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Literacy outcomes for Deaf and Hard of Hearing primary school children: A cohort comparison study

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A cohort comparison study

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Abstract

Purpose: This study compared the language and literacy of two cohorts of children with severe-profound hearing loss, recruited 10 years apart, to determine whether outcomes had improved in line with the introduction of newborn hearing screening and access to improved hearing aid technology.

Method: Forty-two deaf children, aged 5 -7 years with a mean unaided loss of 102 DB, were assessed on language, reading and phonological skills. Their performance was compared to that of a similar group of 32 deaf children assessed 10 years earlier, and also a group of 40 hearing children of similar single word reading ability.

Results: English vocabulary was significantly higher in the new cohort, although it was still below chronological age. Phonological awareness and reading ability had not significantly changed over time. In both cohorts English vocabulary predicted reading but phonological awareness was only a significant predictor for the new cohort.

Conclusions: The current results show that vocabulary knowledge of children with severe-profound hearing loss has improved over time but there has not been a commensurate improvement in phonological skills or reading. They suggest that children with severe-profound hearing loss will require continued support to develop robust phonological coding skills to underpin reading.

Introduction

Although there is widespread agreement about the importance of literacy for children with hearing loss – as for all children – many children with severe-profound prelingual hearing loss do not read or write at an age-appropriate level; and, arguably, their overall level of achievement has not changed significantly since the first systematic assessments were carried out in the 1970s (Allen, 1986; Conrad, 1979; DiFrancesca, 1972; Kronenberger, Colson, Henning, & Pisoni, 2014; Lane & Baker, 1974; Lewis, 1996; Marschark & Harris, 1996; Mayer, 2007; Mayer & Moksos, 1998; Moog & Geers, 1985; Trybus & Karchmer, 1977). The last ten years have, however, witnessed two major technological advances that might be expected to have a major impact on the literacy outcomes for children who are deaf or hard-of-hearing (DHH). The first is the introduction of newborn hearing screening and the second is the increasing effectiveness of hearing aid technology, including cochlear implants.

In the UK, the implementation of universal newborn hearing screening (UNHS) began in 2000 and was completed in 2005, potentially reducing the mean age of diagnosis of hearing loss from 17 months to a few weeks (Davis et al., 1997). It is clear from studies carried out in Canada (Durieux-Smith, Fitzpatrick, & Whittingham, 2008) and the UK (Kennedy, McCann, Campbell, Kimm, & Thornton, 2005) that newborn hearing screening provides a very reliable way of identifying hearing loss, providing that the automated screening that takes place shortly after birth is followed up by audiology appointments to enable a confirmatory diagnosis. The Wessex trial (Kennedy et al., 2006), showed that DHH children who had benefited from UNHS had significantly higher receptive language scores than comparable DHH children in the UK who had not

been part of early trials. A recent review of the benefits of UNHS (Pimperton & Kennedy, 2012) reports consistent evidence from studies in Colorado and Australia showing that UNHS, and associated early diagnosis of hearing loss, does bring benefits for language development.

In terms of hearing aid technology, the most high profile change has been in the provision of cochlear implants although there have also been considerable advances in digital hearing aids (Ackley & Decker, 2006). In the UK, cochlear implants are provided by the National Health Service (NHS) for all suitable candidates, following approval by the National Institute for Health and Care Excellence (NICE) in 2009 (NICE, 2009). As a result of early identification, many children with a profound hearing loss are implanted well before they begin formal schooling; and there has been a gradual move towards earlier implantation and the provision of bilateral implants. The majority of children for whom a cochlear implant (CI) is not considered appropriate or desirable are now using digital hearing aids, also supplied by the NHS.

Many studies have now documented the benefits of CIs for language comprehension and production (Archbold et al., 2000; Cleary, Pisoni, & Geers, 2001; Geers, 2002; Kronenberger et al., 2014; O'Donoghue, Nikolopoulos, & Archbold, 2000; Pisoni & Geers, 1998; Reading, 2012; Tait, Nikolopoulos, Archbold, & O'Donoghue, 2001; Thoutenhoofd et al., 2005; Watson, Archbold, & Nikolopoulos, 2006; Watson, Hardie, Archbold, & Wheeler, 2008). However, evidence about the impact on literacy has been rather less consistent (Harris, 2016). Among studies of reading in primary school, those carried out more recently are likely to show the best outcomes because, over time, the technology of both implants and hearing aids has steadily advanced and age-at-implant

has fallen. Age-at-implant is a well-established predictor of effectiveness in that children who receive early intervention are most likely to show benefits (Archbold et al., 2008; Kronenberger et al., 2014; Reading, 2012).

A study by Geers found that, in a group of children from a number of centers in the US who had been implanted before the age of 5 years, over half were reading at an age-appropriate level at 8 years (Geers, 2003). Studies of large cohorts in Scotland (Thoutenhoofd, 2006) and the Netherlands (Vermeulen, van Bon, Schreuder, Knoors, & Snik, 2007) found that children with cochlear implants scored comparatively higher on reading and writing than peers with hearing aids but were still delayed when compared to hearing peers. In all three of these studies, which were carried out some years ago, children with a range of cognitive abilities were included. A UK study (Archbold et al., 2008) found age-appropriate reading among children with a nonverbal IQ of 85 or above who had been implanted at or under the age of 42 months. However, in a recent UK study in which children were not selected on the basis of IQ, Herman and colleagues (Herman, Roy, & Kyle, 2014) found that only just over half the children (52%) in a sample of orally-educated 10-11-year-olds were reading single words at an age appropriate level. The majority of the children in this study had received a CI. Taken as a whole, these studies suggest that around half of the children with severe-profound hearing loss are not reading at an age-appropriate level.

In order to understand why the benefits of earlier diagnosis of hearing loss and better hearing aid technology might have a greater impact on language skills than on reading, it is pertinent to consider the skills that underpin literacy. The simple view of reading (Hoover & Gough, 1990) argues that two core abilities lie at the heart of becoming

literate - decoding and linguistic comprehension. Decoding is the ability to recognize the sounds (phonemes) represented by individual letters and letter strings and the ability to identify and blend these sounds within words. Linguistic comprehension is the ability to understand the meaning of what has been decoded: It involves understanding the meaning of individual words, individual sentences and the text as a whole. For hearing children, the development of decoding skills predicts success in the early stages of learning to read (Muter, Hulme, Snowling, & Stevenson, 2004) as does the development of linguistic comprehension skills that are, in turn, predicted by oral language and vocabulary (Nation & Snowling, 2004).

