Concurrent and longitudinal predictors of reading for deaf and hearing children in primary school

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Forty-one children with severe-profound prelingual hearing loss were assessed on single word reading, reading comprehension, English vocabulary, phonological awareness and speechreading at three time points, one year apart (T1, T2, T3). Their progress was compared with that of a group of hearing children of similar non-verbal IQ, initially reading at the same level. Single word reading improved at each assessment point for the deaf children but there was no growth in reading comprehension from T2 to T3. There were no differences between children with cochlear implants and those with hearing aids on either reading measure but orally-educated children had higher scores than children who signed in the classroom. English vocabulary and speechreading were the most consistent longitudinal predictors of reading for the deaf children. Phonological awareness was the most consistent longitudinal predictor for the hearing group and also a concurrent predictor of reading at T3 for both groups. There were many more significant correlations among the various measures for the deaf children than the hearing at both T1 and T3, suggesting that skills underpinning reading, including phonological awareness and vocabulary, are more closely related for deaf children. Implications of these findings for of deaf children's literacy are explored.

A large number of studies have highlighted the significant difficulties that many children with severe-profound prelingual hearing loss experience in learning to read and write (Kronenberger, Colson, Henning, & Pisoni, 2014; Marschark & Harris, 1996). Although there is general agreement about the extent of these difficulties, there is rather less agreement about their underlying cause, with a major area of disagreement being the importance or otherwise of phonological skills (Bochner & Kelstone, 2016; Harris, 2016; Mayberry, del Giudice, & Lieberman, 2011). For example, a meta-analysis by Mayberry et al. (2011) suggested that phonological skills play only a minor role in deaf children's reading whereas other authors have argued that these skills are key to success (Bochner & Kelstone, 2016; Kyle & Harris, 2010, 2011; Miller, Lederberg, & Easterbrooks, 2013).

One way to determine which factors contribute to success in learning to read is to gather longitudinal data and to look at factors that predict outcomes over time. Such studies have been very important in determining the factors underpinning reading success for hearing children where they have paved the way for intervention studies to support children who are at risk for reading difficulties (Hulme & Snowling, 2009). While there have been many longitudinal studies of hearing children's reading, there have been relatively few studies of deaf children. Arguably, the design of longitudinal studies with deaf children and the interpretation of outcomes is more difficult than for hearing children because of the wide range of factors that can affect development. The age of diagnosis and severity of hearing loss, the effectiveness of hearing aid technology and age at intervention, and the level of parental and educational support can all impact outcomes (Harris, 2015). Furthermore, whereas studies of hearing children tend to focus on rather similar predictors – albeit with variation at a more granular level – studies of deaf

children's reading have used a range of measures, according to the particular focus of the study. For this reason, making comparisons among studies is not always straightforward.

An early longitudinal study (Harris & Beech, 1998) found that speech intelligibility, phonological awareness and language comprehension predicted reading development between the ages of 5 and 7 years in children with severe-profound hearing loss. In a study of orally-educated French children, early phonological awareness skills, including rhyme judgement and rhyme generation, predicted reading progress made between the age of 6 and 7 years (Colin, Magnan, Ecalle, & Leybaert, 2007). Kyle and Harris (2010) found that English vocabulary and speechreading skills at age 7, but not phonological awareness, predicted reading at age 10 although phonological awareness became a significant predictor by the end of the study. Notably, reading ability predicted later phonological awareness rather than phonological awareness predicting reading ability, which is the most common pattern for hearing children (Hulme & Snowling, 2009). Similarly, in a group of beginning deaf readers, those children with better English vocabulary and speechreading skills (providing access to the phonological structure of spoken language) made more progress over the first few years of reading instruction (Kyle & Harris, 2011).

More recent studies have focused on children with cochlear implants. A long term study by Geers and colleagues (Geers, 2003; Geers, Tobey, Moog, & Brenner, 2008) found that phonological coding ability and linguistic competence were both predictive skills for reading in primary school and, in a follow-up of reading in secondary school (Geers & Hayes, 2011), phonological processing skills were found to be a major contributor to literacy outcomes. This study also reported relatively poor levels of reading among secondary school pupils in comparison to performance in primary school and the authors suggest that the gap between deaf

children and hearing peers continues to widen with age. This conclusion is in line with the outcomes of a study of reading among adolescents in the UK (Harris & Terlektsi, 2011), which found an average reading delay of over 3 years in a group of 12 to 16-year-olds.

In another US study, speech production and language comprehension skills accounted for a substantial proportion of the variance in written word comprehension three years later (Spencer & Oleson, 2008) and, in a longitudinal study of children in Australia with cochlear implants and hearing aids (Ching, Day, & Cupples, 2014; Cupples, Ching, Crowe, Day, & Seeto, 2014), phonological awareness was a significant predictor of reading at age 5, after controlling for receptive vocabulary and nonverbal cognitive ability. Taken together, these studies point towards language and phonological skills as important for deaf children's reading development, especially for those who are receiving an oral education.

