Top Lang Disorders
Vol. 35, No. 2, pp. 120–132

The Impact of New Technologies on the Literacy Attainment of Deaf Children

Margaret Harris

To become successful readers, hearing children require competence in both decoding—the ability to read individual words, underpinned by phonological skills and letter-sound knowledge—and linguistic comprehension—the ability to understand what they read—underpinned by language skills, including vocabulary knowledge. Children who are born with a severe-profound hearing loss, or who acquire such a loss in the first months of life, need to develop the same core skills in decoding and linguistic comprehension although they may develop these skills in a somewhat different manner from hearing peers. This review considers the impact on literacy of universal newborn hearing screening and of improvements in the technologies that give access to sound, including the provision of cochlear implants. The review shows that these new technologies have brought some notable improvements, especially in the early years at school, but that many children with severe-profound hearing loss still find reading a challenge and can benefit from continued support for literacy throughout their years at school. **Key words:** *cochlear implants*, *deaf children*, *literacy*, *newborn hearing screening*, *phonological coding*, *speechreading*

SUPPORTING the development of reading and writing in children who are born with severe-profound hearing loss— or who acquire such a loss in the first months of life—has proved a major challenge to educators ever since the first schools for the deaf were founded in the 19th century. Traditionally, the majority of such children have found literacy to be a challenge, attaining levels that are significantly behind hearing peers in both reading (Allen, 1986; Conrad, 1979; DiFrancesca, 1972; Lane & Baker, 1974; Lewis, 1996; Moog & Geers, 1985) and writing (Mayer, 2007; Mayer & Moksos, 1998). Notably, literacy levels have tended to fall further and further behind hearing peers as children with severe-profound hearing loss progress through school (Kyle & Harris, 2011; Marschark & Harris, 1996). Thus, many leave the education system without having attained functional literacy—something that is essential for success in a literate society. It is important to point out that by no means all children with severe-profound hearing loss have difficulty in learning to read. Later in the article, I consider some of the factors that have been identified with reading success in this population.

The main focus of this article is on the impact that developments in technology have had on the reading of children with severe-profound hearing loss. To provide a framework for a discussion of this issue, the article begins with a consideration of the processes that are involved in learning to read and possible differences between these

Author Affiliation: *Department of Psychology, Social Work and Public Health, Oxford Brookes University, Oxford, United Kingdom.*

Research reported in this article was supported by a grant to the author from the Economic and Social Research Council (ES/K005251/1).

The author has indicated that she has no financial and no nonfinancial relationships to disclose.

Corresponding Author: *Margaret Harris, PhD, Department of Psychology, Social Work and Public Health, Oxford Brookes University, Gipsy Lane, Oxford, OX3 0BP, United Kingdom (margaretharris@brookes.ac.uk).*

DOI: 10.1097/TLD.0000000000000052

processes in hearing children and children with a severe–profound hearing loss. I then consider in detail the changes that have occurred in the provision for children who have a severe–profound hearing loss, beginning with an assessment of the advances that have occurred in the provision of technology that gives access to sound and going on to consider early diagnosis of hearing loss through routine screening shortly after birth. In each case, I consider the impact of these developments on literacy. Finally I consider what needs to be done to support children with severe–profound hearing loss to attain the most benefit from these technological advances so that the development of reading can be supported.

PREDICTORS OF SUCCESS IN LEARNING TO READ

The simple view of reading (Hoover & Gough, 1990) is that two distinct skills—decoding and linguistic comprehension—lie at the heart of becoming a skilled reader. Decoding is the ability to read individual words and linguistic comprehension is the ability to understand the meaning of text. The ability to identify and manipulate phonemes within words—core aspects of phonological awareness—has been shown to be key to early reading success for hearing children (Muter, Hulme, Snowling, & Stevenson, 2004). These skills enable children to become good decoders. Equally importantly, oral language and vocabulary predict reading development (Nation & Snowling, 2004) because such skills underpin the development of reading comprehension. For hearing children to become proficient readers, they need both good phonological skills and good oral language and vocabulary knowledge.

Although there is wide agreement about the skills that are important for hearing children's literacy attainment, there remains considerable debate about what skills are important for children who are deaf and hard of hearing (DHH) and especially for those whose hearing loss is in the severe–profound range. It is important to recognize that unpacking the components of reading success is notably more complex in the case of DHH children than it is in the case of hearing children. This is because, as a population, DHH children are more heterogeneous than their hearing peers. They vary, among other things, in degree of hearing loss, age of diagnosis, age of provision of hearing aid technology, preferred form of communication, educational setting, and hearing status of their parents. All of these variables can have an impact on literacy (Lederberg, Schick, & Spencer, 2012; Marschark & Harris, 1996). Another issue that is relevant is the general ability level of the children and the presence of complex needs, such as visual or attentional problems, that might have an impact on literacy (Edwards, 2007).