Studies of children with CIs suggest that decoding skills and linguistic comprehension are also important for DHH children. Tobey et al. (2003) report that phonological coding ability and linguistic competence were both predictive skills for reading and Spencer & Oleson (2008) found that speech production and comprehension skills 48 months after implantation accounted for 59% of the variance in written word comprehension three years later. However, detailed assessment of phonological skills in DHH children has shown that they are still lower than those of hearing peers (Herman et al., 2014; Spencer & Tomblin, 2009); and that the benefits of implant technology are greater for language than for phonological skills (Nittrouer, Sansom, Low, Rice, & Caldwell-Tarr, 2014). Nittrouer et al. argue that the signal quality available to CI users makes the acquisition of phonological structure problematic for children in comparison to the learning of grammar and vocabulary.

The main aim of the present study was to make a direct comparison of the language, reading and phonological skills of a cohort of DHH children recruited in 2013-14 (Cohort

2) with that of a similar group of children, recruited a decade earlier (Cohort 1), to see whether outcomes had improved in line with early diagnosis and better hearing aid technology. The children in the earlier cohort were those first described by Kyle and Harris (2006; 2011) and recruited between 2003 and 2005. In Cohort 1, only a small number of children had received a cochlear implant and the majority had not been screened for hearing loss at birth. The children recruited for Cohort 2 were selected to be as similar as possible to the children recruited for the earlier study in terms of chronological age, geographical location, degree of hearing loss and absence of additional difficulties that might impact on literacy. In both cohorts, all children had a severe-profound hearing loss and a nonverbal IQ of at least 85. Detailed data for each of the cohorts are reported in Table 1 and discussed below.

The reading, language and phonological abilities of the children in Cohort 2 were also compared with those of group of hearing children, matched on reading age. There were three reasons for choosing reading age as the matching variable rather than chronological age. First, as part of a larger study, we wanted to be able to track the reading progress of the children over time and so we thought it important to equate the initial reading levels for the two groups of deaf and hearing children. Secondly, we followed the approach adopted by Kyle and Harris (2006; 2010) so that we could make direct comparisons between the cohorts. We used a measure of single word reading as a basis for matching, following the approach of Kyle and Harris. However, the deaf and hearing children also had similar levels of reading comprehension (See Table 2). The third reason for matching on reading age was to enable a comparison of the predictors of

reading ability. Since predictors can change with reading level, we wanted to ensure that the children in all three groups were reading at a similar level.

The assessments chosen for the present study, which are described in detail below, were similar or identical to those used by Kyle and Harris (2006) to enable direct comparisons between the two cohorts. They assessed single word reading, reading comprehension, English vocabulary, phonological awareness and letter-sound knowledge.

The specific aims of the study were:

(1) To compare the levels of language, reading and phonological skills in two age-matched cohorts of deaf children, recruited 10 years apart, to determine whether these had changed over time.

(2) To compare the levels of language, reading and phonological skills in the current cohort of deaf children with those of a group of hearing children, matched on reading age.

(3) To explore the associations between chronological age, phonological awareness, English vocabulary and reading in Cohorts 1 and 2 and the reading-age matched group of hearing children.

Method

Participants

DHH children

The age of the children in Cohort 2 spanned that of the two groups recruited by Kyle and Harris (2006; 2011). As these two groups were recruited at the same time, a sub-sample

of children from both studies was selected for Cohort 1 on the basis of age. Cohort 1 comprised 12 children from the younger sample (Kyle & Harris, 2011) and 20 from the older sample (Kyle & Harris, 2006). The children in Cohort 1 ranged in age from 65 months to 93 months and all had a severe-profound hearing loss (mean unaided hearing loss of 99 dB). There were 12 boys. They were recruited from a total of 14 sites.

Forty-two children (26 boys) were recruited for Cohort 2. Like the children in Cohort 1, they all had severe-profound hearing loss (mean unaided hearing loss = 102 dB). The children in Cohort 2 were recruited from a total of 25 sites in the southern part of England. Seven of the sites were identical to those in Cohort 1 (providing a total of 16 children for cohort 2) and all other sites came from the same geographical area in the southern part of England.

The same selection criteria were used for both cohorts, that is, chronological age of between 5 and 7 years, severe-profound prelingual hearing loss and a score of at least 85 on a measure of nonverbal intelligence. There was no significant difference between the children in Cohort 2 and those in Cohort 1 on either chronological age, $t(72) = 1.43$, ns, or degree of unaided hearing loss, $t(71) = .62$, ns. There was, however, a significant difference in nonverbal IQ (see Table 1) and so this was controlled in statistical comparisons between the two cohorts.

The mean age of diagnosis of hearing loss was 14.1 months for Cohort 1 and 11.7 months for Cohort 2. Although the mean age was lower for Cohort 2 the difference was not significant, $t(71) = 0.47$, ns. Twenty of the children in Cohort 2 wore digital hearing aids and 22 were fitted with cochlear implants (17 bilateral). Only 8 children from cohort

1 were fitted with cochlear implants and none had bilateral implants. This difference was significant χ^2 (2, N=74) = 5. 64, p = .03.

In the new cohort, 15 children (36%) came from families where one or both parents were DHH, compared to 32% in the earlier cohort. These proportions were not significantly different, χ^2 (2, N=74) = 1. 54, p = .46. The proportions of children with preferences for signing, oral language and total communication were also very similar in the two cohorts. In the current cohort, signing was preferred by 16 (38%) of the children, 18 (43%) used spoken language and the remaining 8 (19%) used a combination of sign and speech. The corresponding figures for Cohort 1 were 15 (47%), 14 (44%) and 3 (9%) out of 32 and these were not significantly different, χ^2 (2, N = 74) = 1.48, p = .477.

<Table 1 about here>

Table 1 shows how the children in the two cohorts were distributed across the different educational settings. Over the intervening years a number of schools for the deaf and specialist resource bases (a unit attached to a mainstream school) had closed and more deaf pupils were being educated in a mainstream classroom. It can be seen that there were differences in the proportion of children in the three settings. Statistical analysis using Chi Square showed that there was a significant difference in the distribution of educational setting for the two cohorts, χ^2 (2, N = 74) =12.35, p = .002. The most notable change was in the number of children who were in a mainstream setting in Cohort 2.

Written consent for children to take part in the study was initially obtained from the head teacher and/or the head of the specialist resource base. In addition, written consent was obtained from parents unless they had assigned this responsibility to the school.

Hearing children

There were 40 hearing children (21 boys), mean age 5 years 10 months (SD = 3.4 months, range 5;05 – 6;05). All children achieved a score of at least 85 on a measure of nonverbal intelligence test (see below) and they were matched to the DHH children in Cohort 2 on reading age, assessed using a single word reading test (see below). The hearing children were recruited from 5 mainstream schools in the south east of England. Consent was obtained as for the deaf children. There were no significant differences between the DHH and hearing children on either reading age, $t(80) = 1.40$, ns, or nonverbal intelligence, $t(80) = 1.48$, ns. (See Table 1.)