The conclusion that these two skills are both important for learning to read is in line with the simple view of reading (Hoover & Gough, 1990), which argues that two core components lie at the heart of becoming literate – decoding (recognizing a sequence of letters as a word) and linguistic comprehension (understanding the meaning of what is read). This model has been used to explain what hearing children need to learn in order to become efficient readers and it would appear from the studies cited above that deaf children are making use of similar skills (see also Kyle, 2015). However, both decoding and linguistic comprehension are broad skills and making a direct comparison between the longitudinal predictors of reading for deaf and hearing children can shed further light on the similarities and differences of the two groups.

In a study of children who had just completed kindergarten (Nittrouer, Caldwell, Lowenstein, Tarr, & Holloman, 2012), spoken language and syllable counting were the strongest predictors of both word reading and reading comprehension for deaf children. This contrasted

with the pattern for hearing children of similar age for whom phonemic awareness was the strongest predictor of word reading and expressive vocabulary was the only significant predictor of reading comprehension. Nittrouer et al. concluded that oral language skills explained more variance in emergent literacy for children with CIs than for children with normal hearing. Kyle and Harris (2011) also found differences between deaf and hearing children. In their study, English vocabulary and speechreading ability at age 5 years were strong longitudinal predictors of reading at age 7 years whereas, for the hearing children of the same age, phonological awareness was the strongest predictor, followed by speechreading. The studies by Kyle and Harris (2011) and Nittrouer et al. (2012) both suggest that deaf children's knowledge of English vocabulary is a more important longitudinal predictor of reading than it is for hearing children. For most hearing children, knowledge of vocabulary can be taken for granted and support with language skills is not usually necessary to enable the development of reading. This is why the majority of studies with hearing children place emphasis on the importance of supporting the development of phonological skills (Harris, 2015). However, for children who are deaf, vocabulary knowledge may well not be age-appropriate and, if this is the case, variations in vocabulary knowledge will be a major predictor of success in learning to read.

In order to the examine the development of reading ability over time, this study assessed deaf and hearing children at three time points, approximately one year apart, beginning when they were aged between 5 and 7 years. The aims of the study were twofold. The first aim was to chart the development of single word reading and reading comprehension over a 2 year period of primary school, comparing the trajectories for deaf children and hearing children of initially similar reading ability. The second aim was to examine the longitudinal predictors of reading in the two groups of children. The predictors considered were English vocabulary,

phonological awareness and speechreading and the patterns of prediction from the first (T1)

and second (T2) assessments to reading at the third assessment (T3) were compared for the

deaf and hearing children.

Method

Participants

The sample of deaf and hearing children described below includes only children who were

available for assessment at all three time points (T1- T3) and it is a subsample of the

participants described in (Harris, Terlektsi, & Kyle, in press). During the course of the study a

number of children moved out of the local area and were unavailable for follow up.

Deaf children

Forty-one deaf children (26 boys), mean age 6 years 7 months (range 5;05 – 7;06), were

recruited from a total of 25 sites in the southern part of England. 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.

The children's mean unaided hearing loss was 106 dB (SD = 15.7) and ranged from 72 dB

to greater than 120 dB, according to four-frequency averaging of the pure-tone thresholds at

0·5, 1, 2, and 4 kHz. Information on Speech intelligibility was gathered for the participants in

T1 using the Speech Intelligibility Rate (SIR) but it was not found to be a predictor for reading

or to account for any additional variance. We therefore used the pure tone audiometry

measures. Nineteen of the children wore digital hearing aids and 22 were fitted with cochlear

implants (17 bilateral). Mean age of diagnosis of hearing loss was 10.5 months (SD = 12.9)

with a range from birth to 52 months of age. All children were prelingually deaf and all achieved a score of at least 85 on a measure of non-verbal intelligence, with a mean of 123 (SD = 30). Fifteen of the children (37%) used sign language as their preferred mode of communication, 18 (44%) preferred oral communication and the remaining 8 (19%) used a combination of sign and speech.

Data are reported for the above 41 children with the exception of the speechreading score for T3, which was only obtained for 40 participants owing to the illness of one child.

Hearing children

There were 32 reading-aged matched hearing children (17 boys). Their mean age was 5 years 10 months (range 5;05 – 6;05). All children achieved a score of at least 85 on a measure of non-verbal intelligence test with a mean of 115 (SD=15.3) and they were matched to the deaf children 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 deaf and hearing children on either single word reading age, $t(71)=1.53$, ns, or nonverbal intelligence, $t(80)=1.07$, ns but the hearing children were significantly younger, $t(71)= 6.16$, $p<.001$, $r =.61$.

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 deaf 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 no mild or moderate learning difficulties that might have gone undetected.

Reading ability

All participants were initially given the Single Word Reading Test 6-16 (Foster, 2007) in which children are asked to read aloud individual words. Children had the option of signing words or reading them aloud. The children who preferred to sign did not attempt to mouth the words for which they were unable to produce the sign. Standard scores and reading ages were calculated from the raw scores, which were used to select the appropriate starting passage in the York Assessment of Reading for 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 deaf children (Kyle & Harris, 2006, 2010, 2011). The YARC presents children with a series of graded passages, each illustrated by a picture. After reading a passage, 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 acceptable only when they produced both the correct sign and mouthed the English word. This 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 in deaf children (Kyle, Campbell, & MacSweeney, 2016).

