National Center on
Accessible Educational Materials

AEM Center Brief:
The Potential Benefits of Accessible Digital Learning Materials for Students Who Are Deaf or Hard of Hearing

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Published: 2020

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Education Programs

This issue brief discusses the potential benefits of accessible digital learning materials for students who are deaf or hard of hearing (DHH). The first section describes the nature of the reading challenges that may be experienced by DHH students. The second section focuses on research highlighting some of the ways in which accessible digital learning materials can be used to help support DHH children with their reading.

Section I: The Nature of the Reading Challenges that May Be Experienced by DHH Students

Many studies have found that children who are DHH tend to read at levels below those of their hearing peers (Harris et al., 2017b; Qi & Mitchell, 2011; Traxler, 2000; Wauters et al., 2006). Moreover, there is evidence that the discrepancies in reading achievement between DHH and hearing students tend to increase with age (Harris et al., 2017a; Kyle & Harris, 2010, 2011; Worsfold et al., 2018). An often-cited investigation of the norming sample for the Stanford Achievement Test showed that the median reading comprehension scores of DHH students, aged 14 or higher, fell in the "Below Basic" category, which corresponds to a grade equivalent between third and fourth grade (Traxler, 2000). While many DHH children struggle with reading, it is important to note that they are not a homogeneous group. Some DHH readers become highly proficient (Banner & Wang, 2010; Wang et al., 2018). A number of studies have also found that children with cochlear implants tend to read at levels more comparable to those of their hearing peers, although wide variability exists within this group as well, with factors such as age at implantation playing a role (see Mayer & Trezek, 2017 for a review).

One area that researchers have identified as potentially contributing to reading challenges for DHH children is that they may experience a weakness with respect to phonological awareness and processing (see Hartman et al., 2019; Trezek et al., 2011 for overviews). In hearing children, these phonological skills have been shown to play an important role in the early stages of reading development, during which the focus is largely on the decoding of written words (National Reading Panel, 2000; National Research Council, 1998). DHH children, however, who tend to have limited auditory access to spoken language, may have difficulty developing an understanding of the phonological structure of language and how it relates to the written word (Luckner et al., 2005/2006). While the relationship between phonological skills and reading for DHH children has received much attention in the literature, there is not complete agreement regarding the specific role that phonological skills play. In a meta-analysis of studies focusing on the phonological coding and awareness skills of deaf children and adults, Mayberry et al. (2011) found that half of the studies reported evidence of such skills, while the other half did not. Mayberry et al. (2011) further found that within the studies that included an examination of reading proficiency, phonological skills accounted for

only 11% of the variance. The authors concluded that phonological skills are only a low to moderate predictor of the reading achievement of deaf individuals.

Regardless of the extent to which DHH students access phonological skills during reading, it appears that the inclusion of visual stimuli and supports can be of value to them in the process of learning to read. For example, for those DHH children who develop phonological skills, some do so using visual methods such as speechreading, cued speech, or visual phonics (Hartman et al., 2019). It has also been shown that DHH students who rely on their hearing to develop phonological skills may still benefit from the use of visual support to aid in their processing of auditory language (Morere, 2011). Moreover, some DHH students learn to read using alternative, *nonphonological-based* approaches that also rely on the visual modality – namely, signing, fingerspelling, and orthographic/print-based coding (Trezek et al., 2011; Visual Language and Visual Learning Science of Learning Center, 2011). For all DHH children, researchers have identified the early exposure to a rich language environment as being extremely important (Marshall et al., 2015; Visual Language and Visual Learning Science of Learning Center, 2011).

Similarly, researchers have found that DHH children tend to struggle with phonological working memory tasks – i.e., tasks that require the recall of auditory information (Briscoe et al., 2001; Pisoni et al., 2011) – but may perform better with respect to some tasks associated with visuospatial working memory. Working memory refers to a "set of cognitive functions that allow individuals to actively maintain and manipulate information in the service of cognition" (Hall & Bavelier, 2010, p. 459). While there is some evidence that DHH children do not perform as well as hearing children on tasks that require the serial recall of linguistic visuospatial items (e.g., pictures or signs) (Bavelier et al., 2006; Koo et al., 2008), DHH children tend to demonstrate enhanced serial recall of *non*linguistic visuospatial items such as those comprising block tests (Bharadwaj et al., 2015; Wilson, 1997). Moreover, in a summary of the research, Hamilton (2011) noted that one of the strengths of DHH children "appears to lie in the recall of information presented in static visuospatial format … for both nonlinguistic and linguistic items" (p. 406). In particular, DHH children who are exposed to sign language since birth by deaf parents may perform better on visuospatial working memory tasks than those who are not native signers (Marshall et al., 2015). Section II will discuss the adaption of digital technology and materials to provide support in the visual modality, tapping into a potential strength of DHH children in this area.

