Language and speech outcomes of children with hearing loss and additional disabilities: Identifying the variables that influence performance at 5 years of age

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Acronyms and Abbreviations

ASD	Autism spectrum disorder
CDI	Child Development Inventory
CP	Cerebral palsy
CI	Cochlear implant
DHH	Deaf or hard-of-hearing
DD	Developmental delay
DEAP	Diagnostic Evaluation of Articulation and Phonology
4FAHL	Four-frequency-average hearing loss in the better ear
HA	Hearing aid
IRSAD	Index of relative socioeconomic advantage and disadvantage
IT-MAIS	Infant-Toddler Meaningful Auditory Integration Scale
LOCHI	Longitudinal outcomes of children with hearing impairment
MatEd	Maternal level of education
Mode	Mode of communication
PPVT-4	Peabody Picture Vocabulary Test (4^{th} Edition)
PLS-4	Preschool Language Scale (4^{th} edition)
WNV	Wechsler Nonverbal Scale of Ability

Abstract

Objective. This study examined language and speech outcomes in young children with hearing loss and additional disabilities.

Design. Receptive and expressive language skills and speech output accuracy were evaluated using direct assessment and caregiver report. Results were analysed first for the entire participant cohort, and then to compare results for children with hearing aids (HAs) versus cochlear implants (CIs).

Study sample. A population-based cohort of 146 5-year-old children with hearing loss and additional disabilities took part.

Results. Across all participants, multiple regressions showed that better language outcomes were associated with milder hearing loss, use of oral communication, higher levels of cognitive ability and maternal education, and earlier device fitting. Speech output accuracy was associated with use of oral communication only. Average outcomes were similar for children with HAs versus CIs, but their associations with demographic variables differed. For HA users, results resembled those for the whole cohort. For CI users, only use of oral communication and higher cognitive ability levels were significantly associated with better language outcomes.

Conclusions. The results underscore the importance of early device fitting for children with additional disabilities. Strong conclusions cannot be drawn for CI users given the small number of participants with complete data.

Introduction

Children born with hearing loss form a heterogeneous population with respect to a range of variables that might impact on development of their speech and language skills. Recent research indicates that, at 3 years of age, relevant variables include gender, severity of hearing loss, maternal level of education, and for children with cochlear implants (CIs), age at switch-on (Ching et al., 2013). Most importantly for present purposes, children who have a significant disability in addition to their hearing loss achieve poorer language outcomes than children with no additional disability (Ching et al., 2013). Given that approximately 20-40% of deaf or hard-of-hearing (DHH) children have a significant additional disability (Gallaudet Research Institute, 2011; Picard, 2004), it is crucially important to understand the achievements of this large subgroup of children in order to provide informed advice to parents and caregivers who are considering intervention options, such as hearing aids (HAs) or CIs.

Benefits of Audiological Intervention for DHH Children with Additional Disabilities

Most previous published studies of outcomes in DHH children with additional disabilities focused on the benefits of cochlear implantation (e.g., Beer et al., 2012; Dammeyer, 2009; Donaldson et al., 2004; Fukuda et al., 2003; Hamzavi et al., 2000; Holt & Kirk, 2005; Palmieri et al., 2012; Wakil et al., 2014; Waltzman et al., 2000). Findings generally showed that these children benefit from CIs, albeit more slowly and/or to a lesser degree than children who have a hearing loss but no additional disabilities (e.g., Beer et al., 2012; Holt & Kirk, 2005; Palmieri et al., 2014; Pyman et al., 2000; Waltzman,et al., 2000; Yang et al., 2004). Substantial individual variation is also evident, however, in the outcomes achieved by these children, especially on formal assessments of speech and language processing.

Waltzman et al. (2000) reported on 29 DHH children who were diagnosed with a diverse set of additional disabilities including delayed cognition, learning disability, motor and oral-motor delays, attention deficit disorder, autism spectrum disorder (ASD), and others. The children, who received their CIs between 1.9 and 12 years of age, were assessed on various auditory-linguistic measures prior to cochlear implantation and at subsequent yearly intervals from 1 to 8 years. Although there was a gradual increase from year to year in both the number of children able to complete assessments and the scores they obtained, there was also marked variability within the sample. At the children's final postoperative assessments, scores ranged from below 10% to greater than 90% on all of the individual open-set speech recognition tasks. Hamzavi et al. (2000) reported on a smaller group of 10 DHH children with additional disabilities who received their CIs between 8 and 77 months of age. After postoperative periods ranging from 12 to 55 months, just 2 of the 10 children were able to recognise spoken words and sentences, with a further 3 children being able to produce and/or understand a few words. The remaining 5 children developed no speech perception or production skills during the study period. Donaldson et al. (2004) also reported marked variability in formal testing outcomes for a group of 7 children with ASD who were fitted with CIs between 3 and 9 years of age. After postoperative periods ranging from 6 to 60 months, 4 of the 7 children remained unable to complete formal assessments of expressive and receptive vocabulary, or open-set speech recognition of familiar words and phrases.

The highly variable nature of the outcomes achieved by DHH children with additional disabilities on formal assessments of speech and language might partly reflect the lack of suitability of these assessment methods for this population. Berrettini et al. (2008) raised this possibility along with the related concern that use of such methods "may result in inappropriate estimation of the effects of CIs in terms of quality of life and educational and social gains" (p. 200). Some support for this view comes from Donaldson et al.'s (2004) research examining outcomes in children with ASD. Although numerous missing scores made the results from children's formal assessments difficult to interpret, parental ratings of communicative skills were much more convincing in showing consistent improvement during the postoperative period in aspects such as reacting to sound, vocalizing, making eye contact, responding to verbal requests, and attending to people.

By contrast with the growing body of literature on the benefits of CIs for DHH children with additional disabilities, few researchers have examined the benefits of HAs in this population. An exception is a study by Kaga et al. (2007), which examined auditory outcomes in 28 children who were fitted with HAs between 1 and 5 years of age. Of the 28 participants, only 17 showed improved auditory behaviours in the months following HA fitting. Six of the remaining children could not adapt to using HAs, and five used their HAs but showed no improvement in auditory behaviours. Interpretation of these outcomes is complicated, however, since no information was provided regarding the children's degree of hearing loss.

The studies described above provide support for the effectiveness of CIs for DHH children with additional disabilities considered as a group. They also reveal, however, that outcomes can vary markedly across individual participants and different assessment measures. Variability between participants might reflect the influence of uncontrolled demographic and cognitive variables, but investigation of this possibility has been hampered by the use of small, heterogeneous samples. Most previous studies in this area involved fewer than 30 participants who usually varied widely in the nature of their additional disabilities, age at implantation, age at assessment, and duration of device use.

