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Literacy Attainment Among Children Who Are Deaf or Hard of Hearing

The Past, the Present, and the Future

Margaret Harris and Emmanouella Terlektsi

Abstract

The chapter begins by looking back at the review of literacy outcomes among children who are deaf or hard of hearing (DHH), published in 1996 by Marschark and Harris. In the light of developments in hearing aid technology and the age at which hearing loss is now identified, the chapter considers whether the picture described in the review has changed significantly in the two decades that have elapsed since its publication. It assesses evidence about levels of literacy attainment across the two decades and shows that, while spoken language has improved for many children, levels of literacy have not seen a commensurate improvement. The chapter also considers how views of the skills that predict success and failure in learning to read have evolved. It ends by considering how children who are DHH can be taught most effectively to read, and it speculates about future developments both in technology and in teaching.

Keywords: deafness, reading, spoken language, cochlear implants, hearing aids, intervention

In 1996, Marc Marschark and Margaret Harris (the first author) published an overview of the current state of reading attainment among children who were born with a significant hearing loss (Marschark & Harris, 1996). The chapter came about following their meeting at a conference sponsored by Bracco and held in the Centro Diagnostico Italiano, Milan in May

1994. The theme of the conference was children's reading comprehension difficulties. The majority of papers focused on the difficulties encountered by hearing children, but both Marschark and Harris spoke about children with a severe to profound prelingual hearing loss. They had prepared their talks not knowing that there would be another presentation on the same topic, but it was fortunate, although not surprising, that they presented a very similar view of the extensive challenges that confronted many children who were deaf and hard of hearing (DHH). Marschark and Harris decided to join forces to write a chapter for the volume that emerged from the conference, and it was entitled "Success and Failure in Learning to Read: The Special (?) Case of Deaf Children."

The Marschark and Harris chapter has now accrued over 250 citations. It made a number of key points about the process of learning to read as well as providing a reflection on the general level of reading attainment among DHH children in the period up to the mid-1990s. A great deal has changed over the period of nearly 25 years that have elapsed since the publication of that chapter. These changes have not only been in the use of terminology—where the term "deaf" that was prevalent in the 1990s has been replaced by "deaf and hard of hearing"—but also in the identification of hearing loss, the types of amplification that are available, and approaches to deaf education. There has also been a very considerable amount of research into the processes that underpin literacy for children who are deaf. For example, a recent search on Web of Science for the intersection of the terms "deaf*," "children," and "reading" identified over 700 publications. It is therefore timely to revisit Marschark and Harris's conclusions to see if there have been fundamental changes in literacy outcomes for deaf and hard-of-hearing children as the second decade of the 21st century draws to a close and to review what is now known about the nature of learning to read in this population. We will also speculate about the future of educational and technological support.

The Past: Conclusions from Marschark and Harris (1996)

The 1996 chapter began by highlighting the long-standing difficulties with reading that the great majority of children who are DHH from birth or soon afterward experienced. The authors noted that these reading difficulties persisted despite the extensive research that had been carried out in the preceding two decades. They cited studies from the 1970s and 1980s (Allen, 1986; DiFrancesca, 1972; Gaines, Mandler, & Bryant, 1981) showing how few children were reading at an age-appropriate level by the time they left school. They also pointed out that having a reading level that could cope with the demands of everyday life in a literate society, or functional literacy, required children to attain a reading level equivalent to grade 11 or 12; and on this measure, more than 30% of children who were DHH were functionally illiterate. However, it was clear from all the assessments of reading ability that there was very considerable variation among this population with some children reading at or above age level while others made little progress. Given this considerable degree of heterogeneity, the chapter set out to explore the factors that were related to reading attainment. Among other things, Marschark and Harris focused on the importance of sign language and the significance of phonological coding and vocabulary for literacy development.

Sign Language and Literacy

Children's familiarity with a signed language and its relationship to reading had been the subject of a number of studies. As Marschark and Harris pointed out, it is not straightforward to compare outcomes for children who are fluent signers with those who know little or no sign language. This is because children who are fluent signers are likely to have parents who are deaf and use sign language at home. Children of deaf parents constitute a small minority

of children who are DHH, since the great majority (over 90%) are born to typically hearing parents who are unlikely to have any sign expertise. Hearing parents may choose to learn to sign and their children may attend a school where sign language is used, but for the most part, the experience of sign language is very different for children of hearing parents in comparison to those who grow up in a signing household. Marschark had highlighted the many differences between these two groups of children in a series of publications (Marschark, 1993; Vaccari & Marschark, 1997). He noted that deaf and hearing parents were likely to have very different expectations of their DHH children in that hearing parents were often concerned that hearing loss would make academic attainment very difficult. In addition, hearing parents typically had little or no experience of how to communicate effectively with a deaf child. This latter point had also emerged from the study Harris had carried out on maternal signing strategies (Harris, Clibbens, Chasin, & Tibbitts, 1989). These studies showed how well mothers who were deaf were able to adapt the visibility and timing of their signs so that they were accessible to very young children.