Phonological awareness

Phonological awareness was assessed using a picture-based phonological similarity task developed by Kyle and Harris (2006; 2010; 2011). The items selected for this task were all high frequency words, acquired at an early age. In addition, the words in the onset and rime sections were matched on word frequency, age of acquisition and density of phonological and orthographic neighborhoods (Kyle & Harris, 2006). This task was chosen as it uses pictures to present the stimuli and it only requires participants to point at the correct response. It is therefore an appropriate task for children who do not have good spoken language. At T2, a sub-group of children in the study was also given a standardized assessment of phonological awareness, the sound deletion task from the YARC. The correlation between performance on the YARC sound deletion task and the Kyle and Harris phonological awareness task was .62.

In this study, the items used at T1 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.

In light of high scores on this task at T1, for assessment at T2 and T3 the task was made more difficult by replacing the items with words that included initial and/or final consonant clusters. For the 12 onset trials children had to match initial clusters (e.g., *bread-brush*) and, for the 12 rime trials, they had to match final clusters (e.g., *king ring*). The final set of items was selected through a pilot study with a small group of hearing children that showed the inclusion of clusters increased the difficulty of the task. Within the sample of deaf children, scores at T1 and T2 were significantly correlated, r_s = .51, p = .001, as were scores at T2 and T3, r_s = .51, p < .001, which used identical items.

Speechreading ability

Speechreading was assessed using the words and sentences subtests from the Test of Child Speechreading (ToCS) (Kyle, Campbell, Mohammed, Coleman, & MacSweeney, 2013). The ToCS is a video-to-picture matching test, standardized for deaf and hearing children aged 5 to 14 years, and designed to test speechreading abilities. It has been found to have good reliability (α = .08) and high validity (r = .84, p <.001). After seeing a short familiarization

video of two speakers saying the days of the week (without sound), children watched brief video clips of a man or woman saying either a word (section 1) or a sentence (section 2). After each clip there were four pictures and children had to select the one that best matched what the speaker said. There are three test trials at the beginning of each section where feedback was given but no feedback was given during the test trials. One point was given for each correct answer and the maximum overall score for the two sections was 30. The instructions for each subtest were presented on the screen and also given by the researcher in the participant's preferred mode of communication.

Procedure

All participants were assessed in their schools and all assessment sessions took place in a separate room, close by the child's classroom. As noted above, instructions for each assessment were presented in the child's preferred mode of communication. All assessments were carried out in one or two sessions depending on the needs of an individual child. Assessments of the deaf children were carried out by the second author who is a qualified Teacher of the Deaf with BSL Level 2 qualification (which enables everyday conversation) and considerable experience of conducting language assessments with deaf children. Hearing children were assessed by a postgraduate researcher with experience of conducting research in schools with children of similar age. For the deaf children whose speech was less intelligible or 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 (ensuring that fidelity of test administration and scoring) but not

interfering with the assessment protocol. Double blind scoring was conducted for all assessments.

We also carried out classroom observations between T1 and T2 in order to find out how the children were being encouraged to read unfamiliar words that they encountered in their reading books. Observations took place when children were reading individually with a teacher.

Results

Gains over time

Table 1 shows the children's mean ages for single word reading, reading comprehension and English vocabulary and mean scores for phonological awareness and speechreading at each of the three assessments. Some of the data for the T1 assessment has already been reported (Harris et al., in press) but the data shown in Table 1 are for the 41 children who completed all three sessions rather than the 42 children who were initially recruited.

<Table 1 about here>

It can be seen that the deaf and hearing children showed rather different patterns over time for each of the measures. For both reading measures, the gains over time were considerably higher for the hearing children than for the deaf children. For single word reading, the deaf children show a mean gain of almost 13 months from the first to the third assessment while the hearing children show a gain of just over 31months. For reading comprehension the corresponding gains were just over 13 months and just under 24 months. ANOVA showed a main effect of time and hearing status and a significant hearing status x time interaction for single word reading (Status, $F(1,71) = 10.37$, $p = .002$, $\eta^2_p = .13$; Time,

F(2,142) = 152.69, p < .001, η^2_p = .68; Status x Time, F(2,142) = 27.67, p<.001, η^2_p = .28).

For reading comprehension, Status was not significant, F(1,71) = 3.24, p = .08, η^2_p = .04 but there was a significant main effect of Time, F(2,142) = 69.97, p < .001, η^2_p = .50, and a significant Status x Time interaction, F(2,142) = 8.5, p<.001, η^2_p = .11). Table 1 shows that the hearing children showed year-on-year gains between each assessment point for both reading measures whereas the deaf children showed a year-on-year gain for single word reading but their reading comprehension scores increased from T1 to T2 but not from T2 to T3.

