Phonological Awareness at 5 years of age in Children who use Hearing Aids or Cochlear Implants

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Conflicts of interest

None were declared.

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Abstract

Children with hearing loss typically underachieve in reading, possibly as a result of their underdeveloped phonological skills. This study addressed the questions of whether the development of phonological awareness (PA) is influenced by 1) the degree of hearing loss; and 2) whether performance of children with severe-profound hearing loss differed according to the hearing devices used. Drawing on data collected as part of the Longitudinal Outcomes of Children with Hearing Impairment (LOCHI, www.outcomes.nal.gov.au) study, the authors found that sound-matching scores of children with hearing loss ranging from mild to profound degrees were, on average, within the normal range. The degree of hearing loss did not have a significant impact on scores, but there was a non-significant tendency for the proportion of children who achieved zero scores to increase with increase in hearing loss. For children with severe hearing loss, there was no significant group difference in scores among children who used bilateral hearing aids, bimodal fitting (a cochlear implant and a hearing aid in contralateral ears), and bilateral cochlear implants. Although there is a need for further prospective research, professionals have an important role in targeting PA skills for rehabilitation of young children with hearing loss.

About three children in every thousand are fitted with hearing aids or receive cochlear implants by school entry for a permanent hearing loss (Australian Hearing, 2011). Many of them struggle to learn to read, a skill that is crucial to academic achievement. In the US, the median reading level of high school graduates with hearing loss falls between the fourth and fifth grade level (Helfand et al., 2001; Qi & Mitchell, 2012). In a similar vein, a lag in reading performance by nearly ten months has been reported for an Australian population sample of 7-8 year olds with hearing loss (Wake, Hughes, Poulakis, Collins, & Rickards, 2004). This underachievement in reading skills may be related to an underdevelopment of phonological skills (Musselman, 2000; Perfetti & Sandak, 2000). This association has been reported for children with typical development (see Melby-Kervag, Lyster, & Hulme, 2012, for a review), but previous studies on children with hearing loss have produced conflicting findings. Some reported a significant link (Colin, Magnan, Ecalle, & Leybaert, 2007; Dillon, de Jong, & Pisoni, 2012; Easterbrooks, Lederberg, Miller, Bergeron, & Connor, 2008; Spencer & Tomblin, 2009), whereas others showed either no significant association (Gibbs, 2004; Izzo, 2002) or an association that was mediated by degree of hearing loss (Kyle & Harris, 2006) or vocabulary knowledge (Johnson & Goswami, 2010). By controlling for the effects of known confounders, our earlier paper provided clear evidence of the role of phonological awareness (PA) in oral word reading of children at 5 years of age (Cupples, Ching, Crowe, Day, & Seeto, 2014). In this context, the present paper addresses the question of whether there is a significant association between PA and severity of hearing loss; and whether device type (hearing aids vs cochlear implants) influences PA development of children with severe hearing loss.

PA refers to an awareness or conscious knowledge of the sound structure of a language and/or the ability to manipulate this sound structure (Stahl & Murray, 1994). PA skills are commonly assessed using tasks of segmentation, blending, and judgements of phonological similarity or difference. Segmentation involves the ability to count or identify the component sounds in words or non-words (e.g. ‘cat’ = /k/+/æ/+/t/). Blending involves the ability to put small phonological units, such as phonemes or syllables, together in a sequence to form words or non-words (e.g., /m/+/æ/+/t/ = ‘mat’). Finally, judgments of similarity or difference are commonly used to assess awareness of alliteration or rhyme, both of which rely on the ability to identify the sub-syllabic units of onset (the initial consonant or consonant cluster) and rime (the vowel and any following consonants), such as /p/+/æn/ or /sp/+/æn/.

Auditory access to the sound structure of language may be expected to be an essential condition for acquiring sensitivity to it. If speech cannot be heard, its structure cannot be brought to conscious awareness. Children with congenital hearing loss rely on the auditory input delivered via a hearing aid or a cochlear implant to acquire sensitivity to the sound structure of speech. A hearing aid (HA) amplifies sounds to an audible level. This increases access to the time-varying spectral information that signals vowel quality and consonant contrasts in the spoken language to support a child’s acquisition of phonological skills. The ability to extract information from an audible signal, however, decreases as hearing loss increases (Ching, Dillon, Katsch, & Byrne, 2001). Unlike a hearing aid, a cochlear implant system uses processing strategies that filter a continuous speech spectrum into a number of discrete bands, extract the short-term amplitude structure of each band, and use it to govern the stimulation levels of electrodes that are positioned close to the basilar membrane of the user. Relative to a hearing aid, the signal delivered by a cochlear implant is inferior in spectral content. For a child with profound hearing loss, cochlear implantation may be the only option to provide audibility. When a device is worn, the spectral resolution of a user is determined by not only the quality of the input signal, but also the neural survival and auditory analytic ability of the user (Henry & Turner, 2003; 2005). For a child with severe hearing loss, whether the use of hearing aids or cochlear implants is more effective for the acquisition of sensitivity to the sound structure of language is uncertain.

