk was a better predictor of children's linguistic outcomes than any other feature of their early language experiences. Other studies have provided support for this notion, finding that children of talkative mothers exhibit stronger vocabulary growth and faster lexical processing than children of less voluble mothers (Huttenlocher et al. 1991; Hoff & Naigles 2002; Hurtado et al. 2008).

The importance of linguistic input for language learning is evident from the earliest stages in development. During the first year of life, infants demonstrate an increasing ability to track statistical regularities in the linguistic input to which they are exposed. For example, Saffran and colleagues (1996) reported that infants use statistical properties of language to identify

word boundaries in the stream of linguistic input provided by their caregivers. The process of learning words is similarly data driven; children must first learn to segment word forms into their phonological components and then must map the meaning of the word onto its phonological form. Language learning of this type is facilitated by high rates of linguistic input, as larger amounts of input provide children with more information from which to identify and learn the patterns of language.

Simply exposing children to high rates of linguistic input is not sufficient for language learning though, as demonstrated in recent work by the Language Learning Lab at Stanford University (Fernald & Weisleder, Reference Note 1; Marchman & Weisleder, Reference Note 2). The research team examined the contributions of two types of caregiver speech in the environments of 18-month-old Latino children: speech that was directed to the child and speech that was directed to an adult but overheard by the child. The team found that the amount of child-directed speech at 18 months of age was correlated with the size of children's productive vocabularies and the speed of their language processing at 24 months of age. However, the amount of overheard speech was not predictive of later vocabularies or processing speeds. This work supports the concept that social interactions are necessary to promote children's early language learning (Kuhl 2004, 2010). During parent-child interactions, parents and young children are likely to be focused on a topic of shared joint attention, which may increase the probability that the parent is providing linguistic input about a topic of interest to the child and that the child will attend to and benefit from the linguistic input (Tomasello & Farrar 1986). Additionally, during these interactions parents are likely to adapt their language input to the child's language level, thus making the input particularly accessible to the child. These situations also encourage the child to communicate with the adult, thus giving the child practice with their own language skills and the parents the opportunity to provide their child with responsive feedback. This latter aspect may be especially important, as children whose mothers are highly responsive to their communicative attempts tend to develop stronger language skills than children whose mothers are less responsive (Baumwell et al. 1997; Nittrouer 2010). This finding has been reported for both children with NH and children with HL.

Input Quantity: Parent and Child Contributions

Differences in talkativeness have been identified between groups of parents. For example, more advantaged parents (i.e., those with more education or higher incomes) tend to be more talkative than less advantaged parents (Hoff-Ginsberg 1994; Hart & Risley 1995; Hoff 2003b; Shimpi & Huttenlocher 2007; Rowe 2008). This is true both in interactions with other adults and with their own children (Huttenlocher et al. 1991; Hoff 2003a), which implies that there may be inherent differences in talkativeness between parents of different socioeconomic backgrounds. Although there are differences in how talkative different parents are, in general an individual parent's tendency to be talkative or taciturn is relatively stable across interactional situations and over time. That is, parents who are talkative in interactions with their own young children are likely to also be talkative when interacting with adults and other children (Smolak & Weinraub 1983; Huttenlocher et al. 1991; Hoff 2003b) and with their own children when they are older (Olsen-Fulero 1982; Huttenlocher et al. 1991; Shimpi & Huttenlocher 2007).

¹Fernald, A., Weisleder, A. (2011, April). How and why early experience is so crucial in learning language. Paper presented at the LENA Users Conference, Denver, CO.

²Marchman, V. A., Weisleder, A. (2011, June). Exploring meaningful differences in the lives of children: Strengths and limitations of LENA in research using naturalistic language sampling. Paper presented at the Symposium on Research in Child Language Disorders, Madison, WI.

Although general parent talkativeness is driven by factors independent of the child, there is also likely a bidirectional relationship between quantity of parental linguistic input and child language abilities. Evidence of child influences comes from findings that the frequency and/or length of parent-child conversational interactions increase across the first two years of children's lives (Gilkerson & Richards 2008), presumably as children's language skills develop and they become more capable conversationalists. However, child language abilities do not independently drive quantity of parental linguistic input. Recent studies indicate that the frequency with which parents talk to their children (Hurtado et al. 2008) and engage their children in conversational turns (Zimmerman et al. 2009) contributes unique variance to children's later language abilities, even after controlling for earlier child language abilities. Thus both child and parent characteristics contribute to the relationship between linguistic input and child language, making it difficult to tease apart the separate influences of each conversational partner.