Assessments

Nonverbal intelligence

Nonverbal intelligence was assessed using the pattern construction subtest from the British Ability Scale III (Elliott & Smith, 2011). This has been used in previous research with DHH children and has been shown to have a high correlation with the composite nonverbal IQ score derived from this and two other subtests (Harris & Moreno, 2006). This measure was used to ensure that all children had a nonverbal intelligence score of at least 85 and therefore were unlikely to have any mild or moderate learning difficulties that had gone undetected. Teachers confirmed that the children did not have any significant additional needs.

Reading ability

All participants were initially given the Single Word Reading Test 6-16 (Foster, 2007) in which children are asked to read aloud a maximum of 60 individual words. As in Kyle and Harris (2006; 2011), children had the option of signing words or reading them aloud. Standard scores and reading ages were calculated from the raw scores, which were also used to select the appropriate starting passage in the York Assessment of Reading Comprehension (YARC) (Snowling et al., 2011) .

The YARC is very similar in format to the The Neale Analysis of Reading Ability (NARA) (Neale, 1989), which has been used in previous studies of reading with DHH children, including Kyle and Harris (2006; 2011). It presents children with a series of graded passages, each illustrated by a picture. After reading a passage (with help to sound out or sign any unfamiliar words), children were given a series of comprehension questions. They were allowed to refer back to the passage to answer these. Participants whose preferred mode of communication was British Sign Language (BSL) signed the meaning of each word that they were able to read. For this reason, only the reading comprehension score of the YARC was used, and reading accuracy (i.e. correct pronunciation of individual words during the initial reading of each passage) was not assessed.

English vocabulary

Participants' expressive English vocabulary skills were assessed using the Expressive One Word Picture Vocabulary Test 4 (EOWPVT) (Martin & Brownell, 2011), which includes norms from 2 years of age. Children were required to name, in English, colored pictures of objects, actions or concepts. For children who preferred to communicate in

BSL, responses were accepted only when they demonstrated that they knew the English label, typically by producing both the correct sign and mouthing the English word. This was similar to the procedure used by Kyle and Harris (2006) and reflects the fact that signing accompanied by mouthing is common in BSL. As this test was developed in the USA, *raccoon* was changed to *badger* and the word *post* was accepted as well as *mail* to reflect British English usage. This test has been shown to be suitable for assessing vocabulary skills of DHH children (Kyle, Campbell & MacSweeney, 2016) and it is similar in format to the British Abilities Scale Expressive Vocabulary subtest, used by Kyle and Harris (2006; 2011).

Phonological awareness

Phonological awareness was assessed using a picture-based phonological similarity task developed by Kyle and Harris (2006; 2010; 2011). In this study, the items were identical to the original but presentation made use of a laptop computer rather than showing pictures on cards. On each trial, children were presented with a picture of a familiar object and asked to name it. Then, two more pictures (target and distractor) appeared, which the children were also asked to name. Children who communicated in BSL were asked to produce the sign and mouth the English word. Finally they were asked to select the picture that sounded the same as the first one they had seen. There were 24 trials in total. For the 12 onset trials, presented first, the child had to make an alliteration judgment (e.g., *d*oll- *d*oor). For the remaining 12 rime trials the child had to make a judgment based on rhyme similarity. For half of the rime trials the item and target pair were orthographically congruent (e.g., sp*oon* - m*oon*) and for the other six trials the rhyme has a different spelling (e.g., h*ead* - b*ed*). Two practice trials, with feedback,

preceded both onset and rime trials. One point was scored for each correct answer and so the maximum score was 24. (For further details of the stimuli selection, see Kyle and Harris, 2006.)

Letter sound knowledge

To assess letter knowledge, children were asked to say the sound of each letter of the English alphabet, using 26 lower case magnetic letters presented on a magnetic board. Children who used BSL and those with less intelligible speech (who use visual phonics in their school) were also asked to produce the corresponding visual phonic. Each letter was presented in turn, following the order used in the letter sound knowledge subtest of the YARC Early Reading test (Hulme et al., 2011). Participants scored one point for each correctly identified letter sound.

Procedure

All participants were assessed in their schools in a separate room, close to the child's classroom. All assessments were carried out in one or two sessions depending on the needs of an individual child. The second author, who is a qualified Teacher of the Deaf with a BSL Level 2 qualification (out of 6) - sufficient for everyday conversations - and considerable experience of conducting language assessments with deaf children, carried out the assessments with the DHH children. For children whose speech was less intelligible or who used signed communication, the children's Teaching Assistant or Communication Support Worker was present during the assessments, to assist the researcher in understanding children's responses but not interfering with the assessment

protocol. Instructions for each assessment were presented in the child's preferred mode of communication.

Results

Comparisons of DHH children in Cohorts 1 and 2

Reading and language assessments

Table 2 shows the mean scores for the assessments that were common to the two cohorts, single word reading, phonological awareness and English vocabulary. Not all the children in Cohort 1 were assessed for letter-sound knowledge or reading comprehension and so comparisons could not be made on these two measures. As noted above, the phonological awareness assessment used identical items for both cohorts. The test of both single word reading and English vocabulary were different, reflecting the development of new tests with up-to date-norms since the assessment of Cohort 1 (see Kyle & Harris, 2006, for further details of the assessments used for Cohort 1). In order to make comparisons, the age equivalent scores were used for these tests since the two cohorts were matched for chronological age.

The DHH children in the current cohort had significantly higher nonverbal IQ scores than the earlier cohort, $t(72) = 6.01$, $p<.001$, $d = 1.42$ but their scores were not significantly different from those of the hearing children. The test used has been re-normed since the original cohort was assessed and the new norms were used for Cohort 2 so this difference does represent a significant increase in scores between the cohorts. In order to take a conservative view of the comparison between the two cohorts, nonverbal

IQ score was entered as a covariate in all statistical comparisons of the two cohorts of DHH children.

As Table 2 shows, the mean single word reading age-equivalent scores of the two cohorts were very similar, differing by only 4 months, with a standard deviation of over 12 months. There was no significant difference between these scores $F(1,71) = .001$, $MSE = 175.81$, ns. There was also no significant difference in phonological awareness scores, $F(1,71) = .93$, $MSE = 15.65$, ns. However, vocabulary age was more than two years higher in the current cohort and this difference was highly significant, $F(1,71) = 15.8$, $MSE = 336.71$, $p < .001$, $d = .94$.