As with hearing children, the most compelling data come from longitudinal studies that examine factors predicting reading outcomes over a period of 1 or more years as well as studies of children with particular difficulties. In one of the first longitudinal studies, we (Harris & Beech, 1998) found speech intelligibility, phonological awareness, and language comprehension to predict reading development between the ages of 5 and 7 years in a sample of children with severe–profound hearing loss who came from a range of educational settings. In a study of orally educated French children, early phonological awareness skills, including rhyme judgment and rhyme generation, predicted reading progress made between the age of 6 and 7 years (Colin, Magnan, Ecalle, & Leybaert, 2007). Another skill emerged as important for reading proficiency in a comparison of matched groups of 8-year-old good and poor readers, all of whom had a severe–profound hearing loss (Harris & Moreno, 2006). The only skill that reliably distinguished these two groups was speechreading, with the better readers scoring higher on a test of speechreading (or silent lipreading) than the poor readers.

There are two reasons for examining the possible role of speechreading ability in the development of literacy skills in children who are DHH. First, information gained through speechreading has been seen as a support for phonological development in children with significant levels of hearing loss (Campbell, 1997). Second, recent brain imaging studies have shown that speech perception is a multimodal phenomenon. For example, a comparison of functional magnetic resonance images of adults listening to words and speechreading a face silently mouthing words showed a high degree of overlap in the regions of the brain that are activated (Rosenblum, 2008)—both speechreading and listening activated primary auditory and auditory-association cortex.

Speechreading ability emerged as an important predictor of reading ability in a longitudinal study. Kyle and Harris (2010) examined reading progress over a 3-year period, from the age of 7 to 10 years. The children, who had severe–profound prelingual hearing loss, came from a range of educational settings—schools for the deaf, hearing-impaired units, and mainstream classrooms. Although most children showed reading delays at the end of the study, those with better English vocabulary and speechreading skills at the age of 7 years exhibited less severe delays.

All these studies, with the exception of the study by Colin et al. (2007), assessed children from a variety of educational settings; so these findings do not appear to be specific to the type of communication used in the classroom. Knowledge of spoken English and speechreading skills appear to be equally important for children who sign and for those whose education is predominantly oral. Surprisingly, speechreading ability is also associated with reading ability for hearing children (Kyle, MacSweeney, Mohammed, & Campbell, 2009), so this might suggest that phonological skills are best thought of as multimodal rather than exclusively aural.

The longitudinal relationship between phonological awareness and speechreading appears, however, to be a complex one. In the study by Kyle and Harris (2006), speechreading ability at 7 years predicted phonological awareness 1 year later. At the first assessment, phonological awareness was not correlated with reading ability. However, by the end of the study 3 years later, phonological awareness was significantly correlated with reading ability (Kyle & Harris, 2010). However, it was reading ability that predicted later phonological awareness rather than the other way around. What this suggests is that the phonological abilities of DHH children may develop as a consequence of learning to read rather than being something that children bring to reading, and that, in the early stages, the development of reading ability is mediated by speechreading.

In the study by Kyle and Harris (2010), speechreading was the strongest predictor of single word reading ability, whereas vocabulary knowledge was the strongest predictor of written sentence comprehension. This echoes the principle of the simple view of reading (Hoover & Gough, 1990) that two core skills, decoding and linguistic comprehension, enable children to become proficient readers. What these findings suggest is that, at a general level, the simple view of reading applies equally to DHH and hearing children. For both groups, phonological coding skills and English vocabulary are important. The difference, if there is one, is that for DHH children, phonological coding skills develop to a greater extent during the course of learning to read and are supported by speechreading.

COCHLEAR IMPLANTS

Evaluating the impact of cochlear implants

There have been important technological developments in the provision of devices that improve access to speech and other sounds. The most high-profile change has been in the provision of cochlear implants (CI). In the United Kingdom, following approval by the National Institute for Health and Care Excellence in 2009, CIs are routinely provided by the National Health Service (NHS). In effect, this means that all children in the United Kingdom, for whom a CI is considered appropriate, can receive an implant. As a result of early identification, many children with a profound hearing loss now receive a CI well before they begin formal schooling, and, although the United Kingdom has lagged behind a number of European countries, there has been a marked trend toward earlier implantation. The National Institute for Health and Care Excellence now supports the provision of a bilateral implant for children, so an increasing number of children have a CI in both ears. A similar pattern is evident in many other countries in the developed world, with increasing numbers of children with severe–profound hearing loss receiving a CI before their second birthday.

We might expect that CIs would make it easier for children with profound hearing loss to develop both key skills that are required for successful reading. Better access to spoken language should enable DHH children to develop phonological awareness skills that are more in line with hearing peers and better oral language skills to support reading comprehension skills.

