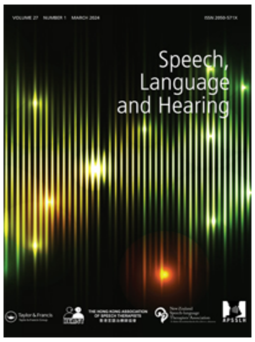

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Analysis of natural language input in preschool children with and without hearing loss: quantity, caregiver response types, and influence of demographic factors

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ABSTRACT

This study investigated language input (adult word count, AWC; conversational turn count, CTC; response types; high-, mid-, and low-level) and language outcomes (receptive, expressive) in children aged 2–5 years with hearing loss (CwHL) and those with normal hearing (CwNH). Associations between language input and outcomes, relationships between language input, and demographics were examined. Language input was analyzed using full-day Language Environment Analysis (LENA) audio-recordings, and language outcomes were assessed using standardized language assessments in 14 CwHL and 20 CwNH. There were no significant differences in language input between CwHL (AWC/hr: $M = 1137$, $SD = 554$; CTC/hr: $M = 48.26$, $SD = 19.18$) and CwNH (AWC/hr: $M = 1243$, $SD = 426$; CTC/hr: $M = 60.94$, $SD = 21.34$). There were, however, significant differences between groups in response types and language outcomes. Caregivers of CwHL used less high- and more mid- and low-level responses than caregivers of CwNH ($p = < .01$). Language input in CwHL showed no association with language outcomes, and there were no correlations with demographic factors. For CwNH, receptive language was correlated with AWC/hr, CTC/hr, and high- and low-level response types ($p = < .01$); and expressive language was correlated with AWC/hr ($p = < .01$), CTC/hr ($p = .02$), and high- ($p = .02$) and low-level ($p = < .01$) response types significantly. Correlations were negative for low-level response types, with lower language scores associated with relatively more use of low-level responses. For CwNH, maternal education correlated with AWC/hr ($p = < .01$), and caregivers of younger CwNH had significantly more CTC/hr ($p = < .01$). Quantitative LENA data suggested comparable interaction frequency between groups. CwHL were exposed to more low-level response types, had significantly lower language scores. Further investigation into response types, child language outcomes, and therapeutic implications for CwHL is needed.

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Linguistic environment; natural language input; language input; quantity of language input; caregiver-child interaction; response types; language outcomes; language development

Introduction

Caregiver-child verbal interaction plays a crucial role in the development of oral language skills in children with hearing loss (CwHL) (Ambrose, VanDam, & Moeller, 2014; Carr, Xu, & Yoshinaga-Itano, 2014; Caskey, Stephens, Tucker, & Vohr, 2011; Farran, Lederberg, & Jackson, 2009; Sacks et al., 2014; Wiggin, Gabbard, Thompson, Goberis, & Yoshinaga-Itano, 2012). CwHL often miss out on incidental learning experiences (Snow, 1994) due to delayed access to some speech sounds and a poorer acoustic signal, compared to their typically hearing peers (Reynolds, Werfel, Vachio, & Lund, 2023). Despite receiving newborn hearing screening and early fitting with hearing devices (Stika et al., 2015; Tomblin, Oleson, Ambrose, Walker, & Moeller, 2014; Wake, Poulakis, Hughes, Carey-Sargeant, & Rickards, 2005), some children still experience challenges in terms of language development. Nott, Cowan, Brown, and Wigglesworth (2009) investigated early spoken language milestones, focusing on the acquisition of lexicon and word combinations in young CwHL compared to age-matched children with normal hearing (CwNH). The CwHL who were fitted with cochlear implants and switched-on before 30 months of age, exhibited significant delays in word acquisition and word combination development compared to their age matched CwNH. While many CwHL develop speech/language skills in line with their chronological age (Fulcher, Purcell, Baker, & Munro, 2012), there is significant variability in these language outcomes (Ambrose et al., 2014; Geers, Strube, Tobey, Pisoni, & Moog, 2011). The language

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environment plays a significant role in developing verbal language skills in CwHL (Arora et al., 2020). Specifically, the quantity of language input and the types of responses during caregiver-child verbal interaction significantly influence verbal language development (Brock & Bass-Ringdahl, 2023; Cruz, Quittner, Marker, & DesJardin, 2013).

Quantity of language input

Verbal language can be quantified using the number of words (i.e., adult word count, AWC) and the number of conversational exchanges between child and adult interactional partners (i.e., their conversational turn count, CTC) (Gilkerson & Richards, 2009; Hart & Risley, 1995). Caregivers vary in how much they talk to their children. Overall, the children of more talkative parents show stronger lexical ability in comparison to less talkative parents (Hoff & Naigles, 2002; Hurtado, Marchman, & Fernald, 2008; Huttenlocher, Haight, Bryk, Seltzer, & Lyons, 1991). Typically developing children with more advanced language abilities, especially those who are good turn-takers or who have stronger conversational skills, elicit more talk from their mothers (Hoff-Ginsberg, 1986). In typically developing hearing children aged 7–36 months, more spoken words were associated with stronger vocabulary learning and faster lexical processing (Hart & Risley, 1995; Hoff & Naigles, 2002; Hurtado et al., 2008; Huttenlocher et al., 1991).

Caregivers tend to adjust the way they talk, or their response types, based on the cognitive and language development stages of their children (Dale, Tosto, Hayiou-Thomas, & Plomin, 2015). They do so by providing simpler language input and employing linguistic mapping, such as interpreting the child's unintelligible vocalizations into recognizable words, especially for children who have just started talking (DesJardin et al., 2014; Peccei, 2006). Consequently, variations in child language development may contribute to differences in caregiver language input. High CTCs also promote receptive and expressive language development in typically developing children aged 2–48 months (Zimmerman et al., 2009) and result in greater activation in the left inferior frontal Broca's area, a well-established language center for speech production, in children aged 4–6 (Romeo et al., 2018).

In young CwHL, increased parental engagement in verbal interactions is associated with stronger language outcomes. This is supported by studies showing significant correlations between CTCs and children's language skills evaluated through standardized tests (Ambrose et al., 2014; VanDam, Ambrose, & Moeller, 2012; Vohr, Topol, Watson, St Pierre, & Tucker, 2014). Ambrose et al. (2014) assessed 2-year-olds using the Mullen Scales of Early Learning and 3-year-olds through the Comprehensive Assessment of Spoken Language. Results showed a significant correlation between CTCs and receptive language ($r = .61$, $p = < .01$), and expressive language ($r = .45$, $p = < .05$). Vohr et al. (2014) observed the use of higher CTCs correlated with stronger receptive and expressive language outcomes. Similarly, VanDam et al. (2012) determined significant associations between CTCs and receptive language skills in 2-year-old children. The wide range of language outcomes in CwHL (Geers et al., 2011) highlights the importance of comparing language input quantities between CwHL and typically developing CwNH.

A small number of studies have investigated the quantity of language input (AWCs and CTCs) for CwHL compared with CwNH using Language ENvironment Analysis 'LENA' (see detail under '*Materials*') calculations based on day-long recordings (Ambrose, Walker, Unflat-Berry, Oleson, & Moeller, 2015; VanDam et al., 2012; Vohr et al., 2014). Two studies with relatively small sample sizes of children aged 24–36 months (VanDam et al., 2012) and 14–32 months old (Aragon & Yoshinaga-Itano, 2012) found that CwHL and CwNH were exposed to equal AWCs and CTCs. In contrast, Vohr et al. (2014) found that CwHL were exposed to more AWCs and CTCs than CwNH in a longitudinal study with a larger sample of older children (aged 6–8 years). Such differences in quantity of language input between CwHL and CwNH may be associated with variations in caregiver's language behaviour during caregiver-child interactions (DesJardin et al., 2014). Caregivers adapt their language behaviors when interacting with children, such as expressing enthusiasm during verbal activities to engage children more actively in communication (DesJardin, 2005). Consequently, language exposure differs significantly between parents, not just in terms of quantity (Gilkerson & Richards, 2008) but also in parents' verbal interaction styles or response types (Suter, 2006).

Response types

Previous studies have described caregiver response types and how they relate to the language acquisition of hearing children (Eyberg, Nelson, Duke, & Boggs, 2005; Girolametto & Weitzman, 2002). These studies have demonstrated the positive impact of highly responsive verbal interactions on language development. These verbal interactions include responding contingently to child initiations and asking questions to maintain the child's focus (Baumwell, Tamis-LeMonda, & Bornstein, 1997; Landry, Smith, & Swank, 2006).

