

A whole new world: Technology and its impact on students who are deaf or hard-of-hearing

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Abstract. In this article, the author describes technology used with children or students who are deaf or hard-of-hearing. Specifically, three technological developments are highlighted: cochlear implants, universal newborn infant hearing screening, and telepractice. The positive impact of each type of technology on students who are deaf or hard-of-hearing is described with an emphasis on the development of speech, language, and hearing skills. In addition, the use of these technologies beyond the United States of America is discussed. Furthermore, current limitations of each type of technology are noted.

Keywords: Cochlear implants, service delivery, telepractice, universal newborn hearing screening

Introduction

In the United States of America (USA), the education of students who are deaf or hard-of-hearing dates back to 1817 with the establishment in Hartford, Connecticut of the Connecticut Asylum for the Education and Instruction of Deaf and Dumb Persons, now known as the American School for the Deaf, by Thomas Hopkins Gallaudet and Laurent Clerc (Van Cleve & Crouch, 1989). The technology used at that time was basic: pens, paper, and chalkboards. However, as the education of students who are deaf or hard-of-hearing progressed in the USA through the remainder of the 19th century and into the 20th century, technological innovations started to play an increasingly important role. Recent examples of these technological innovations include cochlear implants (Chute & Nevins, 2006; Mishra, Boddupally & Rayapati, 2015), multimedia instructional applications/software (Beal-Alvarez & Cannon, 2013; Cannon et al., 2011), speech-to-text (Stinson, et al., 2009; Szaikowska et al., 2011), telepractice (Hopkins, Keefe & Bruno, 2012; Houston & Stredler-Brown, 2012), universal newborn hearing screening (Krishnan & VanHytte, 2014; White, 2007), and virtual reality (Karpouzis et al., 2007; Sigal, 2014). While results using these various technologies are promising, further research still needs to be conducted to determine their efficacy. For example, technological interventions used with students who are deaf or hard-of-hearing lack an evidence base (Beal-Alvarez & Cannon, 2013).

In the following sections, three of the aforementioned technological innovations are highlighted and their influence on the education of students who are deaf or hard-of-hearing is discussed: cochlear implants, universal newborn hearing screening, and telepractice. Potential benefits of each technological device, especially as these relate to speech, language, and hearing development are delineated along with possible limitations. In describing these innovations, it is hoped that the reader will understand how technology has opened up a whole new world that, in many respects, was previously unknown or unavailable to children and students who are deaf or hard-of-hearing.

Technological Innovations

Cochlear Implants

Historically, there have been several technological innovations that have impacted the education of students who are deaf or hard-of-hearing in the United States such as the introduction of hearing aids to the development of the teletypewriter (Edwards, 2005). However, a convincing case can be made that no other recent technological innovation has had as large of an impact as the introduction of the cochlear implant (CI), especially for children who are deaf or hard-of-hearing (Niparko, 2009; Sarant & Garrard, 2014).

A CI consists of an electrode array that is surgically implanted in the cochlea, which results in direct stimulation of the auditory nerve. In essence, it bypasses the portion of the cochlea that is damaged, thereby allowing the brain to perceive and process sound (O' Donoghue, Nikolopoulos & Archbold, 2000). Although a CI can provide access to sound often superior to what a hearing aid can provide (Luckhurst, Lauback & Unterstein Van Skiver, 2013), it does not restore normal hearing (Beer et al., 2014). At this point in time it is impossible to regenerate the damaged hair cells of the cochlea in humans (Stone & Puel, 2013). Therefore, persons with a hearing loss will continue to be reliant upon either hearing aids, which amplify sound, but still depend upon the damaged cochlea to transmit sound to the auditory nerve or upon CIs, which stimulate the auditory nerve directly without relying upon the damaged cochlea for the transmission of sound. Although the sound generated by CIs may be different from typical hearing, children or adults who are implanted can nevertheless learn to develop effective communication skills (Cole & Flexer, 2010).