Impact of Electronic Media on Quantity of Linguistic Input

Environmental factors also play a role in the quantity of linguistic input to which children are exposed. One such environmental factor is the background or foreground presence of electronic media, such as television programming, video-games, and DVDs/videos. In a recent survey, almost half of all children under the age of three were reported to watch more than an hour of direct television programming per day (Rideout et al. 2003). Additionally, recent research indicates that children between the ages of 8 and 24 months are exposed to an average of 5 ½ hours of background television each day (Lapierre et al. 2012). These findings are worrisome, given research documenting a negative relationship between television exposure and the language outcomes of young children (Vandewater et al. 2005; Chonchaiya & Pruksananonda 2008; Tomopoulos et al. 2010). It has been hypothesized that the negative effect of television exposure on language outcomes is mediated by a negative relationship between television exposure and parent-child verbal interactions (Tanimura et al. 2007). That is, in the presence of electronic media, parents may engage their children in high-quality conversational interactions less frequently and, in turn, children may be presented with fewer language-learning opportunities. This notion was supported by a study examining television exposure and parent-child conversations in the environments of 275 children between 2 and 48 months of age (Zimmerman et al. 2009); the authors found that television exposure had a negative effect on language outcomes, but that the effect was fully mediated by rates of adult-child conversations.

The reasons for the negative effects of electronic media on the quantity and quality of parent-child linguistic interactions have not been firmly established. One possibility is that television serves as an audiovisual distractor for parents and children, thus decreasing the likelihood that they will participate in sustained interactions in the presence of visible or audible electronic media. Indeed, in the presence of television, toddlers have been reported to demonstrate decreases in their ability to sustain focused attention on an activity (Schmidt et al. 2008) and parents have been reported to be less responsive to their children's bids for attention (Kirkorian et al. 2009). Additionally, television viewing may displace parent-child activities that are known to be especially rich in linguistic input, such as book reading (Vandewater et al. 2006; Nathanson & Rasmussen 2011).

Linguistic Input to Children who are Hard of Hearing

Given the inconsistent auditory access experienced by children who are HH, they may need to be exposed to even larger amounts of linguistic input than children with NH to experience the same levels of input and ultimately uptake. This concept is supported by several word-learning studies indicating that children who are HH require more exposures to a word than

children with NH to add it to their lexicon (Lederberg et al. 2000; Stelmachowicz et al. 2004; Pittman et al. 2005; Lederberg & Spencer 2009). Additionally, children who are HH have difficulty accessing linguistic input when the speaker is at a distance, which results in these children having less access to overheard speech than children with NH who can utilize this route for word learning by 18 months of age (Gampe et al. 2012). This indicates that linguistic input within conversational interactions (during which the parent and child are likely to be located in close proximity to one another) may be especially critical for this population.

The majority of research on linguistic input to children with HL was conducted before recent advances in newborn hearing screening and amplification technologies or has focused exclusively on linguistic input to children who are deaf and use cochlear implants. Although a comprehensive review of the literature involving these children is beyond the scope of the current work, there are two pertinent studies that examined linguistic input to children with a range of HL (both deaf and HH). Aragon and Yoshinaga-Itano (2012) found that the toddlers with HL in their study were exposed to adult words and engaged in conversational interactions at similar rates as children with NH. Similarly, Nitttrouer (2010) reported that the parents of children with HL in their study communicated with their children about the same amount as the parents of children with NH. However, between-group differences emerged when examining how verbally responsive the two groups of parents were to their children's communicative attempts, with parents of children with HL being less verbally responsive. Further, for the children with HL, parental verbal responsiveness, but not overall amount of talk, was related to children's outcomes. That is, children whose parents were more verbally responsive developed stronger language abilities than children with less verbally responsive parents.