In CwNH, response types such as imitation, labelling, pointing, commenting on the child's actions, and directing commands to the child (Hampson & Nelson, 1993) tend to facilitate early language developmental stages (0–2 years) (Eyberg et al., 2005;

Walker, Bigelow, Harjusola-Webb, Small, & Kirk, 2004). When children reach 2–6 years, open-ended/wh-questions, expansion, and comments can promote the use of grammatical sentence structure and phrases (Walker et al., 2004). A longitudinal study by Rowe (2012) highlighted the importance of expansions and narrations for stronger vocabulary development in CwNH aged 12–48 months.

Few studies have measured caregiver response types for CwHL and their impact on language outcomes. One longitudinal study of 97 CwHL aged less than five years by Cruz et al. (2013) classified language facilitative strategies into two major categories and found high-level language facilitative strategies including parallel talk, wh-questions, expansion, explanation, and recast were more effective and low-level language facilitative strategies including linguistic mapping, comments, imitation, labelling, directives, and close-ended questions were less effective. In comparison studies involving CwHL and CwNH, DesJardin et al. (2014) observed that, during storybook interactions, CwHL were exposed to a higher frequency of low-level language strategies such as labelling, commenting, and linguistic mapping compared to CwNH, and these low-level language facilitative techniques (pointing and labelling) were associated with lower language comprehension scores in CwHL. In contrast, caregivers of CwNH used higher-level language facilitative techniques, including open-ended questions, expansions, and recasts, particularly with children who exhibited better language skills. DesJardin et al. concluded that caregivers of CwHL used lower level/less effective language strategies with the belief that their CwHL might lack the language skills necessary for more advanced verbal interactional communications. Consistent with this, Nittrouer (2010) noted that caregivers of CwHL tend to be less verbally responsive to their children's communicative attempts compared to caregivers of CwNH. Both DesJardin et al. (2014) and Lederberg and Everhart (2000) observed that, when interacting with their CwHL exhibiting lower language skills, mothers often compensated by utilizing more low-level strategies, particularly close-ended questions.

Geers et al. (2011) found that variability in language input was associated with family and child demographic factors including gender, family size, and socioeconomic status (SES). Few studies have explored the effect of demographic factors on language input. This is a critical and timely area of research because Geers et al.'s findings suggest the importance of including family factors when planning language interventions.

Family and child demographics

Many child and family demographic variables could impact outcomes; just a few of the more commonly investigated factors are considered here. Family and child demographics associated with better language input including higher socioeconomic status (SES) (Hoff, 2003), higher level of maternal education (Dollaghan et al., 1999), having more adults in the family (Beitchman et al., 2008), the number of siblings and birth order (Hoff-Ginsberg, 1998), race/ethnicity/culture (Heath, 1983), and child age (Phillips, 1973; Snow, 1972). For example, mothers used a higher mean length of utterance (MLU) when interacting with 28-month-olds compared to 18-month-olds (Phillips, 1973).

Although caregiver education levels (Dollaghan et al., 1999) and SES (Hoff, 2003) explain variation in language exposure for children, studies differ in terms of how these factors were defined. For example, SES had been defined by income level, education level, and/or profession/occupation using self-report questionnaires (Ambrose et al., 2015; Hart & Risley, 1992). Hart and Risley (1992) found that parents categorized as 'professional families' talked significantly more, with an average of 215 words/hr, with their children in comparison to parents from 'working-class and welfare families'. More recent studies have defined low- and high-SES using deprivation scores (1–10, where 1 = areas with the least deprived scores reflecting high-SES, and 10 = most deprived areas reflecting low-SES) (Atkinson, Salmond, & Crampton, 2014). Mahoney, Spiker, and Boyce (1996) found that caregiver-child interactions were influenced by economic, social, and familial factors. Consistent with this, Bridges and Hoff (2014) concluded that there is more language input in households where siblings interact with each other more frequently in daily routines than those where the child only interacts with adult family members. Only Ambrose et al. (2015) provided information regarding the impact of child age on language input for CwHL.

The current study

The current study analysed quantity of language input and facilitative language strategies as response types due to their significant impact on language outcomes in young children. Language facilitative strategies in previous studies have mostly been categorized dichotomously as high- or low-level (Cruz et al., 2013; DesJardin & Eisenberg, 2007). To facilitate a better understanding of how the various caregiver's response types contribute to language development, the current study sought to have a more nuanced three-level classification system with high-, mid-, and low-level response types, informed by a panel of child language experts (speech, language, and hearing professionals with experience working with children and families). This expands on the more traditional two-category system of high versus low language response types. Additionally, the current study analysed the association of several family and child demographics with quantity of language input and response types.

Most of the previous studies reviewed here measured caregiver-child verbal interactions in structured environments. For example, Brown and Remine (2004) and Brown, Rickards, and Bortoli (2001) evaluated interactions during pretend play in the playroom. DesJardin et al. (2014) selected books for reading, while other researchers (Ambrose et al., 2015; Cruz et al., 2013) provided specific instructions for interactions. The short time periods and planned activities in structured environments in these earlier studies may not reflect how caregivers interact with their children in everyday situations. Hence, the current study examined caregiver's natural language input in terms of both quantity and response types for CwHL and CwNH in everyday environments, measured using LENA technology.

There are three research questions. The first research question focused on whether there were differences in language input (AWC, CTC, response types) and language outcomes between CwHL and CwNH. We predicted that CwHL would be exposed to less language input and more low-level response types than CwNH. The second question was to examine whether variations in quantity of language input (AWCs, CTCs), and response types (high-, mid-, low-level) were associated with language outcomes in CwHL and CwNH. We predicted that greater quantity of language input and high-level response types would be significantly associated with better receptive and expressive language abilities. The third research question focused on whether family and child demographics including primary caregiver level of education (PLE), socioeconomic status (SES), number of adults in family, child's age at recording, number of siblings, and birth order were related to the quantity of language input and response types used. We predicted that children whose primary caregivers have higher PLE and high SES, and children who are older or first in birth order or who have more siblings, will be exposed to a greater quantity of language input and more high-level response types.

Method

Participants

CwHL

A convenience sample of 14 children was recruited from the Hearing House (one of the biggest non-profit organizations for CwHL in New Zealand), the Listening and Language Clinic (the University of Auckland), and Early Childcare Centres (ECCs) in Auckland, New Zealand. The recruitment process specified the following inclusion criteria: aged 2–5 years, no other diagnosed disabilities except HL. All children had a congenital permanent bilateral moderate-profound HL (profound = 6, severe-profound = 2, moderate-severe = 4, moderate = 2), identified by newborn hearing screening and diagnosed at 1–6 months (*M* = 3.43, *SD* = 1.22). CwHL were included if they used hearing aids and were fitted with them by 6 months of age and/or used cochlear implants and received the implants before 2 years of age. All children were using hearing devices (hearing aids or cochlear implants). Seven children had bilateral hearing aids received by the age of 3–6 months (*M* = 4.36, *SD* = 1.28). Seven children used bilateral cochlear implants; they were implanted at 6–14 months (*M* = 8.79, *SD* = 1.28). All children were consistent users (all waking hours/per day) of their hearing aid/s and cochlear implant/s, based on data logging and reports from their Hearing House audiologists during regular 2-monthly reviews. The children with hearing aids were fitted using DSLv5 (Scollie, 2007) prescriptive targets with individual ear measurements of real ear to coupler differences (Bagatto et al., 2005) by an accredited paediatric audiologist, as mandated by the Universal Newborn Hearing Screening and Early Intervention Programme National Policy and Quality Standards Diagnostic and Amplification Protocol (Ministry of Health, 2016). Hearing aid settings were adjusted to match the DSLv5 target outputs for soft, average, and loud speech, with a close match to average conversational speech and maximum output targets given priority when verifying the hearing instruments. The Hearing House audiological protocols for cochlear implant users focus on speech audibility (as well as comfort) and include routine measurement of soundfield thresholds at 500–6000 Hz. Aided thresholds confirmed appropriate mapping (Davidson, Geers, & Brenner, 2010) for each CI user; thresholds were typically 20 dB HL or better (83% of thresholds) but were no worse that 25–30 dB HL (17% of thresholds). Amplified hearing age (based on when the children were first amplified and devices were optimized for audibility) was 3–14 months (*M* = 6.82, *SD* = 3.21). All CwHL participated in individual and group speech language therapy/auditory verbal therapy 'AVT' once every two weeks, for 45–60 minutes per session.