Marschark and Harris also questioned the assumption that early exposure to sign language would provide children with an automatic route into reading. The essence of their view was that reading is essentially a process of learning the relationship between the spoken and written forms of a language. The exact nature of the relationship varies, but in alphabetic scripts, such as English, there is a relationship between the way that a word is pronounced and the way that it is spelled. Marschark and Harris concluded:

> Although we acknowledge that early exposure to a regular, conventionalized language is essential for normal reading development, it is important to be cognizant of the fact that the transition from signing to reading is different and more difficult than the transition from a spoken language to reading that same language in printed form. (Marschark & Harris, 1996, p. 282)

This conclusion may have appeared to run in the face of evidence about the superior reading skills of children who were native signers. One of the most widely cited studies compared the reading ability of children with deaf parents and those with hearing parents in a residential school (Schlesinger & Meadow, 1972). The authors reported that the children of deaf parents were, on average, reading at one grade level above the children of hearing parents, although this difference was not statistically significant because of the considerable variability in achievement within both groups. The children were also compared with another group who attended a day school. All these children had hearing parents, but half were being educated in a spoken language–only program and the others in a total communication program that made use of sign language and spoken language. The children attending this latter program had the highest reading level of all, outperforming the children of deaf parents in the residential school.

Although they argued that the significance of signing for literacy was open to interpretation, Marschark and Harris noted that a sign language was often important for providing an early grounding in language. They pointed to studies showing that children who arrived at school with little fluency in either a signed or spoken language often had language difficulties that persisted into adulthood. They concluded: “the early environment most facilitative for deaf children’s future reading abilities is one that combines effective early language experience—usually in the form of sign language—with English experience” (Marschark & Harris, 1996, p. 285).

Phonological Skills

The second major issue that Marschark and Harris discussed was the extent to which children with a significant hearing loss were able to process phonological information and whether this was important when they learned to read. At the time the chapter was written, evidence

was beginning to accumulate about the importance of phonological skills for reading in typically hearing children (Bradley & Bryant, 1983). The Bradley and Bryant study, together with many studies that followed, showed that hearing children's progress in learning to read was closely related to their early phonological skills, including the ability to make judgments about the similarity of rhyme and initial sounds in spoken words.

The evidence about these skills among deaf and hard-of-hearing children was contentious. Some studies suggested that children with a significant prelingual hearing loss had poor phonological skills in comparison to hearing children (Harris & Beech, 1995), while others suggested that they were able to make at least some use of phonological coding in reading (Dodd, 1980). Other studies found no evidence of phonological coding in reading and argued that children were making use of visual coding (Beech & Harris, 1997; Chen, 1976; Waters & Doehring, 1990). An analysis of the methodology of the various studies that had been published by the mid-1990s showed that there was considerable variation in the type of task researchers had used to assess the extent and deployment of phonological skills in reading as well as in the age of the participants who were assessed. Most of the studies were carried out on older children and some were even at college level. This made it difficult to compare studies and left open the possibility that children born with a significant hearing loss might begin learning to read with poor phonological skills but then go on to develop their phonological skills in line with their reading proficiency. Marschark and Harris concluded, "most deaf children begin reading with little phonemic awareness [but] over the next several years [they] become increasingly more likely to use phonological recoding" (Marschark & Harris, 1996, p. 289).

Vocabulary and Grammar

The third issue that Marschark and Harris discussed was the importance of English vocabulary and grammatical knowledge for reading. They highlighted several studies that compared the size of spoken vocabulary in DHH and typically hearing children and found significant differences in favor of hearing children. They also suggested that difficulties in reading comprehension occurred over and above difficulties with identifying individual words. For example, research at that time found DHH children to be less accurate in a cloze vocabulary test (i.e., where they had to fill in the missing word in a phrase or sentence) than typically hearing children who were reading at the same level (Moores, 1967); and to have particular difficulty in understanding more abstract and general words (King & Quigley, 1985).