In 1990, the Federal Drug Administration approved the use of CIs for children with profound hearing losses who were two years and older (Chute & Nevins, 2006; Mascia & Mascia, 2012); currently, children may be implanted by one year (National Institute on Deafness and Other Communication Disorders, 2014; Tye-Murray, 2009). For children diagnosed with a bilateral, severe-to-profound, sensorineural hearing loss and who are implanted in the first or second year of life, they may demonstrate speech and language skills that are commensurate with their typically hearing peers (Ching et al., 2009; Sarant, Harris & Bennet, 2015). Furthermore, children who are implanted tend to have better speech and language outcomes than children with similar degrees of hearing loss who use hearing aids (Tye-Murray, 2009). One reason for this is that CIs enable a person with a severe to profound, bilateral hearing loss to gain access to high frequency sounds, such as /s/, /sh/, /p/, /f/, /t/, and /k/ (Rhoades, 2001). Depending on the type and degree of hearing loss, a person using a hearing aid may struggle to hear these high frequency sounds.

Despite the positive outcomes for some children with cochlear implants, there are other children who display speech and language skills that are significantly behind their typically hearing peers even after years of CI use (Geers et al., 2009; Sarant, Harris & Bennet, 2015). In other words, there is a considerable amount of variability when it comes to speech and language outcomes for children with cochlear implants (Ganek, McConkey Robbins & Niparko, 2012; Niparko et al., 2010; Szagun & Stumper, 2012).

Some factors that contribute to the variability of speech and language outcomes for children with cochlear implants includes the following: duration of implant use (Archbold, Nikolopoulos & Lloyd-Richmond, 2009; Holt & Svirsky, 2008); age of implantation (Ching et al., 2009; Szagun & Stumper, 2012); quality of pre-implant hearing (Cruz et al., 2013; Niparko et al., 2010); type and amount of early intervention services (De Raeve & Lichtert, 2012; Luckhurst, Lauback & Unterstein Van Skiver, 2013); nonverbal cognitive skills (Beer et al., 2014; Houston et al., 2012); gender (Massida et al., 2013; Tianhao, 2011); communication mode (Berg et al., 2007; Geers et al., 2011); socioeconomic status (Holt et al., 2012; Mascia &

Mascia, 2012); and parents' educational status (Geers, Brenner & Davidson, 2003; Szagun & Stumper, 2012). Specifically, parental economic and educational statuses are important factors influencing the vocabulary size, rate of expressive language growth, and auditory comprehension of typically hearing children (Cruz et al., 2013; Geers, Nicholas & Moog, 2007). Furthermore, children implanted in the first or second year of life will tend to have higher language scores than children implanted later although parental education level appears to have an even larger impact on the speech and language outcomes of children with CIs than age of implantation (Geers et al., 2009; Szagun & Stumper, 2012).

Even though there is variability in speech and language outcomes that occur for children with CIs and there is criticism of CIs by some in the Deaf Community (Humphries & Humphries, 2011; Mascia & Mascia, 2012), the popularity of CIs is growing. As of 2010, 28,000 children have been implanted in the United States (Beer et al., 2014). Montag, AuBuchon, Pisoni and Kronenberger (2014) summarized well the current state of affairs for CIs when they said, "Cochlear implantation is currently the standard of care for profoundly deaf children" (p. 2342).

CIs have not only impacted children with severe-to-profound hearing losses, but also professionals working with these children or students, especially teachers of students who are deaf or hard-of-hearing (TSDHHs) (Miller, 2014). As mentioned earlier some children with severe-to-profound hearing losses who are implanted are developing spoken language and listening skills that are commensurate with typically hearing peers. Because of this, these children may be mainstreamed or included in their neighborhood school and supported by an itinerant TSDHH rather than being educated in a self-contained classroom for students who are deaf or hard-of-hearing or attending a school for the deaf (Johnson, 2013; Luckner & Ayantoye, 2013). Furthermore, children who are implanted are less likely to use sign language (Johnston, 2003; Miller, 2008). This does not mean that students with a CI do not use sign, but when a child is implanted, the focus is typically on the development of spoken language and listening skills (Holt & Svirsky, 2008; Montgomery, Magimairaj & Finney, 2010; Nittrouer, Caldwell & Holloman, 2012).