CwNH

A convenience sample of 20 CwNH was recruited from ECCs. The first author contacted managers of local preschools via email and phone calls and visited the managers/supervisors of local ECCs/preschools in Auckland to discuss the objectives and other matters related to the study to obtain their agreement to recruit participants. The recruitment process specified the following inclusion criteria; children aged 2–5 years, no known developmental delay or diagnosed disabilities (e.g., learning/intellectual), and normal hearing reported by the caregivers based on the child passing the newborn hearing screen, caregiver observations, and the Before-School Check result (for children aged 4+ years only). Middle ear status at the time of participation was not evaluated. CwNH and their families recruited to the study all lived in the broader Auckland area (New Zealand). Children in both groups (CwHL, CwNH) were recruited from monolingual English-speaking families with both caregivers having normal hearing. Ethnicity was predominantly New Zealand European for both groups (86% of CwHL, and 60% of CwNH), 7% of children in both groups of Asian ethnicities, and 40% of CwNH were Māori.

Materials

Language ENvironment Analysis (LENA) Technology

LENA technology was used to record and analyse audio recordings of natural everyday interactions. The LENA recorder (a small cassette-sized recorder) that fitted into a pouch sewn onto special LENA clothing (i.e., vest and t-shirt according to the age and size of the child) had the capacity to collect up to 16 hours of continuous recording of child vocalizations, adult words, and environmental sounds within a 4–10 feet radius. After the recordings were completed, the LENA recorder was connected to a computer with LENA software, which automatically analysed the audio signal from the LENA recorder. The LENA algorithm identified the following: (a) AWCs, (b) CTCs, (c) child vocalization counts (CVCs). AWCs indicated the algorithm's estimation of the number of all adult words (adult to adult or/and adult to child) when the adult had spoken near the microphone of the targeted child. CTCs estimated the frequency of adult–child vocal exchanges within 5 s intervals (each CTC is separated by 300 ms of silence). Although LENA software counted the number of speech-related sounds (e.g., babbling, words) produced by the child as CVC, this was not included as a measure in the current study as the focus was on children's receptive and expressive language skills, and not vocalization counts.

Measures of quantity of language input automatically generated by the LENA software have demonstrated reliability and validity (Gilkerson et al., 2017). In previous research by Xu, Yapanel, and Gray (2009), LENA estimates of AWCs strongly correlate with human manual transcription (AWCs: $r = .92$, $p = < .00$), however, the error in these estimates varies as a function of recording time (shorter recordings have more errors). According to Xu et al. (2009), error rates on recordings of at least 3 hours were between 5% and 10%. All recordings used in this study exceeded 4 hours and would be expected to yield low error rates of around 5% (Xu et al., 2009). The reliability of LENA calculations was further checked in the current study by comparing calculation of AWCs and CTCs between manual and automatic measurements (Busch, Sangen, Vanpoucke, & Wieringen, 2018). Pearson product-moment correlation coefficients comparing manual transcription data to LENA calculations (Sultana, Wong, & Purdy, 2020) showed high consistency (AWCs/hr: $r = .93$; CTCs/hr: $r = .91$, all p *values* $< .00$), supporting the reliability of LENA estimates.

The current LENA software only allowed the automatic estimation of the quantity of language input (AWCs, CTCs) and was not a sophisticated tool for the analysis of other essential aspects of language input such as different response types. Thus, information on response types was based on manual transcription and coding of LENA recordings (see detail under '*Response types*').

Preschool Language Scales – Fifth Edition

The Preschool Language Scale – Fifth Edition (PLS-5: Zimmerman, Steiner, & Pond, 2012) was used to determine language outcomes (receptive and expressive language abilities) in CwHL and CwNH. PLS-5 raw scores were obtained manually and converted into standard scores according to PLS-5 instructions (Zimmerman et al., 2012). Only standard scores were used for the current analysis. The PLS-5 is a comprehensive scale for identifying receptive (i.e., basic vocabulary, concepts, morphology, and syntax) and expressive (i.e., naming, describing, expressing quantity, using specific prepositions, grammatical markers, and sentence structures) language skills in children from birth through age 7 years and 11 months. Good test-retest reliability and internal consistency have been reported by Zimmerman et al. (2012) for the PLS-5.

Demographic factors

Information regarding demographic factors such as PLE, SES, the number of adult family members at home including caregivers, child's age at recording, number of siblings, and birth order were obtained using a demographic questionnaire. Simple group comparisons and correlation analysis was used to explore these associations with demographic factors.

Therapy and other commitments of the families limited their capacity to participate. Families were concerned about their privacy due to their uninterrupted full day recordings, despite assurances made in the information and consent forms about data confidentiality. A relatively small sample size was recruited for both groups (20 CwNH and 14 CwHL). Due to the limited recruitment of CwHL, we were unable to separately examine the associations between degree of HL, age of identification, and type of amplification and language input and language outcomes in current sample.

Primary caregiver's level of education

The New Zealand education classification system (New Zealand Qualification Authority, 2019) was used to examine PLE using self-reported demographic information. This system defined level of education as 10 = doctoral, 9 = master's, 8 = bachelor's honors, 7 = bachelor's, 6 = a certificate for theoretical and technical knowledge of skills within a specific field and study, 5 = a certificate for technical knowledge of skills within a specific field and study, 4 = certificate to work or study in broader and specified field/area, 3, 2, 1 = certificate to work in specified field/area at foundation/ beginning level, which is almost equivalent to the level of academic qualifications in Australia, Europe, and the United Kingdom (the New Zealand Qualifications Authority & the European Commission, 2016).

Socioeconomic Status

SES was quantified using the New Zealand Index of Socioeconomic Deprivation (NZDep; Atkinson et al., 2014). The NZDep was derived from current New Zealand national census-based small-area indices of relative socioeconomic deprivation using the same theoretical basis such as SES and position, social class, deprivation, poverty, and living standards (Salmond, Crampton, King, & Waldegrave, 2006). NZDep combines eight variables with good internal consistency (Cronbach's alpha = .86); communication, income, employment, qualifications, own home, support, living space, and transport (Atkinson et al., 2014). The index ranges from 1 to 10, where 1 = areas with the least deprived scores reflecting high-SES, and 10 = most deprived areas reflecting low-SES, associated with low economic activities, a high unemployment rate, unhealthy lifestyles, high-level of limiting long-term illness and disability, low-life expectancy, poor educational attainment, poor housing quality and overcrowding, and high-levels of crime and antisocial behaviors. NZDep has been used in many published studies in New Zealand to examine equity of access to public health services in different SES groups (McFadden, McConnell, Salmond, Crampton, & Fraser, 2004; McKenzie, Ellison-Loschmann, & Jeffreys, 2011; Wilson et al., 2012). It should be noted that deprivation scores in the current study were applied to areas rather than individuals (Atkinson et al., 2014). PLE and SES are separate but overlapping constructs (Fergusson, Horwood, & Boden, 2008), and thus they were considered separately in the current study.

Procedure

Ethical approval was obtained from the Human Research Ethics Committee via the Faculty Research Ethics Committee of the University of Hong Kong, the Human Participants Ethics Committee of the University of Auckland, and the Programme Research and Development Committee of the Hearing House (Auckland). Approved information and consent forms for the families were distributed by the centers (The Hearing House, Listening and Language Clinic, The University of Auckland, ECCs). After consent was obtained, the first author contacted families to discuss the use of the LENA audio recorders in more detail and liaise with families to deliver and return the LENA recorders.

Children wore the LENA recorder in a vest for all waking hours during usual activities (e.g., shopping, staying home), except bath time. Families were instructed not to record days with special occasions (e.g., birthday parties, family gatherings), and they should behave naturally and interact with their children as usual. Total AWCs and CTCs for each participant per hour/per day were calculated by the LENA. The primary researcher was available by phone or e-mail during the recording periods to answer questions. The families were informed that if they felt uncomfortable with the recording due to an unusual day, they could stop recording or withdraw their participation at any time during the data collection process; no caregivers requested this. Caregiver were informed that AWCs and CTCs would be calculated, and some recording segments would be transcribed and coded to examine response types. Caregivers were not told that the study would examine specific response types at specific times of the day, in order not to introduce subject bias.

Recordings on four typical days in a week (two weekdays and two weekend days) with CwHL and only two typical weekend days in CwNH were evaluated to check for day-to-day variations in exposure to language input. The statistical analysis showed no significant differences in language input across days of the week for either group (CwHL and CwNH) (Supplemental Digital Content 1A & 1B for language input across days in CwHL and CwNH). Only data from weekend days was included to evaluate the differences in language input in CwHL and CwNH, due to the lack of weekday data for the CwNH who were enrolled at ECCs/preschools 5 days/week.

To determine language outcomes in both groups (CwHL, CwNH), the PLS-5 was administered in the Hearing House clinic by the primary investigator, who was an experienced speech and language pathologist following the standard PLS-5 protocols. Test raw scores were recorded and converted to age-standardized scores based on published norms. Standard scores were used for correlation analysis with language input. The two groups were analysed separately based on evidence that caregivers adapted their language input for CwHL.