There is now a substantial body of evidence showing that cochlear implantation improves speech perception and production and facilitates the development of spoken language (Archbold et al., 2000; Cleary, Pisoni, & Geers, 2001; Geers, 2002; O'Donoghue, Nikolopoulos, & Archbold, 2000; Pisoni & Geers, 2000; Tait, Nikolopoulos, Archbold, & O'Donoghue, 2001; Thoutenhoofd et al., 2005; Watson, Hardie, Archbold, & Wheeler, 2008) However, the outcomes for literacy have proved to be considerably more difficult to demonstrate (Marschark, Sarchet, Rhoten, & Zupan, 2010).

Age at implantation for CIs seems to be an important determinant of outcome. A study of reading levels 5 and 7 years post-implant in children who were part of the Nottingham Cochlear Implant Programme (Archbold et al., 2008) showed that age at implant accounted for 50% of the variance in reading ability, with children who had received implant at a younger age achieving higher reading scores. Similar findings emerged from another UK study (Johnson & Goswami, 2010) that found significantly better reading among children who had received early implant than those who had received later implant. A study of children in Belgium and the Netherlands (van der Kant, Vermeulen, De Raeve, & Schreuder, 2010) showed an almost identical pattern, with 56% of the variance in reading comprehension scores being accounted for by age at implant and years of implant use (which are themselves highly correlated).

Age at implantation can also have indirect effects on literacy by affecting skills that relate to reading. Children who receive a CI later may develop better speechreading skills than children who receive an implant earlier (Geers, Brenner, & Davidson, 2003) and they may also make greater use of sign language (Watson et al., 2008). Thus, children who receive an implant later may show a rather different pattern in learning to read than children who receive an implant earlier.

The age at which reading is assessed is also very important in evaluating outcomes. The benefits of a CI appear to be greatest during the primary school years. In an extensive study of children who had received an implant before the age of 5 years (Geers, 2003), over half were reading at an age-appropriate level at 8–9 years of age, and in the UK study mentioned previously (Archbold et al., 2008), children who had received a CI at or before 42 months were reading at an age-appropriate level 5 and 7 years later (as they approached the end of primary school).

The picture of reading in secondary school appears considerably less positive. Geers, Tobey, Moog, and Brenner (2008) found that there was a decline in relative reading ability between the ages of 8–9 years and 15–16 years in their original sample. In a recent UK study (Harris & Terlektsi, 2011), we found the reading levels of children with a CI, aged from 12 to 16 years, to be significantly lower than reading levels of similar children who were using a hearing aid. Importantly, both groups of children were reading at a level that was considerably lower than chronological age. The children with hearing aids were, on average, reading single words at a level that was over 3 years below their chronological age and reading text at a level that was nearly 2 years below. The children with CIs were earning reading scores that were even lower for text reading, with deficits of more than 3 years. In relation to this finding, it is important to note that there have been considerable technological advances in hearing aids over the last decade or so (Ackley & Decker, 2006). The majority of children with profound hearing loss, for whom a CI is not considered appropriate or desirable, are now using digital aids. In the UK, these are also supplied by the NHS and they are routinely provided in many other countries. Digital hearing aids would also be expected to give considerably better access to speech than analogue devices.

Another factor to consider is that many children who receive a CI have complex needs that place limitations on their capacity to become functionally literate (Edwards, 2007). In addition to the children whose complex needs have been identified, there are other DHH children who do not have any recognized complex needs but who have a level of nonverbal intelligence that is significantly below normal (Harris & Terlektsi, 2011; Marschark et al., 2010). It would not be expected that children with an IQ score that is more than 1 *SD* below the mean would show age-appropriate reading.

Finally, it is important to consider how children are being taught to read. There are ongoing debates about the type of instruction that should be adopted for children who are DHH. For example, van der Kant et al. (2010) argue that the emphasis on spoken language in the education of young Belgian children was an important factor in their greater reading success in comparison with Dutch children whose education was delivered through a bilingual curriculum involving Sign Language of the Netherlands and Sign Supported Dutch. In contrast, other researchers have advocated the use of a sign-bilingual approach in reading instruction, pointing to links between language ability in general (either oral or signed) and reading level (Mayberry, 2011). The wide availability of CIs has led to renewed questioning of the best approach to teaching reading (Knoors & Marschark, 2012). It is important that the ongoing debate is dispassionate and well-informed by a clear understanding of how DHH children are learning to read and how their development can be most effectively supported.

Cochlear implants and literacy

Given that the benefits of CIs for literacy are most likely to be evident in the early years, what evidence is there that primary school children who have received an implant are reading better than might be expected? In addition, what can we learn from children with CIs about the two components that are essential for reading—decoding and reading comprehension? In attempting to answer these questions, it is important to remember that age at implantation has declined and so many children are now receiving an implant well before their second birthday. And, as we have already noted, there continue to be technological advances in the implants themselves, including the software used in the speech processor.