A related question of interest is whether the use of bimodal fitting (a hearing aid and a cochlear implant in contralateral ears) may be more beneficial than bilateral cochlear implantation for PA development in young children. When a child has profound hearing loss in both ears, bilateral cochlear implantation provides audibility in both ears. But when a child has a unilateral cochlear implant in one ear and residual hearing in the non-implanted ear, there is ample evidence to indicate that bimodal fitting provides speech perceptual benefits (see Ching, van Wanrooy, & Dillon, 2007, for a review). Hearing aid amplification provides access to low-frequency voice pitch information that contributes to voicing and manner contrasts in consonant perception. This complements the predominately high-frequency information transmitted by the cochlear implant to enhance consonant perception (Ching, 2011; Incerti, Ching, & Hill, 2011). It has also been shown that bimodal experience is beneficial for language development in young children with one or two cochlear implants (Nittrouer & Chapman, 2009; Nittrouer, Sansom, Low, Rice, & Caldwell-Tarr, 2014).

Previous studies on PA skills of children with mild or moderate hearing loss have shown that some achieved scores similar to their peers with normal hearing whereas others lagged behind. Briscoe, Bishop, and Norbury (2001) assessed the abilities of 19 children with hearing loss (mean age 8.6 years) to match words of similar onset or rime. Thirteen of the children had mild hearing loss (pure tone average or PTA from 0.25 to 4 kHz ≤ 40 dB HL), three had moderate hearing loss (PTA between 41 and 70 dB HL) and three had high-frequency hearing loss (PTA <20 dB HL, but thresholds at 2 and 4 kHz >25 dB HL). On average, PA scores of children with hearing loss were significantly lower than those of children with normal hearing. Gibbs (2004) reported awareness of rhyme and initial phonemes in 15 children with moderate hearing loss (PTA = 56 dB HL) who were between 7 and 9 years of age. On average, the 7-year-old children with hearing loss had PA scores that were similar to those of 6-year-old children with normal hearing, and vocabulary scores that were comparable to 5-year-old children with normal hearing. There were significant negative correlations between rhyme awareness and hearing thresholds at 500 Hz; and between phoneme awareness and hearing thresholds at 2 and 4 kHz. Nine of the 15 children had PA scores within the normal range. On average, their hearing thresholds were not significantly different from the 6 children who exhibited PA deficits. As the studies pertain to children at school age, the results may have been confounded by differences in the formal instructions children received in alphabetic reading as part of their schooling, or their varied stages of reading development. The influence of degree of hearing loss on early PA development is uncertain.

Previous studies on children with severe or profound hearing loss (PTA >71 dB HL) have reported abilities similar to those with normal hearing in awareness of syllable (Sterne & Goswami, 2000; James et al., 2005) or rhyme (Charlier & Leybaert, 2000); but deficiencies in awareness of onset-rime (Harris & Beech, 1998) and phoneme (James, Rajput, Brinton, & Goswami, 2008; Most, Aram, & Andoorn, 2006). Studies that have included an orthographic component in their tests have shown that school-aged students and college students used orthographic knowledge to make phonological judgments (James, et al., 2008; Sterne & Goswami, 2000; Transler, Leybaert, & Gombert, 1999). The findings on PA abilities varied, depending on age at testing, age at audiological intervention, exposure to different communication modes (oral language, cued speech and/or signed language) in educational environments, and experience in formal education.

Recent studies on children with severe or profound hearing loss focussed on assessing the efficacy of cochlear implantation. There is general agreement that children with CIs performed within the normal range for tasks involving syllable counting or tracking, but exhibited deficiencies for tasks that required detection and manipulation at the level of phonemes. Dillon et al. (2012) assessed 27 children who used cochlear implants, ranging in age from 6 to 14 years. The tasks included similarity judgments of isolated phonemes, tracking the number and order of phonemes in a syllable, counting the number of syllables, tracking the number and order of syllables, and tracking changes in phonemes or syllables. Children were required to respond to each test by manipulating blocks. On average, children scored 0.8 standard deviation (SD) below the normative mean. There was considerable variability in performance across tasks, with the highest average scores obtained for judgment of isolated phonemes and counting syllables. Only seven children obtained a score of 50% or higher in the tracking phoneme task. When the tracking syllables and phonemes task was administered to them, three obtained zero scores. There was considerable individual variability, which the authors attributed to variations in demographic characteristics and educational environments.