Analysis strategy

Measurement of quantity of language input

LENA recordings ranged from 9 hours; 39 minutes to 14 hours; 24 minutes (including only the child's waking time) for two weekend days and hence variation could be possible in AWCs and CTCs depending on recording time. To correct for variations in recording time across families, AWCs/min and CTCs/min were calculated by dividing the observed daily values by the number of total minutes and converting the results to AWCs/hr and CTCs/hr, following the process described by VanDam et al. (2012). To check the reliability between LENA automatic calculations of AWCs and CTCs and manual calculations, five sets of 5 minutes LENA audio recordings were randomly extracted to estimate AWCs and CTCs. The descriptive statistics and Cohen's kappa agreement between LENA automatic calculations and manual calculations for AWCs and CTCs showed a very good agreement: AWCs: $M_{\text{LENA}} = 135.64$ ($SD = 110.49$) versus M_{manual} calculation = 131.60 ($SD = 105.29$), Cohen's kappa .91. For CTCs: $M_{\text{LENA}} = 22.20$ ($SD = 17.71$) versus M_{manual} calculation = 22.40 ($SD = 16.65$), Cohen's kappa .93. This level of interrater agreement is consistent with previous studies (DesJardin & Eisenberg, 2007; Girolametto & Weitzman, 2002; Sultana et al., 2020).

Measurement of response types

Response types were compared between CwHL and CwNH for two weekends due to unavailability of participants attending preschools on weekdays. Twenty minutes of recording; two 5 minutes/day, one from the morning and one from the evening were extracted for each participant, where highest CTCs were observed in the LENA output graph during extracted time from morning and evening. The LENA pro-software version (V3.4.0-143) was used to identify the two 5-minute intervals with the greatest CTCs for manual transcription and coding, from morning (8:30 AM–11:30 AM) and evening (4:00 PM–8:00 PM). The 20 minutes of recordings per child were composed of one 5-minute audio excerpt per morning, and one per evening, following the method used by D'Apice and Von Stumm (2020). During these times, children were engaged in meals, playing with toys, dressing and clothing, etc., with caregivers. Recordings were played offline and manually transcribed by the first author. Response types were mapped onto 17 predefined response types (Comment [CM], Wh-Question [Wh-Q], Positive Marker [PM], Recast-Question [RC-Q], Expansion [EX], Reason [RS], Closed-ended Question [CQ], Labelling [LB], Repetition [RP], Action [AC], Joint Speech [JS], Directive [DR], One Word [OW], Linguistic Mapping [LM], Imitation [IM], Negative Marker [NM], Other [OT]; see detail in Table 1). These 17 styles were selected from previous literature (Cruz et al., 2013; DesJardin & Eisenberg, 2007; Eyberg et al., 2005; Girolametto & Weitzman, 2002).

To calculate a frequency score for caregiver use of each response type, the pre-identified codes for each response type (Table 1) were assigned by the first author to each adult utterance/sentence or phrase for the four transcripts for each child (2/day, for 2 days). Coding reliability was confirmed using two additional coders who were native English-speaking researchers/experts in manual transcription and were trained by a certified speech-language therapist. During training, a speech-language therapist defined and played examples for different interaction that were coded. During training, all coders independently coded a recoded segment of a sample of caregiver-child interaction; this provided foundation for coding of the response types in the current study. After 100% agreement was achieved for the sample of caregiver-child verbal interaction, two coders independently transcribed (25% of transcripts, 240 minutes of recordings) and this coded for 17 response types to verify inter-rater reliability (Cruz et al., 2013; D'Apice & Von Stumm, 2020; Girolametto & Weitzman, 2002). In the few cases of disagreement, the two raters/coders reviewed the recordings and transcripts together and reached a consensus.

Following the method used by Girolametto and Weitzman (2002), the percent agreement between two transcribers/coders after the consensus process was calculated as 100% for each utterance (linguistic phrase or sentence). The interrater reliability for all 17 response types was high (92% for LM, RP, AC, LB, Wh-Q, CQ, OW, JS, NM, and OT; 91% for PM, RC-Q, and DR; 90% for RS and EX; and 88% for CM). Overall interrater reliability agreement obtained using Cohen's kappa was in the range between .88 and .93. This level of interrater agreement is within the range of 88% – 98% of interrater agreement found in previous studies (DesJardin & Eisenberg, 2007; Girolametto & Weitzman, 2002).

Categorization of response types

An expert panel was asked to categorize the 17 response types into fewer categories for data analysis. The panel consisted of 10 experts including audiologists (who received a master's degree and/or certification in clinical competence), therapists (who received a master's degree with certification in auditory-verbal therapy), speech-language therapist/pathologists (who received a master's degree in speech-language pathology/therapy), and early interventionists (who received a master's degree in special

Table 1. A list of all response types with descriptions and examples.

Categories	Response Types	Description	Examples
High-level	*Comment (CM)*	The parent makes a statement or comment as a signal that the message has been received or to keep their conversation going.	The parent says 'you are working hard' or 'you saw this book before'.
	'WH' Question (Wh-Q)	Use a '*Wh*' question and a phrase or sentence as a simple justification for the child to give an answer using more than two words.	The parent asks, 'What is that?' or 'why are you interested in listening to this story'?
	Positive Marker (PM)	The parent shows verbal excitement about the child's actions using words.	The parent says 'all right', 'great', 'good job', 'well done', 'nice', 'pretty work', etc.
	Recast Question (RC-Q)	The parent rephrases the child's vocalization as a question.	The child says, 'Anna went … ' and the mother says, 'Where did Anna go'?
	Expansion (EX)	The parent repeats the child's verbalization and completes it accurately using a more grammatical and complete language model with the addition of one or more words, without adding new information.	The child says, 'Doggie goes … ' and the parent says, 'The dog is going'. Or the child says, 'Baby cry … ' and the parent says, 'The baby is crying' etc.
	Reason (RS)	The parent provides child with a simple explanation about why they need to carry out a task.	The parent says, 'You should wash your hands because they are dirty'.
Mid-level	*Closed-ended Question (CQ)*	The parent makes a statement to which the child can only answer with one word.	The parent says, 'Do you want to go to the park'? or 'do you need water'?
	Labelling (LB)	The parent indicates the name of the animal, building, road, fruit, object, etc.	The child asks, 'What's that'? The mother says, 'The moon', 'a lady', 'a sticker', 'a pond', 'a bird', etc.
	Repetition (RP)	The parent responds to the child vocalisation or the parent alerts the child to a specific item or action. Then, the parent repeats name of the object or action, even if the child does not respond. This repetition resembles auditory bombardment as multiple repetitions are consistently given.	The parent says 'I see a ball', it's a ball', 'the ball is big', 'here is ball'.
	Action (AC)	The parent uses action words (verbs) to describe an ongoing continuous action, rather than an action word to direct a child to follow an instruction. with action verbs.	The parent says, 'He is walking', 'stars are shining', etc.
Low-level	*Joint Speech (JS)*	The parent and child speak together while reading, rhyming, and singing.	The parent and child speak at the same time, 'knees and toes, knees and toes', etc.
	Directive (DR)	The parent gives a direct command to the child to do something.	The parent says, 'Come here', 'listen carefully', 'read the word', 'sit down', 'hold it', etc.
	One Word (OW)	The parent uses only one word to answer the child.	The parent says 'yes', 'no', 'yeah', 'okay', 'right', etc.
	Linguistic Mapping (LM)	The parent creates word-based information based on the child's unrecognisable vocalisation.	The child vocalizes 'wa, wa' and the parent says 'water'. Or the child says, 'hoda hoda' and the parent says 'hiding'.
	Imitation (IM)	The parent imitates the child's vocalisation or words without adding new extra words.	The child says 'a choc-bar' and the parent repeats 'a choc-bar'.
	Negative Marker (NM)	The parent responds negatively to the child's verbal attempts.	The parent says, 'No, that's not right', 'very bad', etc.
	Other (OT)	The parent gives an answer to the child in an improper form of language.	The parent says 'hmmm', 'hahaha', 'umm', 'uh', 'oh', 'oop'.

Note: These 17 response types were selected from previous literature (Cruz et al., 2013; DesJardin & Eisenberg, 2007; Eyberg et al., 2005; Girolametto & Weitzman, 2002). Additionally, these response types were refined through discussions with speech and language therapists actively engaged with families, aiming to enrich language input in terms of response types for the development of verbal skills in young children with HL.

education/early childhood education). They had on average 5 years of experience working with young children in the Ministries of Education and Health in New Zealand.