Marschark (1993) had suggested that difficulties at the vocabulary level were likely to have an impact on higher level reading skills both because they would limit understanding at the sentence level and also because they would tie up the cognitive resources required for such skills as text integration and the resolution of anaphora. At the time Marschark and Harris wrote their chapter there was some preliminary evidence that this was the case. For example, one study showed that deaf children had single-word reading and spelling skills that were better than predicted by their reading comprehension scores (Burden & Campbell, 1994).

There were also studies pointing to the difficulties that many DHH children had in understanding English syntax. Marschark and Harris reported the stark statistic emanating from Quigley and his colleagues (Quigley, Power, & Steinkamp, 1977) that "the syntactic abilities of the average, deaf 18-year-old were at a level below that of the average, hearing 8-year-old" (p. 293). Quigley et al. found that the greatest difficulties lay in the understanding of more complex grammatical constructions such as questions, complements, and the use of pronouns where the performance of deaf children lagged considerably behind that of hearing

peers. The gap in understanding of simpler constructions involving negation and conjunctions was much smaller.

The Present

The Marschark and Harris (1996) review drew several conclusions about literacy among DHH children. These conclusions addressed two broad issues. The first concerned levels of reading proficiency with the conclusion being that, although there were very considerable individual differences, the majority of children did not reach a level that educators and researchers could deem functional literacy by the time they left school. The second set of conclusions was concerned with the way that children who were DHH learned to read. The key question was whether this group of children learned to read in the same way or a different way from hearing children. In this section we consider what more recent evidence suggests about each of these issues.

Literacy Attainment

Two significant technological developments in the subsequent three decades have brought about changes for many DHH children. The first innovation was the introduction of newborn hearing screening, and the second has been the increasing effectiveness of hearing aid technology, including the introduction of cochlear implants. Both these developments seemed likely to have an impact on literacy.

A publication by the World Health Organization (WHO, 2010) provides a fascinating overview of the global availability of newborn hearing screening. This document reveals that newborn hearing screening is widely available in many developed countries. However, lack of universal health care around childbirth means that it is often not available in

underresourced countries. In particular, the WHO report highlights the fact that the issues around newborn hearing screening not only concern the technology itself but of equal, if not more, importance is "the building of capacity, and the creation of the required infrastructures, services and support for individuals, families and care providers" (WHO, 2010, p. 8).

The need for an appropriate infrastructure meant that the implementation of newborn hearing screening took several years. For example, in the United Kingdom, this began in 2000 and was completed in 2005 (Davis et al., 1997). It also took considerable time to provide evidence about long-term benefits for children whose hearing loss was identified shortly after birth, and this was considered important for determining whether newborn hearing screening was cost-effective. The WHO report notes that, in 1999, the United States Preventative Services Task Force was very cautious about recommending newborn hearing screening because there was no good evidence of benefits to children's speech and language skills at age 3 and beyond. Evidence did begin to accumulate over the next few years so that, in 2008, the Task Force recommended that all children be screened for hearing loss. Studies carried out in Canada (Durieux-Smith, Fitzpatrick, & Whittingham, 2008) and the United Kingdom (Kennedy, McCann, Campbell, Kimm, & Thornton, 2005) found that newborn hearing screening provided a very reliable way of identifying hearing loss, provided that the automated screening shortly after birth was followed up by audiology appointments to enable more extensive testing. A review of the benefits of newborn hearing screening (Pimperton & Kennedy, 2012) summarized evidence from published studies in the United States, Australia, and the United Kingdom showing that screening, and associated early diagnosis of hearing loss, was associated with higher scores in both receptive and expressive language.

Developments in hearing aid technology have been very widely researched. Although the most high-profile change has been in the development and increasing availability of cochlear implants to more children and at a younger age, there have also been important advances in

hearing aids with the provision of digital aids (Ackley & Decker, 2006). The provision of hearing aids varies in line with access to health care. In the United Kingdom, the National Health Service (NHS), following approval by the National Institute for Health and Care Excellence (NICE) in 2009 (NICE, 2009), provides all suitable candidates with the opportunity to receive a cochlear implant. As a result of early identification, many children with a profound hearing loss are implanted well before they begin formal schooling; and there has been a gradual move toward implantation before the age of 2 years and the provision of bilateral implants. Not all children with a profound hearing loss are suitable candidates for a cochlear implant because of damage to the auditory nerve—and some parents do not wish their child to receive an implant—but a digital hearing aid can also enhance hearing.