James et al. (2008) reported PA skills of 19 children who received cochlear implants between 2 and 7 years of age. The children were assessed at a mean age of 8.4 years, using tests that required similarity judgments of syllable, rhyme and initial phoneme. On average, scores for the syllable test were within the normal range, those for the rhyme test were at 1 SD below the normative mean, and those for the phoneme test were below 1.5 SD of the normative mean. Nittrouer et al. (2014) assessed performance of 27 children with CIs at 82 months of age, using tasks that required them to count syllables in a word, judge whether initial consonants of pairs of words were the same or different, and choose one out of three words that have the same final consonant as a target word. The study found that children with CIs did not differ significantly from children with normal hearing in the syllable counting task, but were more than 1.5 SD below the mean of the normative population in tasks that required judgments of initial and final consonants.

Two studies reported a comparison of PA skills in children who use CIs or HAs. James et al. (2005) investigated syllable, rhyme, and phoneme awareness in 19 children who used CIs and 21 children with severe or profound hearing loss who used hearing aids. The children with CIs had significantly lower scores for the rhyme test than children with severe hearing loss who used HAs, but equivalent scores in the tests of syllable or phoneme awareness. On the other hand, Nittrouer et al. (2012) compared PA skills of 27 children using CIs (mean age 81 months) to those of 8 children with moderate hearing loss using HAs (mean age 78 months). Two children with CIs could not do the tasks. On average, the scores on syllable counting were equivalent among the two groups of children with hearing loss and a control group of children with normal hearing. However, both groups of children with hearing loss had significantly lower scores than children with normal hearing on tests relating to initial and final consonants. On average, there were no significant differences in PA skills between children with HAs and children with CIs. The authors attributed the lack of significant group difference between HA and CI to the small size of the sample of children with HAs. Having one or two cochlear implants did not have a significant effect on scores. No studies to date have considered the possible benefit of bimodal fitting in supporting early PA development of children with severe or profound hearing loss.

The present study extends earlier work in several ways. In particular, this study was designed to examine the relationship between PA skills and measures of hearing ability thought to underlie PA acquisition: severity of hearing loss and choice of hearing device (HA or CI). By including children with hearing loss ranging from mild to profound degrees, and assessing them at a young age to minimise the possible impact of formal literacy instruction, this study should provide valuable information to guide rehabilitation for improving outcomes of children with hearing loss.

Recent advances in technology for early detection of hearing loss have made it possible for intervention, including hearing aid or cochlear implantation, to be provided early in life. In Australia, all children with hearing loss have access to the consistent, high-quality hearing service provided by the government-funded organisation, Australian Hearing (AH), up to 26 years of age at no cost to the families. The children also have similar access to the full range of early intervention services (including centre- and home-based programs, and oral/aural, total communication or bilingual communication options), and to cochlear implants, at no cost to families. The effectiveness of these forms of early intervention for supporting PA acquisition is not known, given that most previous studies included children who received later intervention by current standards. By drawing on the cohort of the Longitudinal Outcomes of Children with Hearing Impairment (LOCHI) study (Ching, Leigh, & Dillon, 2013), the present paper examined the relationship between hearing ability and PA acquisition at 5 years of age in children with hearing loss who received early intervention.

Two primary research questions were addressed.

1. Does PA vary according to device type (HA vs. CI) in children with severe or profound hearing losses? A subsidiary question regarding device configuration was whether PA varied according to whether children used bilateral CIs or bimodal fitting (CI + HA).
2. Does PA vary according to severity of hearing loss in children who use HAs?

Based on current knowledge, we hypothesized that PA skills would decrease with an increase in hearing loss; and that PA skills of children with severe or profound hearing loss who used HAs would not differ from those who used CIs.

Method

Participants

Data are reported for a sample of 101 children drawn from a population-based cohort who were part of the LOCHI study. They had spoken English as a primary form of communication, either alone or in combination with sign (simultaneous communication) or another spoken language (bilingualism). A total of 104 other potential participants were excluded from the study sample for a variety of reasons: 29 were unavailable for assessment, 29 had a significant disability in addition to hearing loss, 6 did not use their hearing devices at the time of assessment or were fitted after 3 years of age, 5 had a non-English language background, 4 had hearing within normal limits, 1 had missing data, and the remaining 30 were unable to achieve valid scores on the standardized PA tests of elision, blending words and sound matching, even though they met the other inclusion criteria.

Table 1 presents relevant background data on the included sample of 101 children. Custom-designed questionnaires were used to elicit demographic information from caregivers (for further details, see Ching et al., 2013). Audiological information was collected from the databases of Australian Hearing and relevant intervention agencies.

Table 1. Participants' background information (*N* = 101).