While there has been debate over the relationship between phonological skills and reading for DHH children, researchers have generally been more in agreement regarding the strong role that language plays in the development of reading proficiency

by DHH children. Three specific language-based skills that have been identified in the literature as contributing to the reading challenges of DHH children are vocabulary, syntax, and metacognition (Trezek et al., 2011). These skills are all known to play a role in the acquisition of reading comprehension by hearing children (Adlof et al., 2010; Foorman et al., 2020; National Reading Panel, 2000). With respect to vocabulary knowledge, Luckner and Cooke (2010) reported in a review of the literature that DHH children tend to "[be] delayed in their acquisition of vocabulary knowledge, have smaller lexicons, acquire new words at slower rates, and have a narrower range of contexts that result in word learning" (p. 40). Harris et al. (2017a) found that the vocabulary knowledge of DHH children was a longitudinal predictor of their single word reading and reading comprehension skills, whereas phonological awareness was not (see also Kyle & Harris, 2010). In a related study, Harris et al. (2017b) showed that the vocabulary scores of DHH children from a new cohort were significantly higher than those of a comparable group of DHH children ten years earlier, although the scores of the new group still lagged behind those of hearing children. At the same time, some studies have found that children with cochlear implants perform within the average range of their hearing peers on vocabulary assessments (Geers et al., 2009).

Research has similarly highlighted challenges with respect to syntax for DHH children. For example, in a recent study of 336 DHH children, enrolled in kindergarten through second grade, Antia et al. (2020) found that the DHH children performed 1.5 and 2.5 standard deviations below the age norms for hearing children on receptive and expressive English syntax, respectively (see also Geers, 2003). At the same time, Antia also showed that DHH children who had access to sign language (either through sign-only or bimodal instruction) made significant gains in sign language receptive syntax. Research has further pointed out that the syntactic difficulties of DHH children contribute to challenges with respect to their reading comprehension (Barajas et al., 2016; Kelly, 1996; Szterman & Friedmann, 2020). In another recent study, Worsfold et al. (2018) demonstrated that the language skills of DHH children (vocabulary and syntax combined) at age 8 were a significant predictor of their reading comprehension at age 17, even after controlling for reading achievement at age 8. Similarly, as part of their meta-analysis discussed earlier, Mayberry et al. (2011) concluded that the language skills of deaf participants were a stronger predictor of reading achievement than were their phonological skills.

Finally, research has shown that some DHH children may manifest a weakness in the area of metacognition – i.e., thinking about one's own thoughts and learning processes and understanding how to make improvements (Hartman et al., 2019; Strassman, 1997; Walton et al., 2019). Metacognition involves self-monitoring strategies that are important for reading comprehension, including the recognition by the individual of when

comprehension has or has not taken place and the selection of an alternative strategy if necessary (Trezek et al., 2011). In a review of the literature on metacognition and DHH students, Strassman (1997) questioned whether the fact that DHH children are provided low-level reading material based on their reading scores results in their not being sufficiently supported in the development of more advanced metacognitive skills. While much of the research has focused on limitations in the metacognitive skills of DHH readers, some research has found that more skilled DHH readers tend to utilize metacognitive strategies (Banner & Wang, 2010; Wang et al., 2018).

In summary, a number of possible explanations have been presented in the research as to why DHH children tend to read at levels below those of their hearing peers. One suggested explanation is that limited auditory access to spoken language may make it difficult for DHH children to understand the phonological structure of language and its relationship to the written word. The importance of phonological skills with respect to the development of reading proficiency in DHH students, however, has been debated. Regardless of the extent to which DHH students access phonological skills, research has highlighted the importance of visual stimuli and supports as aids to their reading development. Similarly, while DHH children may experience challenges with respect to phonological working memory, some aspects of visuospatial working memory have been found to be skills with which DHH children experience greater success. In particular, DHH children who have been sign language users since birth with deaf parents tend to perform better in this regard. Finally, some DHH children also struggle with particular language-based skills, including vocabulary, syntax, and metacognition, that are associated with more advanced levels of reading comprehension in hearing children. All of these challenge areas help point to the difficulties that DHH students may encounter as they begin to learn to read and subsequently strive to become more mature readers.

