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Brief History of Auditory-Based Interventions and Related Developments

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Abstract

This is a brief but broad narrative and non-systematic review of developments that led up to how 21st century digital technology and translational research influenced, in particular, cognitive psychology and our improved understanding of mental resources among children who are deaf or hard of hearing (DHH). In turn, systemic multi-disciplinary research findings gave birth to Auditory Cognitive Neuroscience (ACN). Three broad constructs unique to ACN (i.e., auditory attention, effortful listening, and auditory fatigue) are then described in relation to children who are DHH. This review concludes with a brief examination of future opportunities for researchers and clinicians who can ensure that children who are DHH will benefit from cross-disciplinary translational research findings.

Keywords: hearing loss, science, evidence-based, cochlear implants

Acronyms: ACN = Auditory Cognitive Neuroscience; DHH = deaf or hard of hearing; EBP = evidence-based practice; EF = executive functions; LSL = listening and spoken language

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Prior to the mid-19thth century, a child who was deaf or hard of hearing (DHH) was typically objectified as a *deaf-mute* or *the deaf and dumb* (e.g., Burnes, 1967; Huizing, 1959). However, educational practices and technological developments of the past century made huge differences in the lives of families and their children diagnosed as either deaf or hard-of-hearing. Person-first language, such as *child who is deaf or hard of hearing* is now standard in medical settings and is becoming more widespread in society (e.g., Rhoades, 2010b).

The evolution of auditory-based interventions for families and their children came about as the result of many helping hands, particularly those in the audiological and otological professions as well as science inventors (for reviews, see Felisata, 2007; Nogueira et al., 2007; Vogel et al., 2007). Wearable electric or vacuum tube hearing aids were used at the outset of the 20th century; these devices enabled some children with severe hearing loss to access conversational sound (Howard, 1998). Consequently, some American and European educators, audiologists, and otologists began earnestly advocating for the use of residual hearing (e.g., Ewing et al., 1936; Goldstein, 1928; Kroiss, 1903; Urbantschitsch, 1895; Wright, 1915).

By the mid-20th century, portable transistorized hearing aids became widely available (Bello, 1953). Concurrently, aural rehabilitation programs were being developed to include tests of hearing, speech perception, and hearing aid selection while counseling, and placement services were also being developed (e.g., Carhart, 1946; Ross, 1997). These programs included the teaching of speech reading and auditory skills coupled with the use of assistive hearing technology. Early intervention programs were also established for families and their children who are DHH (e.g., Fiedler, 1952). Many of those programs were designed to promote listening and spoken language (LSL) skills (e.g., Beebe, 1953; Griffiths, 1955; Huizing & Pollack, 1951; Wedenberg & Fant, 1949).

Digital Technological Revolution

The advent of digital technology during the latter part of the 20th century dramatically changed hearing technology and LSL interventions. The transition from analog to digital hearing aids enabled clinicians to better meet individual needs (e.g., Gustafson et al., 2014; Levitt, 2007; Packer, 2016; Reinhart et al., 2019). Cochlear implants, developed and first worn in 1961 (Eshraghi et al., 2012), were soon followed by other types of auditory implants (Møller, 2006). The same circuitry found in computers and smart phones is now used in hearing devices along with Bluetooth capability. This provides hearing device users with the capability of hearing the sound source as if it were directly in their ear.

In addition to empowering audiologists with more specialized and complex diagnostic equipment to facilitate the selection and programming of hearing devices, digital technology gave rise to the development of equipment that identified the nature and origin of hearing loss (Hoth & Baljić, 2017). It also expanded potential therapeutic or rehabilitation options for hearing device users (e.g., Flynn, 2005; Stagiopoulos et al., 2016; Zeitler et al., 2019).

Moreover, as digital technology has gained worldwide prominence, it facilitated the widespread sharing and management of research data in hearing healthcare. This digital transformation gave rise to early identification and tele-intervention programs for families and their babies who are DHH (e.g., Alam et al., 2016; McCarthy et al., 2010).