Variable		No. of Participants (Percentage)[a]
Gender		
	Male	60 (59.4%)
	Female	41 (40.6%)
Degree Hearing Loss		
	Mild (20-40 dB)	13 (12.9%)
	Moderate (41-60 dB)	45 (44.6%)
	Severe-to-Profound (>60 dB)	43 (42.6%)

Audiological Device	
1. Hearing Aid – bilateral	68 (67.3%)
2. Hearing Aid – unilateral	3 (3.0%)
3. Cochlear Implant – bilateral	20 (19.8%)
4. Cochlear Implant + Hearing Aid	10 (9.9%)
Maternal Education (*n* = 99)	
1. University Qualification	42 (42.4%)
2. Diploma or Certificate	28 (28.3%)
3. 12 years or less of schooling	29 (29.3%)

Note: Hearing Loss is represented as a four-frequency average (at 0.5, 1, 2, and 4 KHz) pure tone threshold in the better ear.

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

Children had been diagnosed with a hearing loss at 11.0 months of age on average (SD = 10.9, range = 0–36) and first fitted with HAs approximately three to four months later (mean = 14.7, SD = 11.1, range = 1–36). At 5 years of age, the majority of children used unilateral or bilateral HAs (70.3%), with just under one third (29.7%) using unilateral or bilateral CIs. Those using unilateral CIs also wore a hearing aid in the contralateral ear (see Table 1). For children using CIs, devices were first switched on between 7 and 46 months of age (mean = 22.3, SD = 12.1). Of the 30 children with CIs, 27 (90%) had more than 24 months' experience with their device, and the remaining three (10%) had between 17 and 24 months' experience. Of the 71 children with HAs, all had at least 24 months experience with their device. The majority of children (87 out of 101 or 86.1%) communicated using speech only either at home, or in early intervention, or both. The remaining 14 children (13.9%) were reported to use a combined mode of communication in at least one setting.

Given our focus on investigating whether children's levels of PA varied according to the severity of their hearing loss, it was important to establish whether the subgroup of children who met the inclusion criteria but could not achieve valid PA scores had more severe levels of hearing loss than the included children. A non-repeated measures *t-test* was conducted to compare 4FAs in the better ear for these two groups of children. There was no significant difference between the groups, with means of 67.8 dB (SD = 30.7, n = 101) and 68.8 dB (SD = 26.9, n = 28) for included and non-included children respectively (t[127] = 0.142, p = .887).

Assessment Tools

The data reported here were collected using standardized assessments of receptive vocabulary, PA, and nonverbal cognitive ability.

Receptive Vocabulary

Children's receptive vocabulary knowledge was assessed using the PPVT-4 (Dunn & Dunn, 2007), which was administered according to instructions in the test manual. Spoken words were presented one at a time to the child, who was asked to indicate which of four pictures best showed the word's meaning. Standard scores were used for descriptive and analysis purposes.

PA

Children's PA was assessed using three subtests from the CTOPP (Wagner, Torgsesen, & Rashotte, 1999). In elision (20 items), children were asked to repeat a spoken word and then say the word again after omitting specified sounds. In blending words (20 items), children were asked to listen to a sequence of syllables or phonemes and then to put them together "to make a whole word." In sound matching, a target word and three optional words were presented in spoken and pictorial form on each trial, and the child was asked to indicate which optional word either began (10 items) or ended (10 items) with the same sound as the target. However, most children (87 out of 101 or 86.1%) did not progress to final sound matching because they reached the specified ceiling (four out of seven errors) on initial sound matching. Standard scores (*Mean* = 10, *SD* = 3) were computed for individual subtests.

Nonverbal Cognitive Ability

Nonverbal cognitive ability was assessed using the Wechsler Nonverbal Scale of Ability (WNV; Wechsler & Naglieri, 2006), which was designed specifically for linguistically diverse populations, including people with hearing loss. The assessment contains four subtests, the results of which combine to provide a full-scale IQ score. For children ages 4;0–7;11, the relevant subtests are matrices, coding, object assembly, and recognition. Standardized (full-scale IQ) scores were used for descriptive and analysis purposes to minimize interpretive difficulties resulting from variation in age at testing.

Procedure

A team of research speech pathologists directly assessed children in their homes, early intervention or preschool settings, or schools. All assessments were administered using spoken English according to the guidelines provided in the respective test manuals. During evaluations, children wore HAs and/or CIs at their personal settings. As far as possible, research speech pathologists were blinded to children's severity of hearing loss and settings in their hearing aids or cochlear implants.

The assessments described here were administered when participants in the LOCHI study reached a chronological age of approximately 5 years, although there was some variability across children, with administration ages ranging from 60 to 73 months for CTOPP, 57 to 68 months for PPVT-4, and 59 to 98 months (*Mean* = 70.7, *SD* = 10.4) for the WNV. More detailed information regarding age at administration of the CTOPP is provided in Table 2.

All response forms for the primary measure of PA (CTOPP) were double-scored by the second author. Agreement was high, with only a handful of errors (<1%) detected and corrected.