The current investigation makes use of the LENA (Language ENvironment Analysis) system to collect and analyze full-day recordings of the auditory environments of children who are HH. Early findings from this work were reported in a recent manuscript examining whether young children who are HH received similar levels of exposure to linguistic input as age-matched peers with normal-hearing (VanDam et al. 2012). Twenty-two HH children and eight NH children contributed data to the study when they were 24 to 36 months of age and comparisons were made to normative data from the LENA Foundation. Our findings fit with those of the two previously described studies; the HH children were exposed to similar numbers of adult words and engaged in similar numbers of conversational turns as children with NH (VanDam et al. 2012). For a subgroup of 19 children, we also examined the relationships between quantity of linguistic input and children's receptive language abilities at the same time point. We found that the number of conversational turns, but not the number of adult words, was related to children's receptive language abilities.

In the current manuscript, we further explore the relationships between linguistic input and communication outcomes for a larger group of HH toddlers ($n = 28$). This effort includes expansion of the communication outcomes to include both receptive and expressive language at two years of age and a communication outcomes measure at three years of age. Additionally, we have extended the focus of our work to also examine the relationships between quantity of electronic media in HH children's auditory environments and their communication outcomes. Currently, we know little about how exposure to electronic media is related to language outcomes for children who are HH. However, if high rates of linguistic input are especially critical for children who are HH and rates of linguistic input decrease with increasing exposure to electronic media, then electronic media exposure may be especially detrimental for children who are HH. Additionally, children who are HH have well-documented difficulties with word recognition in the presence of background noise (Finitzo-Hieber & Tillman 1978) and electronic media serves as one source for background

noise. Thus, the potential for children who are HH to benefit from linguistic input provided in the presence of electronic media, or to engage in conversational interactions when in the presence of electronic media, may be decreased in comparison to their NH peers. We hypothesized that electronic media exposure would be negatively related to outcomes for HH children and that this relationship would be mediated, at least in part, by a negative relationship between electronic media exposure and adult-child conversations.

Objectives

The first objective of this study was to examine the quantity of adult talk, adult-child conversations, and electronic media exposure in the auditory environments of toddlers who are HH. The second objective was to examine whether these variables contributed to variability in HH children's communication outcomes.

Method

Participants

Twenty-eight children (10 males, 18 females) with borderline normal-to-severe, bilateral, permanent HL and their families participated in this study. Families lived in six US states and represent a subgroup of families participating in the Outcomes of Children with Hearing Loss (OCHL) study; a multi-center, longitudinal study investigating the outcomes of children who are HH. Families of OCHL participants were invited to participate in the investigation on auditory environments if the participant was between the ages of 12 and 36 months during the recruitment window. Comparison of maternal education and household income identified no differences between the substudy participants and the full OCHL cohort. This study was approved by the Internal Review Boards at Boys Town National Research Hospital, the University of Iowa, and the University of North Carolina Chapel Hill.

Eligibility criteria for children in the current study were 1) a bilateral HL (sensorineural, mixed, or permanent conductive) with a better-ear three- or four frequency pure-tone average (PTA) no better than 25 dB HL and no poorer than 75 dB HL¹, 2) no reported or observed major cognitive, visual, or motor impairments, 3) spoken English as the primary communication mode, and 4) at least one caregiver in the home who spoke English. Data for this study were collected during study visits that were conducted as close as possible to children's second and third birthdays and from recordings of auditory environments that were collected within 6 months of the child's second birthday (as described in the Procedures section).

During study visits, parents were asked to report on maternal education, their child's audiologic history, and the duration of their child's hearing aid use on a typical day (see Table 1). The majority of children (89%) were identified through newborn hearing screening programs and all children were fit with hearing aids by 12 months of age. Twenty-seven children wore bilateral behind-the-ear (BTE) air-conduction hearing aids and one child wore a bone conduction aid. All children regularly wore their hearing aids, with the majority (24 of 28) typically wearing their hearing aids for eight or more hours per day.

To fully characterize children's hearing losses, audiologic evaluations were completed by a certified audiologist with pediatric experience and a test assistant. The audiologist attempted

¹Exceptions to this criterion were made to allow for inclusion of children with bilateral, high-frequency hearing loss that resulted in a better ear PTA of at least 20 dB HL. Additionally, children with hearing losses that initially fit this criterion but that later progressed beyond 75 dB HL were retained in the study, unless they received a cochlear implant.

to obtain air-conduction and bone-conduction thresholds at 500, 1000, 2000, and 4000 Hz at a minimum, using visual reinforcement audiometry or conditioned play audiometry, depending on the age of the child. All attempts were made to obtain ear-specific thresholds utilizing insert earphones, circumaural headphones, or the child's own earmolds paired with insert earphones. Audiologists obtained soundfield thresholds if the child would not tolerate the testing with earphones or headphones. Twenty-one children had bilateral sensorineural HL and one child had a permanent bilateral conductive loss. For the remaining seven children, bone conduction testing could not be completed during the study visit, thus the loss type could not be definitively categorized as either a pure sensorineural loss or a mixed loss. Better-ear PTAs are displayed in Table 1.