Outcomes in Relation to Demographic Variables

Until recently, there has been limited evidence to suggest that differences in audiological and family-related demographic variables influence the outcomes achieved by DHH participants with additional disabilities. In a small group of 20 children, Meinzen-Derr et al. (2010) found that after controlling for variation in nonverbal cognitive ability, earlier age at diagnosis of hearing loss was associated with better receptive and expressive language outcomes on the Preschool Language Scale 4th Edition (PLS-4) (Zimmerman et al., 2002). In the same study, however, they also reported that children's language outcomes were not significantly associated with parental education or income, and that duration of CI use was negatively associated with language skill; that is, longer duration of CI use was linked to poorer language outcomes. They suggested that the latter, counterintuitive finding might reflect inclusion in their participant sample of several long-term implant users with poor language skills (Meinzen-Derr et al., 2010). In a subsequent study, Meinzen-Derr et al. (2011) reported that neither age at CI switch-on nor degree of hearing loss accounted for significant unique variance in children's PLS-4 outcomes after controlling for nonverbal cognitive ability.

Using a different outcome measure based on parental report, the Infant-Toddler Meaningful Auditory Integration Scale (IT-MAIS) (Zimmerman-Phillips et al., 2000), Beer et al. (2012) also found a nonsignificant association between age at CI switch-on and outcomes. They concluded that "established early predictors of functional auditory benefit may not be as critical or meaningful in predicting benefit in deaf children with ADs" (Beer et al., 2012, p. 497). On the other hand, Palmieri et al. (2012) reported a positive association between duration of CI use and children's degree of improvement on the language and communication scales of a new Deafness and Additional Disabilities Questionnaire (DADQ). The questionnaire, which is administered to parents in interview format, was designed by Palmieri et al. to collect information on five areas: (A) perceptual skills, (B) preferred communication mode, (C) communicative behaviors, (D) attention and memory skills, and (E) social interaction, behaviour control, and self government.

A larger and more recent study reported by Cupples et al. (2014) provides stronger evidence for a link between demographic variables and language outcomes in DHH children with additional disabilities. Cupples et al. investigated outcomes achieved by 119 3-year-olds on the directly administered PLS-4 and the caregiver reported Child Development Inventory (CDI) (Ireton, 2005). These children were drawn from a population-based cohort who participated in the 3-year-old assessment phase of the Longitudinal Outcomes of Children with Hearing Impairment (LOCHI) study (Ching et al., 2013). After controlling for a range of variables including gender, degree of hearing loss, audiological device (HA or CI), and communication mode (oral or mixed), Cupples et al. found that type of additional disability was the strongest predictor of children's expressive and receptive language outcomes. A combined group of children with autism, cerebral palsy (CP), and/or developmental delay (DD) achieved consistently poorer outcomes than a combined group of children with other disabilities, including vision or speech output impairments, syndromes not entailing DD, and medical disorders. Better receptive and expressive language outcomes were also linked to higher levels of maternal education, especially for the group of children with autism, CP, and/or DD. For children with other disabilities the most important predictor of outcomes was degree of hearing loss.

A notable strength of the Cupples et al. (2014) study is the large number of included participants, which made it possible to evaluate the influence on children's outcomes of a range of potentially important demographic variables, while simultaneously controlling for others. There was, however, one important measure that was not included in the assessment of LOCHI children at 3 years of age, namely, cognitive ability. Thus, while significantly poorer language outcomes in children with autism, CP, or DD compared to children with other types of additional disabilities might have been attributable to lower levels of cognitive ability, Cupples et al. had no objective empirical evidence with which to evaluate this assertion.

Outcomes in Relation to Cognitive Ability

Previous research has provided evidence of a positive association between children's level of intellectual or cognitive functioning and their outcomes following cochlear implantation (e.g., Beer et al. 2012; Dettman et al., 2004; Edwards et al., 2006; Lee et al., 2010; Meinzen-Derr et al., 2010; Wiley et al., 2008; Wakil et al., 2014). Meinzen-Derr et al. (2010) reported on a group of 20 DHH children with additional disabilities who received their CIs at least 10 months earlier at ages ranging from 13.5 to 54 months. Receptive and expressive language skills were assessed using the PLS-4. The results from multiple regression analyses showed that nonverbal cognition was the strongest predictor of children's postoperative language ability, accounting for 67% and 71% of variance in receptive and expressive language quotients respectively.

More recently, Wakil et al. (2014) reported retrospective, chart review data for a group of 21 DHH children with developmental delay who were aged between 1.6 and 11.7 years at the time of cochlear implantation. At the children's most recent postoperative assessments, 10 out of 13 children with a severe developmental delay were unable to complete formal assessments of speech recognition and their scores on the IT-MAIS remained well below ceiling despite long term use of CIs (> 7 years). By contrast, 8 children with mild to moderate developmental delays achieved open-set speech recognition scores of between 48% and 94%.

Although it seems logical that degree of cognitive ability would predict outcomes in DHH children, not all previous studies have provided evidence consistent with this view. In an investigation of 23 DHH children with additional disabilities, Berrettini et al. (2008) reported that outcomes for a sub-group of 10 children with intellectual disability were similar to those obtained for the entire sample. Furthermore, within the intellectually disabled subgroup, there was no significant association between degree of intellectual disability and any of the post-implant outcome measures, which included assessments of auditory word recognition and communicative behaviour (based on a parent questionnaire). Cautious interpretation of these findings is warranted, however, because 8 of the 10 children with an intellectual disability were classified as mildly disabled.

In an earlier study, Holt and Kirk (2005) also failed to provide unequivocal support for the importance of cognitive ability in determining outcomes achieved by DHH children. Although some of their included assessment measures revealed a significant difference between children with mild intellectual disability and those without (e.g., in open-set sentence recognition), other comparisons either failed to reach significance (e.g., for the IT-MAIS) or only reached significance when children with intellectual disability were compared to a subgroup of control participants using either oral or total communication. By way of example, children with intellectual disability achieved lower receptive vocabulary scores than a control group of total communicators, but they did not differ in receptive vocabulary from a control group of oral communicators.

To summarise, previous research has shown that DHH children with additional disabilities tend to achieve poorer and more variable speech and language outcomes than children with hearing loss alone. A major focus of recent research has been to examine the benefits of cochlear implantation for this population of children. A secondary focus has been the extent to which audiological, cognitive, and demographic variables influence their performance on outcome measures. Although published findings are inconclusive due to the inclusion of small and heterogeneous participant samples in most studies, they suggest possible roles for type of additional disability, cognitive ability, level of maternal education, duration of CI use, and in some children, degree of hearing loss. Further research is needed to consider the benefits of HAs as well as CIs in larger samples of children.