There have been notable changes to spoken language for many DHH children as a result of changes in the age of diagnosis of hearing loss, together with improvements in hearing aid technology (Archbold et al., 2000; Cleary, Pisoni, & Geers, 2001; Geers, 2002; Kronenberger, Colson, Henning, & Pisoni, 2014; O'Donoghue, Nikolopoulos, & Archbold, 2000; Pisoni & Geers, 1998; Reading, 2012; Tait, Nikolopoulos, Archbold, & O'Donoghue, 2001; Thoutenhoofd et al., 2005; Watson, Archbold, & Nikolopoulos, 2006; Watson, Hardie, Archbold, & Wheeler, 2008). Evidence about commensurate changes in literacy has been much less clear cut (Harris, 2016). Evaluating the evidence is challenging because, in addition to the inherent variability of the population in terms of nonverbal IQ and additional difficulties, there has been a steady improvement in the hearing aid technology itself and, in the case of cochlear implants, a decrease in the age at which implantation occurs. Age at implant has a significant effect on language outcomes, with children who are implanted at a younger age receiving the most benefit (Archbold et al., 2008; Kronenberger et al., 2014; Reading, 2012).

Some of the early findings about literacy were encouraging. Geers and her colleagues followed 181 children from across the United States and Canada who had received a cochlear implant before the age of 5 years. By the time they were 8 years old, over half of the children were reading within the average range for their age in both word recognition and sentence comprehension (Geers, 2003). Studies of large cohorts of DHH children in primary and secondary school in Scotland (Thoutenhoofd, 2006) and the Netherlands (Vermeulen, van Bon, Schreuder, Knoors, & Snik, 2007) found that those with cochlear implants had higher scores on reading and writing (including assessments of word reading and passage comprehension) than peers with hearing aids, although they were still delayed when compared to hearing children of the same age. In all three of these early studies, children with a range of cognitive abilities were included, and so it is difficult to evaluate the outcomes because children with low cognitive abilities often experience difficulties with literacy. The contrasting results of two UK studies illustrate the impact of cognitive ability on outcomes. Herman and colleagues, who did not select children on the basis of IQ (Herman, Roy, & Kyle, 2014), found that only just over half the children (52%) in a sample of 10- to 11-year-olds who were using spoken English in the classroom were reading single words at an age-appropriate level. In contrast, Archbold and colleagues (Archbold et al., 2008) analyzed the reading levels of children with a nonverbal IQ of 85 or above and found the mean level of reading to be age appropriate in a test that assessed both single-word reading and text comprehension. One factor that may be relevant to this latter study is that many of the children in the sample received ongoing support with language and literacy from trained professionals who were involved with the implant program. The potential value of targeted intervention to support the development of literacy skills is an issue that we return to later in the chapter.

Because making comparisons among the various studies that have considered literacy attainment has been problematic, one way to provide a more definitive picture of the current state of reading achievement among deaf and hard-of-hearing children is to make a direct comparison between children who are currently in school with those of similar age, intellectual level, and level of hearing loss who were in school some years before. With this aim, Harris, Terlektsi, and Kyle (2017a) compared the language, reading, and phonological skills of a cohort of 41 children recruited in 2013–2014 with that of a similar group of children recruited a decade earlier in 2003–2005. Children in both cohorts had a severe to profound hearing loss and a nonverbal IQ of at least 85 and were between 5 and 7 years of age at the initial assessment. The children came from 25 different settings in England with some using British Sign Language in the classroom while others used only spoken English. The children were assessed on single-word reading, reading comprehension, English vocabulary, phonological awareness, and letter-sound knowledge.

Given the important developments in technology and the demonstrable advances in the spoken language skills of many deaf children, the authors expected that literacy levels would have improved. However, the single-word reading scores of the two cohorts were very similar, differing by only 4 months, with a standard deviation of over 12 months. The average reading level of children in the 2013 cohort was 6 months below their chronological age. This might not appear to be a large gap, but the children were only 6 years 7 months old and had only just begun to read. This gap increased over time and was 15 months by the time the children were 8 years 5 months, echoing the findings from the earlier cohort (Kyle & Harris, 2011). There was also no significant difference in the phonological awareness scores, assessed using a picture-based sound similarity judgment task. In line with other studies, there was a significant improvement in language ability with the spoken vocabulary age of children in the 2013 cohort being more than 2 years higher than that of children in the earlier

cohort. This represented an enormous change over the 10-year period, although, importantly, it still did not bring the language levels of the deaf children up to those of hearing peers. A similar conclusion was drawn by Lederberg and her colleagues in a study of language and literacy in over 300 DHH children who were in the very early stages of learning to read (Lederberg, Branum-Martin, Webb, Schick, & Antia, 2019). They highlighted the difficulties with grammar that were evident in the spoken language of many children with a significant hearing loss, echoing the conclusion Marschark and Harris (1996) drew.