One of the first studies to be carried out was that of Geers and colleagues as part of a CI program (Geers, 2003; Tobey, Geers, Brenner, Altuna, & Gabbert, 2003). There were 181 children, all of whom had received an implant before the age of 5 years. Over half of the children were reading at an age-appropriate level at 8 years of age. As with all studies of CIs, there was considerable variability within the group and a number of factors predicted reading ability. In the context of this review, it is notable that use of phonological coding and linguistic competence were predictive (Tobey et al., 2003). Unlike other studies discussed earlier, however, Geers (2003) did not find an association between reading level and age at implantation.

Two European studies, carried out at around the same time, compared literacy attainment in DHH children with CIs and peers with hearing aids. A study of 152 children in Scotland (covering both primary and secondary school pupils) found that those with CIs scored comparatively higher on reading and writing than peers with hearing aids (Thoutenhoofd, 2006), and a similar pattern emerged from a study of 550 pupils in the Netherlands (Vermeulen, van Bon, Schreuder, Knoors, & Snik, 2007). In both studies, however, children with implants were delayed in their reading in comparison with hearing children. The mean age at implantation was 37 months for primary school pupils and 91 months for secondary school pupils in the Scottish study and 74 months in the Dutch study. So age at implantation was comparatively late in both studies, especially the Dutch one, and this is likely to have had an impact on the outcome.

A study of children in the United Kingdom who received implant by the Nottingham Cochlear Implant Team (Archbold et al., 2008) presents one of the most optimistic pictures of literacy attainment following cochlear implantation. This study followed 105 children and assessed their reading levels at 5 years and 7 years postimplant. There was wide variation in age at implantation and so the sample was divided into those who received implant relatively early (i.e., at or before the age of 42 months) and those who received implant later (i.e., between 43 and 84 months). There was a strong and positive association between outcomes and age at implantation. In addition, among the subgroup of children whose nonverbal IQ was 85 or above, those who had received implant at or less than 42 months of age were reading at an age-appropriate level at both assessment points. In other words, they had reached parity with hearing peers.

The findings of two, more recent, studies are less optimistic. Both studies make a direct comparison between children with CIs and children with hearing aids. The first study was carried out by Herman, Roy, and Kyle (2014) in the United Kingdom. It compared the profiles of DHH children on reading and reading-related tasks with the profiles of hearing dyslexic children. This is an interesting comparison to make because hearing children with the most common form of dyslexia are known to have problems with phonologically based decoding. Herman et al. (2014) used an extensive battery of tests that included literary skills, phonological skills, speechreading ability, and language skills. The DHH children were all orally educated and aged between 10 and 11 years. The hearing dyslexic children were slightly younger.

Within the sample of 79 deaf children, almost two-thirds had one or more CIs and the remainder used digital hearing aids. The reading scores of the children with CIs did not differ from those with hearing aids on any measure. Across the sample, only just over half the children (52%) were reading single words at an age-appropriate level, and the distribution of standard scores on literacy and phonological measures was generally skewed toward lower levels (being ~1 *SD* lower than the hearing standardization sample). Speechreading scores were higher among the more proficient readers than the less proficient, although the great majority of DHH children found the speechreading task to be easy, compared with less than half of the hearing dyslexic children. Both DHH and hearing dyslexic children were well below average on nonword reading, scoring at similar low levels. However, the most striking differences between the two groups were in spoken English vocabulary and two of the phonological measures (phoneme deletion and forward recall of digits) in which the DHH children scored considerably lower than the hearing dyslexic children. It will be noted that these are measures associated with the two core reading skills—phonological decoding and language comprehension.

This pattern of results shows that, in spite of the number of children with CIs, there were still significant delays in reading among the sample of 79 DHH children. Furthermore, as Herman et al. (2014) pointed out, the fact that many of the children with age-appropriate single-word reading had low English vocabulary scores suggests that they would be likely to have reading problems in the future.

The second study is ongoing and assesses children in primary school with severe–profound hearing loss (Harris, Terlektsi, Kyle,

& Corder, 2015). It provides more direct evidence of the impact of CIs and digital hearing aids on literacy. The study makes a direct comparison between data on reading and reading-related skills collected just over a decade ago, with data collected from a comparable cohort of children who were in primary school in 2014. The data from the earlier study came from Kyle and Harris (2006, 2010, 2011). The two cohorts are similar in age (6 years) with unaided hearing loss (around 99 dB), and they come from the same geographical area in the United Kingdom. They are also similar in having nonverbal IQ within normal range and no additional difficulties.

One difference between the two cohorts has been immediately apparent. Although the unaided hearing loss is identical, the aided threshold is significantly lower in the newly recruited cohort, with average loss being only 39 dB (compared with 53 dB in the original cohort). Just more than half of the children have at least one CI compared with only 25% in the original cohort. This reflects the advances in provision of hearing aid technology that were discussed earlier.