Design and Statistical Considerations

The research questions were investigated using a quantitative, pre-experimental design. The first primary comparison involved two independent groups of children, all with a severe or profound hearing loss, who were fitted with CIs or HAs. A subsidiary analysis conducted within the CI group compared children with bilateral CIs to those who used bimodal fitting (CI + HA). The second primary comparison involved three independent groups of children, all of whom were fitted with HAs, with different levels of hearing loss (mild vs. moderate vs. severe-to-profound).

Analyses of variance and covariance were performed to investigate the primary research questions. All statistical analyses were conducted using SPSS. In line with standard practice, a type I error rate of $\alpha = .05$ (two-tailed) was adopted.

Results

Initial analyses of the results from the three included measures of PA revealed floor effects for two tasks: Out of 101 participants, 60 (59.4%) achieved a zero score on elision and 47

(46.5%) scored zero on blending. Further analyses were therefore focused on results from the sound matching task, on which 87 participants (86.1%) achieved a score greater than zero.

Table 2 shows average scores for the sound matching task, PPVT-4, and WNV. Findings are reported according to type of hearing device (HA vs. CI) and, within the group of users of hearing aids, severity of hearing loss. Across the entire cohort, children's average standard scores on the sound matching task were consistently below age-appropriate levels (*Mean* = 8.40, *SD* = 1.66 for sound matching). They were, nevertheless, within 1 SD of the mean for the normative sample. Receptive vocabulary scores were also below age expectations for the cohort overall (*Mean* = 90.05, *SD* = 15.56), although children with a mild hearing loss were an apparent exception to this pattern achieving a mean standard score of 101.4 (see Table 2). Finally, children's cognitive ability was at or slightly above age-appropriate levels, with an average WNV score of 104.34 (*SD* = 12.10) across the cohort. Correlational analyses revealed small-to-moderate positive associations between these three variables, with Pearson's *r* ranging from .33 (p = .001) for matching and WNV scores to .36 (p < .001) for matching and vocabulary.

Table 2. PA, receptive vocabulary and nonverbal ability as a function of device type and degree of hearing loss (*N* = 101).

Measure	**Device Type: Hearing Aid**			**Cochlear Implant**
	Mild (n = 13)	**Moderate (n = 45)**	**Severe / Profound (n = 13)**	**(n = 30)**
PA-Sound Matching				
Mean Raw Score (SD)	4.2 (3.8)	3.2 (2.9)	3.8 (4.6)	2.9 (3.0)
Mean Standard Score (SD)	8.9 (1.5)	8.4 (1.5)	8.5 (2.3)	8.2 (1.6)
No. of zero scores (%)	1 (7.7)	4 (8.9)	2 (15.4)	7 (23.3)

Mean age (SD)[a]	61.3 (1.0)	61.6 (1.8)	62.8 (3.9)	61.8 (1.3)
Age range	60 - 63	60 - 68	60 - 73	60 - 64
Receptive Vocab[b]				
PPVT-4 Standard Score	101.4	93.8	82.5	82.6
(SD)	(10.9)	(13.3)	(15.2)	(16.2)
Cognitive Ability[c]				
WNV Full scale IQ	106.8	104.2	110.8	100.8
(SD)	(10.5)	(14.2)	(8.8)	(9.5)

[a]Age in months; [b]Data were missing for n = 2 participants – means based on 44 participants with moderate loss and 29 participants with CIs; [c]Data were missing for n = 7 participants - means based on 12 participants with mild loss, 41 with moderate loss, 12 with severe-to-profound loss who used HAs, and 29 with CIs.

Device Type

To compare levels of PA in children with HAs versus CIs, data were considered from a subgroup of 43 children, all of whom had a severe or profound hearing loss. Thirteen of these children used HAs, whereas 30 used CIs. The groups did not differ from one another in receptive vocabulary ($F < 1$), but children with HAs performed significantly better than children with CIs on the included measure of cognitive ability, the WNV ($F[1,39] = 9.79$, $p = .003$). With respect to PA, there was little difference in the sound matching scores attained by children in the two groups, resulting in a non-significant main effect of device for both standard scores and raw scores (both Fs < 1). Importantly, this pattern of results was essentially unaffected when WNV score, which varied across the participant groups, was included as a covariate in the statistical analyses.

Regarding the subsidiary question of whether PA varied in children with bilateral CIs versus bimodal fitting (CI+HA), Figure 1 shows the mean standard scores on sound matching for children in these subgroups as compared to those with HAs. The difference between the CI subgroups was not significant ($F < 1$).