By the end of the 20th century, partly due to information technology, the professions of otology, laryngology, and rhinology were dramatically altered. These disciplines combined to form the broader and more complex cross-disciplinary profession now known as otorhinolaryngology; this embraces a multitude of sub-specialties that include pediatric otorhinolaryngology, some of whose physicians may be referred to as Children's Ear, Nose and Throat (ENT) physicians (Weir, 2000). Significant improvements have since been made in identifying and managing hearing-related syndromes (e.g., Hone & Smith, 2003) as well as such common childhood hearing health issues as otitis media (Bluestone & Shurin, 1974).

Simultaneously, the field of psychology was undergoing a metamorphosis (for reviews, see Miller, 2003; Saffran & Kirkham, 2017). Insights into the human brain and mind were flourishing and linguistics was being redefined (e.g., Chomsky, 1965; Pinker, 1994). Teachers of the deaf, audiologists, and speech-language pathologists were directly affected by this cognitively-driven linguistic revolution (e.g. Furth, 1966; Levine, 1960; Myklebust, 1960; Van Uden, 1970; Weikart et al., 1971). Consequent to the considerably expanded knowledge base of how language develops as well as advances in hearing technology, increasingly more programs promoting auditory-verbal practices were established (e.g., Rhoades, 1982).

Cognitive psychologists began integrating information processing models, such as computer science (Aaronson, 1994), into their study of mental resources, that is, the cognitive processes of purposeful goal-directed behaviors as well as hearing and language (Barkley, 2012; Goldstein et al., 2014). Research data gave rise to constructs widely referred to as *statistical learning* and *executive functioning* (e.g., de Boysson-Bardies, 1999; Eisenberg, 1976; Gopnik et al., 1999; Tomasello, 2003; Yang, 2006). The meta-construct referred to as *Executive Functions* (EF) involves those interrelated foundation skills carried out by the prefrontal areas of the brain; those capacities include attention, working memory, fluency or speed of processing information, self-regulation or response inhibition, and cognitive flexibility—all considered essential for learning, creativity, problem-solving, self-regulation, empathy, and socio-emotional behaviors (e.g., Meltzer, 2007; Sarma & Thomas, 2020). Cognitive psychology revealed underlying differences in learning processes and outcomes.

During the latter half of the 20th century, some children with severe-profound deafness learned to listen and use spoken language quite well and were educated within mainstream classrooms (Goldberg & Flexer, 1993; Rhoades & Chisolm, 2000; Robertson & Flexer, 1993; Wray et al., 1997). However, in spite of much-improved technology and interventions, many other children did not perform as well as expected (Lim & Hogan, 2017). Neurobiological findings that informed the research of developmental psychologists, cognitive psychologists, and neuropsychologists also served to inform practitioners from the disciplines of audiology, deaf education, speech pathology, and otolaryngology (e.g., Faulkner & Pisoni, 2013). Digital technology across these disciplines helped give rise to modern neuroscience which further informs practitioners as to why children who are DHH demonstrate tremendous variability in learning how to listen and use spoken language.

During the initial rise of data-driven research findings, clinicians were not integrating the scientific evidence into their practice (Carnine, 1997; Davies, 1999). Near the end of the 20th century, demands were repeatedly made for *evidence-based practice* (EBP; e.g., Davies, 1999; Foster, 1999; Sackett et al., 1996). EBP indicates that well-designed research findings, that is, verifiable scientific evidence, should affect clinical decision-making and how clinicians trained in auditory-verbal therapy should systematically implement carefully designed services for families and their children who are DHH (Rhoades, 2010a).

21st Century Translational Research

The first decade of the 21st century amplified and broadened the call for implementing data-driven evidence (e.g., Eccles & Mittman, 2006; Gallagher, 2004; Odom, 2009). *Implementation science* called for effective strategies that would facilitate clinician learning and behavioral changes, something that had not yet occurred on a wide scale (Burns & Ysseldyke, 2009). However, before scientific evidence can be incorporated into practices, the evidence must be rendered meaningful, that is, the knowledge translated so that clinicians understand it.