Within Cohort 2, the scores of children who had digital hearing aids were compared with those of peers with cochlear implants. Only one significant difference was found: Letter sound knowledge of children in the CI subgroup was higher than that of children in the hearing aid subgroup, $t(40) = 2.87$, $p = .008$, $d = 1.07$ (See Table 2.). In view of the similarities between these two subgroups no further analyses were carried out.

<Table 2 about here>

In order to look at the relationship among the three variables of reading age, phonological awareness and English vocabulary in the two cohorts, these variables were inter-correlated along with chronological age and nonverbal IQ. The simple correlations are shown in Table 3. It can be see that there were both similarities and differences in the pattern of correlations for the two cohorts of DHH children.

In both cohorts, phonological awareness, English vocabulary and chronological age showed a significant positive correlation with single word reading but nonverbal IQ was not correlated. The correlation between single word reading and chronological age was

higher in Cohort 1 (r =.73) than in Cohort 2 (r =.57). However this difference did not reach statistical significance (Z=1.15, p =.25). Phonological awareness showed a significant correlation with English vocabulary in both cohorts but the correlation was much higher in Cohort 1 than Cohort 2. Post hoc analysis showed that this correlation was significantly higher (Z=2.16, p=.03).

<Table 3 about here>

Differences in the pattern of correlations for the two cohorts were reflected in differences in the outcome of a stepwise regression analysis to examine the concurrent predictors of single word reading. Nonverbal IQ was entered at Step 1 and chronological age, phonological awareness and English vocabulary at Step 2. The results of the analysis for each cohort are summarized in Table 4 where it can be see that, in Cohort 1, both chronological age and English vocabulary were significant predictors whereas, in Cohort 2, phonological awareness and English vocabulary were significant predictors. In both cohorts, English vocabulary was the strongest predictor.

<Table 4 about here>

Hearing loss

As noted above, the children in the two cohorts had very similar levels of unaided hearing loss (see Table 1). However, as might be expected, there was marked improvement in the level of aided hearing loss that the children were achieving. Aided hearing loss in the earlier cohort was just over 50 dB and just under 40 dB for the children in Cohort 2, $t(61) = 3.25$, $p = .002$, $d = .82$.

A detailed analysis of the age of diagnosis of hearing loss also reflected the changes that had taken place since the children in the original cohort were recruited. Table 5 shows the number of children who had a confirmatory diagnosis of hearing loss before 6 months, between 6 and 12 months, after 12 months and after 24 months. It can be seen that many more children in Cohort 2 received a confirmatory diagnosis in the first 6 months of life, as might be expected following the national roll out of UNHS. There was an overall difference between the two cohorts in proportions diagnosed at each age, χ^2 (3, N= 73) = 8.50, p = .037, and also a difference between a diagnosis before and after 6 months, Fisher Exact Test, p = .012.

Although there was a significant increase in the proportion who received an early diagnosis of hearing loss, it is notable that 18 children in the current cohort (43%) were not diagnosed until after they were 6 months old. The reasons for late diagnosis were varied. Some children were born in countries where UNHS was not available. One child was born in a private hospital in England where UNHS was not mandatory. In other cases, for children who were subject to UNHS, hearing loss was initially suspected following the Otoacoustic Emissions test (OAE). However, follow up appointments were sometimes delayed either because of parental failure to keep appointments or because OAE results were unclear. Other children passed the UNHS but were later diagnosed with a progressive hearing loss.

<Table 5 about here>

Comparisons of DHH and hearing children in Cohort 2

The final phase of the analysis focused on comparisons between the DHH children in the current cohort and their reading age controls, matched on level of single word reading. The mean scores for the hearing children for single word reading, phonological awareness, English vocabulary and reading comprehension are shown at the bottom of Table 2. The scores of the deaf and hearing children were compared. As reported earlier, there was no significant difference in single word reading as this has been used to match the two groups. There was also no difference in reading comprehension score, $t(80) = 1.23$, p =.ns. There were, however, significant differences for phonological awareness, $t(80) = 4.18$, $p<.001$, $d=.92$, English vocabulary, $t(80) = 2.5$, $p =.02$, $d = .55$, and letter-sound knowledge, $t(80) = 4.49$, $p<.001$, $d =.98$, with the scores of the hearing children being higher in each case.

Turning to the pattern of correlations among measures (see Table 3), there was a strong similarity between the DHH children and hearing children in Cohort 2. In both groups, English vocabulary, phonological awareness and chronological age were significantly correlated with single word reading and phonological awareness was significantly correlated with English vocabulary as well as chronological age. The only notable difference between the two groups was that, for the DHH children, phonological awareness was not significantly correlated with nonverbal IQ but there was a significant correlation for the hearing children.

The regression analysis (see Table 4) showed that English vocabulary was the strongest predictor of single word reading for the hearing children with phonological awareness also being a significant predictor. Chronological age was not a significant

predictor. This pattern of predictors was similar to that shown by the DHH children in Cohort 2 although the R^2 change associated with English vocabulary was higher for the DHH children than the hearing.

Discussion

The first aim of this study was to compare the reading, English language and phonological skills of a cohort of DHH children, currently in primary school in the UK, with those of a comparable cohort assessed 10 years earlier. The most striking difference between the two cohorts was in English vocabulary age. Children in the current cohort had a mean score that was over two years higher than that of the children in Cohort 1. This finding confirms recent observations of the impact of effective early hearing aid technology on spoken language (Kronenberger et al., 2014; Nittrouer, Sansom, et al., 2014). However, although the DHH children in the current cohort had considerably better English vocabulary scores than the earlier cohort, it is important to note that their performance had not reached the level of hearing peers and their mean score was 13 months below chronological age.

The marked improvements in English vocabulary evident in the DHH children in Cohort 2 were not matched by a commensurate improvement in either reading or phonological skills since there was no significant difference between the two cohorts on either of these measures, after controlling for nonverbal IQ. There were, however, some subtle differences between the two cohorts that were evident in the pattern of inter-correlations among measures and in the results of the stepwise regression. The most notable difference in the correlations was in the relationship between phonological

awareness and vocabulary. This was significantly higher for Cohort 1 than Cohort 2. The relationship between chronological age and single word reading was also higher for Cohort 1 than Cohort 2 although this difference was not significant. Taken together, these differences can explain why, for Cohort 1, the regression analysis showed that English vocabulary and chronological age were the significant predictors of single word reading whereas, for Cohort 2, it was English vocabulary and phonological awareness. The correlation between phonological awareness and vocabulary showed that these two variables had just over 50% of their variance in common in Cohort 2. This meant that, once the effects of vocabulary had been accounted for, the additional variance provided by phonological awareness did not reach significance in the regression analysis.