There are also some notable changes in educational setting. In the original cohort, none of the children was being educated in a mainstream setting. In the newly recruited cohort, 10 of the 42 children in the sample are in mainstream. The remaining children are either in schools for the deaf or they attend a specialist resource base within a mainstream school. A specialist resource base is staffed by teachers who are trained to work with children who are DHH, and teaching is carried out in small groups. Typically, children spend around half of their time within the resource base and the remainder being educated alongside hearing peers (usually with individual support).

In terms of reading ability, the two cohorts are remarkably similar. However, there are two clear differences in underpinning language skills. The newly recruited children have considerably better spoken English vocabulary and better phonological awareness as assessed by a picture-based similarity task (Kyle & Harris, 2006). There were, however, no differences between the children with CIs and those with hearing aids except on letter–sound knowledge in which the children with implants had an advantage.

The children in the new study were matched on single-word reading with a group of hearing children. Significantly, the hearing children are younger. This means that, even at this early stage of reading, the children with severe–profound hearing loss are already falling behind their hearing peers by a few months. There is, however, considerable variation in reading performance, with some children reading at a level that is equal to or better than their chronological age. As a group, the children with severe–profound hearing loss are better at speechreading than the hearing children, using a standardized assessment (Kyle et al., 2009).

Taken together, these two recent studies suggest that children with severe–profound hearing loss who are currently in primary school are developing better skills in the two key areas that are required for reading although they have not, as yet, caught up with hearing peers in phonological skills, English vocabulary, or reading. What we might expect to find is that, as these children progress through primary school and into secondary school, their reading will remain closer to that of hearing peers than in previous cohorts because their underlying reading skills are better. Evidence for this hypothesis is yet to be seen.

As we have already noted, DHH children often fall further and further behind hearing peers as they progress through school. The demands of literacy systematically increase as readers are required to deal with more complex sentences, more abstract concepts, and the integration of ideas across extended text. There are analogous demands on writing skills. Geers et al. (2008) were able to follow up with 26 of the children assessed in their earlier study (Geers, 2003). They found that, although the children had been reading at an age-appropriate level at the age of 8–9 years, they had an average reading delay of 2 years by the time they were 15–16 years of age. This suggests that early reading success following a CI may not be sustained in the final years at school.

Harris and Terlektsi (2011) made a direct comparison of three matched groups of young people in secondary school with prelingual severe–profound hearing loss. As noted earlier, we found that all groups were reading significantly less well than peers who are hearing but that the children with hearing aids were reading better than children in the early and late-implanted groups. The children in the study came from a range of educational settings—schools for the deaf, specialist resource bases, and mainstream—and some of the children were receiving an oral education whereas others were in classrooms where signing was used. There was no simple relationship between the language of the classroom and literacy, and there were proficient readers in both oral and signing classrooms.

NEWBORN HEARING SCREENING

Evaluating the impact of early diagnosis on literacy outcomes

Newborn Hearing Screening is carried out in hospitals for all newborn babies in the United Kingdom and an increasing number of other countries in the developed world. It is similar to the program of Early Hearing Detection and Intervention used in the United States. The implementation of universal newborn hearing screening (UNHS) across the United Kingdom began in 2000 and was completed in 2005, potentially reducing in the mean age of diagnosis of hearing loss from 17 months to a few weeks (Davis et al., 1997). Early diagnosis is important because it affords the opportunity for early intervention both in the provision of technology that provides access to sound and in the opportunity for parents to receive support to develop successful communication strategies with their child during the crucial early months of life.

Given all the changes that have taken place in hearing aid technology, it is not straightforward to evaluate the impact of UNHS, especially in relation to later-acquired skills such as literacy. Furthermore, at least within the United Kingdom, it is no longer possible to make comparisons between children who have had an early diagnosis and those who have not because almost all children receive newborn hearing screening shortly after birth. The exceptions to this are mainly children who are born outside the United Kingdom, and they are relatively few in number and do not form an obvious comparison group. We, therefore, have to rely on studies that were begun at the point when newborn hearing screening was in the process of being implemented.

It is clear from studies carried out in Canada (Durieux-Smith, Fitzpatrick, & Whittingham, 2008) and the United Kingdom (Kennedy, McCann, Campbell, Kimm, & Thornton, 2005) that newborn hearing screening provides a very reliable way of identifying hearing loss for children who are deaf or hard of hearing. However, the automated screening that takes place shortly after birth needs to be followed up by audiology appointments in order for a diagnosis of hearing impairment to be confirmed. In the recently recruited cohort of primary school children described previously (Harris et al., 2015), by no means all of the children had received a diagnosis of a hearing loss before the age of 6 months. There had certainly been a significant increase in the number of cases where this occurred: In our earlier study (Kyle & Harris, 2006), only 28% of the children recruited were diagnosed with a hearing loss before 6 months of age and this had increased to 55% in the new sample. Although this is an impressive increase, it remains the case that diagnosis was delayed beyond 6 months for 45% of children.