To estimate the proportion of the amplified speech spectrum that was audible to the children when wearing their hearing aids, hearing aid and real ear measurements were completed using the Audioscan Verifit following ANSI protocol S3.22 (2003). Audioscan Verifit software was then used to calculate the aided speech intelligibility index (SII), using the standard male speech signal (carrot passage) presented at 65 dB SPL, following ANSI S3.5 (1997). Better-ear SII for the 27 children wearing air conduction hearing aids is reported in Table 1.

Procedures

Auditory environment assessment—Recordings were collected and analyzed using the LENA system (Language ENvironment Analysis; LENA Foundation, Boulder, CO). The primary components of the system are the Digital Language Processor (DLP) and related software. The DLP is an acoustic recording device that weighs 2 ounces and is approximately the size of a deck of cards. The device is worn by the child in a chest pocket on an outer piece of specially-designed clothing. The clothing allows for the DLP to be worn comfortably and unobtrusively for a full day while maintaining the microphone at a relatively fixed distance from the child's mouth. The DLP records up to 16 hours of raw audio, which is transferred to a computer after the recording is complete and analyzed with the associated software. The proprietary speech recognition software segments the audio and labels each segment as adult male, adult female, key child, other child, overlapping speech, noise, silence, or *electronic media sound* (e.g., sound from televisions, radios, and computers). The software outputs duration measures for each label, an estimate of the number of adult words in the recording, and an estimate of the number of vocal interactions, or conversational turns, that occur between the key child and an adult during the recording (defined as a key child vocalization followed by an adult vocalization within 5 seconds, or vice versa). Xu and colleagues (2009) examined the reliability and validity of segment categorization in seventy 12-hour recordings. Using the human transcriber as the gold standard, they found that software accurately identified 82% of the adult speech segments, with 2% erroneously coded as child speech and 4% erroneously coded as television. Similarly, the software accurately identified 76% of child speech segments, with 7% of segments erroneously coded as adult speech and 0% erroneously coded as television. The reliability and validity of coding for the language indices has also been assessed and reported in other publications (Zimmerman et al. 2009; Christakis et al. 2009; Oller et al. 2010; VanDam & Silbert 2013). Normative data for the language indices is available via the LENA Foundation Natural Language Study (Gilkerson & Richards 2008).

To collect the recordings, families were shipped the DLP, custom clothing with a pocket to hold the device, paperwork including detailed instructions on device use, and return packaging. Parents were instructed to begin recording as soon as the child awoke in the morning and to have the child wear the device for the full day, with the exception of taking the custom clothing and device off and placing it near the child during bathtime and

naptime. Parents were asked to turn the device off only when the child went to sleep for the final time in the evening. After completion of the recording, parents shipped the device and related items back to the research centers. The LENA software was then utilized to upload and analyze the audio recordings. Similar procedures were followed in previous studies with the LENA system (Oller et al. 2010; Warren et al. 2010), including the LENA Natural Language Study, which provided the data utilized in the primary software (Gilkerson & Richards 2008).

Measures obtained from the LENA software for each day-long recording were 1) estimates of the number of adult words spoken in the child's auditory environment, 2) estimates of the number of conversational turn-taking interactions between the child and adults, and 3) the total duration of all segments classified as electronic media. Children contributed monthly recordings to the project over the course of approximately one year; however for the current study data were only included from recordings collected within 6 months of children's second birthdays. Given that children were enrolled in the project at varying ages, the number of recordings available within 6 months of their second birthdays varied ($M = 6.14$, $SD = 2.79$, range: 1-11). The average age across recordings for each child was 25.75 months. Fifty-five percent of the recordings were collected on weekdays. The recordings ranged from eight to 16 hours in length ($M = 12.19$, $SD = 1.64$). To account for the variability in recording length, the variables of interest were normalized by the recording duration, resulting in adult word count per hour (AWC), conversational turn count per hour (CTC), and percent of each recording classified as electronic media. For the 27 children who contributed more than one recording to the data set, these values were averaged across recordings to control for inter-session variability, a procedure that has been used in other LENA research (Warren et al. 2010; Gilkerson & Richards 2008).