One way to interpret this difference between the cohorts is to view phonological awareness and vocabulary as more independent skills in Cohort 2. This fits in with the finding that, while one had significantly improved in this cohort, the other had not. The general pattern shown by the DHH children in Cohort 2 was similar to that shown by the hearing children, for whom vocabulary and phonological awareness were also not correlated. The fact that phonological skills had not significantly improved over time can explain why the significant gains in English vocabulary in Cohort 2 did not translate into significant gains for reading. Success in reading requires both decoding and linguistic skills to be well developed (Hoover & Gough, 1990). However, as these data were gathered at a single time point, it is not possible to determine the developmental relationship between phonological awareness, English vocabulary and reading. For example, we might expect that phonological awareness would become a stronger predictor of reading over time as the phonological skills of the DHH children improved.

This would be line with the longitudinal findings of Kyle and Harris (2010) that phonological awareness was not initially a predictor of reading for beginning readers but that it became so by the end of the study, three years later.

It is of interest to note that there were no differences in English vocabulary or, indeed, on any of the measures except letter knowledge for the children with cochlear implants and those with digital hearing aids. This finding is in line with other, recent studies that have reported no differences between children with hearing aids and cochlear implants (Harris & Terlektsi, 2011; Herman et al., 2014) and reflects the fact that both cochlear implants and digital hearing aids can be effective when fitted in the right way, at the right time, to the right child. However, the superior letter knowledge of the children with implants might suggest that, over time, differences between the groups might begin to emerge since letter-sound knowledge is a starting point for developing decoding skills and is strongly linked to phonological awareness in DHH children (Goldberg & Lederberg, 2015) .

A number of other recent studies have provided data on the reading ability of children who have benefitted from early diagnosis of hearing loss and provision of more effective hearing aid technology and it is valuable to compare their findings with the data from the present study. Studies by Nittrouer and colleagues (Nittrouer, Caldwell-Tarr, Sansom, Twersky, & Lowenstein, 2014; Nittrouer, Sansom, et al., 2014) have highlighted the fact that, in spite of impressive gains in English language for many children who receive cochlear implants, phonological skills still lag behind. Our findings are consistent with this picture.

Data from a longitudinal follow-up of children in Australia with cochlear implants provides a potentially interesting point of comparison because, as for the children in Cohort 2, both UNHS and CI were widely available when they were born. The data reported on the children at age 5 years (Ching, Day, & Cupples, 2014) shows that their language scores were 1 SD or more below the mean and phonological awareness scores were between 0.5 SD and 0.8 SD below the mean. It is of note that the authors report that more than half the children were unable to cope with the Comprehensive Test of Phonological Processing (CTOPP) (Wagner, Torgesen, & Rashotte, 2001) and so could not be assessed. As the children were only five years old, they were at the very early stage of learning to read. However, their scores were age-appropriate on a word reading test, unlike the children in the present study.

One of the best outcomes in reading for children with CIs was reported by Archbold et al. (2008). Children, who were implanted before the age of 42 months, were reading at an age-appropriate level seven years after implant. These children were reading better than the children in the Cohort 2 of the present study. The children sampled by Herman et al. (2014) were not, however, reading at an age-appropriate level and were more similar to the children in Cohort 2.

As noted in the introduction, the outcomes for reading in children with CI have been variable and, if phonological skills are key to reading for DHH children as a number of recent studies suggest (Goldberg & Lederberg, 2015; Herman et al., 2014; Nittrouer, Caldwell-Tarr, et al., 2014), then outcomes for literacy may well hinge on how well DHH children have developed phonological skills. It is notable that the children in the Archbold et al. (2008) and the Ching et al. (2014) studies were both part of CI programs

in which extensive language support was provided by experienced therapists. Arguably this support was important for developing the children's phonological skills.

Longitudinal studies have established that providing early support to develop phonological skills can reduce the likelihood that hearing children with a predisposition for dyslexia will develop reading problems (Hatcher, Hulme, & Snowling, 2004; Hulme & Snowling, 2009). This study suggests that providing similar support for DHH children would be valuable. There are a number of ways in which the development of decoding skills might be supported and these are not mutually exclusive. DHH children are able to gain knowledge about speech sounds through combining auditory information with information gained through speechreading (Kyle & Harris, 2010). Encouraging children to look at the way sounds are made on the lips - perhaps with the additional information that can be provided by visual phonics (Narr, 2008; Trezek, Wang, Woods, Gampp, & Paul, 2007) - can support the development of more robust phonological coding skills. The finding that letter-sound knowledge was associated with phonological awareness in the present study suggests that training in grapheme-phoneme correspondences might also be helpful as has been shown in a recent computer-based training study carried out in Sweden (Nakeva von Mentzer et al., 2013); and also in an extensive phonological training intervention carried out in the US (Miller, Lederberg, & Easterbrooks, 2013). The clear message of this study is that, in spite of the benefits of early diagnosis and better hearing aid technology, many deaf children will continue to need targeted support in the early years to enable them to become good readers, especially to support the development of their phonological skills. Many children will also need support to develop their English vocabulary because, even though improved hearing aid technology has

improved the access of many DHH children to spoken language, many children still have significant delays in their knowledge of English words.

Another aspect of the present study that is worthy of comment is the data on age of diagnosis of hearing loss. Over half of the children in the current cohort were diagnosed before 6 months of age and this marked a significant change from the earlier cohort. However, it is by no means the case that UNHS had solved all the problems of late diagnosis. Over 30% of the children in the current cohort did not receive a confirmatory diagnosis of hearing loss until after 12 months of age. In some cases this was because there were delays in follow up appointments at audiology clinics. In others, it was because children had a progressive hearing loss that was not identified until later. Given the nature of early hearing loss it is inevitable that some children will pass an initial hearing screen at birth but will subsequently experience deteriorating levels of hearing. It is therefore important that health professionals and parents are alert to this possibility and do not regard UNHS as a failsafe procedure. It is also important that children who were not screened at birth because they were born in a country where this was not available are not overlooked.

The data from Cohort 2 also highlight that fact that many more children with severe-profound hearing loss are being educated in mainstream classrooms. In Cohort 1 there no children were being educated in this setting but nearly one quarter of DHH children in the current cohort were being educated alongside hearing peers, sometimes with one-to-one support but sometimes with no support other than visits from a specialist peripatetic, or itinerant, teacher. The proportion of children in schools for the deaf was similar in the two cohorts but there was a marked change in the proportion being

educated in a specialist resource base. Over three quarters of children in Cohort 1 were being educated in such a setting but this had declined to 43% in the current cohort. It is beyond the scope of this paper to analyze the reason for this change but classroom observation suggests that the improved spoken language skills of the children are a major factor in determining educational setting.