For instance, multidisciplinary translation research can be seen in biometrics. This is a branch of computer science and technology that has become part of the broader research currently serving those who are DHH. 3D ear scanners can now be used to provide custom fit ear molds that are of critical importance to young hearing aid wearers (Liu et al., 2015). Currently, the most common way to create ear molds continues to be through the use of ear mold impression materials; however, 3D ear scanners are a new technology that will likely impact future practice. This is an example of data-driven evidence showing how researchers from seemingly disparate disciplines are significantly affecting treatment for children who are DHH.

The integration of data logging into hearing aids is another example of how cross-disciplinary research benefits children who are DHH. The data logging feature can be used to monitor and hopefully increase the time that acoustic accessibility is provided to language learners (Ambrose, 2019). As a valuable early intervention tool, it encourages collaboration between audiologist and therapists to promote increased hearing aid use. Data logging has many uses for improving hearing aid behavior (e.g., McMillan et al., 2018).

Auditory systems are shaped by complex, dynamic, and reciprocal processes between genetics, neurobiology, and experiences (for review, see Kral & O'Donoghue, 2010). Knowledge of brain mechanisms and cognitive functions supporting auditory learning is critical for understanding the enormous variability of outcomes experienced by children who are DHH (see McLachlan & Wilson, 2010 for a review). Disruptions to auditory functioning such as tinnitus (Mohamed et al., 2016) and auditory neuropathy (Zeng et al., 2005) affect a variety of neurocognitive skills such as spoken language, mental resources, socio-emotional growth, and learning (Kral et al., 2016). Moreover, difficulties arising from disruptions occurring during infancy may persist beyond early childhood. Although critical periods for language learning are established, whether we can extend those periods of plasticity remain under investigation (Werker & Hensch, 2015).

Neurocognitive research findings show that: (a) One's mental resources have a saturation level that can be allocated to behavioral or learning tasks (e.g., Bays, 2018). (b) No two children are alike; there are individual differences in cognitive capacities (e.g., Dingemanse & Goedegebure, 2019; Lofkvist et al., 2020). (c) The amount or degree of mental resources allocated a task increases as the task becomes more difficult or demanding. For example, cognitive load increases and comprehension or learning outcomes decrease when listening to speech in difficult listening conditions because the task of processing information is more complex (e.g., Lehmann & Seufert, 2020; Zekveld et al., 2011). (d) Persons with good working memory capacity may have an advantage when learning languages and listening to speech in noisy backgrounds (e.g., Archibald, 2017; Astle et al., 2018; Michalek et al., 2018). (e) Children with early access to spoken or signed language are less likely to have executive deficits than those with late access to language (e.g., Botting et al., 2017; Hall et al., 2018). (f) Many children who are DHH demonstrate deficits in auditory attention, working memory, and processing speed (e.g., AuBuchon et al., 2015; Beer et al., 2014; Faulkner & Pisoni, 2013; Kronenberger & Pisoni, 2019). (g) Children who readily engage in pattern recognition tend to demonstrate good statistical learning skills that, in turn, can promote rapid language learning and more effective auditory perception (e.g., Arciuli & Conway, 2018; Deocampo et al., 2018; Riecke et al., 2020; Saffran & Kirkham, 2018; Studer-Echenberger et al., 2016). (h) Children who are DHH but have better language and working memory skills have better speech recognition scores in noise and reverberation than peers who are DHH but have lower language and working memory skills (e.g., McCreery et al., 2019; Torkildsen et al., 2019). (i) Among children who are DHH, better aided audibility is linked to stronger spoken language skills (e.g., McCreery et al., 2019). (j) Cognitive training may improve young children's core cognitive capacities of attention and working memory as well as other EF skills and speech perception-in-noise (e.g., Di Lieto et al., 2020; Du & Zatorre, 2017; Dubinsky et al., 2019; Koshimori & Thaut, 2019; Scionti et al., 2020). Figure 1 shows a summary of this information (see Figure 1).