Each panel member was given 17 cards, each labelled with one response type plus a description and examples from the participants on the back of the card and was asked to categorize each response type. The expert panel determined that a simple dichotomy was inappropriate for the broad range of response types examined here and hence they divided them into three level categories (high-, mid-, and low-level). Six response types were grouped by the panel as high-level (CM, Wh-Q, PM, RC-Q, EX, RS), four were grouped as mid-level (CQ, LB, RP, AC), and seven were grouped as low-level (JS, DR, OW, LM, IM, NM, OT) response types. Twelve of the 17 (71%) response types were consistently categorized by 80–100% of the expert panel (see Table in Supplemental Digital Content 2). There was less consensus for the five remaining response types (PM, LB, DR, LM, AC). The final decision on categorization of response types was based on the majority opinion (percentage agreement for the categorization of response types is reported in the Supplemental Digital Content 2).

To avoid penalizing less talkative caregivers, proportion scores for each category of response types were calculated by dividing the total number of uses of each response type by the overall number of response types used by that caregiver. This method of calculation focuses only on response types (Cruz et al., 2013), regardless of AWCs and CTCs.

Results

The first question focused on whether there were differences in language input (quantity; AWCs, CTCs, and response types) and language outcomes (receptive and expressive) between CwHL and CwNH. Caregivers of CwHL used an average of about 1137 AWCs/hr and 48 CTCs/hr over a 12-hour period in a day. CwNH were exposed to an average of about

Table 2. Descriptive data for adult word counts/hr, conversation turn counts/hr, response types, and language outcomes in children with hearing loss (CwHL) and children with normal hearing (CwNH).

Variables Language Input	CwHL (*N* = 14) M (SD), Range	CwNH (*N* = 20) M (SD), Range
Adult word count/hr	**1137** (554), 470–2234	**1243** (426), 668–1978
Conversational turn count/hr	**48.26** (19.18), 13.80–82.50	**60.94** (21.34), 21.41–98.61
Response Types (percentage)		
High-level %	**5.74** (1.50), 2.75–8.55	**9.05** (1.77), 4.56–11.45
Comment (CM)	**17.15** (5.31), 5.88–28.26	**21.40** (8.47), 6.72–39.41
'*Wh*' Question (Wh-Q)	**8.21** (3.97), 2.58–14.81	**16.05** (6.67), 5.08–33.33
Positive Marker (PM)	**3.90** (2.26), .58–8.41	**3.08** (2.66), 00–9.88
Recast Question (RC-Q)	**0.50** (.81), 00–2.60	**0.59** (.91), 00–3.33
Expansion (EX)	**1.96** (1.76), 00–5.63	**7.19** (6.16), 00–20.47
Reason (RS)	**2.73** (3.15), 00–12.13	**6.02** (5.07), 00–17.91
Mid-level %	**6.44** (1.68), 3.45–9.36	**4.25** (1.49), 1.04–7.19
Closed-ended Question (CQ)	**15.36** (4.59), 4.72–23.21	**11.16** (4.79), 00–19.52
Labelling (LB)	**4.48** (4.11), 00–13.24	**3.81** (2.50), 00–10.22
Repetition (RP)	**3.26** (1.85), 0.93–7.34	**1.23** (1.98), 00–6.12
Action (AC)	**2.67** (1.56), 0.62–5.65	**0.79** (1.34), 00–4.13
Low-level %	**5.68** (1.09), 3.89–8.19	**4.05** (1.60), 2.36–7.96
Joint Speech (JS)	**0.44** (0.91), 00–2.50	**0.04** (.16), 00–.71
Directive (DR)	**20.20** (5.01), 13.24–29.02	**15.83** (9.46), 4.21–42.69
One Word (OW)	**6.18** (5.01), 2.73–22.47	**5.75** (5.08), 00–17.41
Linguistic Mapping (LM)	**0.20** (0.54), 00–1.90	**0.05** (0.23), 00–1.02
Imitation (IM)	**3.55** (2.14), 00–6.79	**2.36** (2.10), 00–5.83
Negative Marker (NM)	**6.02** (3.59), 0.65–13.57	**3.11** (3.12), 00–13.66
Other (OT)	**3.18** (3.14), 00–9.23	**1.25** (1.44), 00–4.93
Language Outcome (standard scores)		
Receptive language	**75.78** (13.31), 53–95	**91.40** (16.84), 64–121
Expressive language	**73.35** (13.25), 51–94	**88.00** (19.56), 43–116

Note. Percentage scores were calculated by dividing the total number of uses for each category of response type by the overall number of response types.

1243 AWCs/hr and 61 CTCs/hr over a 12-hour period in a day (Table 2).

Shapiro-Wilk tests showed that the data for AWCs/hr and CTCs/hr were normally distributed ($p => .05$) and appropriate for conducting *t*-tests (i.e., Skew < |2.0|, and Kurtosis < |9.0|; Schmider, Ziegler, Danay, Beyer, & Bühner, 2010). Additionally, the Levene's *F* test revealed the assumption of homogeneity of variance was satisfactory for AWCs/hr ($F = .44$, $p = .51$), and CTCs/hr ($F = .22$, $p = .64$). Independent sample *t*-tests showed AWCs/hr and CTCs/hr did not differ significantly between CwHL and CwNH (Table 3).

Mann-Whitney *U* tests showed statistically significant differences in all three categories of response types (high-, mid-, and low-level) between CwHL and CwNH (Table 3), with large effect sizes for use of high- ($r = .68$), mid- ($r = .61$), and low-level ($r = .52$) response types (Brydges, 2019). CwHL were exposed to more mid- and low-level, and less high-level response types than CwNH. There is considerable variability across participants in the frequency of the response types within the three categories (high-, mid-, and low-level) (Table 1).

Mean PLS-5 standard scores for CwHL were significantly poorer than CwNH for receptive ($z = -2.57$,

Table 3. Comparison of language input (adult word counts, conversational turn counts, response types), and language outcomes between children with hearing loss (CwHL = 14) and children with normal hearing (CwNH = 20).

Language Input		Independent Samples T – Tests			
Quantity	Groups	T	df	*p*-value	Effect size
Adult word counts/hr	CwHL CwNH	−.63	32	.54	.21
Conversational turn counts/hr	CwHL CwNH	−1.78	32	.09	.62
Response Types (Percentage)		Mann – Whitney U Tests			
		Mdn (IQR)	z-score	*p* value	Effect size
High-level %	CwHL CwNH	5.75 (1.62) 9.79 (1.98)	−3.95	<.00*	.68
Mid-level %	CwHL CwNH	5.93 (2.18) 4.70 (1.99)	−3.53	<.00*	.61
Low-level %	CwHL CwNH	5.68 (1.24) 3.76 (1.82)	−3.04	<.00*	.52
Language Outcomes (Standard Scores)		Mann – Whitney U Tests			
Receptive Language	CwHL CwNH	77.00 (27.25) 101.50 (22.50)	−2.57	.01*	.44
Expressive Language	CwHL CwNH	73.00 (26.00) 103.00 (19.75)	−2.25	.02*	.39

$^*p < .05$.
Note. IQR = Inter-quartile range.

$p = < .01$) and expressive language ($z = -2.25$, $p = .02$) with medium effect sizes (receptive: $r = .44$; expressive: $r = .39$). Standard score means, ranges, and standard deviations are reported in Table 2. The family-wise Type 1 error rate across five measures (AWCs, CTCs, high-, mid-, and low-level response types) at the .05 level was controlled using Holm's sequential Bonferroni procedure (Holm, 1979).

The second question focused on whether there were associations between language input (AWCs, CTCs, and high-, mid-, and low-level response types), and language outcomes (receptive and expressive), examined separately for CwHL and CwNH, using Spearman's correlations. For CwHL, AWCs, CTCs, and response types were not associated with receptive and expressive language. In contrast, for CwNH, higher quantities of AWCs, CTCs, and more use of high-level response types were significantly associated with better receptive and expressive language. In CwNH, use of more low-level response types was associated with poorer language scores (Table 5; Figures 1 and 2).