Before concluding this section on changes in literacy attainment it is relevant to note that the communication choices made by children and their parents and educators do appear to have an influence on outcomes. The study by Lederberg et al. (2019) compared DHH children in three different groups. One group was acquiring only English, one was acquiring only sign, and the third group was acquiring both. In all three groups there was a link between language and literacy, including the ability to manipulate the sublexical structure of words (phonological awareness). However, the children from the sign-only group had very low levels of spoken phonological awareness, but they compensated for this by their knowledge of fingerspelling that enabled them to carry out blending and elision of fingerspelled words.

Factors Predicting Literacy Outcomes

Understanding *how* children who are DHH learn to read may shed light on why improvements in literacy have not followed from consistent improvements in spoken language. As Marschark and Harris (1996) argued, a major area of disagreement has concerned the importance or otherwise of phonological skills. Debates about this issue have continued. For example, one meta-analysis (Mayberry, del Giudice, & Lieberman, 2011) suggested that phonological skills play only a minor role in deaf children's reading, whereas

other authors have argued that these skills underpin successful reading both for children educated in spoken language environments and those who use a sign language (Bochner & Kelstone, 2016; Kyle & Harris, 2010, 2011; Miller, Lederberg, & Easterbrooks, 2013).

Writing Systems and Learning to Read

As Marschark and Harris hinted, the importance of phonological skills in learning to read is controversial because of arguments about the role that sign language might play. In theory, it would be possible to learn to read by linking signs directly to individual words. However, this would require children to learn to recognize each word through direct learning rather than being able to develop a strategy that enabled them to pronounce unfamiliar words. A glance at the history of writing systems shows that there is a tendency for scripts to evolve over time in such a way that the pronunciation of an unfamiliar word can be worked out through familiarity with sublexical units such as letters or syllables. This strongly suggests that the ability to use sublexical units makes reading easier.

One of the earliest writing systems was cuneiform, first developed in ancient Mesopotamia around 3500 BCE. In its earliest version, cuneiform comprised pictograms, that is, pictorial representations of important concepts. Over time, the pictograms gradually became simplified in form and more abstract so that they looked much less like pictures. Later still, cuneiform became phonetic, allowing individual vowels and consonants to be represented. However, many words were still represented by single characters and, finally, cuneiform was replaced by fully alphabetic scripts that were developed in Europe in the Roman period (Harris, 2019).

Research into reading Chinese has also shed light on the importance of sublexical components. Chinese words are made up of two distinct components. One is a semantic radical that gives a clue to the meaning of a word, such as the semantic radical for “mouth”

that appears in BLOW, EAT, SING, and SHOUT (McBride, 2016). The other component that appears in many words is phonetic, and this gives a clue to the way a word is pronounced. Chinese is spoken in a number of different regions of China, and the phonetic information is a more or less reliable guide to pronunciation depending on the language that children speak at home. Those who have Putonghua as their home language appear to be at an advantage in utilizing the phonetic information as, for them, this provides a fairly reliable guide to pronunciation (Anderson, Li, Ku, Shu, & Wu, 2003).

Key Skills for Reading

Looking across languages supports the idea that at times reading exploits regularities between the way a word is written and the way it is pronounced. The issue for research on reading by children who are deaf and hard of hearing is whether there is evidence that they too exploit such regularities. If they do, there should be a link between children's phonological knowledge and their reading ability. This was the position that Marschark and Harris set out. They also argued that children's knowledge of the spoken language was important. This is in line with the model set out in the Simple View of Reading (Gough, Hoover, & Peterson, 1996), a model that has been widely adopted by many literacy researchers. A happy accident, Philip Gough argued for his theory at the same 1994 Milan conference where Marschark and Harris first met.

The essence of the Simple View of Reading is that there are two core skills, one to do with decoding and the other to do with understanding the meaning of what is read, and both of which are required for reading. In alphabetic scripts, decoding skills hinge around being able to work out the sequence of sounds associated with a sequence of letters. These are phonological skills and they include not only letter-sound mapping but also the ability to blend sounds together. The other core skill, reading comprehension, requires children to have

a good knowledge of the spoken vocabulary and also of the way that words link together to form sentences and sentences link to form larger units of text. (See Connor & Greenberg, this volume, for additional discussion on the Simple View of Reading.)