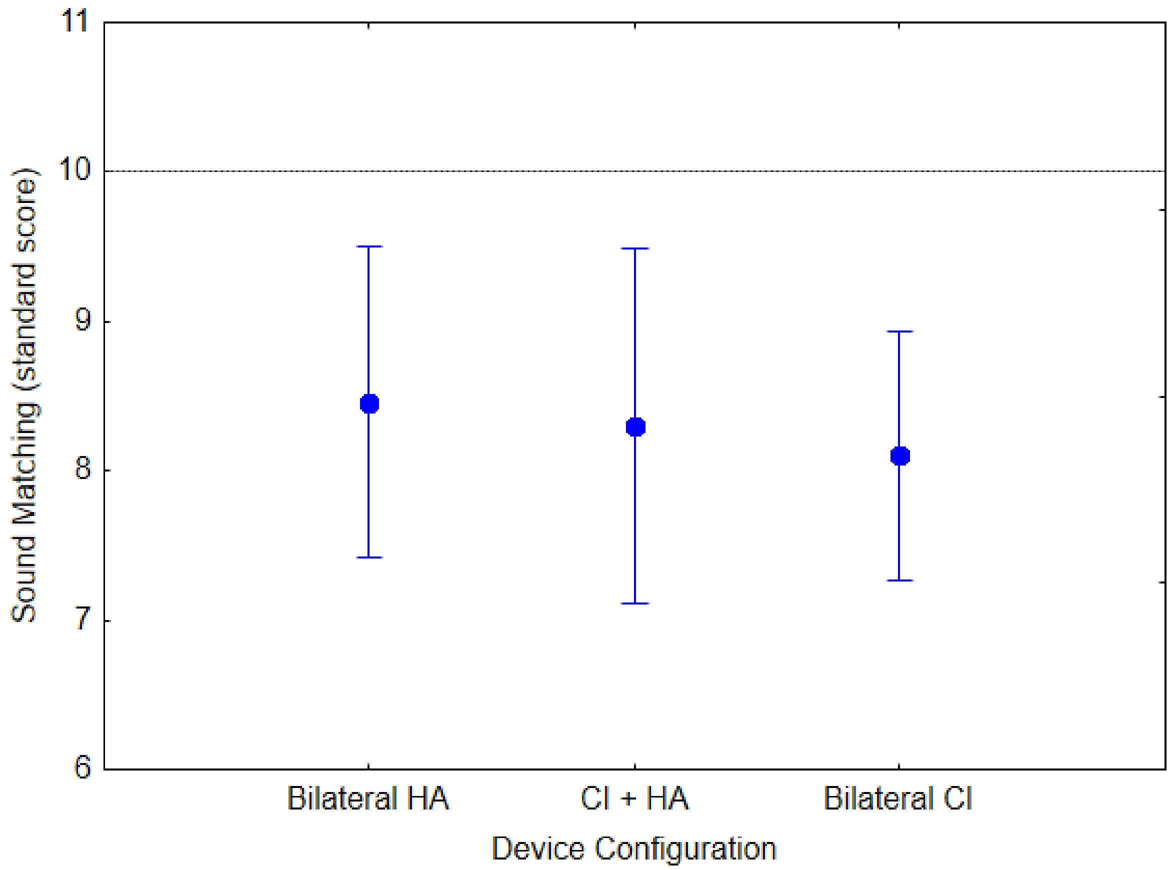

Figure 1. Mean scores on sound matching for children with bilateral HAs, bimodal fitting (CI+HA) and bilateral CIs. The test has a normative mean score of 10, and a standard deviation of 3. Vertical bars depict 95% confidence intervals.

Severity of hearing loss

To address the second research question, data were considered from the subset of children with HAs only. Figure 2 shows the mean sound-matching standard scores of these children grouped according to degree of hearing loss. Thirteen of the children had a mild hearing loss (20-40 dB in the better ear), 45 a moderate loss (41-60 dB), and 13 a severe or profound loss (>60 dB). Initial comparison of the groups revealed a significant difference in receptive vocabulary (with $F[2,67] = 6.74$, $p = .002$ for PPVT-4 scores) but not cognitive ability ($F[2,62] = 1.27$, $p = .288$ for WNV Full Scale scores). With respect to PA, statistical analysis revealed a non-significant difference between the sound matching scores attained by children with different degrees of hearing loss (*F* < 1 for both standard scores and raw scores). In light of the significant difference in vocabulary scores between the participant groups, these analyses were repeated including vocabulary as a covariate. Resulting F-values remained clearly non-significant (*F* < 1 for standard scores, and *F*[2,66] = 1.23, *p* = .300 for raw scores). In addition, the correlation between sound matching standard scores and an alternative measure of severity of hearing loss based on children's high-frequency average (2 and 4 KHz) pure tone thresholds also revealed no significant association (Pearson's *r* = -.11, *p* = .270).