Section II: Potential Benefits of Accessible Digital Learning Materials for DHH Students

The use of digital technology has been identified as a promising tool that can enhance the teaching of reading to DHH students (Easterbrooks & Stephenson, 2013). Accessible digital learning materials, which are adaptable in nature, have the potential to promote access to the general education curriculum for DHH students by presenting information visually as well as auditorily and by embedding scaffolds that can support DHH students in particular areas of challenge. Various studies have been conducted to examine the benefits of specific technology-based interventions for DHH students (see Beal-Alvarez & Cannon, 2015 for a discussion of studies in relation to quality indicators for evidence-based research). The present section summarizes some of the research in

this area in order to highlight different ways in which accessible digital learning materials can be used to help support DHH students with their reading.

Focusing on emergent literacy skills in young DHH children, Wauters and Dirks (2017) explored the use of interactive storybook reading via electronic books (eBooks) on tablets by 18 DHH children (ages 1 to 3) and their parents. As part of the study, parents first participated in a program to learn about interactive reading strategies. These strategies involve interactions between parents and children while reading – for example, parents ask open-ended questions and make connections to their child's personal experiences. Half of the group received 5 print books, while the other half received 5 eBooks along with an iPad, and then the two groups reversed. The results showed that parents for the most part engaged in similar interactive reading behaviors when using eBooks as when using print books. The authors concluded that the use of eBooks can provide additional opportunities beyond traditional print books for parents to engage in interactive reading with their DHH children. In particular, it was noted that tablets are easily transportable to multiple settings and have the capability to store a large collection of eBooks in one place.

Research on the implementation of a multimedia literacy program, titled Cornerstones, is also informative. This program, designed specifically for DHH children and their teachers, centered on animated stories taken from a public broadcasting series. The stories, which contained captions, could also be watched through a hypertext version or through a videotaped version in American Sign Language (ASL), Signing Exact English, or Cued Speech. The materials further included interactive games and activities for the students as well as lesson plans and strategies for the teachers. In a study of 32 DHH students (ages 6 to 12) using the Cornerstones program, Loeterman et al. (2002) found that students' knowledge of words increased. In addition, Wang and Paul (2011) reported statistical differences in word identification and story comprehension between the Cornerstones approach and a "typical" literacy instructional approach for 22 DHH students (ages 7 to 11) in two of three experiments. Participating teachers also indicated that they appreciated the range of multimedia activities and materials available as well as the lesson guides and learning structure provided.

Additional studies have examined the use of digital materials to help DHH students improve with respect to particular language-based challenge areas pertaining to reading comprehension that were identified in Section I – namely, vocabulary, syntax, and metacognition. For example, Massaro and Light (2004) investigated the effectiveness of a computer-animated tutor to teach new vocabulary to 8 DHH students (ages 6 to 10). This 3D animated "talking head" allowed information to be presented not only auditorily, but also visually, through the tutor's facial movements and expressions. The study

found that when students received training by the tutor, their knowledge of the vocabulary words increased and was retained over time. Similarly, Messier and Wood (2015) examined the use of eBooks, which included embedded vocabulary instruction with videos, pictures, and highlighting, by 18 children with cochlear implants (ages 4 to 9). When using the eBooks with the embedded vocabulary instruction, as opposed to reading the eBooks as traditional stories, the children experienced greater benefit with respect to expressive labeling and the generation of definitions as well as enhanced retention of expressive vocabulary. Moreover, Donne and Briley (2015) examined the use of PowerPoint multimedia storybooks containing targeted vocabulary instruction by 7 preschool children (ages 3.5 to 5). The authors found that after using the multimedia vocabulary intervention for 5 weeks, the students' vocabulary, on average, at both the word level and in the context of sentences doubled. In the area of syntax, Cannon et al. (2011) found that the use of a targeted computer software program resulted in significant gains in the comprehension of morphosyntax (morphology and syntax) for 26 DHH students (ages 5 to 12) who were sign language users.