The Current Study

The aim of the present investigation was to provide detailed information about the language and speech outcomes achieved by a large sample of 5-year-old DHH children with additional disabilities. All of the children were fitted with CIs or HAs. The inclusion of a sample of children with HAs distinguished this research from the majority of previous studies in the area, which have focused predominantly on outcomes for children with CIs. In line with recommendations from previous research, outcome measures included both formal assessments of language and speech development and more subjective measures based on parent report.

Research Questions and Hypotheses

Three research questions were addressed.

1. How do the language and speech outcomes of 5-year-old DHH children with additional disabilities compare to those of typically developing peers without hearing loss?

2. Which demographic variables are associated with language and speech outcomes in young DHH children with additional disabilities? Do different outcome measures reveal similar patterns of association? The specific demographic variables under consideration were both audiological (degree of hearing loss, type of sensory device, age at fitting of sensory devices), and child- and family-related (gender, nonverbal cognitive ability, maternal education, communication mode).
3. Do similar demographic variables predict outcomes in DHH children with additional disabilities who use HAs or CIs?

Research question 1 was aimed primarily at documenting the extent to which participants exhibited delays in language and speech outcomes as assessed using standardised, norm-referenced tests. As such, no related hypothesis was proposed. With respect to research questions 2 and 3, we hypothesised that: a) demographic variables, including degree of hearing loss, cognitive ability and maternal level of education, would be associated with variation in children's language and speech outcomes; and b) similar demographic variables would be important in predicting outcomes for children with HAs or CIs.

Method

Participants

Participants were members of a population-based cohort taking part in the LOCHI study described earlier. They were children born with hearing loss between 2002 and 2007 in the Australian states of New South Wales, Victoria, and Queensland. All children who were diagnosed with hearing loss and presented at Australian Hearing, the government-funded hearing service provider for all children in Australia, before 3 years of age were invited to participate. As part of the LOCHI study, caregivers were asked to indicate whether or not their child had been diagnosed with a disability in addition to hearing loss by a qualified professional. A total of 180 children, approximately 39% of the total LOCHI population, had been diagnosed with an additional disability by the age of 5 years. Of these children, data were available for 146. The remaining 34 children were unavailable or unaided at the time of assessment, spoke a language other than English, or had withdrawn from the study. A wide range of additional disabilities was reported, as summarised in Table 1. It is worth noting that these specific diagnoses are included for descriptive purposes. They do not relate directly to our primary aims, and were not formally validated as part of the study.

Table 1

The classification system used here was devised by Cupples et al. (2014). Although each child was allocated to a single category, developmental delay (DD) often occurred in combination with other named disabilities; for example, DD was present in 6 of the 18 children with ASD (category 1), and in 16 of the 25 children with CP (category 2). All 4 children with ASD and CP were diagnosed with DD (category 3). Categories 4 and 5 were groupings in which DD was reported either in combination with disabilities or syndromes other than ASD or CP (category 4), or as a child's only disability (category 5). The remaining four categories encompassed disorders of vision, speech output (i.e., difficulties producing clear, fluent speech), a variety of syndromes that could not be assumed to entail DD, and a diverse set of medical disorders, often affecting major body organs or motor skills (see Table 1).

Also included in Table 1 are the mean standard scores achieved by participants in each disability category on the Wechsler Nonverbal Scale of Ability (WNV) (Wechsler &

Naglieri, 2006). Of the 146 participants, 102 were assessed on the WNV, with 15 scoring more than 1.5 SDs below the typical mean (i.e., standard scores < 78). Consistent with the allocation of participants to disability categories, the majority of these low-scoring participants (12 out of 15) were diagnosed with ASD, CP, and/or DD. These scores are consistent with the allocation of participants to disability categoriesAlso consistent with the current classification system is the finding in showing that children diagnosed with ASD, CP, and/or DD achieved significantly lower average standard scores on the WNV than children in the other four disability groups (*F*[1,100] = 24.92, *p* < .001).

Table 2

Table 2 presents relevant background data on the cohort of 146 participants, more than half of whom were boys. Audiological information was collected from the databases of Australian Hearing and relevant intervention agencies. Hearing loss is represented as a four-frequency-average in the better ear (4FAHL). Across the cohort, hearing loss at 5 years of age ranged from mild to profound (*M* = 62.5, *SD* = 24.8, range = 15.0 - 123.8). The majority of children were HA users, with approximately one third using unilateral or bilateral CIs (see Table 2). Device use was associated with degree of hearing loss. Most children with mild or moderate losses (74 out of 80 or 92.5%) used HAs, as did 68.8% (22 out of 32) of children with a severe loss. By contrast, the majority of children with a profound loss (33 out of 34 or 97.1%) used a CI. On average, children had been diagnosed with a hearing loss at 6.7 months of age (*SD* = 9.6, range = 0 - 48), and first fitted with HAs approximately 3.5 months later (*M* = 10.2, *SD* = 11.2, range = 0 - 58). For children using CIs, devices were first switched-on between 5 and 58 months of age (*M* = 20.0, *SD* = 13.1), which meant that, at the time of assessment, 46 of the 49 children with CIs (93.9%) had more than 12 months experience with their device and 44 (89.8%) had more than 24 months experience.

Most children in the cohort used oral communication only in early intervention, although a substantial minority used a combination of sign and speech (see Table 2). Only 3 children were reported to communicate using sign only in early intervention. In regard to spoken language, all children used English, with a small percentage (n = 15, 10.3%) using another spoken language as well.

Children’s socio-economic status was measured using the Index of Relative Socioeconomic Advantage and Disadvantage (IRSAD) from the Socio-Economic Index for Areas (Australian Bureau of Statistics, 2006). Lower IRSAD scores indicate geographic areas with relatively fewer resources, whereas higher scores indicate geographic areas with relatively more resources. Scores are expressed as deciles. Most children in the current cohort lived in more advantaged areas, with 63% scoring 7 or above on the IRSAD (*Mdn* = 7.0, range = 1 - 10). In regard to maternal education levels, children were evenly divided between those whose mothers had a university qualification, a diploma or certificate, or formal schooling of 12 years or less (see Table 2).

Evaluation Tools

Evaluation tools included assessments of receptive and expressive language, speech output, and nonverbal cognitive ability.

Directly administered assessments

Directly administered assessments included: the PLS-4 (Zimmerman et al., 2002); Peabody Picture Vocabulary Test 4th Edition (PPVT-4) (Dunn & Dunn, 2007); Diagnostic Evaluation of Articulation and Phonology (DEAP) (Dodd et al., 2002); and the WNV (Wechsler & Naglieri, 2006).

The PLS-4 provides a formal assessment of children's overall receptive and expressive language abilities. At 5 years of age, the test incorporates verbal tasks that enable children to demonstrate understanding of and ability to produce English language structures including semantics, morphology, and syntax. In recent studies, the PLS-4 has been used successfully with children who have hearing loss and additional disabilities (e.g., Cupples et al., 2014; Meinzen-Derr et al., 2010, 2011).