There was a striking difference in the growth of English vocabulary in the two groups. For the deaf children, mean vocabulary age increased by 8.5 months between the first and final assessment whereas the hearing children showed an average gain of 33.5 months. ANOVA revealed a significant effect of hearing status, F(1,71) = 20.26, p < .001, η^2_p = .22, and Time, F(2,142) = 71.15, p < .001, η^2_p = .51, and a significant Status x Time interaction, F(2,142) = 26.71, p<.001, η^2_p = .27).

The pattern for speechreading was different from the other measures in that the deaf and hearing children showed an identical increase in mean score from T1 to T3, with the deaf children having a higher score on each occasion. ANOVA showed a main effect of Status, F(1,70) = 9.78, p = .003, η^2_p = .12, and Time, F(2,140) = 11.74, p <.001, η^2_p = .14, but a non-significant Status x Time interaction, F(2,140) = 2.93, p = .06.

The scores for phonological awareness over time were not subject to statistical analysis because the items used at T2 and T3 differed from T1.

Within the sample of deaf children two further sets of comparisons were made. The first was between children with CIs and those with hearing aids. The mean scores at T3 for each sub-

group are shown in Table 1 where it can be see that, for all measures, the scores were very similar and statistical analysis confirmed that there were no significant differences (t(39) = .01 for single word reading, = .64 for reading comprehension, = -.93 for phonological awareness, = -1.5 for English vocabulary, t(38) = -.40 for speechreading). This reflected the pattern of no differences between children with cochlear implants and those with digital hearing aids found at the first assessment (Harris et al., in press).

The second within-sample comparison was between children who exclusively used oral language in the classroom (n = 23) and those who used sign language with or without spoken English (n = 18). As with the comparison by type of hearing aid, the analysis focused on outcomes at T3. The mean scores for the two sub-groups are shown in Table 1. Statistical analysis revealed significant differences between the two sub-groups for single word reading, t(39) = 2.73, p = .01, reading comprehension, t(39) = 2.29, p = .03, English vocabulary, t(39) = 4.41, p <.001, and speechreading, t(39) = 2.83, p<.01. In each case, the scores of the oral language users were higher than those of the children who used sign language .The only score that did not differ was phonological awareness, t(39) = 1.83, p = .08.

Longitudinal predictors of reading

In order to examine the longitudinal predictors of single word reading and reading comprehension at T3, correlation and regression analyses were carried out. Table 2 shows the partial correlations, after co-varying chronological age at T1 and nonverbal IQ, between English vocabulary, phonological awareness and speechreading at T1 and T2 and the two reading measures at T3. It can be seen that the two measures of reading at T3 (single word reading and reading comprehension) were significantly correlated for both groups of children

but the correlation was notably higher for the deaf children (r=.74) than the hearing (r=.44). This difference in the size of the correlations was significant, Z=1.95, p = .05.

<Table 2 about here>

There were some other clear differences between the two groups. For the deaf children, English vocabulary, phonological awareness and speechreading at T1 and T2 were all significantly correlated with single word reading at T3 and, apart from phonological awareness at T1, they were also correlated with reading comprehension at T3. For the hearing children, none of these measures was significantly correlated with single word reading and, for reading comprehension, only vocabulary (at T1 and T2) and phonological awareness at T1 were significantly correlated. One other difference between the deaf and hearing children is of note. The correlation between English vocabulary at T1 and reading comprehension at T3 was notably higher for the deaf children (r=.83) than the hearing (r=.41) and this difference was significant, Z=3.07, p =.001. This echoes that pattern found for simple inter-correlations at T1 (Harris et al., in press) in which the correlation between English vocabulary and single word reading was .80 for the deaf children and .60 for the hearing children, although this difference was not significant.

These differences in the pattern of correlations were reflected in the outcome of the regression analyses (see Table 3). For each regression analysis, the predictor variables were chronological age (entered at Step 1) and English vocabulary, phonological awareness and speechreading at either T1 or T2 (entered at Step 2). The target variable was single word reading or reading comprehension at T3. For the deaf children, the strongest predictor of both T3 reading measures at both T1 and T2 was English vocabulary. Speechreading at T2 was also a significant predictor of both T3 reading measures and speechreading at T1 predicted single

word reading. Phonological awareness was not a significant predictor of either reading measure.

<Table 3 about here>

For the hearing children, phonological awareness at T1 predicted both single word reading and reading comprehension at T3 and vocabulary at T1 predicted reading comprehension. For T2 assessments, the only significant predictor for the hearing children was vocabulary, which predicted reading comprehension. Speechreading was not a significant predictor of either reading measure for the hearing children.

Given that the age of diagnosis of deafness varied within the sample of deaf children, the relationship between this variable and reading at T3 was examined. There was no significant correlation between age of diagnosis and either of the reading measures at T3, $r_s = .17$, $p = .30$ (single word reading), $r_s = .08$, $p = .64$ (reading comprehension).