With respect to metacognition, Alsalem (2018) explored the use of digital books, which were embedded with metacognitive strategies, by 36 DHH higher education students in Saudi Arabia. Half of the students received the embedded digital books, and the other half received print books along with separate metacognitive instruction. The study found that while both groups experienced significant improvement, the students who used the metacognitive strategies-based digital books experienced greater increases in reading comprehension and levels of engagement than the group that used the print books. The authors also noted that the students who used the digital books experienced enhanced opportunities to collaborate with their peers and to work independently without the instructor.

Focusing more broadly on the use of digital learning materials to support the reading comprehension of DHH students, Gentry, Chinn, and Moulton (2004/2005) compared the reading comprehension scores of 25 DHH students (ages 9 to 18) using multimedia CD-ROM generated stories presented in four formats: print only, print together with pictures, print together with sign language, and print together with pictures plus signs. The authors found that the reading comprehension levels of students using any of the formats other than print alone were higher than those of students using print alone, with the highest levels being for students using the print together with pictures format. The authors concluded that "pictures were shown to be a powerful factor in the transfer of factual information during the reading process" (pp. 400-401).

In another study, Nikolaraizi, Vekiri, and Easterbrooks (2013) examined the ways in which 8 DHH students (ages 8 to 12) used a multimedia software package consisting of

narrative texts along with Greek Sign Language (GSL) videos, pictures, and concept maps. The researchers found that the students used the various visual resources; however, they did not do so in a strategic manner. The authors concluded that these results demonstrate a need for targeted instruction in the use of "visual aids" to support students' reading comprehension.

Finally, the use of digital learning materials has also been investigated as a support for DHH students with respect to specific content areas such as math and science. For example, Cannon et al. (2010) found that the use of videos of expository math texts presented in ASL helped increase the math vocabulary recognition of 4 DHH students (ages 10 to 12), who were also English Language Learners, when the videos were accompanied by pre-teaching of the vocabulary words. In the area of science, Dowaliby and Lang (1999) compared the following five conditions as part of a computer-based science lesson for 144 DHH college students with varying reading levels: (a) text only, (b) text and content movies, (c) text and sign movies, (d) text and adjunct questions, and (e) all of the conditions together. The study found that students with lower reading levels participating in the lesson with text and adjunct questions and the lesson with all conditions performed comparably to students with higher reading levels participating in the lesson with text only. In an additional study, Vesel (2005) reported on the early results of a digital science program that included a signing avatar, noting that the content knowledge of DHH students in grades 3-8 improved when using the digital program. Teachers also indicated that the program helped to standardize ASL signs corresponding to difficult scientific terminology and to free up their time to focus more on actual instruction.

In summary, while the above studies differ in various respects, including the specifics of the digital materials used, sample size, age of participants (from preschool through higher education), and areas targeted, collectively they illustrate that accessible digital learning materials, particularly when accompanied by supplemental instruction, can be a valuable resource to support DHH students in reading and understanding text. These materials allow information to be presented in multiple ways, including through visual means. Moreover, accessible digital learning materials have the potential to address specific areas of challenge such as vocabulary, syntax, and metacognition, which in turn can lead to improved reading comprehension as well as greater ability to understand particular content such as math and science. Finally, accessible digital learning materials have been found to promote greater student engagement, while concomitantly helping to support teachers in their instructional practices.

Conclusion

DHH students comprise a heterogeneous group. While some become proficient and advanced readers, research has shown that many struggle with various aspects of reading. Section I of this brief discussed potential areas of weakness that have been identified by researchers as contributing to the reading challenges experienced by DHH students – namely, phonological skills (although the relative importance of phonological skills with respect to reading for DHH students has been debated), certain aspects of working memory, and language-based skills such as vocabulary, syntax, and metacognition. Section I also highlighted the benefits of visual stimuli and supports for DHH children as they learn to read as well as the value of an early language-rich environment. Section II presented a variety of intervention studies that have used accessible digital learning materials to address some of the reading challenges experienced by DHH students. Given that much of the general education curriculum is transmitted through the medium of print, accessible digital learning materials, which allow for greater flexibility and support, serve as a promising educational tool for DHH children. It is anticipated that the intervention studies described in Section II can lead to the development of improved digital learning materials in the future. Since technology continues to advance at a rapid pace, greater opportunities will emerge to take advantage of its flexible and supportive nature to design learning materials that further address the reading challenges of DHH students, increase their levels of engagement, and support teachers in the provision of instructional practices for their DHH students.

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