Translational research currently promotes the multidirectional and multidisciplinary integration of patient-oriented research and population-based research (Rubio et al., 2010). Although cross-collaborative efforts are challenging, the fields of inquiry are ever-expanding. Science and innovation have become too complex for some audiologists, otolaryngologists, and auditory-based clinicians to fully comprehend and thus implement widely effective interventions (Woolf, 2008). A different type of researcher, such as one whose expertise cuts across

Figure 1

Neurocognitive Research Findings at a Glance (adapted from a variety of sources and discussed throughout this paper)

Neurocognitive Research Findings at a Glance

1. Cognitive capacities exist and can be saturated by specific tasks.
2. Individual differences exist for cognitive capacity.
3. Cognitive load increases as the complexity of the task increases.
4. High working memory capacity may be advantageous when learning in noisy environments.
5. Children with late access to spoken or signed language have increased executive function delays.
6. Children who are deaf or hard of hearing often demonstrate difficulty with auditory attention, working memory, and processing speed.
7. Pattern recognition and statistical learning skills promote language learning and auditory perception.
8. Children who are deaf or hard of hearing who have increased working memory skills have better speech recognition skills in noisy environments.
9. Better aided hearing audibility is linked to improved spoken language skills.
10. Cognitive training may improve cognitive capacity in the areas of attention and working memory as well as executive function skills and speech perception in noise.

many branches of knowledge, is bridging the translational divide. This type of researcher harnesses knowledge from seemingly disparate, complex disciplines to generate new knowledge for the benefit of evidence-based practitioners who, in turn, can implement new treatments (La Velle, 2015; Mitchell, 2016; Rubio et al., 2010).

The effort to build on basic scientific research from multiple fields of study is widespread (Lustig & Akil, 2012; Millett, 2020; Pichora-Fuller, 2014). Researchers are translating knowledge from across varied areas of specialization to inform auditory-based interventions (Butler, 2008). For example, genome sequencing may soon complement universal physiologic newborn screenings so that more children with syndromic and nonhereditary sensorineural hearing loss, such as congenital cytomegalovirus, will benefit from early identification and individualized interventions to meet specific needs (Goderis et al., 2014; Shearer et al., 2019). This will translate into more positive outcomes for children with complex needs.

Auditory Cognitive Neuroscience

Modern neuroscience is evolving to encompass many branches. Cognitive neuroscience is the study of the biological mechanisms underlying cognition. Auditory cognitive neuroscience (ACN) covers all aspects of auditory cognition that include perception of speech, music, and natural sounds to emotion, memory, attention, and production of auditory events as well as assessment of listening difficulties (e.g., Moore, 2015; Roessig & Mücke, 2019).

ACN research methods can include psychophysics or other behavioral paradigms, neurophysiology, anatomy, neuroimaging techniques (including MEG, fMRI, PET, EEG, TMS, and optical imaging), motion capture, modeling, neuropharmacology, and behavioral genetics. ACN scientists are interested in collaborating across disciplines and applying these methods to human development and those with hearing differences and/or disorders (Arlinger et al., 2009; Azhari et al., 2020; Pichora-Fuller, 2014). For example, pupillometry is the study of changes in the diameter of the pupil as a function of cognitive processing. This is now used widely in psychological and neurological research. Use of the pupil dilation response will permit improved understanding of the cognitive processes experienced by infants and older children who are deaf or hard of hearing (Kaldy & Blaser, 2020; Naylor et al., 2018).

Progress in understanding the structure and function of our children's responses to and the production of sounds necessitates crossing many disciplines that include disciplines within psychology as well as neuroscience, neurobiology, computer science, physiology, psychoacoustics, speech and hearing sciences, physics, and between theory and practice. ACN is the forum for such cutting-edge research.