The PPVT-4 was used to obtain a formal measure of children's receptive vocabulary. This widely used test is based on a four-alternative, forced-choice, picture-selection format, and has been used successfully to assess children from a range of special populations.

The phonology subtest of the DEAP was included to provide a quantitative measure of children's speech production ability. Single-word utterances are elicited using pictures, verbal cues, and/or imitation. For present purposes, children's speech output is represented as a standard score based on the number of phonemes correctly produced (i.e., both consonants and vowels).

Nonverbal cognitive ability was assessed using the WNV. This assessment was designed specifically for linguistically diverse populations, including people with hearing loss. It contains four subtests, the results of which combine to provide a full-scale IQ score. For children ages 4;0 – 7;11 (years;months) the relevant subtests are matrices, coding, object assembly, and recognition.

Report-based evaluation

The CDI (Ireton, 2005) was used to obtain a caregiver report of participants' receptive and expressive language abilities. This questionnaire comprises 300 statements to which caregivers are asked to respond "yes" or "no" based on observations of their child's behaviours. It contains eight scales, results for two of which are reported here: language comprehension (50 items) and expressive language (50 items).

Procedure

The 5-year-old LOCHI test battery included assessments of language, speech, and nonverbal cognitive ability. Language and speech data were collected when children reached 5 years of age. Although there was some variation in age at testing across children and tasks (*range*: 60 to 69 months for PLS-4, PPVT-4, and DEAP; and 59 to 69 months for CDI), just over 90% of language and speech assessments were conducted between 60 and 64 months of age. WNVs were administered between 56 and 98 months of age, with the majority (121 out of 146 or 82.9%) conducted within a 1-year age bracket, when children were between 60 and 72 months old.

A team of research speech pathologists directly assessed children in a location of best convenience for the families (including homes, schools, early intervention centres, childcare centres, or Australian Hearing offices). During evaluation, children wore their devices (HAs or CIs) at the settings prescribed by their audiologist. When possible, speech pathologists were blinded to children's age of intervention and severity of hearing loss.

All language and speech assessments were administered in 1 to 2 sessions, with no systematic counterbalancing of presentation order. The Wechsler nonverbal cognitive assessment was administered in a separate session by a professional psychologist. Tasks were administered according to instructions in their respective manuals where each child's abilities allowed. When direct assessments of language and speech could not be administered in spoken language only (e.g., for the three children who communicated using sign), assessments were either not administered or administered in nonstandard format, typically using a combination of speech and sign. In these cases, standard scores were not assigned.

Reliability

Inter-rater reliability was computed for the group of participants in the larger LOCHI study. Formal assessments were video/audio recorded, and randomly selected samples were subjected to a second, independent scoring by a member of the research speech pathologist team who was not involved in the initial test administration or scoring. Approximately 5-10% of PLS-4 and PPVT-4 assessments were double-scored. Agreement was uniformly high on test items administered for PLS-4 receptive (99.4%), PLS-4 expressive (98.4), and PPVT-4 (99.8%).

Statistical considerations and preliminary data analysis

Statistical analysis was conducted using standard scores for PLS-4, PPVT-4 and DEAP, developmental quotients for the CDI, and full scale IQ scores for the WNV. Standard scores on the PLS-4 and PPVT-4, and full scale IQ scores on the WNV have a mean of 100 and SD of 15. For the DEAP, standard scores have a mean of 10 and SD of 3. For the CDI, developmental quotients are computed by dividing language age by chronological age and multiplying by 100. A quotient of 70 or below represents impaired performance (i.e., at least

30% below age expectations). The use of these various standardised scores enabled us to fulfil our aims of: (1) documenting the extent to which this cohort of DHH children exhibited delays in language and speech outcomes on standardised, norm-referenced tests; (2) examining language and speech outcomes as a function of demographic and ability-related variables within the entire cohort; and (3) examining language and speech outcomes within subgroups of children with HAs or CIs.

In line with these primary research aims, the first step in data analysis was to examine the mean scores achieved by the cohort across the range of outcome measures. The second step was to examine the extent to which children's language and speech outcomes were associated with each of a group of audiological variables (4FAHL, sensory device [HA or CI], age at fitting of HAs, age at CI switch-on), and child and family-related variables (gender, cognitive ability, maternal education, communication mode in early intervention) across the entire participant cohort. This second step was achieved using correlations and regression procedures. Participants were included in individual regression analyses only if their data were complete (i.e., if they had valid scores on the dependent variable and all predictor variables). Three regression models were fitted for each of the six dependent variables (PLS-4 receptive and expressive, CDI receptive and expressive, PPVT-4, DEAP phonemes correct). The first model included four categorical variables and one continuous variable. Categorical variables were gender, device type (HA or CI), communication mode in early intervention (oral or mixed), and maternal education, which was recoded as two binary variables using university level education as the reference category. The continuous variable was 4FAHL. In the second model, the continuous variable of age at intervention with the child's current device was added to the set of predictors. This single variable was operationalised as age at first HA fitting for children using HAs, and age at first CI switch-on for children with CIs. In the third and final model the continuous variable of cognitive ability was added to the regression model.

The final set of analyses was designed to address the question of whether similar demographic variables are important in predicting outcomes for DHH children with additional disabilities who use HAs or CIs. Correlations and regression techniques as described above were used for this purpose omitting the predictor variable of device type.

In line with standard practice, a Type I error rate of α = .05 (two-tailed) was adopted for all statistical analyses, which were performed using SPSS version 22.0 (IBM Corp., 2013).

Results

Of the 146 participants, 29 who did not have valid scores on any of the language and speech outcome measures were omitted from all further analyses. Average hearing loss was more severe in these omitted participants than in those with at least one valid score (4FAHL = 74.1 vs. 59.6 respectively; $t[144] = 2.89$, $p = .005$), but there was no significant difference in maternal education ($\chi^2[2] = 3.18$, $p = .20$). In cases where valid scores were not achieved, the major contributing factors were: participants' inability to cope with the task demands; use of nonstandard administration (e.g., a combination of speech and sign), which precluded the use of standard scores; unavailability for testing; and, in the case of the CDI, a failure to return completed caregiver-report forms.

Table 3 shows the number of participants ~~(out of 146) who achieved~~with valid scores on the ~~various~~ individual language and speech outcome measures and the assessment of nonverbal cognitive ability. Also shown ~~in Table 3~~ are participants' mean scores and standard deviations on the individual assessment tasks. These scores were computed using all available data. Thus, means for each task are based on somewhat different participant subgroups. A second set of means was also computed, however, for participants who achieved valid scores on all tasks. Because these means showed the same pattern of results as those reported in Table 3, they are not included here.