The third question focused on whether demographic factors (PLE, SES, number of adults in family, child's age at recording, birth order, number of siblings) relate to the language input (quantity; AWCs/hr, CTCs/hr) and response types. There was no significant difference between fathers' and mothers' education levels based on a Wilcoxon-Signed ranks test for CwHL (Father: *Mdn* = 7.00, *IQR* = .25; Mother: *Mdn* = 7.00, *IQR* = 1.00, $z = -.87$, $p = .41$) or CwNH (Father: *Mdn* = 7.00, *IQR* = 3.75; Mother: *Mdn* = 7.00, *IQR* = 5.00, $z = -1.49$, $p = .14$). Only mother's education level (mothers were the primary caregiver for all children except one where the father was the primary caregiver) was included for further PLE analyses. Group differences in other factors such as number of attendances for ECCs, number of hours spending with caregiver at home for both groups were determined. All CwHL were enrolled in ECCs three-days per/week and CwNH were attending ECCs five days per week. Mann–Whitney *U* tests showed no significant differences in family demographics. However, the number of siblings and birth order were significantly different between CwHL and CwNH (Table 4); on average CwHL had more siblings and they tended to be older than their siblings. In CwHL, only number of siblings was significantly associated with use of more low-level response types. For CwNH, high PLE and high SES were associated with significantly increased AWCs and CTCs. Response types were not

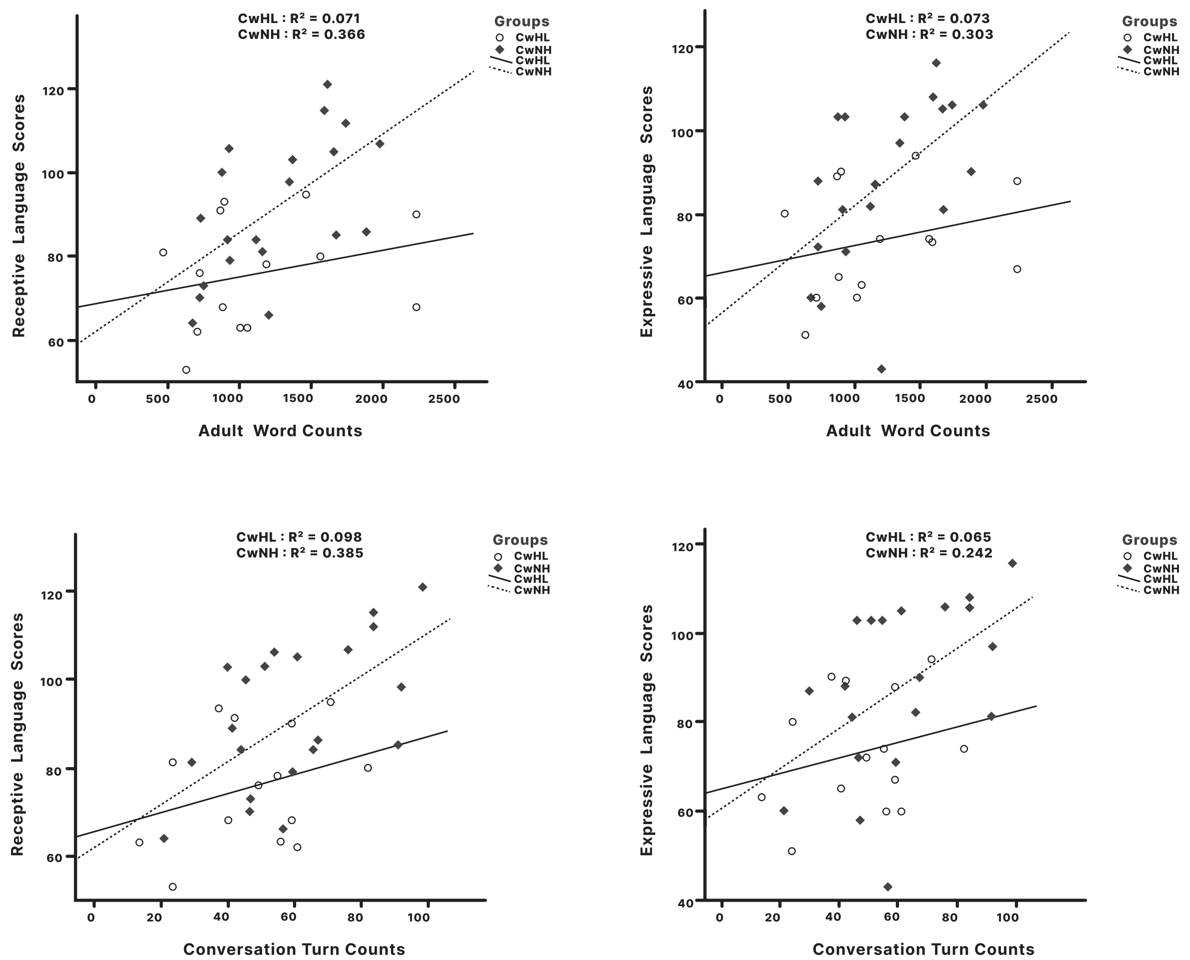

Figure 1. Scatter plots show the associations between adult word counts/hr, conversation turn counts/hr, and receptive and expressive language standard scores in children with hearing loss (CwHL) and children with normal hearing (CwNH). (Page 20).

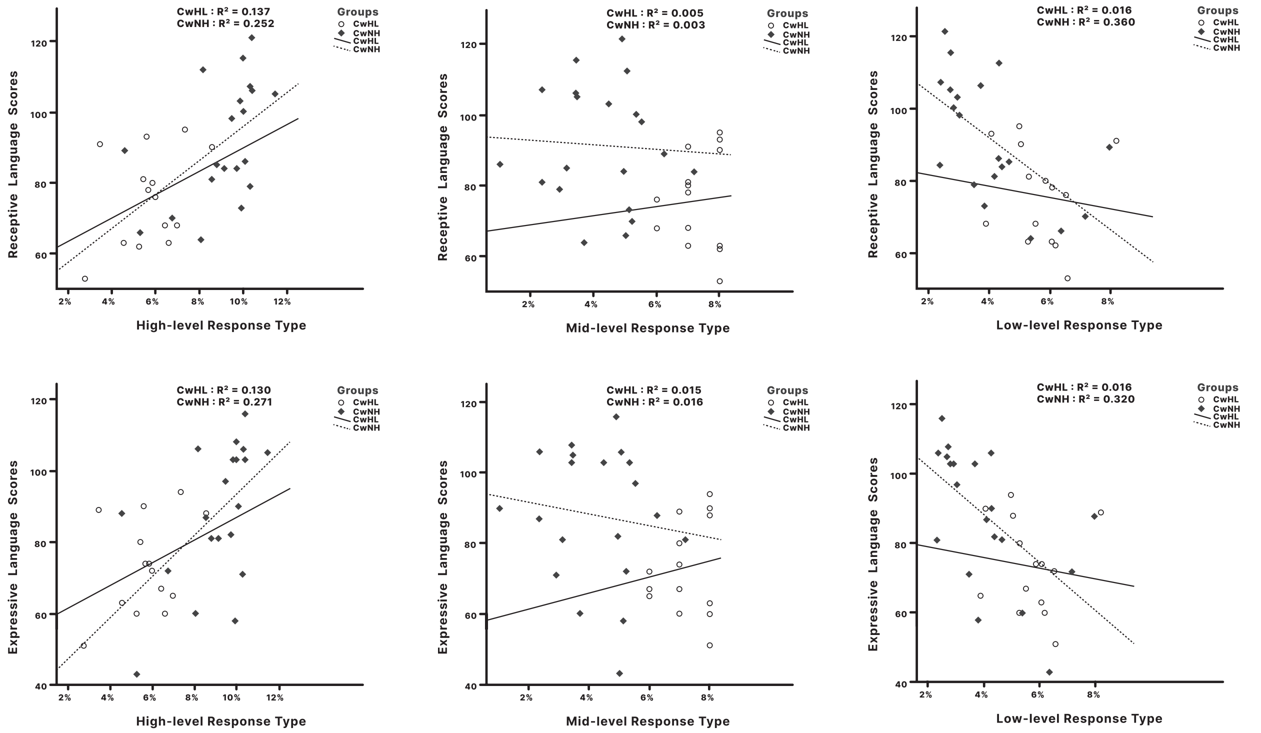

Figure 2. Scatter plots show the associations between receptive and expressive language standard scores and percentages of response types (high-, mid-, low-level) in children with hearing loss (CwHL) and children with normal hearing (CwNH). (page 20).

significantly associated with child's age at recording, and birth order was not significantly associated with the quantity of language input in either group (Table 5).

Multiple linear regression models were used to examine the relationships between demographic factors and quantity of language input (AWCs/hr, CTCs/hr). The two groups (CwHL, CwNH) were combined for this regression analysis ($N = 34$) due to the small sample size in each group (14 CwHL, 20 CwNH). The significance of the model statistics, F (7,33) = 1.96, $p = .10$, $R^2 = 34.6\%$ for AWCs/hr and F (7,33) = 3.98, $p = .00$, $R^2 = 51.7\%$ for CTCs/hr, show the overall goodness of fit of the models. The multiple linear regression model for AWCs showed that, after controlling for other covariates, higher PLE significantly increased AWCs/hr by 135 per level increase in PLE category (with PLE category 10 reflecting highest [PhD] level of education, and 1 being lowest) ($p = .05$); other covariates were not statistically significant ($p => .05$). For CTCs, child age was significant ($p = .03$); CTCs/hr decreased by .73 for each increase in chronological age by one month (Table 6). The power of the test was 45% and the estimated probability of type II error was 55% (probability of failing to reject the null hypothesis when it is false due to the small sample size).