Auditory Attention and Spatial Perception

Sensory attention is important to information processing because it controls finite resources, permitting an overall level of alertness or ability to engage with surroundings (Lindsay, 2020). ACN researchers have considerably broadened our understanding of auditory learning. For example, *auditory attention* is an intricate multi-dimensional construct that includes orienting, selecting, and/or focusing on environmental sound stimuli, like speech, for varying periods of time (Pichora-Fuller et al., 2017). Auditory attention serves as a critical core cognitive capacity underlying auditory learning, working memory, and other executive capacities (Engle, 2018; Kaya & Elhilali, 2017; Stavrinos et al., 2018). This attentional capacity operates as a form of sensory gain control, enhancing the attended stimuli whilst suppressing other stimuli. As such, auditory attention interacts with other sensory, motor, and cognitive systems (Zatorre, 2007).

Relative to those with normal hearing, persons who are DHH tend to demonstrate poorer auditory spatial acuity and weaker suppression of auditory distractors (Dai et al., 2018). This is important because attending to a sound is related to identifying the location of sound source or auditory spatial perception (Letowski & Letowski, 2012). Also of interest is that auditory perception is affected by non-spatial features of acoustic stimuli such as other sensory systems (Recanzone, 2011).

Sustained auditory attention is the prolonged focus on auditory stimuli. The listener's brain tracks attended speech through phase-locking of neural activity to the speech envelope known as the onset of a particular speech stream (Petersen et al., 2016). Sustained auditory attentional focus, then, is the neural tracking of pertinent auditory stimuli (Evans & McGettigan, 2017; Kaya & Elhilali, 2017).

Selective auditory attention is the process of allocating one's cognitive capacity on a specific auditory stimulus to the exclusion of other stimuli; this seems to be significantly affected by one's ability to localize sound (Dai et al., 2018). Moreover, selective attention seems biased by reward cues; that is, motivation is an important factor in directing attention to a particular sound (Asutay & Västfjäll, 2016).

Complex sound fields, such as those in classrooms (Gremp & Easterbrooks, 2018) include background noise and reverberation. These acoustic landscapes affect auditory attention and learning for all children, but more so for those with hearing or learning differences (Bhang et al., 2018). As degree of hearing loss increases, the beneficial effect of reduced noise on the speech envelope seems to decrease (Petersen et al., 2016). Better hearing imposes greater sensitivity to changes in the signal-to-noise ratio (Petersen et al., 2016). Restated, tracking of speech gets worse as the hearing loss becomes more severe. Adding to this issue is the finding that sentence complexity imposes additional demands on the listener (Wendt et al., 2016).

Ultimately, then, sustained selective auditory attention is important for optimal learning. This seems to be both reward-dependent and linked to degree of hearing loss, spatial acuity, and cognitive skills (e.g., resistance to distractors), as well as to the linguistic complexity of

explicit verbal direction, and subjective familiarity (Isbell et al., 2016; Tervaniemi et al., 2009; Wendt et al., 2016).

Effortful Listening and Contributing Factors

Listening is the active counterpart of passive hearing (Moore et al., 2020). The act of listening, aided or unaided, is an effort necessitating auditory attention and other mental resources to understand an auditory message (Gagné et al., 2017; McGarrigle et al., 2014). As evidenced neurobiologically, the more effort one expends in listening, the more one's cognitive skills (e.g., attention, working memory, and academic learning decrease) are taxed (Macpherson et al., 2019; Prodi et al., 2019; Roebuck et al., 2018). When auditory attention decreases, then greater effort is needed to listen, understand, and remember (Peelle, 2018). When one engages in *effortful listening*, one's auditory attention must be both focused and selective, deliberate and purposeful (Pichora-Fuller et al., 2017).