Table 3

As the data in Table 3 show, participants' language and speech outcomes on the directly administered tasks (PLS-4, PPVT-4, DEAP) were, in general, approximately 1 to 2 SDs below the means for typically developing children without hearing loss. On the parent-report (CDI) measure, scores were more than 30% below age expectations, representing impaired performance. These marked delays stand in contrast to the children's relatively good performance on the measure of nonverbal cognitive ability, which placed them, on average, within approximately 0.3 ~~0.5~~ SDs of the typical mean (see Table 3). Despite this general pattern of delayed language and speech relative to cognitive ability, there was also variation according to the particular skills assessed. Whereas children scored 2 SDs below the typical mean in speech production (DEAP), their receptive vocabulary scores (PPVT-4) were relatively better, at just below 1 SD of the typical mean.

Associations between demographic variables and outcome measures

Table 4 presents the results of a bivariate correlational analysis conducted to address the second research question, which was aimed at identifying the demographic variables associated with children's language and speech outcomes. As shown, four demographic variables were significantly correlated with the various outcome measures.

Table 4

1. Use of oral communication only rather than a mixed mode (oral/sign) was associated with better outcomes on all language and speech measures.
2. Nonverbal cognitive ability was positively correlated with all language and speech measures.
3. Higher levels of maternal education were associated with better receptive language scores on the PLS-4.
4. More severe levels of hearing loss were associated with poorer outcomes on all language and speech measures except for the receptive language scale of the PLS-4.

None of the four remaining demographic variables (gender, device, age at HA fitting, or age at CI switch-on) was significantly associated with children's language or speech outcomes.

Predicting outcomes as a function of demographic variables

Six multiple regressions were conducted to investigate in more detail the associations described above. The results are summarised in Table 5. For each of the five language outcome measures (PLS-4 receptive and expressive, CDI receptive and expressive, and PPVT4), the full set of predictors accounted for significant total variance ranging from 41% to 57%. For the remaining measure, phonemes correct on the DEAP, the full set of predictors accounted for only 17% of variance, which was not significant. Four other main findings are noteworthy.

Table 5

First, better language outcomes on the PLS-4, CDI, and PPVT-4 were all associated with milder levels of hearing loss, use of oral communication, and higher levels of cognitive ability after controlling for the variance associated with other demographic variables. Second, children whose mothers completed postsecondary education achieved better outcomes on the directly administered language assessments (PLS-4 and PPVT-4) than children whose mothers had 12 years or less formal schooling. Third, age at intervention with the current device (HA or CI) accounted for significant unique variance in PLS-4 receptive language scores and CDI expressive language scores, reflecting better outcomes for children who received their devices earlier. Fourth, communication mode (oral vs. mixed) was the only variable to significantly predict speech output performance on the DEAP (see Table 5).

Predicting outcomes in children with HAs versus CIs

With respect to the study's third aim, Table 6 presents mean standard scores for individual outcome measures and correlations between demographic variables and outcomes for subgroups of children fitted with HAs or CIs. Independent samples t-tests revealed no significant difference in mean outcomes between the participant subgroups (all *p*s > .20); however, a different pattern of associations was observed for children with HAs versus CIs. In particular, results for children with HAs resembled those for the cohort as a whole in that better outcomes were generally associated with higher levels of cognitive ability, use of oral communication, milder levels of hearing loss, and for the PLS-4, higher levels of maternal education. By contrast, for children with CIs, only use of oral communication was consistently associated with better language outcomes, and higher levels of cognitive ability were associated with better outcomes on the PLS-4 receptive language scale (see Table 6).

Tables 6 and 7

Outcomes for HA users were investigated further with multiple regression. The results are presented in Table 7. Once again, the pattern of results resembled that for the cohort as a whole. The predictor variables combined accounted for significant total variance ranging from 24% for the DEAP to 65% for the PPVT-4. Better language outcomes on the PLS-4, CDI, and PPVT-4 were all associated with milder levels of hearing loss, use of oral communication, and higher levels of cognitive ability. Children whose mothers had completed postsecondary education achieved better language outcomes on the directly administered language assessments (PLS-4 and PPVT-4) than children whose mothers had 12 years or less formal schooling. Communication mode was the only variable to significantly predict speech output performance on the DEAP; and age at fitting of HAs accounted for significant unique variance in PLS-4 receptive language scores, reflecting better language outcomes in children who received their devices earlier.

Discussion

The aim of this investigation was to evaluate language and speech outcomes in a large sample of 5-year-old DHH children with additional disabilities. In line with recommendations in the literature, outcome measures involved both direct assessment and caregiver report (e.g., Berrettini et al., 2008; Edwards, 2007). A total of 146 children took part in the study, which was aimed at: (1) documenting their delays in language and speech outcomes relative to nonverbal cognitive ability using standardised, norm-referenced tests; and (2) identifying the demographic variables associated with language and speech outcomes both in the cohort as a whole and in children using different types of sensory devices – HAs or CIs.

As regards these research aims, we note first that children in this study achieved language and speech outcomes on directly administered measures of 1 to 2 SDs below average for hearing children of the same age. They were also more than 30% below age expectations on a caregiver-report measure of receptive and expressive language. By contrast, nonverbal cognitive ability was within approximately 0.30.5 SDs of the typical mean. There was no obvious difference between outcome measures in their sensitivity to the children's difficulties, although receptive vocabulary appeared to be a relative strength.

Second, in the cohort as a whole, three demographic variables were consistently associated with language outcomes on the PLS-4, PPVT-4 and CDI: Children with less severe hearing losses achieved better outcomes, as did children with higher levels of nonverbal cognitive ability and those using oral communication only in early intervention. While these correlations are not indicative of a causal relationship, they are in the expected direction. Other relevant variables were maternal education, which predicted outcomes on two of the three directly administered assessments (PLS-4, PPVT-4), and age at fitting of the current device (HA or CI), which predicted PLS-4 receptive and CDI expressive outcomes. The sixth primary outcome measure, the DEAP, assessed children's speech output accuracy. In this case, just a single demographic variable, communication mode, uniquely predicted performance. It is difficult to interpret this finding in a meaningful way, however, given that both variables essentially measure the same thing; that is, a child's ability to use the oral modality for communication. Finally, when outcomes were considered for children with HAs only, the pattern of results was virtually identical to that for the cohort as a whole: The only exception was that age at fitting of HAs significantly predicted PLS-4 receptive language outcomes, but not CDI expressive outcomes.

Findings from the current study are noteworthy in several respects. First, they provide the strongest evidence yet that audiological, cognitive and demographic variables influence language outcomes in DHH children with additional disabilities. Thus, the current set of well-established, early predictor variables accounted for between 41 and 57% of variance in receptive and expressive language outcomes across the range of measures used. Second, the current findings reveal a marked similarity in the pattern of results obtained across the various language outcome measures, in particular the directly administered PLS-4 and the caregiver reported CDI. Cupples et al. (2014) reported similar consistency between these assessments when LOCHI children were 3 years of age.