Communication outcomes—When children were approximately 2 years of age, their communication abilities were assessed via the receptive and expressive language scales of the Mullen Scales of Early Learning (MSEL; Mullen 1995). The MSEL combines clinician-elicited and parent-reported items. Raw scores are used to calculate an age-normed T-score with a mean of 50 and a standard deviation of 10. When children were approximately 3 years of age, their communication abilities were assessed via the Comprehensive Assessment of Spoken Language (CASL; Carrow-Woolfolk 1999). The CASL is a clinician-elicited standardized test that assesses children's lexical/semantic, syntactic, and pragmatic knowledge. There are three core tests for children who are 3 years of age: Basic Concepts, Syntax Construction, and Pragmatics. Age-normed standard scores were computed for each of the three core tests and were used to calculate a composite standard score with a mean of 100 and a standard deviation of 15.

Results

Descriptive Data

Auditory environments—The children were exposed to an average of approximately 1400 adult words per hour and engaged in approximately 60 conversational turns per hour (see Table 2). Additionally, an average of 8% of each recording was classified as Electronic Media. This equated to children being exposed to approximately one hour of Electronic Media each day. However, there was considerable within-group variability on all three measures, as displayed in Figure 1. On average, children in the highest quartile for AWC were exposed to 2.8 times more words than children in the lowest quartile for AWC and children in the highest quartile for CTC were engaged in 2.6 times more conversational turns than children in the lowest quartile for CTC. Additionally, children in the highest quartile

for Electronic Media were exposed to almost five times as much electronic media as children in the lowest quartile.

Given previous research establishing that quantity of parent talk and television exposure are related to socioeconomic status, we calculated Pearson correlation coefficients for the relationships between maternal education (used as a proxy for socioeconomic status) and the auditory environment variables. No significant relationships emerged (all $p > .376$), which may have been attributable to the relatively narrow range of maternal education in our sample. The lack of significant relationships indicated that it was not necessary to control for maternal education in the remaining analyses. We also examined whether there were differences between males and females on the auditory environment and communication outcome variables, given that gender has been found to play a role in social and linguistic development. No differences were found between males and females for the auditory environment variables (all $p > .18$, all $t < 1.37$) or the communication outcomes (all $p > .42$, all $t < 0.82$). Additionally, we calculated Pearson correlation coefficients to examine whether the three auditory environment variables were related to one another. AWC and CTC were highly correlated ($r = 0.70$, $p < 0.01$). Additionally, there was a significant negative relationship between CTC and Electronic Media ($r = -0.52$, $p < 0.01$). The negative relationship between AWC and Electronic Media did not reach significance ($r = -0.36$, $p = 0.06$).

Communication outcomes—Means, standard deviations, and ranges are presented for the children's scores on the communication outcome measures in Table 2. At the 2-year visit, the children scored, on average, near the normative mean of 50 on the receptive and expressive language scales of the MSEL (Receptive $M = 47.7$, $SD = 14.3$; Expressive $M = 47.1$, $SD = 12.5$). At the 3-year visit, the average score for the HH children ($M = 90.7$, $SD = 15.5$) deviated further from the normative mean, as evidenced by a significant difference between the group's average score and the normative mean of 100 on the CASL ($t = -2.90$, $p < 0.01$). At both time points, approximately one quarter of the sample scored more than one standard deviations below the normative mean. The range of scores was relatively wide, with at least some children scoring more than two standard deviations above and below the normative mean on each measure.

Relationships Between Auditory Environment Variables and Communication Outcomes

Pearson correlations between the auditory environment variables (AWC, CTC, Electronic Media) and the communication outcome variables (MSEL Receptive, MSEL Expressive, CASL) are shown in Table 3. Significant correlations were identified between CTC and the three outcome variables, indicating that children who were engaged in the most conversational turns at 2 years of age demonstrated the strongest communication outcomes at 2 and 3 years of age (see Fig. 2). In addition, there was a significant negative correlation between Electronic Media and MSEL Receptive, indicating that children who were exposed to electronic media most frequently had the weakest receptive language abilities at 2 years of age. No other significant relationships were identified.