Unpacking the skills that children use in learning to read is complex even for typically developing hearing children. A huge body of research on this population has shown that the best way to uncover the processes of learning to read is to carry out longitudinal studies and then to confirm their findings by carrying out an intervention to see if reading can be improved by targeting the skills that have been identified. See Dostal & Lederberg, this volume, for a discussion of intervention design.

Longitudinal Studies of Learning to Read

There are, by now, several longitudinal studies into the reading development of children who are deaf and hard of hearing. The design of such studies with DHH children can be challenging because of the wide range of factors that can affect development, including age of diagnosis and severity of hearing loss, the effectiveness of hearing aid technology, the age at intervention, the language used in the classroom, and the level of parental and educational support (Harris, 2015). Studies of deaf children's reading have also used a range of measures and this can make comparisons among studies difficult. Nevertheless, there are some commonalities in the findings.

An early 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 from both signing classrooms and those that used spoken English. Early phonological awareness skills, including rhyme judgment and rhyme generation, also predicted reading progress in French children of similar age who used spoken language (Colin, Magnan, Ecalle, & Leybaert, 2007).

A slightly different picture emerged from a widely cited study by Kyle and Harris (2010) in which English vocabulary and speechreading skills at age 7, but not phonological awareness, predicted children's reading ability at age 10. However, phonological awareness became a significant predictor by the end of the study; and reading ability predicted later phonological awareness rather than phonological awareness predicting reading ability, suggesting that children were developing their phonological skills in the course of learning to read. In a similar study of younger children, beginning readers with better English vocabulary and speechreading skills made more progress over the first few years of reading instruction (Kyle & Harris, 2011).

Other studies have considered children with cochlear implants. Geers and colleagues (Geers, 2003; Geers, Tobey, Moog, & Brenner, 2008) found that phonological coding ability and linguistic competence were both predictive of word reading and reading comprehension in primary school-age DHH children. In another US study, speech production and language comprehension skills accounted for a substantial proportion of the variance in written word comprehension after 3 years (Spencer & Oleson, 2008); and phonological awareness was a significant predictor of reading at age 5, after controlling for receptive vocabulary and nonverbal cognitive ability in a sample of Australian DHH children (Ching, Day, & Cupples, 2014; Cupples, Ching, Crowe, Day, & Seeto, 2014).

Taken together, these longitudinal studies point toward language and phonological skills as important for DHH children's reading development, especially for those who are receiving an education in spoken language. On a broad view, this might suggest that children with a significant hearing loss learn to read in the same way as hearing children. However, a detailed comparison between reading processes in deaf and hearing children suggests that there are some subtle, but important, differences.

In a study of children with cochlear implants 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. The pattern for hearing children of similar age was that phonemic awareness was the strongest predictor of word reading, and expressive vocabulary was the only significant predictor of reading comprehension. Kyle and Harris (2011) also found subtle differences between deaf and hearing children in their study. As noted earlier, English vocabulary and speechreading ability at age 5 years were strong longitudinal predictors of reading at age 7 years. However, for hearing children of the same age, phonological awareness was the strongest predictor, followed by speechreading. Taken together, these two studies suggest that deaf children's knowledge of English vocabulary is a more important longitudinal predictor of reading than it is for hearing children. There is further support for this view in a recent paper by the authors that analyzed the longitudinal data collected from the children recruited for the cohort comparison study (Harris, Terlektsi, & Kyle, 2017b).

The children in the 2013 cohort were being educated in a variety of settings with some making use of signing as part of Total Communication while others used spoken language. We compared the interrelation of the various reading and reading-related assessments with that evident in a sample of hearing children of similar reading age at the start of the study. The correlation between English vocabulary at time 1 (T1); when children were 6 years 7 months) and reading comprehension at time 3 (T3, 2 years later) was significantly higher for the deaf children (r = .83) than the hearing (r = .41). These differences in the pattern of correlations were reflected in the outcome of the regression analyzes in which the predictor variables were chronological age and English vocabulary, phonological awareness, and speechreading, and the target variables were single-word reading and reading comprehension at T3. For the children with a significant hearing loss, English vocabulary at T1 and

speechreading at time 2 (T2) were the strongest predictors of both T3 reading measures. Speechreading at T1 also predicted single-word reading. Notably, phonological awareness was not a significant predictor of either reading measure. The pattern for the hearing children was markedly different in that phonological awareness at T1 predicted both single-word reading and reading comprehension and vocabulary at T1 also predicted reading comprehension.