Relationships among measures at T3

The final analyses carried out in this study were a series of partial correlations among the reading and language measures at T3, controlling for chronological age at T3 and nonverbal IQ. These are shown in Table 4. As with the inter-correlation of measures at T1 and T2, there were some clear differences between the deaf and hearing children. For the hearing children, single word reading scores were significantly correlated with phonological awareness, $r = .53$, $p < .01$, and there was a similar level of correlation between English vocabulary and reading comprehension, $r = .53$, $p < .01$. As reported earlier, the two measures of reading were also significantly correlated, $r = .47$, $p = .01$. There is a very small difference in the size of the correlations between the two

reading measures at T3 as reported in Table 2 and Table 4. This is a result of using a different measure of chronological age in the two sets of analyses.

No other correlations were significant. For the deaf children, not only were the two reading measures highly correlated as noted earlier, but there were also very strong correlations between English vocabulary and both single word reading, r = .82, p < .001, and reading comprehension, r = .81, p < .001. In addition, phonological awareness was significantly correlated with English vocabulary, r = .56, p <.001, and also with both single word reading and reading comprehension at the same level, r = .62, p <.001. Speech reading was significantly correlated with single word reading, r = .46, p < .001.

<Table 4 about here>

Regression analysis (see Table 5) showed that chronological age, English vocabulary and phonological awareness were all significant concurrent predictors of single word reading for the deaf children and that English vocabulary knowledge was the only significant predictor of reading comprehension. The hearing children showed a very similar pattern with English vocabulary and phonological awareness (but not chronological age) being significant concurrent predictors of singe word reading and only English vocabulary predicting reading comprehension. Nonverbal IQ was not entered into the regression analysis as it had been shown to be non-significant predictor of reading at T1 (Harris et al., in press).

Reading strategies

The most common reading strategy, evident in 26 of the 40 children (65%) who were available for observation, was for teachers to encourage the sounding out of unfamiliar words. In 5 cases this was with the help of Visual Phonics by Hand system (see

http://www.visualphonicsbyhand.co.uk). This system focuses on discrimination among phonemes using visual cues based on the BSL fingerspelling alphabet. The remaining 14 children (35%) were encouraged to guess a word from the context.

The finding that a sounding-out strategy was the one most commonly employed is in line with UK national guidelines on the teaching of literacy. This advocates the use of such a strategy for teaching reading in primary school ("Primary framework for literacy and mathematics," 2006). There was no simple relationship between the reading strategy being used and the modality of communication in the classroom; and both signing and oral children were guessing words and others using a sounding-out strategy. However, there was an association between modality of communication and reading strategy with 20/23 (87%) orally-educated children being encouraged to sound out words and only 6/17 (35%) signing children, Fisher Exact Test p = .002.

Discussion

The main aims of the present study were to compare the growth and longitudinal predictors of reading in deaf and hearing children with similar levels of nonverbal IQ who, at the first assessment, were reading at a similar level. The data showed that, in spite of starting out with very similar levels of reading ability, the two groups of children were performing very differently by the end of the study, two years later. As would be expected, the hearing children's reading progressed in line with their chronological age: Their mean score for single word reading was 31 months higher and for reading comprehension 24 months higher at T3. The deaf children made only 13 months progress over the same period in both single word

reading and reading comprehension and no progress at all on the latter measure between T2 and T3. Children with CIs did not make more progress than those with hearing aids, echoing previous findings from a number of recent studies (Harris & Terlektsi, 2011; Nittrouer et al., 2012). However, children who used oral language in the classroom scored more highly on both reading tests and also had higher vocabulary and speechreading scores than children who were using sign language. There was, however, no difference in the score on the phonological awareness assessment at T3.

There are many reasons why some children are undergoing an oral education while others are using signing in the classroom and it is important to be cautious in drawing conclusions about the relative merits of the two approaches for supporting literacy. However, given that both speechreading and English vocabulary were higher for the orally-educated children – the two variables that were longitudinal predictors of reading – it is clear that this sub-group were performing at a higher level in the skills that underpinned reading. The finding that it was orally-educated children who had higher speechreading scores was unexpected and it points to the fact that learning about the visual component of speech is easier when there is plenty of opportunity to use and observe spoken language. This is illustrated by the performance of the best reader in the sample. He had a single word reading score that was 76 months above his chronological age at T3 and also the highest score score (28/30) on the ToCS. He wore a digital hearing aid and was being orally-educated. He had hearing parents.

The deaf children in this study were born after the national implementation of newborn hearing screening in the UK and so, in comparison to children born a decade before the current sample, mean age of diagnosis was significantly lower (Harris et al., in press). The children had also benefited from the latest hearing aid technology. In spite of these

technological advances, their reading levels were still below chronological age although, as the standard deviations show, there was considerable individual variation in performance: Some of the children were reading at or above chronological age.

At a group level, the gap in the reading attainment of the deaf and hearing children increased significantly over time, echoing the findings of other studies that the gap between reading age and chronological age increases as children progress through school (Kyle & Harris, 2010 Geers & Hayes, 2011; Harris & Terlektsi, 2011). The pattern of growth for reading comprehension is of particular note. For the deaf children, there was no increase at all in mean score from T2 to T3. This points to the particular skills required for reading comprehension as being especially problematic for deaf children. One reason for difficulties with reading comprehension could be that relatively low English vocabulary scores did not enable many of the children to make even the simple inferences that were required to answer the comprehension questions in the YARC. For example, in the easiest comprehension passage, children had to infer that if a girl put on an outfit comprising long floppy ears and a fluffy tail, she was going to a fancy dress party as a rabbit. Many of the deaf children found inferences like this, that drew on world knowledge, to be challenging.