Before concluding, it is important to point out that the sample of children in both cohorts is very specific and represents a sub-sample of children in the UK with severe-profound hearing loss. The most distinctive thing about the children is that they all had a nonverbal IQ of 85 or more. There are no good data about the demographics of this sub-population but some indication of their unique characteristics can be gained from Archbold et al (2008). In that study there were initially 105 children for whom reading data were available. When children were selected on the basis of nonverbal IQ (using a similar criterion to the present study) the sample size was reduced to 71. This illustrates that a significant number of DHH children have an IQ indicative of additional cognitive difficulties even though they may not have any identified additional needs. By focusing on children who have a higher IQ, the present study was looking at outcomes in those who might be expected to be reading at an age-appropriate level.

Another distinctive characteristic of the sample is the relatively high proportion of children who used sign language as their preferred form of communication. This is related to a similarly high proportion of children who had one or more deaf parents. The reason for the relatively high proportions within both cohorts was the inclusion of schools for the deaf and specialist resource bases in the study, many of which used signing for classroom communication. As such, this sample should not be seen as proportionally

representative of DHH children in UK school but, rather, as a carefully matched comparison group.

In conclusion, this study has shown that advances in technology have brought about significant improvements for DHH children. Compared with children assessed 10 years ago, children currently in primary school have, on average, an English vocabulary age that is two years higher. This is a substantial improvement. However the marked improvement in vocabulary was not matched by commensurate improvements in either phonological awareness or reading ability, suggesting that the advent of better hearing aid technology has not yet enabled DHH children to read at an age-appropriate level. Hearing aid technology will inevitably continue to improve and it is very likely that, in the future, CIs will better enable to children to access the critical information about speech that underpins the development of phonological skills (Nittrouer, Kuess, & Lowenstein, 2015). However, until that point is reached many DHH children will require ongoing support throughout primary school and into secondary school that will enable them to develop the robust phonological skills and age-appropriate level of English vocabulary that are essential for literacy.

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References

Ackley, R. S., & Decker, T. N. (2006). Audiological advancement in the acquisition of spoken language in deaf children. In P. E. Spencer & M. Marschark (Eds.), *Advances in the spoken language development of deaf and hard-of-hearing children* (pp. 64-84). New York: Oxford University Press.

Allen, T. E. (1986). Patterns of academic achievement among hearing impaired students: 1974 and 1983. In A. N. Schildroth & M. A. Karchmer (Eds.), *Deaf children in America* (pp. 161- 206). San Diego, CA: College-Hill Press.

Archbold, S. M., Harris, M., O'Donoghue, G., Nikolopoulos, T., White, A., & Lloyd Richmond, H. (2008). Reading abilities after cochlear implantation: the effect of age at implantation on outcomes at five and seven years after implantation. *International Journal of Pediatric Otorhinolaryngology, 72*(10), 1471-1478. doi:10.1016/j.ijporl.2008.06.016

Archbold, S. M., Nikolopoulos, T. P., Tait, M., O'Donoghue, G. M., Lutman, M. E., & Gregory, S. (2000). Approach to communication, speech perception and intelligibility and paediatric cochlear implantation. *British Journal of Audiology, 3*(4), 257-264.

Ching, T. Y. C., Day, J., & Cupples, L. (2014). Phonological awareness and early reading skills in children with cochlear implants. *Cochlear Implants International, 15*(S1), S27-S29. doi:10.1179/1467010014Z.000000000172

Cleary, M., Pisoni, D. B., & Geers, A. E. (2001). Some measures of verbal and spatial working memory in eight- and nine-year-old hearing-impaired children with cochlear implants. *Ear & Hearing, 22*, 395-411.

Conrad, R. (1979). *The Deaf School Child: Language and Cognitive Function*. London: Harper & Row.

Davis, A., Bamford, J., Wilson, I., Ramkalawan, T., Forshaw, M., & Wright, S. (1997). A critical review of the role of neonatal hearing screening in the detection of congenital hearing impairment. *Health Technology Assessment, 1*(10), 1-176.

DiFrancesca, S. (1972). *Academic Achievement Test Results of a National Testing Program for Hearing Impaired Students: United States, Spring 1971 (Report No. 9, Series D)*. Washington, DC: Gallaudet College, Office of Demographic Studies.

Durieux-Smith, A., Fitzpatrick, E., & Whittingham, J. (2008). Universal newborn hearing screening: A question of evidence. *International Journal of Audiology, 47*(1), 1-10. doi:10.1080/14992020701703547

Elliott, C. D., & Smith, P. (2011). *British Ability Scales III (BAS III)*. London: GL Assessment.

Foster, H. (2007). *Single Word Reading Test 6-16 (SWRT)* London: GL Assessment.

Geers, A. E. (2002). Factors affecting the development of speech, language and literacy in children with early cochlear implantation. *Language, Speech and Hearing Services in Schools, 33*(3), 172-183. doi:10.1044/0161-1461(2002/015)

Geers, A. E. (2003). Predictors of reading skill development in children with early cochlear implantation. *Ear & Hearing, 24*(1 Suppl), 59S-68S.

Goldberg, H. R., & Lederberg, A. R. (2015). Acquisition of the alphabetic principle in deaf and hard-of-hearing preschoolers: the role of phonology in letter-sound learning. *Reading and Writing, 28,* 509-525. doi:10.1007/s11145-014-9535-y

Harris, M. (2016). The impact of cochlear implants on deaf children's literacy. In M. Marschark & P. E. Spencer (Eds.), *The Oxford Handbook of Deaf Studies in Language* (pp. 407-419). New York: Oxford University Press.

Harris, M., & Moreno, C. (2006). Speech reading and learning to read: a comparison of 8-year-old profoundly deaf children with good and poor reading ability. *Journal of Deaf Studies and Deaf Education, 11*(2), 189-201. doi:10.1093/deafed/enj021

Harris, M., & Terlektsi, E. (2011). Reading and spelling abilities of deaf adolescents with cochlear implants and hearing aids. *Journal of Deaf Studies and Deaf Education, 16*(1), 24-34. doi:10.1093/deafed/enq031

Hatcher, P. J., Hulme, C., & Snowling, M. J. (2004). Explicit phoneme training combined with phonic reading instruction helps young children at risk of reading failure. *Journal of Child Psychology & Psychiatry, 45*(2), 338-358. doi:10.1111/j.1469-7610.2004.00225.x

Herman, R., Roy, P., & Kyle, F. E. (2014). *Reading and dyslexia in oral deaf children: From research to practice*. Retrieved from London:

Hoover, W. A., & Gough, P. B. (1990). The simple view of reading. *Reading and Writing, 2*(2), 127-160.

Hulme, C., & Snowling, M. J. (2009). *Developmental disorders of language learning and cogntion*. Chichester: Wiley-Blackwell.