One reason why a confirmatory diagnosis is delayed is that parents do not attend their audiology appointment on time. Kennedy et al. (2006) noted that this was a problem when they carried out their study, but they thought that it occurred because the implementation of the UNHS program was in its early stages in the United Kingdom, meaning that there was sometimes a delay between the failure at the first stage of screening and an appointment for the confirmatory diagnosis. It would appear, however, that the delays between screening and diagnosis have not entirely disappeared.

Other reasons for a comparatively late diagnosis of hearing loss were that some children had been born outside the United Kingdom, in a country where screening was not available, or that the initial screening had not produced clear-cut results and a child was referred for follow-up at a later time. In a few cases, a child was diagnosed with auditory neuropathy, a condition that it not always identified through newborn hearing screening.

Apart from issues about the consistency with which newborn hearing screening is followed up, there is a question about whether the unique benefits of the screening and subsequent identification of hearing impairment can be firmly established. Durieux-Smith et al. (2008) cautioned that "Improved speech and language development due to [UHNS and early intervention] is unlikely to be proved by acceptable scientific and ethical standards" (p. 9). Their concern was that randomized controlled trials to evaluate the wider benefits of early diagnosis, which are taken to be the gold standard for evaluating medical interventions, are unlikely to be carried out simply because it is already clear that newborn hearing screening is an effective way of identifying hearing loss.

A randomized controlled trial, as its name implies, involves randomly assigning participants either to a treatment condition or to a nontreatment condition. Given that UHNS has been shown to be beneficial, it would be unethical to carry out a study in which one group of children was excluded from UHNS for comparison purposes. Interestingly, the same comment could be made about CIs because there have not been any randomized controlled trials for similar ethical reasons. However, where a new form of assessment or treatment is being systematically implemented, it is possible to make a comparison between two similar areas—one where the new form of assessment or treatment is in place and one where it will become available at a later date. This was the approach adopted in the United Kingdom.

The first report of the UK rollout of UNHS, the Wessex trial, was published in 2006 (Kennedy et al., 2006). It examined the language scores for a cohort of 120 children with a hearing loss of at least 40 dB. Half of the children were born after the introduction of UNHS to a number of centers in southern England. The other half of the cohort came from geographically adjacent centers where UNHS had not been introduced at the time of the study. There were some clear differences between the groups. Children who had received UNHS had significantly higher receptive language scores than those who had not. There were, however, no differences in expressive language scores.

A recent review of the benefits of newborn hearing screening (Pimperton & Kennedy, 2012) showed that there is now consistent evidence from studies in Colorado (United States), Australia, and England that newborn hearing screening, and associated early diagnosis of hearing loss, does bring benefits for language development. The authors of that review recognized that appropriate and timely intervention following early diagnosis is critical and, in practice, the two should go hand in hand. Early diagnosis will not bring benefits unless parents are supported to communicate effectively with their child and appropriate hearing aid technology is provided and used on a regular basis.

Newborn hearing screening and literacy

Two studies have carried out a long-term follow-up of a cohort of children whose hearing loss was identified following newborn hearing screening in the United Kingdom. The children were originally recruited from the Wessex trial (Kennedy et al., 2005). The first assessment of their reading (McCann et al., 2009) was carried out when the children were in primary school and aged between 6 and 10 years. The children in the Wessex sample were combined with similar children in the Greater London sample, giving a total sample of 120 children of whom 61 had received UNHS and 59 had not. The children who had been screened through UNHS all had their diagnosis of hearing loss confirmed before the age of 9 months, whereas the children who had not been part of the UNHS trial had received their confirmatory diagnosis after 9 months.

The children's reading was assessed using two subtests from the Wechsler Objective Reading Dimensions (Wechsler, 2003), which measure basic reading and reading comprehension. On both of these measures, the children who had been part of the UNHS trial were reading better than the children who had not been in the trial, and their receptive and expressive language scores were also higher.

The same children were followed up later between the ages of 13 and 19 years to see how well their reading had progressed in secondary school (Pimperton, 2013). Half of the teenagers in the sample had moderate levels of hearing loss, whereas the other half had severe–profound losses. Reading accuracy and reading comprehension were assessed using the York Assessment of Reading for Comprehension (Snowling et al., 2009). Reading accuracy was measured by the total number of words that were read correctly in a passage and reading comprehension by the answers to comprehension questions about the passage as well as the number of key points correctly recalled in a subsequent summary of the passage.