Previous studies have highlighted the difficulties that many deaf children have with making inferences when they read (Kyle & Cain, 2015; Marschark & Harris, 1996) and it would appear that they remain a considerable hurdle to the development of reading comprehension. In the example given above, and in many of the other questions that require inference in the YARC, world knowledge was required to fully understand the story. World knowledge can be aquired from a number of sources. Some is acquired through direct experience but much comes from what other people tell us, or from what we overhear, or

through reading itself. Arguably, the latter three routes are more problematic for many deaf children who have less opportunity to overhear everyday conversation and less advanced reading ability. They may, therefore, require additional support to build up their world knowledge and associated English vocabulary. The importance of vocabulary knowledge for reading comprehension among the sample of deaf children is evident in the strong correlations between reading comprehension, single word reading and English vocabulary.

The results of the regression analyses also highlight the crucial role of vocabulary knowledge for word decoding as variation in the deaf children's reading ability at T3 was most strongly predicted by their knowledge of English vocabulary and then by their speechreading ability at both T1 and T2. This pattern is in line with the findings of Kyle and Harris (2010; 2011) that both English vocabulary and speechreading were significant predictors of reading and it also supports the claim made by Nittrouer et al. (2012) that oral language is a key driver of reading for deaf children. The results are also in line with recent findings about concurrent predictors of reading in children aged between 5 and 14 years, where both vocabulary and speechreading contributed unique variance (Kyle et al., 2016). The hearing children showed a different pattern in that phonological awareness at T1 was the most consistent predictor of reading, as many other studies have found (Hulme & Snowling, 2009), with vocabulary at both T1 and T2 being a predictor only of reading comprehension.

There was a high correlation of .62 between phonological awareness and both measures of reading at T3 for the deaf children, suggesting that the good readers had good phonological skills. In the regression analysis of T3 data, phonological awareness was a small, but significant, concurrent predictor of single word reading with vocabulary being a very much stronger predictor. A similar pattern was found at T1 (Harris et al., in press). Phonological

awareness was not, however, a longitudinal predictor of reading for the deaf children. This contrasts with the pattern for hearing children for whom phonological awareness was both a concurrent predictor of reading at T3 and a longitudinal predictor.

One interpretation of this pattern of results is that, for deaf children, phonological skills are developing in line with reading rather than being a key driver of reading. It is important to remember that, in this study, the children were, on average, 6;7 at T1. The phonological skills that are important at this age tend to be phonemic skills. Poor phonemic skills have been identified as a common problem among poor hearing readers and a meta-analysis has shown that targeted support to develop phonemic skills can bring benefits for reading to children in preschool, kindergarten and first grade (Ehri et al., 2001). Furthermore, phonemic training is most successful when it makes use of letters so that children are easily able to bring their developing phonemic skills to the task of learning to read. It may well be the case that, for many deaf children, the development of phonemic awareness is closely allied to a developing awareness of the written form of words that can provide additional information about their phonemic structure and also syllabic structure. Previous research has found that deaf readers develop knowledge of the syllabic structure of words once they are able to read (Harris & Moreno, 2004) unlike hearing children who typically have a good awareness of syllables before they begin learning to read. This also fits in with the argument put forward by Kyle and Harris (2010) that many deaf children develop their phonological skills through the experience of learning to read and thus phonological awareness becomes an increasingly significant concurrent correlate as deaf children become older.

Further insight into differences between the deaf and hearing children can be gained from the pattern of inter-correlations among the various assessments. One striking difference

was the large number of significant correlations for the former group compared to the latter. In Table 2, 21 of the 28 correlations among assessments were statistically significant for the deaf children while only 7 were significant for the hearing children. In Table 4, which reported the correlations among measures at T3, 8/10 correlations were significant for the deaf children and only 3/10 for the hearing children.

What this implies is that the various abilities assessed in this study were much more closely linked for the deaf children than the hearing. As confirmed by the regression analysis, one reason for this difference was that speechreading was significantly correlated with many of the other measures for the deaf children whereas it was not correlated with any other measure for the hearing children. However, this was not the only difference. For the deaf children, phonological awareness at T2 was correlated with English vocabulary at both T1 and T2 but this was not the case for the hearing children for whom phonological awareness was not correlated with any other measure (apart from reading comprehension). This difference was also evident in the pattern of correlations among the T3 measures for the deaf and hearing children. For the deaf children, phonological awareness and English vocabulary were correlated at .56 whereas, for the hearing children, the corresponding correlation was only .06 (and non-significant). This suggests that phonological awareness and vocabulary are relatively independent abilities for hearing children but much less so for deaf children.