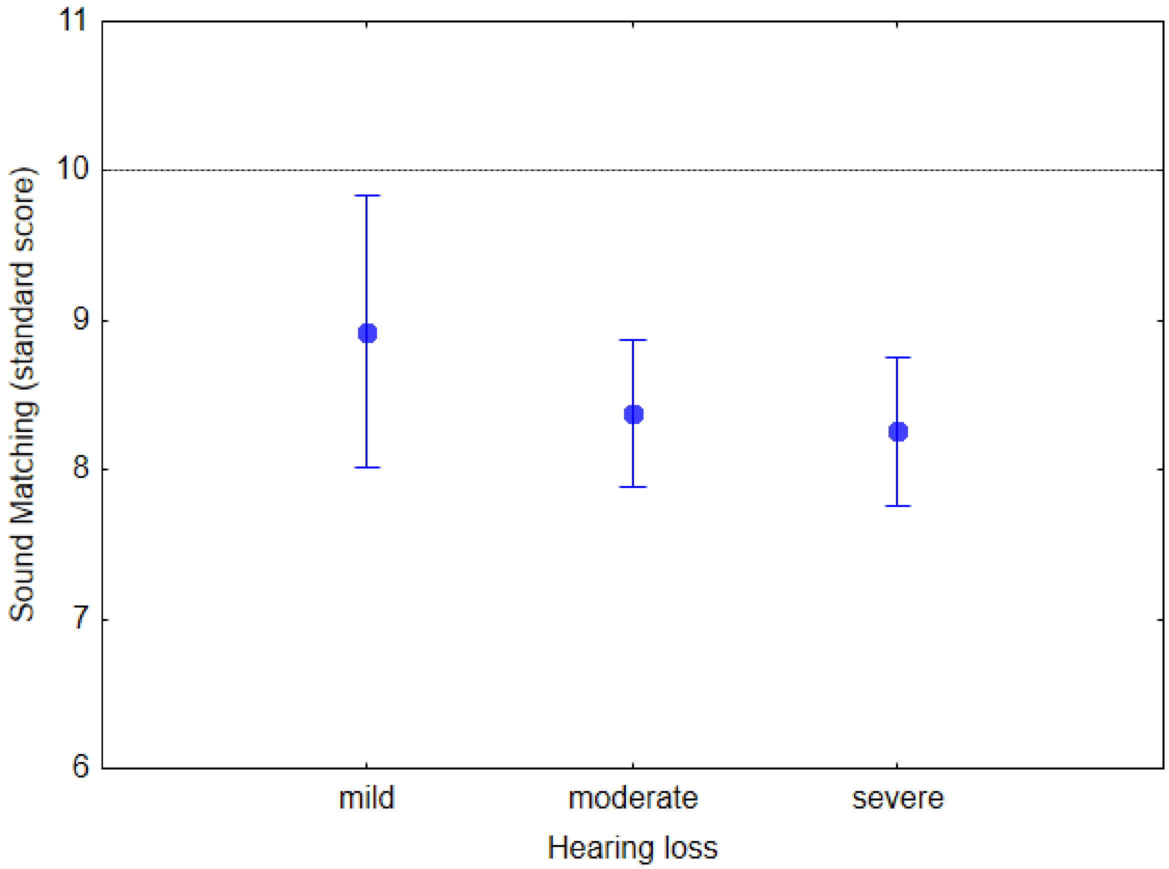

Figure 2. Mean scores on sound matching for children grouped according to degree of hearing loss. Vertical bars depict 95% confidence intervals.

These statistical results suggest that children with more severe hearing losses did not achieve significantly worse PA scores than children with milder hearing losses on average. There was, however, an apparent effect of the severity of hearing loss on the frequency with which children achieved a score of zero in the sound matching task (see Table 2). Children with a severe or profound hearing loss were nearly 2.5 times more likely to score zero (9 out of 43 participants or 20.9%) than children with a mild or moderate hearing loss (5 out of 58 participants or 8.6%) regardless of whether they used a HA or CI. However this difference also failed to reach significance (*chi square* [1] = 3.134, p = .077).

Discussion

This study has examined PA skills in early childhood to reduce the possible impact of formal literacy instruction on PA development. We examined firstly, whether PA skills of children with severe or profound hearing loss differed according to whether they used HAs or CIs. On average, there was no significant difference between the two groups. This finding was consistent with previous studies (Nittrouer, Caldwell, Lowenstein, Tarr, & Holloman, 2012). In contrast to previous studies that reported mean performance levels of -1.5 SD (James, et al., 2008; Nittrouer, et al., 2012; Nittrouer, et al., 2014), the present study found that performance was on average within 1 SD of the mean of the normative population. The enhanced performance of children in the present study may be related to the early age of intervention, the up-to-date hearing technology fitted to the children, and the high-quality hearing service provided by AH, the government-funded national provider of hearing services to all children with hearing loss in Australia. For children who received a cochlear implant in one ear and who have residual hearing in the non-implanted ear, the AH protocols consistently provide hearing-aid amplification and optimization of fitting with a contralateral cochlear implant. We did not find a significant group difference in PA scores between the children who used bilateral cochlear implants and those who used bimodal fitting. The present findings support this approach to prosthetic treatment for children with bilateral severe or profound hearing loss. As this study did not randomly assign children to hearing-aid fitting or cochlear implantation, the present findings do not imply that the devices are equally effective for children with severe or profound hearing loss.