There are many factors that affect effortful listening and those include: (a) room reverberation and background noise which may or may not include music; (b) the listener's quality and levels of unaided and aided hearing as well as level of language comprehension; (c) contextual information within the primary auditory stimuli; (d) clarity of acoustic speech stimuli; and (e) the listener's mental resources (e.g., Dingemanse & Goedegebure, 2019; Mattys et al., 2019; Ohlenforst et al., 2017; Pejovic et al., 2020; Peng & Wang, 2019; Wagner et al., 2015). Researchers are investigating ways to improve speech perception and minimize listening effort (e.g. Barrett et al., 2020; Good et al., 2017; Pejovic, 2020). For example, music-based interventions are being investigated as one way to facilitate speech perception-in-noise, but effectiveness remains debatable (e.g., Akça et al., 2020; Alain et al., 2018; MacCutcheon et al., 2020; Yurgil et al., 2020).

Mental resources that affect one's auditory attention include such psychological issues as the listener's state of mind and mood as well as levels of expectation and motivation (Pichora-Fuller et al., 2017). The listener's processing speed (i.e., reaction time) and working memory are two critical cognitive skills; these mental resources also affect the degree and extent of success at effortful listening (Rudner, 2016). It is uncontested that cognitive capacities influence auditory perception. Noisy situations tend to increase the cognitive demands made of the listener, hence these situations necessitate greater listening effort except, perhaps, when the listener is provided with certain cues, such as those obtained via speech reading (Koelewijn et al., 2015; Newman et al., 2013; Picou et al., 2013).

Auditory Fatigue and Cognitive Capacities

There is substantial evidence that children who are DHH are at risk for difficulties in speech comprehension in adverse environments. Some listeners are unable or unwilling to sustain sufficiently high levels of effort, so they may experience *auditory fatigue* or extreme tiredness (Hornsby et al., 2016; Pichora-Fuller, 2017). This construct is complex and may be best defined by the person experiencing it; this is commonly described as a feeling, mood or state, or demonstrated as a decrement in physical or cognitive performance (Hornsby et al., 2017; Pichora-Fuller et al., 2017).

Relative to those with normal hearing, children who are DHH and have other learning differences must exert greater efforts in the act of listening; thus, when they require more cognitive resources for listening, they may be more prone to listening-related fatigue and irritability (McGarrigle et al., 2014; Taitelbaum-Swead et al., 2019; Werfel & Hendricks, 2016). Additionally, the degree of difficulty involved in understanding a speaker can determine the degree of age-related auditory fatigue experienced by listeners, and this is not necessarily predicted by degree of hearing loss (Alhanbali et al., 2017; Ward et al., 2017).

It is important to avoid making generalizations about effortful listening and listening-related fatigue, since many listener-related factors vary considerably across different situational landscapes (Hornsby et al., 2016). Although fatigue is less likely to occur among listeners with greater cognitive capacities, it potentially compromises classroom learning for all persons who are DHH (Bess et al., 2020; Bess & Hornsby, 2014). If auditory fatigue is severe or recurrent, it may cause undue stress and influence quality of life (Hornsby & Bess, 2016). Conversely, auditory fatigue may decrease with practice in listening over noise (Ayasse & Wingfield, 2020).

Auditory cognitive neuroscientists continue to expand our psychological and physiological knowledge about listening and listening-related issues in adverse listening situations. In doing so, they are paving the way for clinical audiologists to provide many types of signal processing algorithms for hearing device users (e.g., Bierer, 2017; Johnson, 2018). Perhaps, as a result of ongoing multidisciplinary research, hearing technology and interventions will become even more individualized for learners with varied cognitive capacities, thus reducing the current wide variability in developmental outcomes.

The Charge and Challenge: Families & Clinicians

ACN is a highly innovative, multidisciplinary and collaborative approach to the complex scientific challenge of hearing and hearing-related issues. Such an approach necessarily involves research scientists, policymakers, clinicians, and other stakeholders from diverse professions. As such, ACN warrants extensive cross-disciplinary communication and information technology to create a 21st century holistic management of hearing loss. This may require considerable adaptation from clinicians when some intervention strategies warrant modification. However, it will ultimately generate enormous opportunities for persons who are DHH (Dritsakis et al., 2019).