Some degree of caution should be exercised in interpreting the findings about the predictors of the hearing children's reading and the pattern of correlations. The models produced by the regression analysis accounted for a considerably greater proportion of the overall variance for the deaf children than for the hearing. For the former, R^2 ranged between .62 and .75 whereas, for the latter, R^2 ranged between .24 and .35. This difference reflects the

fact that the assessments were designed for the deaf children and, in particular, the picture-based measure of phonological awareness assessed relatively low-level phonological skills and 10 of the hearing children were at ceiling. Phoneme synthesis and deletion tasks were considered to be too difficult for some of the children in the study, especially those with poor oral language skills. For this reason variations in the more complex phonological skills that would be expected in hearing children were not assessed in this study. However, previous studies suggest that phonological skills and vocabulary tend to make independent contributions to learning to read for hearing children (Hulme & Snowling, 2009; Nation & Snowling, 2004) and so the conclusion that there are differences in the relative independence of the two components of reading ability for deaf and hearing children seems warranted. This suggestion is also in line with another recent study that has reported high correlations between phonological skills and vocabulary for deaf children (Webb, Lederberg, Branum-Martin, & Connor, 2015).

Turning now to the practical implications of these findings, the most obvious conclusion to draw is that supporting deaf children to develop both their English vocabulary and their awareness of the non-auditory – speechread – components of speech sounds is important for reading. In the case of speechreading skills, the argument is that the visual component of speech is especially important for the development of phonological skills when access to auditory information is limited. Previous research has shown that deaf children develop better speechreading skills when they have a later cochlear implant and have to place great reliance on the visual components of speech (Geers, 1994). In this study, the speechreading abilities of the deaf children were higher than those of the hearing children and, for both groups, there were improvements over time. Both Visual Phonics (Narr, 2008; Trezek, Wang, Woods,

Gampp, & Paul, 2007) and Cued Speech (Leybaert, Bayard, Colin, & LaSasso, 2016) have been shown to be effective in helping deaf children develop their phonological awareness and they can be seen as providing explicit information about the non-auditory – speechread – components of speech.

Our results also suggest that ongoing support for deaf children to develop their knowledge of English vocabulary is equally crucial for reading. As noted in the introduction, targeted support for hearing children with low reading levels tends to focus on developing their phonological skills. This makes sense because good vocabulary skills can be assumed for the majority of hearing children. This is not, however, the case for deaf children. Even though English vocabulary scores have increased with the advent of early diagnosis of hearing loss and better hearing aid technology, on average, they still lag behind chronological age (Harris et al., in press). Our study suggests that children are making relatively slow progress with vocabulary as they progress through primary school and so many will require support with both their vocabulary and phonological skills in order to become proficient readers.

Limitations

As previously noted, this study was primarily designed to investigate the development of reading and reading-related skills in deaf children. We chose a researcher-developed measure of phonological awareness that was specifically designed for the assessment of deaf children. It does not assess higher-level phonological awareness such as that required for blending and elision. It is now possible to assess blending and elision in deaf children, especially if they are being orally educated (Herman, Roy, & Kyle, 2014). However, it is more problematic to assess these higher-level skills in children with less well-developed spoken language and, for

this reason we preferred a relatively simple assessment that used pictures. Undoubtedly this meant that we did not always capture the full range of phonological skills in the children we assessed, particularly the hearing children, although it was reassuring to find that the assessment we used had a relatively high correlation with a standardised test that assesses deletion, the sound deletion task from the YARC. In future studies we would recommend the inclusion of this test as it uses pictures.

Conclusions

This study has shown that many deaf children are still not making age-appropriate gains in reading in primary school and that reading comprehension poses particular challenges. Children who learned to read well had good phonological skills, since phonological awareness was a concurrent predictor of reading, but the longitudinal predictors of reading were English vocabulary and speechreading. Phonological awareness and vocabulary were much more closely related for the deaf children than hearing children of similar reading age, for whom these two skills were relatively independent. There were no differences between children with cochlear implants and those with digital hearing aids but children who used oral language in the classroom had higher scores on reading, vocabulary and speechreading than those who signed.

There a number of implications for practice. Teaching should employ effective strategies to develop vocabulary knowledge and phonological skills for deaf children as well as promoting world knowledge. Deaf children with cochlear implants should be supported throughout school. Future research should focus on developing new and evaluating existent intervention programmes on deaf children's acquisition of letter sounds and phonological skills.

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Table 1: Means scores (and standard deviations) for single word reading, reading comprehension, phonological awareness, English vocabulary and speechreading in deaf (N= 41) and hearing (N=32) children at T1, T2 and T3