Secondly, we investigated the influence of degree of hearing loss on PA skills. On average, the sound matching scores for children with hearing loss ranging from mild to profound degrees were within the normal range. Furthermore, there was no strong evidence for an association between severity of hearing loss and sound matching score. No significant group difference in scores was apparent between children with mild, moderate or severe-profound hearing loss (defined in terms of a four-frequency average pure tone threshold in the better ear); and the correlation between children's sound matching scores and their high-frequency average pure tone thresholds was non-significant. These findings are consistent with the proposition that the amplification or cochlear implantation provided to children at an early age was effective in providing auditory access to the spoken language, in spite of the hearing loss. This level of achievement is better than that reported in the literature (Briscoe, et al., 2001; Gibbs, 2004), possibly as a consequence of the early age of intervention. When supported by appropriate hearing technology, the degree of hearing loss, per se, does not constrain the acquisition of PA skills.

Nevertheless, the mean sound-matching scores were at 0.4 to 0.5 SD below the mean of the normative population, and the proportion of children who attained zero scores showed a non-significant tendency to increase from 9% for mild or moderate hearing loss to 21% for severe or profound loss. This pattern of results implies that although the children acquired sensitivity to the sound structure of language, they require further support to enhance their acquisition of a range of PA skills to the same level as typically developing children. The need to provide intervention to assist with development of PA is evident. As regards how to achieve better PA outcomes, although the development of PA is predicated on the ability to access the phonological structure of spoken language and to construct phonological representations in the mental lexicon, the representations also become more robust with increasing lexicon size (Dillon, et al., 2012; Studdert-Kennedy, 2002). In this study, the significant positive correlation observed between PA and receptive vocabulary confirms this inter-association between variables. As part of the longitudinal study, the present findings will be extended to examine the way in which early PA abilities and vocabulary size measured at 5 years of age predict later PA, vocabulary, and reading abilities of the cohort at 9 years of age.

Considerations for Professionals and Future Directions

The current findings have implications for clinicians and educators working with children who have hearing loss. In particular they indicate that even children with a severe-to-profound hearing loss can attain PA skills within the normative range if they are supported by appropriate hearing technology and early intervention. On the understanding that PA is a critical skill for children to acquire either before or during the process of learning to read (Wimmer, Landerl, Linortner, & Hummer, 1991), this finding is encouraging. It suggests that early instruction in PA could provide an effective means of guarding against the reading delays evident in previous research with this population (Helfand et al., 2001; Qi & Mitchell, 2012; Wake et al., 2004). Although strong recommendations regarding literacy (and pre-literacy) instruction can be made only on the basis of controlled intervention studies, the findings of this study provide more than sufficient justification for further investigation of this important clinical issue.

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CEU Questions *(The <u>correct answers</u> are underlined).*

1. Which of the following questions has not been addressed in previous studies that have investigated PA outcomes for children with hearing loss?
   A. <u>Does choice of sensory device affect PA outcomes?</u>
   B. Does early PA predict later reading?
   C. Does early reading predict later PA?
   D. Is PA associated with reading after controlling for vocabulary?

2. Which of the following statements is true in regard to the PA results of children with severe or profound hearing loss?
   A. Children with HAs had better PA skills than children with CIs.
   B. Children with HAs had poorer PA skills than children with CIs.
   C. <u>Children with HAs had similar PA skills to children with CIs.</u>
   D. Children did not achieve non-zero scores for any of the PA tasks.

3. Which of the following statements is true in regard to the PA results of children using CIs?
   A. Children using bilateral CIs had better PA skills than children using bimodal fitting.
   B. Children using bilateral CIs had poorer PA skills than children using bimodal fitting.
   C. <u>Children using bilateral CIs had similar PA skills to children using bimodal fitting.</u>
   D. Children using CIs did not achieve non-zero scores for any of the PA tasks.

4. Which of the following statements is true in regard to the PA results of children using HAs?
   A. More severe levels of hearing loss were associated with lower PA scores.
   B. Less severe levels of hearing loss were associated with higher PA scores.
   C. <u>PA scores were not associated with degree of hearing loss.</u>
   D. Children did not achieve non-zero scores for any of the PA tasks.

5. Which of the following statements is true in regard to the participant sample described in this research?
   A. <u>More severe levels of hearing loss were associated with lower receptive vocabulary scores in the group of children with HAs.</u>
   B. More severe levels of hearing loss were associated with lower nonverbal cognitive ability in the group of children with HAs.
   C. Less severe levels of hearing loss were associated with lower receptive vocabulary scores in the group of children with HAs.
   D. Degree of hearing loss was not associated with receptive vocabulary scores in children with HAs.