To explore whether CTC mediated the relationship between Electronic Media and MSEL Receptive, we conducted a multiple linear regression with MSEL Receptive as the dependent variable and CTC and Electronic Media as the independent variables. The overall model was significant, with CTC and Electronic Media explaining a combined 41% of the variance in MSEL Receptive scores, $F(2, 23) = 7.90$, $p < 0.01$. Only CTC was a significant predictor of MSEL Receptive ($b = 0.33$, $t = 2.71$, $p = 0.01$), with the semipartial correlation indicating that CTC uniquely explained 19% of the variance in MSEL Receptive. Electronic Media was not a significant predictor of MSEL Receptive after controlling for CTC ($b =$

$-0.65, t = -1.15, p = 0.26$). Thus, while Electronic Media was significantly correlated with MSEL Receptive, Electronic Media did not explain a significant amount of the variance in this variable after accounting for CTC. This indicates that the effect of Electronic Media on MSEL Receptive was fully mediated by CTC. To further explore the relationship between Electronic Media and CTC, we conducted a simple linear regression with Electronic Media as the independent variable and CTC as the dependent variable (see Fig. 3). The slope of the regression line indicated that for every percent increase in Electronic Media, CTC decreased by 2.44, on average ($t = -3.12, p < 0.01$).

Discussion

Linguistic Input: Adult-Talk and Adult-Child Conversations

The average rates of linguistic input for the HH children in this study were remarkably similar to the average rates recently reported for twenty-four 14- to 32-month-old children who were deaf or HH (Aragon & Yoshinaga-Itano 2012). Additionally, the average rates for both groups were higher than those rates reported for the 50th percentile in the normative data for 24-month-old children with NH (Gilkerson & Richards 2008). The differences between the normative sample's linguistic exposure rates and those of both samples of children with HL may be partially attributable to differences in socioeconomic status (SES). In the normative sample, 14% of the mothers had not completed high school and only 25% had a college degree. In contrast, in the current study and the Aragon and Yoshinaga-Itano study, all mothers had completed high school and over 60% had completed a college degree. In their examination of the normative data, Gilkerson and Richards (2009) found that parents who had not completed high school provided their children with significantly less linguistic input than parents who had a college degree. Although we did not find a relationship between maternal education and linguistic input rates in the current study, this may be attributable to the relatively narrow range of maternal education in our sample.

SES is likely not the only factor contributing to differences between the auditory environments of the children with HL and the children with NH. In VanDam et al. (2012), we hypothesized that differences in linguistic input to children who are HH and NH might also be attributable to the fact that all of the HH families' were involved in early intervention services. Early intervention service providers often coach parents regarding communication techniques that are likely to promote their children's language development, including providing children with high rates of linguistic input and engaging children in frequent conversational interactions (Cole & Flexer 2008). However, as our work and the Aragon and Yoshinaga-Itano (2012) study did not directly examine the intervention contexts, further research is needed to make definitive conclusions regarding the contributions of early intervention to rates of linguistic input.

To determine whether high rates of linguistic input promoted communication development for toddlers who were HH, we examined the contributions of AWC and CTC at 2 years of age to children's communication abilities at 2 and 3 years of age. We found that variability in CTC, but not AWC, was associated with variability in children's communication outcomes at both time points, with children who were engaged in the most conversational turns demonstrating stronger language abilities than children who were engaged in fewer conversational turns. There are a number of possible explanations for these findings. The relationship between CTC and communication outcomes may be, in part, attributable to the contributions of linguistic input within conversational interactions to promoting language development (Tomasello & Farrar 1986; Zimmerman et al. 2009; Tomasello & Farrar 1984; Fernald & Weisleder, Reference Note 1). This input may be even more beneficial for children's language development than adult-directed input or monologues, which are both represented in AWC, because conversational interactions are likely to include episodes of

joint attention and provision of contingent responses, features which are known to be facilitative of language development. Nitttrouer's (2010) finding that quantity of parental verbal responses was more important than quantity of other parental linguistic input for children with HL emphasizes the importance of this characteristic of conversational interactions. For children who are HH, another possible advantage of linguistic input within conversational interactions is that this input may be especially likely to occur when parents and children are in close physical proximity to one another, which would increase the likelihood that the input is audible and therefore accessible to HH children. Additionally, parents are able to monitor whether their children are successfully accessing linguistic input within these interactions and thus can make adaptations in the environment or their own language use as necessary. Another explanation for our findings is that the relationship between CTC and communication outcomes is likely bidirectional. That is, children with more advanced language skills may be more capable of responding to input from their parents, thus increasing the number and length of conversational interactions.