To our knowledge, the current study was the first attempt to examine differences in the natural language input (quantity and response types) during caregiver-child verbal interactions while considering family/child demographic factors (i.e., PLE and SES, number of adults in the family, child's age at recording, birth order, number of siblings) and association with language outcomes in CwHL and CwNH.

Table 4. Descriptive data for family and child demographics of children with hearing loss (CwHL) and children with normal hearing (CwNH).

Family Factors	CwHL (*N* = 14) M (SD), Range	CwNH (*N* = 20) M (SD), Range	Mann-Whitney U tests	
			z	*p*-value
Maternal level of education	7.29 (0.73), 6–8	6.80 (2.57), 3–10	− .22	.83
Socioeconomic status	3.43 (1.34), 1–5	5.30 (2.87), 1–10	−1.79	.07
Number of Adults in the family (including parents)	2.71 (0.83), 2–4	3.35 (1.31), 2–6	−1.38	.17
Maternal amount of interaction on the weekend (hours)	10.86 (1.88), 6–12	11.1 (2.10), 6–13	.52	.83
Maternal amount of interaction on the weekday (hours)	5.93 (1.49), 4–10	4.90 (1.64), 2–9	−1.34	.17
Child Factors				
Age at recording (months)	36.21 (12.44), 25–57	39.80 (12.50), 24–58	-.63	.53
Number of siblings	2.57 (0.85), 1–4	1.10 (1.70), 1–4	−2.73	**.01**
Birth order	2.36 (0.84), 1–4	1.60 (0.88), 1–4	−2.54	**.01**

Note. Parental education ranged from 3 to 10 levels (i.e., 3 = certificate to work in specified field/area, 4 = certificate to work or study in broader and specified field/area, 5 = a certificate for technical knowledge and skills within a specific field and study, 6 = a certificate for theoretical and technical knowledge and skills within a specific field and study, 7 = bachelor's, 8 = bachelor's honors, 9 = master's, 10 = doctoral). Socioeconomic status falls between the number 1 and 10 (1 = high socioeconomic status), and 10 = low socioeconomic status.

Table 5. Spearman's correlation coefficients between language input, language outcomes and associated factors in children with hearing loss (CwHL) and children with normal hearing (CwNH).

		CwHL		CwNH	
Language Outcomes	Language Input	Correlation coefficient	*p*-value	Correlation coefficient	*p*-value
Receptive language	Adult word counts/hr	.29	.31	.60	**.01**
	Conversation turn counts/hr	.20	.50	.58	**.01**
	High-level response types	.31	.28	.56	**.01**
	Mid-level response types	−.37	.19	−.12	.63
	Low-level response types	−.37	.20	−.59	**.01**
Expressive language	Adult word counts/hr	.30	.30	−.59	**.01**
	Conversation turn counts/hr	.19	.53	.51	**.02**
	High-level response types	.27	.35	.53	**.02**
	Mid-level response types	−.37	.19	−.16	.51
	Low-level response types	−.33	.25	−.59	**.01**
Associated Factors					
Family and Child Demographics					
Maternal level of education	Adult word counts/hr	.11	.71	.71	**.00**
	Conversation turn counts/hr	.00	1.00	.71	**.00**
	High-level response types	−.23	.43	.28	.24
	Mid-level response types	.16	.58	−.17	.47
	Low-level response types	−.05	.87	−.29	.22
Socioeconomic status	Adult word counts/hr	.14	.63	−.56	**.01**
	Conversation turn counts/hr	.19	.52	−.56	**.01**
	High-level response types	.44	.11	.04	.86
	Mid-level response types	−.48	.08	−.14	.56
	Low-level response types	−.16	.57	.20	.40
Number of adults in family	Adult word counts/hr	−.15	.60	−.02	.94
	Conversation turn counts/hr	−.06	.85	−.09	.72
	High-level response types	−.25	.38	.37	.11
	Mid-level response types	.23	.44	−.21	.37
	Low-level response types	−.01	.99	−.11	.65
Age at recording	Adult word counts/hr	−.34	.24	−.21	.37
	Conversation turn counts/hr	−.37	.20	−.26	.27
	High-level response types	−.49	.07	−.14	.56
	Mid-level response types	.18	.53	−.06	.79
	Low-level response types	.52	.06	.38	.10
Number of siblings	Adult word counts/hr	−.21	.46	.00	.99
	Conversation turn counts/hr	−.11	.70	.13	.58
	High-level response types	−.44	.12	.06	.82
	Mid-level response types	−.11	.71	−.19	.42
	Low-level response types	.59	**.03**	.16	.51
Birth order	Adult word counts/hr	−.17	.56	.01	.96
	Conversation turn counts/hr	.18	.54	.14	.55
	High-level response types	−.21	.47	.04	.88
	Mid-level response types	.27	.35	−.18	.46
	Low-level response types	.35	.21	.17	.47

Discussion

This study generated several important findings regarding the exposure to language input in both groups and the association between language input and outcomes. First, there were group differences in response types but not quantity of language input. Independent samples *t*-tests identified no significant differences in CTCs and AWCs between CwHL and CwNH based on our data from natural LENA recordings. VanDam et al. (2012) also reported equal number of AWCs for CwHL ($n = 22$) and age-matched CwNH ($n = 8$), however, several studies (Aragon & Yoshinaga-Itano, 2012; McDaniel & Purdy, 2011; Vohr et al., 2014) have found higher AWCs in CwHL compared with age-matched CwNH. CwHL were exposed to less high-level and more low-level response types in language input than CwNH. Second, in CwNH, better language scores were associated with the greater quantity of language input (AWCs, CTCs), and more use of high-level response types; this association between language input and language outcomes was not evident in CwHL. Finally, after controlling for the effects of other covariates using regression analysis, we found caregivers with higher levels of education used significantly more AWCs with their children and significantly fewer CTCs with older children, regardless of hearing status.

Table 6. Multiple linear regression analysis for family and child demographics and quantity of language input (AWCs/hr, CTCs/hr) in all children ($N = 34$).

Family and Child Demographics	AWCs/hr				CTCs/hr			
	β	*SE*	*t*	*p*	β	*SE*	*t*	*p*
Maternal level of education	134.94	65.28	2.067	**.05**	4.39	2.48	1.77	.09
Socioeconomic status	15.09	56.44	.267	.79	−.85	2.15	− .40	.69
Number of adults in family	−52.78	71.79	− .735	.45	−1.16	2.73	− .42	.68
Child's age at recording	−7.55	08.07	− .935	.36	−73	.31	−2.38	**.03**
Number of siblings	55.95	217.60	.257	.80	6.43	8.28	.78	.44
Birth order	−117.25	233.88	− .501	.62	−1.64	8.90	− .18	.86

Conversations are prime opportunities for children's verbal language development (Tomasello & Farrar, 1984; Zimmerman et al., 2009). It is important to note that, even though CwHL were exposed to as many adult words on average as CwNH in the current study, the CwHL may not have equal access to language input due to their HL and other factors like environmental noise/electronic media affecting audibility of spoken language. In the current study, we did not consider analysis of LENA data on electronic media/noise. Hence, AWCs may not fully reflect 'usable' language input for CwHL. CTCs are more reflective of the child's verbal interactions. There are other factors potentially contributing to variability in AWCs and CTCs. The LENA device does not differentiate between speech directed to the child and speech directed to others nearby (LENA Research Foundation, 2014). Hence, in situations where there were multiple conversational partners, AWCs and CTCs from parents could be overestimated. AWCs could be increased in some households due to the counting of adult-to-adult talk.

The between-group comparisons of CTCs were consistent with VanDam et al. (2012) who found that caregivers of CwHL and CwNH engaged their children in equivalent numbers of CTCs during natural interactions. The CTC results differed from Vohr et al. (2014) who found CwHL ($n = 23$, aged 7–8 years) was exposed to a higher number of CTCs than CwNH ($n = 41$, aged 6 years). Variations in results between studies might reflect differences in sample composition/context and study design. For example, children in the current study and in VanDam et al. (2012) were younger than those in Vohr et al. (2014). Vohr et al. collected LENA recordings when the children were aged 6–8 years, and their sample of CwHL did not include cochlear implant users.