In order to support students who are deaf or hard-of-hearing with CIs, TSDHHs have had to adjust existing skills or acquire new skills. For example, because of CIs, TSDHHs have needed to increase their knowledge and skills of developing spoken language and listening skills. Increasingly, parents of children who are deaf or hard-of-hearing with CIs are seeking educators who are skilled in developing spoken language and listening skills, such as those possessing the Listening and Spoken Language Specialist (LSLS) Certification developed by the Alexander Graham Bell Association for the Deaf; this certification ensures that TSDHHs, speech-language pathologists (SLPs), or audiologists have the knowledge and skills to competently work on spoken language and listening skills with children who have a hearing loss, in particular those with CIs (Goldberg, Dickson & Flexer, 2010; Listening and Spoken Language, 2015).

While TSDHHs typically work with children or students with CIs, it is also common for SLPs to work with them, too. However, SLPs often lack confidence in working with children or students with CIs. In part, this derives from the fact that preparation programs are not adequately preparing SLPs to work with this unique population. Compton, Tucker and Flynn (2009) found that there was a significant lack of coursework and practicum experiences related to CI technology and related aural (re)habilitation topics in undergraduate and graduate training programs at least in the State of North Carolina. Furthermore, they reported that SLPs in North Carolina reported not having access to workshops, inservices, or printed materials about working with children or students with CIs. In response to this, Nazareth College in Rochester, New York developed a speciality

program within its master's degree in speech-language pathology to provide its students with the skills necessary to effectively work with children or students with CIs (Brown & Quenin, 2010). Clearly, more SLP training programs will need to incorporate coursework and practicum experiences specific to working with children and students with CIs.

The USA is not the only country where SLPs are lacking in confidence or in professional development as these relate to working with children or students with CIs. In Greece, approximately one-third of the SLPs responding to a survey indicated that they had received formal training with CIs and an even greater percentage revealed that they attended continuous education seminars on this topic. However, these SLPs indicated that implanted children needed different, specialized services as compared to children using hearing aids. In summary, they desired more training and supervision relative to working with children or students with CIs (Okalidou et al., 2014).

Despite the impressive speech and language outcomes that children with CIs may achieve, there are those who are critical of these devices. For example, the National Association for the Deaf (NAD) took a strong position against cochlear implants in a position paper it issued on cochlear implants in 1991 (Edwards, 2005). In 2000, NAD (2000) issued an updated position statement on cochlear implants where it recognized all technological advances that could improve the quality of life for someone who is deaf or hard-of-hearing, including cochlear implants. However, it emphasized the importance of sign language during the habilitation process required for a cochlear implant to ensure that a child who is deaf or hard-of-hearing is achieving age-appropriate development in social, cognitive, and language domains. Still, some if not many in the Deaf community perceive CIs as a means of promoting an oralist philosophy where the development of oral speech and language skills is viewed as preferable to sign language (Gale, 2011; Solomon, 2012). Edwards (2005) summed up the fears of the Deaf community when he said, "The potential return of oral education, with its oppression of Deaf ways and language strikes fear in the Deaf Community. If oralists again perceive sign language as hindering the development of speech, it may once more be forbidden" (p. 914).

In conclusion, CIs are dramatically impacting the education of children who are deaf or hard-of-hearing and the educators who serve them. The speech and language outcomes for children with CIs vary and as do opinions regarding the necessity for CIs. However, it cannot be denied that CIs have positively impacted the lives of many children, students, and adults with severe-to-profound hearing loss. In describing her hearing loss and the impact of a CI on her life, Kooser (2014) said, "Cochlear implantation improves the ability to hear and understand the various sounds that make up living in our world. This ability to hear keeps us connected to everything and everyone around us" (p. 53).

Universal Newborn Hearing Screening

There was a time when diagnosing a child with a hearing loss under the age of two was an accomplishment (Russ et al., 2010). Now, it is commonplace due to the introduction of universal newborn hearing screening (Cole & Flexer, 2010). For example in the USA, the average age for diagnosis for a hearing loss has declined from 2 to 3 years, to 2 to 3 months (White et al., 2010). As Korres et al. (2005) said, "The earlier in life the diagnosis of hearing loss is made the earlier we can establish an intervention and the better the final outcome for the child, the family and society" (p. 293).