Families as well as LSL early intervention service providers, educators, speech-language pathologists, and audiologists are broadening their perspectives. Hearing, auditory learning, and spoken language are just part of the larger intervention process (Zatorre, 2007). New data

and technologies are informing a wider variety of device programming, assessment, and treatment options for families and their children who are DHH (e.g., Dai et al., 2018; Han et al., 2019). Ultimately, this implies greater potential management options that address the specific needs of children who are DHH.

Cultural differences, not discussed here, certainly contribute to the brain's complexity and how a person behaves, thinks, and feels. Psychology and neuroscience are broad and deep in that each involves many different branches having to do with the mind and behavior. These multi-layered disciplines have much to offer auditory-based clinicians working with families and their children who are deaf or hard of hearing (Pichora-Fuller, 2014). It has been proven that cultural, psychological, and neural processes are interwoven (Ambady & Bharueha, 2009; Edwards & Crocker, 2008; Han & Ma, 2014; Huang et al., 2019). Given that each human being represents a highly organized information processing system, it is imperative that clinicians adopt a *systems approach* in how interventions for families and their children who are DHH are viewed and offered (Faulkner & Pisoni, 2013; Rhoades, 2017).

However, scientific evidence is useless unless clinicians take up the charge by first understanding and then implementing the knowledge that has been synthesized and translated for ease in comprehension by all stakeholders (Cook & Odom, 2013). The assumption that clinicians will automatically implement evidence-based practices is shown to be faulty (Douglas et al., 2015; Odom et al., 2020). Therefore, the challenging task of modifying practices and strategies is largely dependent on *active drivers*—both from within organizational systems and data-driven clinician perspectives (Sugai & Horner, 2020).

Clinicians are no longer alone in providing auditory-based interventions and implementing strategies to improve developmental outcomes. The village has evolved to become a sprawling urban mass. It is imperative that all clinicians embrace the findings from other disciplines, including the many different branches of psychology and neuroscience. Translating their findings into workable strategies can serve to minimize the developmental vulnerabilities often experienced by families and their children who are DHH (Evans-Whipp et al., 2017). Vulnerabilities arise as a result of a mismatch between these families' characteristics and those of treatment providers (Sossauer et al., 2019). To minimize gaps between these families' needs and the means intended to meet them, flexibility in clinician application is critical.

Research findings that inform clinicians serving families and their children who are DHH cannot continue without the involvement and express approval of parents and other caregivers. It is critical that clinicians explicitly support researchers in the quest to better understand all those factors that work for or against children who are DHH. Ways in which parents and other caregivers as well as clinicians can assist in the multi-layered world of auditory cognitive neuroscience are listed in Figure 2.

Clinicians, parents, and other caregivers play a vital role in moving science and evidence-based practices forward. With greater participation in inter-disciplinary and cross-professional collaborative studies as well as greater flexibility in the application of scientific data to auditory-based intervention practices, the outcomes for children

Figure 2

Recommended Practical Steps for Clinicians and Caregivers

Some Practical Steps

Clinicians

1. **Actively support researchers in their quest to involve large numbers of families.**
2. **Encourage parents and other caregivers to express their opinions on matters involving policies, regulatory action, and the trajectories of future research.**
3. **Encourage parents and other caregivers to participate in surveys and other research-based studies that have been approved by such institutions as universities and their school districts.**
4. **Provide parents and other caregivers with appropriate informational counseling pertaining to the implications of peer-reviewed research studies as well as legislation and regulatory policies.**
5. **Provide parents and other caregivers with contact information pertaining to all above sources.**

Caregivers

1. **Document your child's progress in a "progress notebook" or journal that can be shared with the entire care team.**
2. **Participate in research study opportunities (including surveys) to contribute to future policy development and impact future service provision.**
3. **Be consistent in following recommendations provided for your child by your care team.**
4. **Communicate reports and progress as well as concerns with all care team members.**
5. **Encourage care team members to consistently communicate and share reports, clinic notes, and care plans.**

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