Response types

In the current study, the caregivers of CwHL used less high-level and more mid- and low-level response types than the caregivers of CwNH. Previous studies have suggested that the significant difference in quantity or response types of adult language input and child language outcomes between CwNH and CwHL indicates that caregivers are sensitive to their child's language ability and may tailor their language input to their child's communication/language level rather than their chronological age (Ambrose et al., 2015; Su & Roberts, 2019). Children in the current study were on average aged 36 months old at the time of testing and had received audiological intervention by 6 months of age on average. This meets the 1-3-6 goals for screening-diagnosis-treatment, but some children may still exhibit delays in language ability in terms of receptive and expressive language (Grey, Deutchki, Lund, & Werfel, 2022), and this was evident in the data. These group differences encourage us to explore further the links between quantity of language input, response types, and language outcomes.

Association between language input and language outcomes

We predicted that a greater quantity of language input and more high-level response types would be associated with better receptive and expressive language abilities in CwHL and CwNH. However, this association was only evident for CwNH. The lack of association between language input (AWC, CTC, response type) and language outcomes for CwHL was surprising. Other than a lack of power due to the small sample size, one possible explanation for the lack of association between language input and outcomes in the CwHL could be that CwHL may have reduced attention to language during daily interactions, even with early identification and optimal aided hearing (Houston & Bergeson, 2014; Wang, Shafto, & Houston, 2018). If CwHL pay less attention to speech than their peers, this could impact how they understand sounds and connect words with their meanings, potentially impacting their early language development (Houston & Bergeson, 2014). The significant relationship between language input and outcomes that was evident for CwNH supports earlier research that suggests the importance of a high quantity of language input. Previous research in CwNH has found significant associations between a greater quantity of language input (AWCs, CTCs) and receptive and expressive language abilities (Hoff & Naigles, 2002; Hurtado et al., 2008; Huttenlocher et al., 1991; Zimmerman et al., 2009), and between the use of high-level response types and better receptive and expressive language scores (Baxendale & Hesketh, 2003; Girolametto & Weitzman, 2009; Walker et al., 2004). In contrast, for CwHL, caregiver's language input (AWCs, CTCs, response types) was not significantly associated with language outcomes in the current study. Caregivers of CwHL may have adjusted their response types according to the language ability of their children. Further research is required to verify these results.

The findings in our study regarding CwHL differ from previous studies. For example, DesJardin and Eisenberg (2007) observed that mothers' MLU and use of high-level response types were positively correlated with better receptive and expressive language scores in their children with cochlear implants. Similarly, Cruz et al. (2013) identified positive correlations between high-level response types and receptive and expressive language scores in CwHL. Differences between our current results and existing literature might stem from our use of a novel method for categorizing response types. Although the validity of the categorization system for response types was supported by the correlations observed for CwNH, refinements of our categorization approach should be considered for a future study as there was less consensus in the expert panel for several response types.

Another important factor not considered in the current or earlier studies reviewed here was caregiver responsiveness to the support of language learning. The current study focused on language input but not specifically on responsive or 'contingent' communication; other studies have addressed the need for caregiver communication to be responsive in order to support children's language, cognitive and social development (Landry, Smith, Miller-Loncar, & Swank, 1997; Lieberman, Lohmander, & Gustavsson, 2019; Swanson, 2020). Responsiveness relates to adult utterances that are contingent on the child's attention/previous utterance or action, and hence this requires analysis of the nature and timing of adult utterances and child responses and vice versa. This was captured in a simple way by CTCs, but more sophisticated analysis is needed to differentiate between responsive and non-responsive utterances to determine the importance of this for enhancing language. Future studies should consider responsivity as a factor contributing to language outcomes of CwHL.

Future research could also assess whether there is consistency in language input (AWCs, CTCs, range of response types) across days of the week and if stability and reliability of day-to-day recorded interactions can be established. In addition, audiological factors—age of amplification, aided hearing, hours of device use, access to speech sounds, and environmental factors; caregiver concerns about language development, responsive behaviors, verbal interactional engagement in daily routines that have not been detailed in past studies (Ambrose et al., 2014; Aragon & Yoshinaga-Itano, 2012; Cruz et al., 2013; DesJardin & Eisenberg, 2007) could be considered.

Relationships between family and child demographics and language input

Caregivers' education was significantly associated with a high number of AWCs. Previous research has shown that mothers with lower education and lower SES tend to use fewer words and turn-taking with young children and our findings for CwHL were consistent with these studies of CwNH (Gilkerson & Richards, 2009; Greenwood, Thiemann-Bourque, Walker, Buzhardt, & Gilkerson, 2011; Hart & Risley, 1992; Hoff, 2003; Suskind et al., 2016; Weisleder & Fernald, 2013; Wood, Diehm, & Callender, 2016).

The current study found decreased CTCs in caregivers' response types with the older children (aged 4–5); caregivers in both groups were more engaged with their young children (2–3 years). Kondaurova, Zheng, VanDam, and Kinney (2022) observed turn-taking among female and male adults and typically developing 2–5-year-olds and found turn taking increased more with child age for adult females than for adult males. Thus, the impact of child age on CTCs may be influenced by complex factors such as the number and gender of adults in the household. The absence of observed relationships between other family and child demographics such as number of siblings, birth order, and quantity of language input in the current study may be due to the small sample size. A larger sample size was required for such analysis examining the impacts of multiple factors. The lack of relationships between SES and language input may also reflect the smaller sample size and the relatively high SES of the families of CwHL in the current study, which is not representative of the wider population of CwHL in New Zealand (Digby, Purdy, & Kelly, 2020). Furthermore, most of the recordings in the current sample for both groups were collected from New Zealand European monolingual English-speaking families. Ethnicity/cultural norms may influence caregiver/child engagement in conversational activities; this may be an area of interest for future research in New Zealand's Māori and other indigenous communities. For example, Reese, Hayne, and MacDonald (2008) found that Māori ($n = 15$) mothers provided a richer narrative environment for their children than New Zealand European ($n = 17$) mothers, based on the sharing of stories of shared past events with their children aged 3–4 or 7–8 years, suggesting potential differences in language styles between these groups (Reese et al., 2008).

Limitations

Despite the contributions of this study, we acknowledge several factors that limit our conclusions and warrant future investigation. First, due to the cross-sectional study design and our relatively small sample size, the broad age range limits the generalization of results. Top of FormAlthough a larger sample size was planned, many families were reluctant to participate because of the use of recording during everyday activities, which is a factor to consider in future LENA studies. Second, several other factors (i.e., presence of middle ear pathology, hearing age, degree of HL) were not considered. For CwHL, degree of HL is an important consideration in language studies. Unfortunately, no previous study has specifically controlled for the degree of HL when examining language input for CwHL (Ambrose et al., 2014; Aragon & Yoshinaga-Itano, 2012; Vohr et al., 2014). Third, our results are not generalizable to CwHL with additional disabilities who can have more difficulty learning language (Cupples et al., 2014). CwHL from non-English-speaking/bilingual backgrounds were also not included. Fourth, it was difficult to know whether caregivers completely followed the data collection protocol with fidelity. Detailed instructions were provided, and the researchers were readily available for questions. Finally, due to the nature of the LENA technology and its data collection procedures, only spoken language from adults and children was recorded and examined. There is no information regarding the types of words in AWCs and CTCs or the structure and complexity of sentences in CTCs. Non-verbal components of interactions such as facial expressions, body language, sign language, gestures, eye contact, maternal involvement in shared activities, and sensitivity (Delaney & Kaiser, 2001) during verbal interactions play an important role during interaction (Hall, 2020), but were also not considered in the current study. Finally, it is important to note that there was less agreement among the expert panel regarding certain response types, and further research is needed to confirm the categorization of these response types as high-, mid-, or low-level.

Conclusions and clinical implications

The current study adds to the literature regarding the quantity of language input, response types, and relationship to language outcomes in preschool children with and without HL. To our knowledge, this is the first study to use full-day naturalistic recordings during routine caregiver-child verbal interaction to compare quantitative language input, response types, and language outcomes in CwHL and CwNH. Examining caregiver's language input in terms of quantity and response types contributes to a holistic understanding of child's language skills. This information on quantity of language input and response types can be integrated with other assessment various aspects of the child's linguistic and cognitive skills. Our results may help clinicians working with families of CwHL to enhance language outcomes through better understanding of caregiver-child verbal interactions in daily routines. Clinicians can work with caregivers to modify their response types to better support their children's language development. We suggest evaluating whether caregivers are providing language input that is commensurate with the language ability of their child, addressing the use of high-level response types in therapy, and tracking changes in language input over time as the child's language develops.

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