The impetus for universal newborn hearing screening began in 1993 when the NIH Consensus Development Conference recommended that all babies be screened for hearing

loss before being discharged from the hospital (Krishnan & Van Hyfte, 2014). This recommendation was also supported by the Joint Committee on Infant Hearing Year 2000 position statement (Cole & Flexer, 2010).

Hearing loss is one of the most common congenital disorders (Houston, Bradham & Guignard, 2011). Typically, there are 1 to 3 infants per thousand born with a hearing loss (Holte et al., 2012) although this can be as high especially for infants in the NICU (Declau et al., 2005; Parving, 1993). In the United States, there are between 16,000 to 18,000 babies and infants identified with a hearing loss each year (Cole & Flexer, 2010). If babies and infants with a hearing loss are not identified early, then there are potential ramifications for the not only the child, but for society as well. The longer it takes to identify a child with a hearing loss, the longer the delay of early intervention services, thus placing this child at risk for language, academic, and social-emotional development (Nelson, Bougatsos & Nygren, 2008; Patel & Feldman, 2011).

For society, it is cost-effective to identify a child with a disability as early as possible and provide appropriate early intervention services to ameliorate the deficits that a disability may cause. Early intervention will only result in a developmental advantage for a child if this process is linked to timely and effective interventions (Holte et al., 2012). For those infants whose hearing loss is diagnosed early and for whom interventions begin before six months, there is a good chance that this child will develop age-appropriate communication skills by the time he or she enters Kindergarten (Houston, Bradham & Guignard, 2011). Without this screening, a child with a severe to profound hearing loss is likely to graduate from high school with language and reading levels commensurate with a 9- or 10-year-old typically hearing student (Patel & Feldman, 2011).

In order to screen for hearing loss with infants, it is recommended to use otoacoustic emissions testing (OAE) followed by auditory brainstem response (ABR) for infants who fail the initial screening (Korres et al., 2005). OAE is a form of energy measured as sound that is generated by the outer hair cells of a healthy cochlea in response to received auditory input. OAE testing is able to determine the inner ear's ability to respond to sound. Generally, when there is a hearing loss of 30dB or greater, this response is usually absent. ABR records the brainstem electrical activity in response to sounds presented to the infant via headphones (Patel & Feldman, 2011). ABR is able to assess the brain's response to sound. Both tests are passive in that the infant is not required to respond; they can even be asleep (Centers for Disease Control and Prevention, 2015).

One advantage of ABR is that it can assist in the diagnosis of auditory neuropathy, a condition in which sound enters the inner ear normally, but the transmission of signals from the inner ear to the brain is impaired (National Institute on Deafness and Other Communication Disorders, 2015); however, the cochlear outer hair cell function appears normal when using OAE testing. Auditory neuropathy may account for 3% to 5% of all neonatal hearing losses (Declau et al., 2005).

To screen newborns for hearing loss, Early Hearing Detection and Intervention (EHDI) programs were established in many U.S. states and territories (Centers for Disease Control and Prevention, 2010). The responsibilities of EDHI programs include promoting the detection of hearing loss, providing and monitoring effective intervention systems, and tracking infants and children identified with hearing loss (Krishnan & Van Hyfte, 2014). As of 2011, 98% of infants were screened for hearing loss by EDHI programs (Holte et al., 2012). These programs emphasize a benchmark approach called 1-3-6. This means that by 1 month newborn hearing screening will have been completed for an infant; by 3 months, a diagnosis of hearing loss will have been determined; by 6 months, an infant identified with a hearing

loss will be enrolled in an early intervention program (American Academy of Pediatrics, 2010). Finally, once an infant is confirmed with a hearing loss, then the goal is to have amplification fitted within one month of the confirmation of the hearing loss (American Academy of Pediatrics, Joint Committee on Infant Hearing, 2007).

As of 2011, 97.9% of eligible newborns were screened in the USA with 1.8% not passing. Of those who did not pass, 39% had normal hearing, 8.9% had a hearing loss, and 45.1% were lost to follow-up (Holte et al., 2012). Furthermore, of those who did not pass, 57% received their diagnosis after three months (Krishnan & Van Hyfte, 2014).