The teenagers who had received the early confirmatory diagnosis of hearing loss were still reading better than their peers who had received a later diagnosis. Furthermore, the gap between the two groups had grown, with the latter group falling further behind in reading. The results of this study were presented as Z scores in comparison with hearing children and adjusted for a number of key variables, including nonverbal IQ, maternal education, and severity of hearing loss. There were significant differences between the early and late-diagnosed groups on both reading comprehension and summarization in favor of the UNHS group, although the difference in reading accuracy did not reach significance. Notably, however, none of the mean Z scores was positive, implying that the majority of the teenagers were not reading at an age-appropriate level even though half of them had only moderate levels of hearing loss.

As with the review of the impact of CIs, it is important to note that the teenagers who took part in the early trials of UNHS were at the forefront of technological developments, and both the UNHS and the provision for infants following confirmatory diagnosis have continued to improve. However, as we have already noted, although there will continue to be new evidence about the potential impact of CIs, it is unlikely that there will be new studies of UNHS, simply because its benefits have been so clearly demonstrated.

CONCLUSIONS

The advent of UNHS has made it possible for many more children to receive an early confirmatory diagnosis of hearing loss. This in turn enables the early provision of appropriate support for children and their parents, including the early provision of technology that improves access to speech. Early diagnosis coupled with good support can benefit the development of reading skills.

There is evidence that CIs are producing improvements in reading in primary school but, so far, these improvements have typically not been sustained as children confront the increased demands of literacy in secondary school. Children with CIs are reading at a similar level to those with digital hearing aids. However, studies of children who more recently received implant suggest that they are developing better phonological skills and better English vocabulary than children who received implant long ago, so it is to be hoped that the full benefits of CIs for literacy are still to be seen. It is likely, however, that many children with a severe–profound hearing loss will continue to need support to become proficient readers and that this support may need to continue throughout their years at school.

There are a number of ways in which DHH children can be supported to become proficient readers. The most appropriate approach will depend both on the child and on the educational setting. Returning to the simple view of reading (Hoover & Gough, 1990), the two key skills to promote are phonological skills to support decoding and vocabulary to support linguistic comprehension. Recent intervention studies have shown that targeted support can improve phonological skills both through oral methods (Lederberg, Miller, & Easterbrooks, 2014; Miller, Lederberg, & Easterbrooks, 2013) and through the use of visual ways of representing speech sounds through visual phonics (Narr, 2008; Trezek, Wang, Woods, Gampp, & Paul, 2007). Both approaches encourage children to look at the way that sounds are made on the lips as well as listening. Both approaches can be used with children who sign and with children who are being orally educated. Speechreading, in particular, can help supplement auditory information about speech for all children who are DHH. Visual phonics can also be used with children who are being orally educated although the most common usage is with children who sign (Narr, 2008).

Children also need to be supported to develop a good knowledge of the relevant oral language vocabulary because this is what they are learning to read. For DHH children who are learning to read English, knowledge of English vocabulary is the most powerful concurrent and longitudinal predictor of reading and spelling (Harris et al., 2015; Kyle & Harris, 2010, 2011).

Many children who are DHH will continue to require literacy support as they progress through school. The vulnerability of early progress in reading, highlighted by Geers et al. (2008) and Harris and Terlektsi (2011), points to the need for continuing support in secondary school. It is important to remember that the technological advances described in this article, although greatly beneficial for children who are DHH, do not solve all of the traditional problems that they have had in learning to read and spell.

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, NY: Oxford University Press.

Allen, T. E. (1986). Patterns of academic achievement among hearing impaired students: 1974 and 1983. In A. N. Schildoth & 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.

Campbell, R. (1997). Read the lips: Speculations on the nature and role of lipreading in cognitive development of deaf children. In M. Marschark, P. Simple, D. Lillo-Martin, R. Campbell, & V. S. Everhart (Eds.), *Relations of language and thought: The view from sign language and deaf children* (pp. 147–152). New York, NY: Oxford University Press.

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 and Hearing*, *22*, 395–411.

Colin, S., Magnan, A., Ecalle, J., & Leybaert, J. (2007). Relation between deaf children's phonological skills in kindergarten and word recognition performance in first grade *Journal of Child Psychology and Psychiatry*, *48*(2), 139–146.

Conrad, R. (1979). *The deaf schoolchild: Language and cognitive function*. London: Harper and 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*. Washington, DC: Gallaudet College, Office for 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

Edwards, L. C. (2007). Children with cochlear implants and complex needs: A review of outcome research and psychological practice. *Journal of Deaf Studies and Deaf Education*, *12*(3), 258–268.

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 and Hearing*, *24*(1 Suppl.), 59S–68S.

Geers, A. E., Brenner, C., & Davidson, L. (2003). Factors associated with development of speech perception skills in children implanted by age five. *Ear and Hearing*, *24*(1 Suppl.), 24S–35S.