Harris et al. (2017b) determined the pattern of intercorrelations among the various assessments of reading and reading-related skills, which provided further insights into differences between TH and DHH children. Across the 2 years of the study, 21 of the 28 correlations among assessments were statistically significant for the deaf children while only 7 were significant for the hearing children; and at the end of the study, 8/10 correlations were significant for the deaf children and only 3/10 for the hearing. These differing patterns imply that the various abilities Harris et al. assessed (i.e., phonological awareness, English vocabulary, and reading) were much more closely linked for the deaf children than the hearing children. One reason for this difference between the two groups was that speechreading was significantly correlated with many of the other measures for the DHH children, whereas it was not correlated with any other measure for the typically hearing children. Equally significant was the finding that phonological awareness at T2 was correlated with English vocabulary at both T1 and T2 for the deaf children, 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. At the end of the study, phonological awareness and English vocabulary were correlated at 0.56 for the deaf children, whereas for the hearing children, the corresponding correlation was only 0.06.

The differing patterns of correlations suggest that phonological awareness and vocabulary are relatively independent abilities for hearing children but are much more

interdependent among deaf children. The conclusion that these two abilities are independent for hearing children is in line with the findings of other studies (Hulme & Snowling, 2009; Nation & Snowling, 2004); and a recent study that reports high correlations between phonological skills and vocabulary (Webb, Lederberg, Branum-Martin, & Connor, 2015) suggests that these abilities are interdependent among deaf children.

Intervention Studies

Given that some deaf children are still not achieving age-appropriate reading skills (Harris et al., 2017b), it is important that they receive appropriate support. A recent review of the literature (Terlektsi et al., 2019) assessed peer-reviewed international evidence on the most effective interventions to support literacy skills of deaf learners. Although literacy was identified as the most researched topic in deaf education, of the 36 intervention studies that met the criteria for inclusion in the review (published between 1980 and 2017 in English and including participants aged 0–25), only 25 provided moderate to strong evidence of effectiveness. The majority of the literacy interventions focused on the explicit instruction of either phonology or vocabulary. Only four interventions focused on a range of phonological and language skills to support the acquisition and development of reading skills for deaf children. These were syllabic awareness, phonemic awareness of both initial and final sounds, blending, and letter-sound knowledge.

The most effective intervention was "Foundations for Literacy" (Lederberg, Miller, Easterbrooks, & Connor, 2014). Designed in the United States, it is the only literacy curriculum developed specifically for preschool deaf children, providing systematic, intensive, and explicit instruction to target the skills that research has shown to underpin literacy for young children (Harris, Terlektsi, & Kyle, 2017b. These include phonological awareness, alphabetic knowledge, word reading, vocabulary, and narrative skills.

The Future

The review of recent studies on literacy skills of deaf children suggests a number of conclusions about the development of literacy skills of deaf children in an era of great advancements in technology and identification. First, despite the compelling evidence of the benefits of improved hearing aid technology for language skills among children who are DHH using spoken language, reading levels are still not age appropriate for many children, and considerable variations in performance remain. Second, vocabulary and phonological skills are closely interrelated for deaf children using spoken language and are strong predictors of their literacy attainments. Third, effective interventions to support literacy skills of deaf children are scarce.

Advancements in Hearing Aid Technology and Diagnosis

Despite the introduction of newborn hearing screening and diagnosis of permanent childhood hearing loss soon after birth, there are still a significant number of deaf children who receive a late diagnosis (Ching et al., 2013). These include children who are born in countries where newborn hearing screening is not available or in private hospitals where screening is not compulsory and suspected hearing loss is not followed up (Harris et al., 2017a). There are also cases where hearing loss is progressive and where home births are on the rise as a result of immigration status.