There are a few limitations to hearing screening. First, false positives, i.e. infants who fail, but who actually have normal hearing, may account for 2% to 4% of infants who are screened. Furthermore, less severe congenital hearing losses (i.e., less than 30dB to 40dB) may not be detected. Finally, progressive or late-onset hearing loss will not be detected (Patel & Feldman, 2011).

Timely diagnosis and loss to follow-up continue to be challenges for universal newborn hearing screening programs in the U.S. Some of the factors negatively impacting a timely diagnosis and loss to follow-up include parental noncompliance in scheduling appointments, middle ear fluid, infants having other medical conditions, distance from a testing facility, variability in test protocols, and co-occurring birth defects (Holte et al., 2012; Krishnan & Van Hyfte, 2014). Possible solutions to these challenges include improving conversations with parents by using consistent and scripted messages when communicating with families about screening results as well as using more culturally and linguistically appropriate communication (National Center for Hearing Assessment and Management, 2015). Other suggestions include improving documentation, involving primary care providers before hospital discharge, direct referral from the hospital to the clinic (the responsibility of scheduling an appointment is on the hospital), and placing the responsibility of follow-up appointments with the clinic rather than the parents (American Speech-Language-Hearing Association, 2008), and provision of educational materials to families and educational training and resources to providers (Krishnan & Van Hyfte, 2014).

Besides the USA, there are several other countries that have implemented universal newborn hearing screening programs. The European Consensus Development Conference on Neonatal Hearing Screening published a consensus statement in 1998 recommending universal newborn hearing screening (European Consensus Statement, 1999). Greece was one of the first to adopt an infant hearing screening program beginning in 1999 at a hospital in Athens (Korres et al., 2005). The countries in Europe that have been the most successful in establishing universal newborn hearing screening programs are Austria, Belgium, Denmark, Croatia, England, Luxembourg, and the Netherlands (Aurelio & Tochetto, 2010).

The aforementioned countries are facing some of the same challenges as the USA in terms of timely diagnosis and loss to follow-up as well as other challenges. For example, some countries lack suitable testing environments, which is further compounded by a lack of professionals who can engage in such type of testing. Moreover, there is often little information available to distribute about the benefits of such testing to families and other professionals (Aurelio & Tochetto, 2010). For some countries, it is difficult to schedule and contact families for appointments. Also, there may be parents who do not recognize the importance of such a screening program. Finally, there are members of the medical community in some countries that have a negative attitude towards this type of testing (Korres et al., 2005).

Telepractice

The most common form of service delivery for school-age students who are deaf or hard-of-hearing in the United States is that of an itinerant teacher (Luckner & Antoye, 2013; Miller, 2014). The itinerant model is defined by teachers traveling between public, private, and nonpublic schools to support students who are deaf or hard-of-hearing (Bullard & Luckner, 2013). While itinerant teachers can be instrumental in the success of students who are deaf or hard-of-hearing in general education settings (Foster & Cue, 2008), there are challenges that these teachers sometimes confront in providing this support. Depending on where itinerant teachers work, they may contend with traffic congestion, adverse weather conditions, construction, or great distances between schools all of which may impede maintaining a schedule (Behl, Houston & Stredler-Brown, 2012; McCarthy, Duncan & Leigh, 2012).

Similarly, parents of children that are deaf or hard-of-hearing, especially infants, toddlers, and preschoolers, may contend with long distances in order to procure services for their child. For example, parents may desire a TSDHH or SLP with the LSLC Certification, but this person may not live in close proximity.

Professors or supervisors may also find distance a challenge when supervising student teachers whose placements are far away from colleges or universities. It can be challenging and time consuming for supervisors to perform onsite observations of these students (McCarthy, Duncan & Leigh, 2012).

Because of innovations in technology, TSDHHs, SLPs, parents, professors and supervisors are able to deliver educational services, procure specialized services, or provide supervision without ever getting in a vehicle. By using videoconferencing technology along with web-based software that supports two-way, synchronous communication, it is possible for TSDHHs or SLPs to deliver services to their students, parents to receive services in their homes for their children who are deaf or hard-of-hearing, and professors or supervisors to observe student teachers without ever leaving school, home, or office (Houston & Stredler-Brown, 2012).