Geers, A. E., Tobey, E. A., Moog, J., & Brenner, C. (2008). Long-term outcomes of cochlear implantation in the preschool years: From elementary grades to high school. *International Journal of Audiology*, *27*(Suppl. 2), 21–30.

Harris, M., & Beech, J. R. (1998). Implicit phonological awareness and early reading development in prelingually deaf children. *Journal of Deaf Studies and Deaf Education*, *3*, 205–216.

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

Harris, M., Terlektsi, E., Kyle, F. E., & Corder, E. (2015). *Concurrent predictors of reading in deaf primary school children: A cohort comparison study*. Manuscript submitted for publication.

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

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

Johnson, C., & Goswami, U. (2010). Phonological awareness, vocabulary, and reading in deaf children with cochlear implants. *Journal of Speech, Language, and Hearing Research*, *53*(2), 237–261.

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., et al. (2006). Language ability after early detection of permanent childhood hearing impairment. *New England Journal of Medicine*, *354*(20), 2131–2141. doi:10.1056/NEJMoa054915

Knoors, H., & Marschark, M. (2012). Language planning for the 21st century: Revisiting bilingual language policy for deaf children. *Journal of Deaf Studies and Deaf Education*, *17*(3), 291–305. doi:10.1093/deafed/ens018

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

Kyle, F. E., MacSweeney, M., Mohammed, T., & Campbell, R. (2009). *The Development of Speechreading in Deaf and Hearing Children: Introducing a New Test of Child Speechreading (ToCS)*. Paper presented at the AVSP2009: International conference on audio-visual speech processing, University of East Anglia, Norwich, UK.

Lane, H. S., & Baker, D. (1974). Reading achievement of the deaf: Another look. *The Volta Review*, *76*, 489–499.

Lederberg, A. R., Miller, E. M., & Easterbrooks, S. R. (2014). Foundations for Literacy: An early literacy intervention for deaf and hard-of-hearing children. *Journal of Deaf Studies and Deaf Education*, *19*(4), 438–455. doi:10.1093/deafed/enu022

Lederberg, A. R., Schick, B., & Spencer, P. E. (2012). Language and literacy development of deaf and hard-of-hearing children: Successes and challenges. *Developmental Psychology*, *49*(1), 15–30. doi:10.1037/a0029558

Lewis, S. (1996). The reading achievements of a group of severely and profoundly hearing-impaired 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.

Marschark, M., Sarchet, T., Rhoten, C., & Zupan, M. (2010). Will cochlear implants close the reading achievement gap? In M. Marschark & P. E. Spencer (Eds.), *The Oxford handbook of deaf studies, language and education* (Vol. *2*, pp. 127–143). New York, NY: Oxford University Press.

Mayberry, R. I. (2011). Reading achievement in relation to phonological coding and awareness in deaf readers: A Meta-analysis. *Journal of Deaf Studies and Deaf Education*, *16*(2), 164–188. doi:10.1093/deafed/enq049

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 the Teaching of English*, *33*, 158–180.

McCann, D. C., Worsfold, S., Law, C. M., Mullee, M., Petrou, S., Stevenson, J., et al. (2009). Reading and communication skills after universal newborn screening for permanent childhood hearing impairment. *Archives of Disease in Childhood*, *94*, 293–297. doi:10.1136/adc.2008.151217

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. E. (1985). EPIC: A program to accelerate academic progress in profoundly hearing-impaired children. *The Volta Review*, *87*(6), 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

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

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. (2013). *Reading outcomes in teenagers born with hearing loss: Early confirmation of deafness matters*. Paper presented at the British Psychological Society CogDev Conference, University of Reading, Reading, England.

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 implants: Correlations between digit span and measures of spoken language processing. *Annals of Otology, Rhinology and Laryngology. Supplement*, *185*, 92–93.

Rosenblum, L. D. (2008). Speech perception as a multimodal phenomenon. *Current Directions in Psychological Science*, *17*(6), 405–409. doi:10.1111/j.1467-8721.2008.00615.x

Snowling, M. J., Stothard, S. E., Clarke, P., Bowyer-Crane, C., Harrington, A., Truelove, E., et al. (2009). *York assessment of reading for comprehension: Passage reading primary* London: GL Assessment.

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.

Tobey, E. A., Geers, A. E., Brenner, C., Altuna, D., & Gabbert, G. (2003). Factors associated with development of speech production skills in children implanted by age five. *Ear & Hearing*, *24*(1 Suppl.), 36S–45S.

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

van der Kant, A., Vermeulen, A., De Raeve, L., & Schreuder, R. (2010). Reading comprehension of Flemish deaf Children in Belgium: Sources of variability in reading comprehension after cochlear implantation. *Deafness and Education International*, *12*(2), 77–98. doi:10.1179/146431510×126269820 43769

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

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

Wechsler, D. (2003). *Wechsler objective reading dimensions*. London: The Psychological Corporation.