Better understanding of the nature and cause of hearing loss can assist in early diagnosis and ensure that fewer children are lost to follow-up. Genetic factors account for nearly 40% of prelingual hearing loss. However, not all the genes that cause deafness can be identified and, for most, there is no routine test. Thus, even if deafness is inherited, it is often difficult to identify this with a genetic test. The use of Next-Generation/Massively parallel DNA

sequencing promises to reveal new information about the genetic causes of deafness that can be used for effective screening (Shearer & Smith, 2015). Next-Generation/Massively parallel DNA sequencing is a high-throughput approach to DNA sequencing (the process of determining the order of nucleotides in DNA) using the concept of massively parallel processing (i.e., the use of multiple interconnected computers to work simultaneously on different aspects of a problem). According to the American College of Medical Genetics, this approach is now integral to the effective diagnosis of nonsyndromic hearing loss (Alford et al., 2014). Early fitting of hearing aid technology is expected to evolve in the future specifically with the use of cortical auditory evoked potentials to provide an objective measure of a response to auditory stimuli, including speech sounds (Mehta et al., 2017). Mehta and colleagues investigated the impact of including cortical evoked potential reports into the audiology pathway and explaining these tests and measurements to parents. They compared two sequential cohorts of children: a cohort of 34 children (aged 1.3 months) who had followed an audiology pathway prior to the introduction of the cortical evoked potentials, and 44 children (aged 0.9 months) who followed a pathway after the introduction of cortical auditory evoked potentials. They concluded that the use of cortical evoked potential reports enabled audiologists to identify hearing detection for low-, mid-, and high-frequency speech sounds, enabling hearing aid fitting in early infancy in children with mild or moderate hearing losses. The use of the cortical evoked potentials may offer the chance to fit hearing aids very early and can be used as an evaluative tool for parents. Early fitting of hearing aid technology may support the development of stronger phonological awareness skills and thereby improve reading skills for deaf children. Nittrouer, Kuess, and Lowenstein (2015) assessed a sample of 44 ten-year-old children with cochlear implants on recognition of sine-wave replicas of sentences and on vocabulary knowledge, phonemic awareness, and use of top-down language constraints. They concluded that continuing development of cochlear

implant technology would provide better information about speech sounds to enable the development of robust phonological awareness.

Evidence-Based Support for Deaf Children

Although schools worldwide employ a number of interventions and literacy schemes to support deaf children's learning, the paucity of published evidence of the effectiveness of those interventions and the persistent gap in literacy skills between deaf and hearing children raise questions about the effectiveness of those schemes (Terlektsi et al., 2019). Effective interventions require careful planning and selection of appropriate outcome measures (see Dostal & Lederberg, this volume, for additional discussion). Educators who can interpret evidence and make judgments about how interventions should be modified and implemented for individual children best achieve this (see Cawthon & Easterbrooks, this volume, for discussion of bridging research to practice).

In relation to outcome measures, caution should be applied when considering appropriate assessments for deaf children's reading since standardized assessments have been developed and standardized on the hearing population. Thus, although standardized assessments provide information on the performance of the target sample in comparison to the population, enabling comparisons between groups (e.g., between hearing and deaf children), the appropriateness of these assessments to evaluate deaf children's developmental progress is doubtful (see chapter by Morere and chapter by Enns and McQuarrie, this volume, for additional discussion of assessment). For instance, Harris et al. (2017b) suggested that deaf children's underachievement in reading comprehension can be attributed partially to the fact that the comprehension questions asked in a standardized test require children to make inferences to provide the correct answer. However, many deaf children find inferences that draw on world knowledge to be challenging.

Second, the educator must make use of information from assessments and then determine which interventions may be beneficial to an individual child's learning and development. The challenge for the educators involved is deciding upon the appropriate combination of interventions and having the appropriate skills to implement them.

The need for teaching children effective strategies to develop vocabulary knowledge and phonological skills as well as promoting world knowledge is clear. However, the approach to teaching those strategies to children must be geared toward those that enable children to become independent readers. In an analysis of the strategies that deaf children in primary school used to read novel words in the classroom (Harris et al., 2017), 26 out of 40 children used a sounding-out strategy, but the remainder relied on guessing or asking an adult. Improvement of literacy skills of deaf children in the future can only be achieved by teaching provisions that support children to develop their capacity to become independent readers (see Silvestri & Ehrenberg, this volume, for a discussion of reading strategies).

Conclusion

Marschark and Harris (1996) identified the foundations for understanding the importance of English vocabulary, phonological awareness, and grammatical knowledge for literacy. Many subsequent studies have confirmed the importance of these skills as well as charting the benefits of early diagnosis and provision of high-quality hearing aids. We suspect that the future will see significant developments in the field of very early fitting of hearing aid technology and cochlear implants. However, for the foreseeable future, deaf children will continue to need support by specialist educators who are able to design and implement effective interventions and to interpret outcomes, taking account of individual strengths and weaknesses. The present has paved the way for better literacy skills in deaf children, and the

future is promising. In the words of Marschark (2017, p. 4), "It has never been a better time to be a deaf child or the parent or teacher of one."

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