Hulme, C., Stothard, S. E., Clarke, P., Bowyer-Crane, C., Harrington, A., Truelove, E., & Snowling, M. J. (2011). *York Assessment of Reading for Comprehension: Early Reading*. London: GL Assessment.

Kennedy, C. R., McCann, D., Campbell, M. J., Kimm, L., & Thornton, R. (2005). Universal newborn screening for permanent childhood hearing impairment: An 8-year follow-up of a controlled trial. *Lancet, 366*(9486), 660-662. doi:10.1016/S0140-6736(05)67138-3

Kennedy, C. R., McCann, D. C., Campbell, M. J., Law, C. M., Mullee, M., Petrou, S., . . . Stevenson, J. (2006). Language ability after early detection of permanent childhood hearing impairment. *New England Journal of Medicine, 354*(20), 2131-2141. doi:10.1056/NEJMoa054915

Kronenberger, W. G., Colson, B. G., Henning, S. C., & Pisoni, D. B. (2014). Executive functioning and speech-language skills following long-term use of cochlear implants. *Journal of Deaf Studies and Deaf Education, 19*(4), 456-470. doi:doi:10.1093/deafed/enu011

Kyle, F. E., & Harris, M. (2006). Concurrent correlates and predictors of reading and spelling achievement in deaf and hearing school children. *Journal of Deaf Studies and Deaf Education, 11*(3), 273-288. doi:10.1093/deafed/enj037

Kyle, F. E., & Harris, M. (2010). Predictors of reading development in deaf children: A three year longitudinal study. *Journal of Experimental Child Psychology, 107*(3), 229-243. doi:10.1016/j.jecp.2010.04.011

Kyle, F. E., & Harris, M. (2011). Longitudinal patterns of emerging literacy in beginning deaf and hearing readers. *Journal of Deaf Studies and Deaf Education, 16*(3), 289-304. doi:10.1093/deafed/enq069

Lane, H. S., & Baker, D. (1974). Reading Achievement of The Deaf: Another Look. *The Volta Review, 76*, 489-499.

Lewis, S. (1996). The Reading Achievements of a Group of Severely and Profoundly Hearing-Imapired School Leavers educated within a Natural Aural Approach. *Journal of British Association of Teachers of the Deaf, 20*(1), 1-7.

Marschark, M., & Harris, M. (1996). Success and failure in learning to read: The special (?) case of deaf children. In C. Cornoldi & J. Oakhill (Eds.), *Reading comprehension difficulties: Processes and intervention* (pp. 279-300). Hillsdale, NJ: Lawrence Erlbaum Associates Inc.

Martin, N., & Brownell, M. A. (2011). *Expressive one word picture vocabulary test 4 (EOWPVT)* Novato, CA: Academic Therapy Publications (ATP Assessments).

Mayer, C. (2007). What really matters in the early literacy development of deaf children. *Journal of Deaf Studies and Deaf Education, 12*(4), 411-431. doi:10.1093/deafed/enm020

Mayer, C., & Moksos, E. (1998). Deaf children learning to spell. *Research in theTeaching of English, 33,* 158-180.

Miller, E. M., Lederberg, A. R., & Easterbrooks, S. R. (2013). Phonological awareness: Explicit instruction for young deaf and head-of-hearing children. *Journal of Deaf Studies and Deaf Education, 18*(2), 206-227. doi:10.1093/deafed/ens067

Moog, J., & Geers, A. (1985). EPIC: A Program to Accelerate Academic Progress in Profoundly Hearing-Imapired Children. *The Volta Review, 87*, 259-277.

Muter, V., Hulme, C., Snowling, M. J., & Stevenson, J. (2004). Phonemes, rimes, and language skills as foundations of early reading development: Evidence from a longitudinal study. *Developmental Psychology, 40*(5), 663-681. doi:10.1037/0012-1649.40.5.665

Nakeva von Mentzer, C., Lyxell, B., Sahlen, B., Wass, M., Lindgren, M., Ors, M., . . . Uhlen, I. (2013). Computer-assisted training of phoneme-grapheme correspondence for children who are deaf and hard of hearing: effects on phonological processing skills. *International Journal of Pediatric Otorhinolaryngology*, *77*(12), 2049-2057. doi:10.1016/j.ijporl.2013.10.007

Narr, R. F. (2008). Phonological awareness and decoding in deaf/hard-of-hearing students who use visual phonics. *Journal of Deaf Studies and Deaf Education, 13*(3), 405-416. doi:10.1093/deafed/enm064

Nation, K., & Snowling, M. J. (2004). Beyond phonological skills: broader language skills contribute to the development of reading. *Journal of Research in Reading, 27*(4), 342–356. doi:10.1111/j.1467-9817.2004.00238.x

Neale, M. D. (1989). The Neale analysis of reading ability (revised). Windsor: NFER-Nelson.

NICE. (2009). NICE technology appraisals: Cochlear implants for children and adults with severe to profound deafness. Retrieved from http://www.nice.org.uk/guidance/ta166

Nittrouer, S., Caldwell-Tarr, A., Sansom, E., Twersky, J., & Lowenstein, J. H. (2014). Nonword repetition in children with cochlear implants: A potential clinical marker of poor language acquisition. *American Journal of Speech-Language Pathology, 23*, 679-695. doi:10.1044/2014_AJSLP-14-0040

Nittrouer, S., Sansom, E., Low, K., Rice, C., & Caldwell-Tarr, A. (2014). Language structures used by kindergartners with cochlear implants: relationship to

phonological awareness, lexical knowledge and hearing loss. *Ear Hear, 35*(5), 506-518. doi:10.1097/aud.0000000000000051

O'Donoghue, G. M., Nikolopoulos, T. P., & Archbold, S. M. (2000). Determinants of speech perception in children after cochlear implantation. *The Lancet., 356*, 466-468.

Pimperton, H., & Kennedy, C. R. (2012). The impact of early identification of permanent childhood hearing impairment on speech and language outcomes. *Archives of Disease in Childhood, 97*, 648-653. doi:10.1136/archdischild-648 2011-301501

Pisoni, D. B., & Geers, A. E. (1998). Working memory in deaf children with cochlear implantats: Correlations between digit span and measures of spoken language processing *Research on Spoken Language Processing: Progress Report no 22*. Indiana University.

Reading, R. (2012). Predictors of spopken language development following pediatric cochlear implantation. *Child: care, health and development, 38*(5), 759-760. doi:10.1111/j.1365-2214.2012.01418_5.x

Snowling, M. J., Stothard, S. E., Clarke, P., Bowyer-Crane, C., Harrington, A., Truelove, E., . . . Hulme, C. (2011). *York assessment of reading for comprehension: Early reading and passage reading primary (YARC Primary)* London: GL Assessment.