Besides eliminating the need to drive, there are other benefits of telepractice. These include the timely delivery of services, fewer cancellations, conducting face-to-face meetings virtually, more efficient and effective use of time, and cost savings related to mileage reimbursement (Houston & Stredler-Brown, 2012; Miller, 2014); furthermore, there are comparable gains in speech and language skills with those provided in a more traditional side-by-side arrangement (Grogan-Johnson et al., 2010; Grogan-Johnson et al., 2013). Telepractice is also an effective medium for using parent coaching. Parents who elect to use telepractice are usually by themselves; the teacher is present virtually, but not physically. By not having a teacher physically present, this requires a parent to take a more active role in the therapy session by learning how to reinforce appropriate listening, speech, and language targets (Houston & Stredler-Brown, 2012).

On the other hand, there are some potential shortcomings with telepractice. First, high quality videoconferencing equipment is cost prohibitive (McCarthy, Duncan & Leigh, 2012). Second, families may not have the needed hardware to enable telepractice sessions. Third, internet connectivity may be problematic in certain parts of a state or of a country (Hamron & Quigley, 2012). Fourth, parents may be intimidated by technology (Houston & Stredler-Brown, 2012). Fifth, there is a paucity of research demonstrating the effectiveness of services delivered via telepractice (Edwards, Stredler-Brown & Houston, 2012).

Telepractice is not only used in the USA. Other countries, such as Australia (McCarthy, Duncan & Leigh, 2012) are also using telepractice for similar reasons. Australia is one of the

largest countries, which means there can be vast distances between providers and recipients of services, thus making it an ideal situation for the use of telepractice. Even smaller countries, such as Greece, present challenges when it comes to providing services to children who are deaf or hard-of-hearing in rural areas or on its many islands. However, telepractice is an underutilized and virtually untapped resource for children who are deaf or hard-of-hearing and their families in Greece (Okalidou et al., 2014). Of course, large, metropolitan areas in many countries can be challenging for families to access desired educational services easily, which may make telepractice appealing. Finally, because there may be a shortage of qualified professionals in these countries, such as those with LSLS Certification, telepractice may be able to help meet this challenge, too (Goldberg, Dickson & Flexer, 2010).

Conclusion

This article provides an overview of technologies that have been beneficial in the education of students who are deaf or hard-of-hearing, especially during the past 25 years. CIs, digital hearing aids, universal newborn hearing screening, and telepractice have all significantly impacted children and students who are deaf or hard-of-hearing, particularly in the development of speech, language, and hearing skills. These technological innovations have resulted in children who are deaf or hard-of-hearing being identified earlier and receiving early intervention services more quickly. Furthermore, technology has provided children and students with access to sound that previously was not always possible, especially for those using CIs. Lastly, technology has even overcome the obstacle of distance with telepractice, which has provided a convenient and effective way for families to access services for their children who are deaf or hard-of-hearing without leaving home as well as a way for TSDHHs, SLPs, professors, and supervisors to support students without leaving the office.

Despite the promising results of the aforementioned technologies used with students who are deaf or hard-of-hearing, there are limitations. For example, many children and students benefit from CIs, but there is wide variability in their performance. Universal newborn hearing screening is helping identify children with hearing loss at birth, but the loss to follow-up rate is troubling, in particular in the USA. Finally, telepractice is providing a convenient way for families and schools to access the services of trained personnel for children and students who have a hearing loss that may be difficult to obtain otherwise. However, this is predicated on having the necessary equipment and access to the internet, which may be challenging especially for some families.

In attempting to summarize information on technology used with students who are deaf or hard-of-hearing, it must be acknowledged that several important technological developments as well as pertinent studies have been mentioned briefly or not at all. It is hoped that information provided in this article will serve as an introduction to more in-depth study of the various technologies used with these students.

In conclusion, the exciting developments in technology described in this article are not only benefiting children and students in the USA, but in other countries as well. Indeed, it is a whole, new world for children and students who are deaf or hard-of-hearing and technology is allowing them to experience it in new ways that is positively impacting their speech, language, and hearing skills and resulting in improved educational outcomes worldwide.

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