A third noteworthy aspect relates to the increased number of demographic variables significantly associated with language outcomes in the current cohort of 5-year-old children as compared to the earlier, 3-year-old cohort. Despite the increased number of significant predictors identified in the current study, the two data sets reveal a high degree of consistency. Indeed, the only significant predictor to emerge at 5 years of age that was not identified in the 3-year-old data was age at device fitting. Of the remaining significant 5-year-old predictors: maternal education predicted 3-year-old PLS-4 outcomes; and degree of hearing loss and communication mode predicted the performance of a subgroup of 3-year-old children who were identified as having impairments to vision or speech output, various syndromes not entailing DD, or medical disorders (Cupples et al., 2014). Finally, nonverbal cognitive ability was most likely reflected in the variable of "disability type" at 3 years of age, given the marked differences in WNV standard scores observed between children with different types of disabilities in the current study (see Table 1).

The stronger and more consistent associations observed between predictor variables and outcome measures at 5 years of age than at 3 years of age probably reflects an increase in the reliability and validity of the test results achieved by children as they get older and become more able to cope with the demands of direct assessment. As regards the positive influence of earlier device fitting on selected language outcomes at 5 years of age, we interpret this finding as confirming our previous suggestion that a stronger effect of early auditory stimulation on language development may emerge at an age older than 3 years (Cupples et al., 2014). More importantly, this finding underscores the clinical need for early fitting of HAs or CIs in children with additional disabilities.

A question arises as to why previous studies have often failed to find evidence of associations between well-established early predictors and language outcomes in DHH children with additional disabilities (e.g., Beer et al., 2012; Meinzen-Derr et al., 2011). The answer is clear with respect to the role of age at HA fitting, since previous studies have focused more narrowly on the benefits of cochlear implantation. With respect to the other significant predictors identified here, the previous literature is dominated by investigations of small heterogeneous samples and individual cases, thus reducing generalisability and contributing to a pattern of mixed and inconsistent findings (e.g., Beer et al., 2012; Berrettini et al., 2008; Fukuda et al., 2003; Meinzen-Derr et al., 2010, 2011; Wiley et al., 2008). By contrast, a major strength of the research reported here is the inclusion of a large and heterogeneous participant sample, comprising 146 children with a diverse range of additional disabilities. This large sample made it feasible to evaluate the unique influence of a range of demographic variables while controlling for others, an approach that was not possible in most previous studies. Despite the large number of children included in the current participant sample, however, missing data meant that the cohort of children with CIs was not large enough to enable use of multiple regression analyses to investigate the unique predictors of language and speech outcomes in that sub-group. The 9-year-old assessments conducted as part of the wider LOCHI study may enable us to address this shortcoming, as more participants develop the ability to cope with task requirements.

An advantage that follows from the large number of participants included in this research is enhanced generalisability of the findings to the population of DHH children with additional disabilities. Also noteworthy in this regard is that the current sample was drawn from an Australian, population-based cohort who participated in the 5-year-old assessment phase of the LOCHI study. The only criterion for inclusion in the current analyses was the presence of a diagnosed disability in addition to hearing loss by the age of 5 years. Also encouraging are the nature and distribution of disability types within our sample. At 39% the total percentage of children with reported additional disabilities is similar to that reported in the Annual Survey of Deaf and Hard of Hearing Children in the United States (Gallaudet Research Institute, 2011). Also the range of reported disability types and their relative frequencies (although computed differently) are similar in revealing a large percentage of children with developmental delay (including intellectual disability and learning disability), and smaller percentages with other disabilities such as visual impairment (or deafblindness), orthopaedic impairment (including CP), and ASD.

In conclusion, this investigation demonstrates an important role for well-established early predictors of outcomes in DHH children with additional disabilities who use HAs or CIs. More specifically, severity of hearing loss, cognitive ability, and mode of communication all made a significant unique contribution to children's receptive and expressive language outcomes on both directly administered and caregiver report measures. Maternal education and age at fitting of the child's current audiological device also made a unique contribution to some, but not all, outcome measures. This pattern of results was obtained when data from the full participant sample were analysed, and when analyses were restricted to a cohort of children who were fitted with HAs. Through its focus on the effectiveness of HAs in particular for DHH children with additional disabilities, this research fills a significant gap in the literature. Moreover, it provides important clinical data regarding the potential benefits of early device fitting for this population.

Declaration of interest

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Table 1.

Mean nonverbal IQs (Wechsler Nonverbal full scale scores) - children grouped according to type of disability (N = 146)

Type of Disability	**No. of children (%)**		**Mean IQ (SD; range, n)**
1. Autism spectrum disorder (ASD)	18	(12.3)	92.2 (9.5; 77-107; n=10)
2. Cerebral palsy (CP)	25	(17.1)	96.5 (19.6; 60-123; n=15)
3. ASD + CP	4	(2.7)	68.0 (26.5; 39-91; n=3)
4. Developmental delay (DD) with a syndrome/condition other than ASD or CP	30	(20.5)	82.2 (12.7; 58-96; n=17)
5. DD only	7	(4.8)	79.6 (14.1; 64-93; n=5)
6. Vision[a]	15	(10.3)	108.0 (11.6; 91-128; n=12)
7. Speech output	6	(4.1)	101.8 (13.4; 78-118; n=6)
8. Various syndromes (not entailing DD)[b]	26	(17.8)	100.5 (14.5; 72-130; n=21)
9. Medical[c]	15	(10.3)	102.8 (16.8; 67-120; n=13)
TOTAL PARTICIPANTS	**146**		

[a]Category 6 contains children with a visual disability only (n = 13) or a combined visual/medical disability (n = 2). An additional 28 children who had a visual disability combined with ASD, CP, DD, or another syndrome not entailing DD were included in categories 1, 2, 3, 4 or 8 as appropriate. [b]Category includes: Waardenburg (n = 5), Treacher-Collins (n = 4), LVAS (n = 2), Pendred (n = 2), bronchio-oto-renal (BOR), OSMED, Goldenhar, Stickler, proximal symphalangism, glycogen storage disorder, sensory overload, choreoathetosis, translocation of chromosomes 2 and 6, cystic fibrosis, oppositional defiance disorder (n = 1 each), and 2 unspecified disorders. [c]Category includes disorders of the brain (microcephaly), heart, kidneys, thyroid, bones, muscles, and nervous system.

Table 2.