Electronic Media Exposure

We also examined the quantity of Electronic Media in the auditory environments of toddlers who are HH, in part because of a concern that electronic media may interfere with audibility and/or accessibility of linguistic input for children who are HH. We found that an average of 8% of each recording (the equivalent of 58 minutes in a 12-hour recording) was classified as electronic media, which is the same figure reported for toddlers with HL in the Aragon and Yoshinaga-Itano (2012) study. Although no normative data are available for this measure, this amount of electronic media exposure is similar to figures reported by Zimmerman and colleagues (2009) for 275 children with NH between the ages of 2 and 48 months: an average of one hour per full-day recording.

We found that Electronic Media was negatively correlated with children's scores on a measure of receptive language, thus indicating that HH toddlers who were exposed to higher rates of electronic media demonstrated weaker receptive language abilities. No significant correlations were identified between Electronic Media and children's expressive language abilities at 2 years or communication outcomes at 3 years. As we anticipated, regression analyses indicated that the effect of Electronic Media on children's receptive language abilities was fully mediated by CTC. That is, children who were exposed to higher rates of Electronic Media were also engaged in fewer conversational turns and that relationship, in turn, was associated with weaker receptive language abilities. These findings fit with those reported by Zimmerman and colleagues (2009); they found a negative relationship between electronic media exposure and NH children's language outcomes 18 months later, even when controlling for children's earlier language abilities. This led the authors to conclude that the adverse effects of electronic media exposure operated by reducing opportunities for parent-child interactions, a finding that also appears to apply to the HH children in our sample.

Clinical Implications

This work provides additional support for current early intervention practices that encourage parents to engage their children in language-rich activities that involve joint attention, turn-taking, and high rates of linguistic input. It appears that these techniques may already be working for some families, given the relatively high rates of linguistic input we observed, on average, in the auditory environments of HH toddlers. However, we also found that despite enrollment in early intervention programs, some families were providing their children with substantially less linguistic input than others. These findings justify using LENA technology to identify these families. Additionally, a recent preliminary study has demonstrated that

LENA technology may be a useful tool for stimulating positive changes in the linguistic behaviors of caregivers (Suskind et al. 2013).

Our results also suggest that parents should be directly counseled regarding the potentially negative effects of foreground and background electronic media, such as television programming and DVD viewing, on the frequency of parent-child interactions. Although the detrimental effects of such exposure for toddlers may seem obvious, there are numerous television programs and DVDs that are marketed to parents of infants and toddlers with promises of promoting children's cognitive and linguistic development. However, research findings do not support the potential for such benefits (Vandewater et al. 2005; Chonchaiya & Pruksananonda 2008; Tomopoulos et al. 2010). In this study, we found that although some HH toddlers were being exposed to negligible amounts of electronic media, others were being exposed to electronic media for as much as 20% of their day. Families in this circumstance may benefit from encouragement to reduce children's exposure to electronic media, potentially with use of LENA technology to provide ongoing feedback on their progress and the impact of their efforts on the rate of parent-child linguistic interactions.

Limitations and Future Research Directions

There are several methodological characteristics of the current study, including the small sample size, that limit the generalizability of our findings to other groups of HH children. One limitation was the limited variability in SES, thus future investigations should examine linguistic input and electronic media exposure in the environments of low-SES families with HH children. Additionally, we examined children's auditory environments during a relatively narrow age window, thus these results may not be generalizable to children who are younger or older than our current sample. Future investigations with other ages are warranted, as electronic media exposure and its effect on conversational interactions and language development may differ across ages. It is unclear whether children at older ages might be even more susceptible than younger children to the negative effects of electronic media on linguistic development or, on the other hand, whether they may be more capable of benefitting from linguistic input provided by electronic media. Additionally, future investigations should include a wider array of communication outcome measures, as high rates of linguistic input may be more beneficial for some aspects of language learning than others.