Spencer, L. J., & Tomblin, J. B. (2009). Evaluating phonological processing skills in children with prelingual deafness who use cochlear implants. *Journal of Deaf Studies and Deaf Education, 14*(1), 2-21. doi:doi:10.1093/deafed/enn013

Tait, M., Nikolopoulos, T. P., Archbold, S. M., & O'Donoghue, G. M. (2001). Use of the telephone in prelingually deaf children with a multi-channel cochlear implant. *Otology & Neurotology, 22*, 47-52.

Thoutenhoofd, E. D. (2006). Cochlear implanted pupils in Scottish schools: 4-year school attainment data (2000-2004). *Journal of Deaf Studies and Deaf Education, 11*(2), 171-188. doi:10.1093/deafed/enj029

Thoutenhoofd, E. D., Archbold, S. M., Gregory, S., Lutman, M. E., Nikolopoulos, T. P., & Sach, T. H. (2005). *Paediatric cochlear implantation: Evaluating outcomes*. London: Whurr.

Trezek, B. J., Wang, Y., Woods, D. G., Gampp, T. L., & Paul, P. V. (2007). Using visual phonics to supplement beginning reading instruction for students who are deaf or hard of hearing. *Journal of Deaf Studies and Deaf Education, 12*(3), 373-384. doi:10.1093/deafed/enm014

Trybus, R. J., & Karchmer, M. A. (1977). School Achievement Scores of Hearing Impaired Children: National Data on Achievement Status and Growth Patterns. *American Annals of the Deaf, 122*(2), 62-69.

Vermeulen, A. M., van Bon, W., Schreuder, R., Knoors, H., & Snik, A. (2007). Reading comprehension of deaf children with cochlear implants. *Journal of Deaf Studies and Deaf Education, 12*(3), 283-302. doi:10.1093/deafed/enm017

Wagner, R., Torgesen, J., & Rashotte, C. (2001). *Comprehensive Test of Phonological Processing*. Austin, TX: Pro-Ed.

Watson, L. M., Archbold, S. M., & Nikolopoulos, T. (2006). Children's communication code five years after cochlear implantation: Changes over time according to age at implant. *Cochlear Implants International, 7*(2), 77-91.

Watson, L. M., Hardie, T., Archbold, S. M., & Wheeler, A. (2008). Parents' views on changing communication mode after cochlear implantation. *Journal of Deaf Studies and Deaf Education, 13*, 104-116. doi:10.1093/deafed/enm036.

Table 1: *Mean (and standard deviation) of chronological age, nonverbal IQ, age of diagnosis and levels of hearing loss for the Cohorts 1 and 2 and distribution across educational settings*

Cohort	n	Chronological age (months)	Nonverbal IQ	Age of diagnosis (months)	Unaided hearing loss	Aided hearing loss	Educational setting		
							School for the deaf	Specialist resource base	Mainstream classroom
DHH children									
Cohort 1	32	76.1 (9.2)	94 (7.9)	14.0 (12.9)	99 (15)	53 (17.4)	7 (22%)	25 (78%)	0
DHH children									
Cohort 2	42	78.9 (6.9)	123 (30)	11.7 (14.9)	102 (15.5)	39 (14.8)	14 (33%)	18 (43%)	10 (24%)
Hearing children									
Cohort 2	40	70.4 (3.4)	115 (15.3)						

Note. Data on aided hearing loss were available for 23 participants in Cohort 1 and 40 participants in Cohort 2.

Table 2: *Means scores (and standard deviations) for single word reading, reading comprehension, phonological awareness, English vocabulary and letter-sound knowledge in Cohorts 1 (C1) and 2 (C2)*

		Chronological Age (months)	Single Word Reading Age (months)	Reading Comprehension Age (months)	Phonological Awareness (max = 24)	English Vocabulary Age	Letter-Sound Knowledge
Cohort	n	M (SD)	M (SD)	M (SD)	M (SD)	M (SD)	M (SD)
DHH children C1	32	76.1 (9.2)	69.2 (12.3)		16.0 (3.8)	38.4 (10.0)	
DHH children C2	42	78.9 (6.9)	73.1 (14.4)	71.9 (19.4)	18.3 (4.2)	65.9 (23.8)	19.2 (7.7)
Hearing aids C2	*20*	*78.4 (7.7)*	*73.00 (13.4)*	*71.0 (19.2)*	*17.2 (3.9)*	*69.00 (24.9)*	*15.8 (8.9)*
Cochlear implants C2	*22*	*79.3 (6.2)*	*73.27 (15.6)*	*72.7 (19.4)*	*19.4 (4.3)*	*63.14 (23.1)*	*22.3 (4.9)*
Hearing children C2	40	70.4 (3.4)	77.50 (13.5)	76.3 (12.5)	21.6 (2.6)	76.25 (11.8)	24.7 (1.6)

Table 3: *Correlations between single word reading, phonological awareness English vocabulary, chronological age and nonverbal IQ in Cohorts 1 and 2*

	Cohort 1 DHH Children				Cohort 2 DHH Children				Cohort 2 Hearing Children			
	2	3	4	5	2	3	4	5	2	3	4	5
1 Single Word Reading	.61 **	.80 **	.73**	.26	.52**	.80**	.57**	.26	.54**	.60**	.51**	.25
2 Phonological Awareness	_	.73**	.30	.51**	_	.38*	.36*	.23	_	.36*	.38*	.42**
3 English Vocabulary		_	.50**	.40*		_	.47**	.30		_	.37*	.30
4 Chronological Age			_	.22			_	.08			_	-.09
5 Nonverbal IQ				_				_				_

* p <.05 ** p<.01

Table 4: *Predictors of single word reading in Cohorts 1 and 2*

		Cohort 1 DHH children		Cohort 2 DHH children		Cohort 2 Hearing children	
Step	Independent variable	ΔR^2	β	ΔR^2	β	ΔR^2	β
1	Nonverbal IQ	.07	.26	.07	.26	.06	.25
2	Chronological age	.13**	.41	_	_	_	_
	Phonological awareness	_	_	.06*	.26	.12*	.40
	English vocabulary	.57**	.82	.56**	.80	.30**	.57
	Total R^2	.77		.70		.48	

**p < .001, * p <= .01

Table 5: *Number (and percentage) of children who received a confirmatory diagnosis of hearing loss at different ages*

Age at confirmatory diagnosis	Cohort 1 (n=31)*	Cohort 2 (n = 42)
0-6 months	9 (29%)	24 (57%)
7 – 12 months	11 (35%)	5 (12%)
13 – 24 months	7 (23%)	6 (14%)
Over 24 months	4 (13%)	7 (17%)

* Information was not available for one child so percentages are shown for 31 children.