Participants' background information (*N* = 146)

Variable	**No. of Participants (Percentage)[a]**	
Gender (Male)	92	(63.0%)
Degree of Hearing Loss (4FAHL)		
Mild (≤ 40 dB)	24	(16.4%)
Moderate (41-60 dB)	56	(38.4%)
Severe (61-80 dB)	32	(21.9%)
Profound (>80 dB)	34	(23.3%)
Device Use		
Hearing Aid: Bilateral	86	(58.9%)
Unilateral	11	(7.5%)
Cochlear Implant: Bilateral	26	(17.8%)
Unilateral	9	(6.2%)
Cochlear Implant plus Hearing Aid	14	(9.6%)
Maternal Education (*n* = 144)		
1. University Qualification	53	(36.8%)
2. Diploma or Certificate	49	(34.0%)
3. 12 years or less of schooling	42	(29.2%)
Communication mode in early intervention (*n* = 145)		
Oral only	83	(57.2%)
Sign	3	(2.1%)
Mixed (sign and speech)	59	(40.7 %)

Note: 4FAHL = the average of hearing threshold levels at 0.5, 1, 2, and 4 KHz in the better ear, represented non-linearly.

[a]Due to missing data for some variables, scores are based on different numbers of participants as specified.

Table 3

Mean language, speech, and cognitive outcomes (standardised scores) for all participants with valid scores

	Outcome Measure						
	Receptive Language			Expressive Language		Speech	Cognition
	CDI	PLS-4	PPVT-4	CDI	PLS-4	DEAP	WNV
Valid N	98	103	96	98	103	96	102
Mean	65.0	77.1	83.2	62.8	74.4	3.93	95.3
(SD)	(23.2)	(20.8)	(18.5)	(25.8)	(20.0)	(1.8)	(17.5)
~~SDs < Mean~~No. of SDs below the mean[a]	…[b]	1.53	1.12	…[b]	1.71	2.02	0.31

Note. CDI = Child Development Inventory developmental quotient; PLS-4 = Preschool Language Scale, 4th edition, standard score; PPVT-4 = Peabody Picture Vocabulary Test, 4th edition, standard score; DEAP = Diagnostic Evaluation of Articulation and Phonology, phonemes correct, standard score; WNV = Wechsler Non-Verbal Full Scale IQ.

[a]No. of SDs below the mean was computed by subtracting the current participants' mean score from the mean standard score obtained from test norms and dividing by the norm-based SD (i.e., for WNV: (100 - 95.3)/15 = 0.31).

[b]Standard scores are not computed for the CDI. Rather, developmental quotients are reported, with quotients of <70% representing impaired performance.

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Table 4

Correlations between demographic variables and outcome measures for all children, with number of paired observations in parentheses

	Mode	MatEd	4FAHL	Device	AgeHA	AgeSO	WNV	CDIRec	PLSRec	PPVT-4	CDIExp	PLSExp	DEAP
Gender	.03	.07	.11	-.06	.04	-.13	.13	.14	.01	.03	.10	.07	-.10
	(145)	(144)	(146)	(146)	(146)	(49)	(102)	(98)	(103)	(96)	(98)	(103)	(96)
Mode	1.00	.13	**.20***	.14	**-.19***	.24	-.15	**-.35*****	**-.30****	**-.50*****	**-.33*****	**-.32*****	**-.20***
	(145)	(143)	**(145)**	(145)	**(145)**	(49)	(102)	**(97)**	**(102)**	**(95)**	**(97)**	**(102)**	**(95)**
MatEd		1.00	-.13	**-.22****	.08	.24	-.14	-.15	**-.27****	-.10	-.15	-.19	.01
		(144)	(144)	**(144)**	(144)	(49)	(101)	(97)	**(102)**	(95)	(97)	(102)	(95)
4FAHL			1.00	**.72*****	**-.34*****	-.21	.05	**-.21***	-.19	**-.32*****	**-.20***	**-.27****	**-.20***
			(146)	**(146)**	**(146)**	(49)	(102)	**(98)**	(103)	**(96)**	**(98)**	**(103)**	**(96)**
Device				1.00	**-.28*****	…[a]	.10	-.11	-.07	-.12	-.11	-.13	-.02
				(146)	**(146)**		(102)	(98)	(103)	(96)	(98)	(103)	(96)

AgeHA	1.00 (146)	.22 (49)	.06 (102)	.04 (98)	-.03 (103)	.19 (96)	.00 (98)	.06 (103)	.11 (96)
AgeSO		1.00 (49)	-.09 (30)	-.23 (31)	-23 (25)	-.35 (26)	-.26 (31)	-.32 (25)	-.16 (23)
WNV			1.00 (102)	**.46***** **(81)**	**.52***** **(85)**	**.49***** **(83)**	**.43***** **(81)**	**.47***** **(85)**	**.23*** **(86)**

Note. Pearson's *r* is reported for correlations involving two continuous variables, Spearman's *rho* for correlations involving maternal education, and point-biserial correlations for associations between one dichotomous and one continuous variable; Gender (0 = male; 1 = female); Mode = Mode of Communication in early intervention (0 = oral; 1 = mixed); MatEd = Maternal Education (1 = university; 2 = diploma/certificate; 3 = ≤12 years formal schooling); 4FAHL = 4 Frequency Average Hearing Loss in the better ear; Device (0 = HA; 1 = CI); AgeHA = Age at Hearing Aid Fitting; AgeSO = Age at CI switch-on; WNV = Wechsler Non-Verbal Full Scale IQ; CDIRec = CDI Receptive Language (Language comprehension) developmental quotient; PLSRec = PLS-4 Receptive Language (Auditory comprehension) standard score; PPVT-4 = PPVT-4 Receptive Vocabulary standard score; CDIExp = CDI Expressive Language developmental quotient; PLSExp = PLS-4 Expressive Communication standard score; DEAP = DEAP Percent phonemes correct standard score.

[a]Age at switch-on applies only to children with CIs

* = $p \leq .05$; ** = $p \leq .01$; *** = $p \leq .001$

Table 5

Multiple regression summaries for language and speech outcomes: All children

	Outcome Measure					
	Receptive Language			Expressive Language		Speech Output
Predictors	CDI	PLS-4	PPVT-4	CDI	PLS-4	DEAP
	R^2 Change					
Gender, 4FAHL, Mode, MatEd, Device	**.27*** **	**.26*** **	**.42*** **	**.22** **	**.31*** **	.13
Age at Intervention (with current device)	.02	**.04* **	.00	**.04* **	.02	.01
Wechsler Nonverbal Full Scale score	**.16*** **	**.21*** **	**.15*** **	**.15*** **	**.16*** **	.03
Total R^2	**.45*** **	**.51*** **	**.57*** **	**.41*** **	**.49*** **	.17
N	80	84	82	80	84	85
	Regression Coefficients					
Gender (reference: male)	5.042	-1.770	1.592	1.787	1.822	-0.317
4FAHL	**-0.440** **	**-0.352** **	**-0.336** **	**-0.431* **	**-0.394** **	-0.018
Device (reference: HA)	11.740	-2.492	2.997	10.017	3.111	0.341
Mode (reference: oral)	**-7.071** **	**-7.238*** **	**-9.338*** **	**-8.824** **	**-7.776*** **	**-0.469* **

MatEd (reference: university)						
Certificate or Diploma	8.448	-1.583	2.598	5.103	1.589	0.226
12 years or less	-6.417	**-14.288****	**-7.916***	-9.977	**-11.742***	-0.414
Age at Intervention (with current device)	-0.257	**-0.351***	-0.123	**-0.465***	-0.251	-0.011
Wechsler Nonverbal Full Scale score	**0.515*****	**0.586*****	**0.426*****	**0.566*****	**0.494*****	0.018

Note. Regression coefficients are for the final model containing all predictor variables; Mode = communication mode in early intervention; MatEd = Maternal education (coded as two binary variables using university education as the reference category); Device = HA versus CI.