	Chronological Age (Months)	Single Word Reading (Age in Months)	Reading Comprehension (Age in Months)	English Vocabulary (Age in Months)	Phonological Awareness (Max = 24)	Speechreading (Max = 30)
Deaf children						
Time 1	78.9 (6.9)	73.1 (14.4)	71.9 (19.4)	65.9 (23.8)	18.3 (4.2)	13.8 (3.8)
Time 2	89.8 (6.8)	80.1 (18.2)	85.1 (26.7)	70.6 (25.8)	17.5 (3.1)	16.4 (3.9)
Time 3	101.0 (6.7)	86.0 (22.9)	85.5 (21.6)	74.5 (27.2)	18.0 (3.7)	16.2 (4.5)
CI	101.4 (6.0)	86.0 (18.8)	83.5 (22.8)	67.8 (22.4)	18.5 (3.9)	16.4 (4.6)
HA	100.5 (7.6)	86.0 (27.4)	87.8 (20.5)	80.3 (30.1)	17.5 (3.5)	16.8 (4.4)
Oral	100.7 (5.7)	94.0 (26.5)	93.5 (23.5)	27.6 (5.7)	19.0 (4.1)	17.7 (4.7)
Signing	101.4 (8.0)	75.8 (11.1)	77.8 (19.4)	57.0 (13.4)	16.9 (2.8)	14.0 (3.2)
Hearing children						
Time 1	70.4 (3.4)	77.5 (13.5)	76.3 (12.5)	76.3 (11.8)	21.6 (2.6)	11.7 (4.0)
Time 2	80.3 (3.3)	90.1 (17.7)	86.4 (9.8)	88.8 (16.1)	19.8 (2.7)	12.5 (4.1)
Time 3	92.8 (3.6)	109.1 (21.3)	100.0 (12.1)	109.9 (21.4)	20.8 (2.5)	14.1 (4.9)

Table 2: Partial correlations between English vocabulary, phonological awareness and speechreading at T1 and T2 and reading at T3 for deaf and hearing children (controlling for chronological age at T1 and nonverbal IQ)

Deaf children	1	2	3	4	5	6	7	8
1 English vocabulary (T1)	-	.20	.38*	.80**	.46**	.15	.61**	.83**
2 Phonological awareness (T1)		-	.16	.34*	.42**	-.06	.35*	.26
3 Speechreading (T1)			-	.32*	.43**	.59**	.53**	.45**
4 English vocabulary (T2)				-	.63**	.11	.79**	.79**
5 Phonological awareness (T2)					-	.26	.57**	.62**
6 Speechreading (T2)						-	.33*	.34*
7 Single word reading (T3)							-	.74**
8 Reading comprehension (T3)								-

Hearing children	1	2	3	4	5	6	7	8
1 English vocabulary (T1)	-	.01	-.05	.63**	.12	.17	.17	.41**
2 Phonological awareness (T1)		-	.11	.19	.51**	-.03	.23	.47**
3 Speechreading (T1)			-	-.21	-.01	.39*	-.06	.08
4 English vocabulary (T2)				-	.31	.21	.24	.60**
5 Phonological awareness (T2)					-	.06	.26	.33
6 Speechreading (T2)						-	.06	.08
7 Single word reading (T3)							-	.44*
8 Reading comprehension (T3)								-

* p <.05 ** p<.01

Table 3: Predictors of reading at T3 in deaf and hearing children from assessments at T1 and T2

		Deaf children				Hearing children			
		Single Word Reading		Reading Comprehension		Single Word Reading		Reading Comprehension	
Step	Predictor	Δr^2	β	Δr^2	β	Δr^2	β	Δr^2	β
1	Chronological Age at T3	.14	.38*	.10	.32	.09	.30	.02	.13
2	T1 Assessments	.48		.64		.15		.30	
	English Vocabulary		.48**		.80**		.18		.38*
	Phon Awareness		.21		.07		.35*		.38*
	Speechreading		.31*		.15		-.05		.03
	Total R^2	.62		.74		.24		.32	
2	T2 assessments	.61		.64		.15		.33	
	English vocabulary		.74**		.71**		.24		.56**
	Phon Awareness		.04		.12		.22		.14
	Speechreading		.24*		.23*		.04		-.08
	Total R^2	.75		.74		.24		.35	

* p <.05 ** p<.01

Table 4: Partial correlations between English vocabulary, phonological awareness, speechreading and reading at T3 for deaf and hearing children (controlling for chronological age at T3 and nonverbal IQ)

Deaf children	1	2	3	4	5
1 English vocabulary	-	.56**	. 38*	.82**	. 81**
2 Phonological awareness		-	.30	.62**	. 62**
3 Speechreading			-	.46**	. 25
4 Single word reading				-	.76 **
5 Reading comprehension					-

Hearing children					
1 English vocabulary	-	.06	.13	. 36	.53**
2 Phonological awareness		-	.04	.53**	. 34
3 Speechreading			-	.27	.06
4 Single word reading				-	.47*
5 Reading comprehension					-

* p <.05 ** p<.01

Table 5: Concurrent predictors of reading at T3 in deaf and hearing children

		Deaf children				Hearing children			
		Single Word Reading		Reading Comprehension		Single Word Reading		Reading Comprehension	
Step	Predictor	Δr^2	β	Δr^2	β	Δr^2	β	Δr^2	β
1	Chronological Age	.15	.38*	.10	.32	.08	.29	.01	.09
2	English Vocabulary	.58	.80**	.59	.80**	.09	.31*	.26	.53*
	Phon Awareness	.04	.25*	-	-	.36	.61**	-	-
	Speechreading	-	-	-	-	-	-	-	-
	Total R^2	.77		.70		.53		.27	

* p <.05 ** p<.01