Our reliance on the automated analyses provided by the LENA technology lead to limitations in the questions we could address. For example, the technology does not encode qualitative aspects of linguistic input that may be important contributors to the language development of children with HL, such as parental use of visual information (e.g., gesture) or the complexity of parents' utterances. Thus we are currently using other methodologies to explore these variables. Additionally, at this point, the LENA technology is only useful in determining whether or not audible electronic media is present in any given audio segment; it is not capable of determining the source of the electronic media (e.g., radio versus television) or whether the source is in the background or foreground. As the LENA technology is continuously revised, it may become possible to investigate whether various sources for electronic media exposure contribute differently to the linguistic input experienced by HH children.

Conclusions

HH toddlers who were engaged in more conversational turns demonstrated stronger linguistic outcomes than HH toddlers who were engaged in fewer conversational turns. The frequency of conversational interactions was decreased in households with high rates of electronic media exposure. To promote optimal language-learning environments for HH

toddlers, parents should continue to be coached to engage their children in frequent linguistic interactions. Additionally, to support this goal, they should be encouraged to reduce their children's exposure to electronic media.

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In this study, the quantity of adult words, adult-child conversational turns, and electronic media in the auditory environments of 28 toddlers who are hard of hearing (HH) was documented and relationships between these variables and children's communication outcomes were explored. Results indicated that HH toddlers who were engaged in more conversational turns demonstrated stronger communication outcomes than HH toddlers who were engaged in fewer conversational turns. The frequency of conversational interactions was found to be decreased in households with high rates of electronic media exposure.

Figure 1. Box-plots displaying medians and quartiles for the auditory environment variables. AWC = Adult Word Count, CTC = Conversational Turn Count.

Figure 2. T-scores for the Receptive and Expressive scales of the Mullen Scales of Early Learning (MSEL) are plotted as a function of Conversational Turn Count (CTC). The solid diagonal line represents the linear regression line for MSEL Receptive and the dotted diagonal line represents the linear regression line for MSEL Expressive.

Figure 3. Conversational Turn Count (CTC) is plotted as a function of Electronic Media. The diagonal line represents the linear regression line.

Table 1

Demographic and Audiologic Data for Participants

Variable	<i>n</i>	<i>M</i>	<i>SD</i>	Range
Maternal education (years)	27 ^a	15.8	2.3	12–20
Age at HA fit (months)	28	4.8	3.0	1.5–12.0
HA use (hours per day)	28	10.2	2.7	2–15
Better ear PTA (db HL)	28	49.9	14.1	22.5–82.5
Better ear aided SII	27 ^b	0.71	0.17	0.28–0.93

^a One family declined to provide information regarding maternal education.

^b SII could not be calculated for one child because the child wore a bone conduction hearing aid.

Note. HA, hearing aid; PTA, pure tone average; SII, speech intelligibility index.

Table 2

Descriptive Data for Auditory Environment and Communication Outcome Variables

Variable	<i>n</i>	<i>M</i>	<i>SD</i>	Range
Auditory environment recordings (age in months)	28	25.8	3.1	20–30
AWC (count per hour)		1429.4	522.2	570–2445
CTC (count per hour)		58.7	21.5	16–103
Electronic Media (% of recording)		8.2	4.6	1–18
2-year communication outcomes (age in months)	26 ^a	24.7	1.0	23–27
MSEL Receptive (T-score)		47.7	14.3	20–71
MSEL Expressive (T-score)		47.1	12.5	25–72
3-year communication outcomes (age in months)	26 ^b	36.6	1.8	34–43
CASL Composite (standard score)		90.7	15.5	63–118

^aTwo children were not administered the MSEL, one due to a late age at enrollment and another due to illness.

^bTwo children were not administered the CASL. One child dropped out of the study and another had a progressive hearing loss and received a cochlear implant.

Note. AWC, Adult Word Count; CASL, Comprehensive Assessment of Spoken Language; CTC, Conversational Turn Count; MSEL, Mullen Scales of Early Learning.

Table 3

Correlations Between Auditory Environment and Communication Outcome Variables

	AWC	CTC	Electronic Media
MSEL Receptive (2 years)	.339	.611**	-.467*
MSEL Expressive (2 years)	.138	.454*	-.188
CASL Composite (3 years)	.021	.449*	-.142

*
 $p < 0.05$.**
 $p < 0.01$.