* = p ≤ .05; ** = p ≤ .01; *** = p ≤ .001

Table 6

Mean language and speech outcome scores and correlations between demographic variables and outcome measures for children with HAs and CIs separately (number of paired observations in parentheses)

	Hearing Aid(s)						Cochlear Implant(s)					
	CDIRec	**PLSRec**	**PPVT-4**	**CDIExp**	**PLSExp**	**DEAP**	**CDIRec**	**PLSRec**	**PPVT-4**	**CDIExp**	**PLSExp**	**DEAP**
Mean	66.7	77.9	84.6	64.6	75.8	3.9	61.2	74.8	79.5	58.8	69.9	3.9
SD	23.3	21.3	19.3	25.2	20.5	1.8	23.1	19.7	16.2	26.8	18.2	1.6
N	67	78	70	67	78	73	31	25	26	31	25	23
Gender	.15 (67)	.05 (78)	.10 (70)	.15 (67)	.12 (78)	-.10 (73)	.10 (31)	-.17 (25)	-.23 (26)	-.03 (31)	-.18 (25)	-.11 (23)
Mode	**-.29*** **(66)**	**-.30**** **(77)**	**-.53***** **(69)**	-.21 (66)	**-.31**** **(77)**	-.20 (72)	**-.47**** **(31)**	-.33 (25)	**-.43*** **(26)**	**-.55***** **(31)**	**-.42*** **(25)**	-.21 (23)

MatEd	-.22 (66)	**-.35** (77)**	-.17 (69)	-.20 (66)	**-.32** (77)**	.00 (72)		-.14 (31)	-.07 (25)	-.01 (26)	-.27 (31)	.04 (25)	-.13 (23)
4FAHL	**-.25* (67)**	**-.23* (78)**	**-.41*** (70)**	-.23 (67)	**-.27* (78)**	**-.31** (73)**		-.08 (31)	-.15 (25)	-.21 (26)	-.11 (31)	-.22 (25)	-.20 (23)
AgeHA	.07 (67)	-.01 (78)	.22 (70)	.02 (67)	.07 (78)	.16 (73)		-.29 (31)	-.32 (25)	-.16 (26)	-.26 (31)	-.27 (25)	-.21 (23)
AgeSO	…[a]	…[a]	…[a]	…[a]	…[a]	…[a]		-.23 (31)	-.23 (25)	-.35 (26)	-.26 (31)	-.32 (25)	-.16 (23)
WNV	**.52*** (57)**	**.55*** (64)**	**.54*** (61)**	**.52*** (57)**	**.53*** (64)**	**.27* (64)**		.30 (24)	**.52* (21)**	.40 (22)	.14 (24)	.32 (21)	.03 (22)

Note. Pearson's *r* is reported for correlations between two continuous variables, Spearman's *rho* for correlations involving maternal education, and point-biserial correlations for associations between one dichotomous and one continuous variable; Gender (0 = male; 1 = female); Mode = Mode of Communication in early intervention (0 = oral; 1 = mixed); MatEd = Maternal Education (1 = university; 2 = diploma/certificate; 3 = ≤12 years formal schooling); 4FAHL = 4 Frequency Average Hearing Loss in the better ear; Device (0 = HA; 1 = CI); AgeHA = Age at Hearing Aid Fitting; AgeSO = Age at CI switch-on; WNV = Wechsler Non-Verbal Full Scale IQ; CDIRec = CDI Receptive Language (Language comprehension) developmental quotient; PLSRec = PLS-4 Receptive Language (Auditory comprehension) standard score; PPVT-4 = PPVT-4 Receptive Vocabulary standard score; CDIExp = CDI Expressive Language developmental quotient; PLSExp = PLS-4 Expressive Communication standard score; DEAP = DEAP Percent phonemes correct standard score.

[a]Age at switch-on applies only to children with CIs

* = $p \leq .05$; ** = $p \leq .01$; *** = $p \leq .001$

Table 7

Multiple regression summaries for language and speech outcomes: Children with HAs only

	Outcome Measure					
	Receptive Language			Expressive Language		Speech Output
Predictors	CDI	PLS-4	PPVT-4	CDI	PLS-4	DEAP
	R^2 Change					
Gender, 4FAHL, Mode, MatEd	**.35*** **	**.32*** **	**.53*** **	**.29** **	**.37*** **	**.20* **
Age at HA fit	.02	**.05* **	.00	.03	.02	.00
Wechsler Nonverbal Full Scale score	**.17*** **	**.21*** **	**.12*** **	**.19*** **	**.17*** **	.04
Total R^2	**.54*** **	**.58*** **	**.65*** **	**.51*** **	**.56*** **	**.24* **
N	56	63	60	56	63	63
	Regression Coefficients					
Gender	7.039	-0.427	3.091	4.808	4.135	-0.496
4FAHL	**-0.635*** **	**-0.441** **	**-0.519*** **	**-0.570** **	**-0.492** **	-0.022
Mode (reference: oral)	**-7.268** **	**-7.626** **	**-10.221*** **	**-7.658* **	**-7.046** **	**-0.501* **
MatEd (reference: university)						

Certificate or Diploma	5.202	-5.172	0.520	4.286	-1.460	0.391
12 years or less	-6.771	**-17.659*** **	**-9.353***	-10.927	**-14.823** **	-0.529
Age at HA fit	-0.287	**-0.424** **	-0.125	-0.417	-0.255	-0.008
Wechsler Nonverbal Full Scale score	**0.510*** **	**0.555*** **	**0.374*** **	**0.592*** **	**0.483*** **	0.020

Note. Regression coefficients are for the final model containing all predictor variables; Mode = Communication mode in early intervention; MatEd = Maternal education (coded as two binary variables using university education as the reference category); Device = HA vs. CI

* = p ≤ .05; ** = p ≤ .01; *** = p ≤ .001