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Advances in Pediatric Hearing Loss: A Road to Better Language Outcomes

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Hearing loss (HL) is one of the most common birth conditions in the United States, affecting approximately 3 in 1,000 newborns. Depending on the degree of HL, children receive different forms of intervention, e.g., hearing aid (HA) or cochlear implantation (CI). Identifying appropriate management for successful language outcome is still often a lengthy process that frequently leads to long-term delays in children's language and cognitive development. Some children who receive CIs develop age-appropriate spoken-language skills, but many are significantly behind their typical peers. This enormous variability in outcome is partly due to appropriate interventions being selected too late. Current standard-of-care practices rely on anatomical and audiometric findings to determine infants' HA or CI candidacy. However, hearing-screening procedures in clinics do not typically include detailed speech-perception measures. Hence, recommendations for treatment are often made without a clear understanding of how well children can process speech input. Here, we explore how some of the techniques and concepts from the field of developmental psychology can be translated for the study of pediatric HL and potentially improve identification and management practices.

What is the significance of this article for the general public?
This article outlines how methods from developmental psychology that probe how typical infants discriminate aspects of speech can be used to evaluate children with various degrees of hearing loss. This approach has the potential to improve intervention practices and language outcomes in children with hearing loss.

Keywords: hearing loss, infancy, speech processing, assessment, language outcomes

"Hearing is the velcro to which other skills such as attention, spoken language, reading, and academic competencies are attached" (Cole & Flexer, 2007). Yet, for thousands of children who are born deaf or hard of hearing (DHH) each year, having access to this fundamental

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ability and successfully navigating a primarily "hearing world" is definitely not a given. Nevertheless, hearing loss (HL) is a reality our society faces, as there is a high incidence of children who are born with hearing difficulties in the United States and around the world. Within the United States, approximately three in 1,000 newborns are affected by HL (Finitzo, Albright, & O'Neal, 1998; Ross et al., 2008). This prevalence rate is comparable to other developed nations, such as the United Kingdom, Australia, Brazil, and Sweden, where statistics are collected (Ching, Oong, & Van Wanrooy, 2006; Fortnum et al., 2001; World Health Organization, 2010). Unfortunately, most countries worldwide (especially developing ones) have not yet adopted early hearing-detection and -intervention practices, and as a result, reliable population-based data on the prevalence of deafness in these countries is very scarce (Mackenzie, 2004). Some of the main causes of HL in newborns are heredity, meningitis, cytomegalovirus (CMV), and low birth weight (Schildroth, 1994). Both CMV and low birth weight have been correlated with lower socioeconomic conditions, and in turn, delayed or no prenatal care (Centers for Disease Control & Prevention, 1999; MacDorman & Atkinson, 1999). This means that African American, Hispanic, and American Indian children are more likely to be born with some degree of HL than Caucasian children in the United States (Schildroth & Hotto, 1995).

About half of DHH children have moderately severe to profound HL, making them unable to adequately perceive and process speech, even after amplification through a hearing aid (HA; Gallaudet Research Institute, 2002). Although there have been extraordinary developments in early identification and intervention, there is still enormous variability in language outcomes for DHH children (Lederberg, Schick, & Spencer, 2013), partly due to appropriate interventions being selected too late. There is a growing amount of evidence suggesting that early access to language and speech is essential for language development (e.g., Houston, Stewart, Moberly, Hollich, & Miyamoto, 2012; Nicholas & Geers, 2013; Tomblin, Barker, & Hubbs, 2007; Werker & Hensch, 2015). It is then vital to comprehend how much activity, if any, is present in the auditory system at an early age, and the extent to which speech sounds can be processed by the infant, depending on the type and degree of HL. This calls for the development of objective measures that can help monitor the benefit of amplification in supporting spoken-language acquisition, and guide timely intervention with cochlear implantation (CI; Niparko et al., 2010). In this article, we lay out how tools from developmental psychology can be translated to help with clinical decision-making in the management of pediatric HL to potentially allow DHH infants earlier access to language input (i.e., by 12 months of age as currently approved by the United States Food and Drug Administration).

HL in infants is often described as being "silent and hidden," two characteristics that make identification of the condition and understanding of its severity particularly challenging. Once a child is diagnosed as having a HL, HA or CI candidacy is typically determined based on anatomical and audiometric findings. As seen in Table 1, depending on the degree of HL, the recommendation for intervention can be very clear—as in the case of the 27% and 32%

Table 1
Classification, Frequency, and Intervention Parameters for the Identification and Management of DHH Children (Gallaudet Research Institute, 2002)

	Diagnostic category	% of DHH population	Recommendation
dB loss ←	Mild to moderate	27%	HA
	Moderate to severe	41%	CI/HA (?)
	Profound	32%	CI

Note. DHH = deaf or hard of hearing; parameters used for determining hearing aid (HA) or cochlear implant (CI) candidacy following a hearing-loss diagnosis; classification into a diagnostic category is based on thresholds obtained through audiometric measures. The two additional columns indicate the frequency of occurrence for each category, and the typical recommended intervention; children in the grey area fall in the moderate-to-severe range, making interventions harder to determine.

of children that fall in mild-to-moderate and profound groups, respectively, or less clear—as in the 41% of cases in the gray area that fall in the moderate-to-severe range (Gallaudet Research Institute, 2002). In addition, following guidelines for early intervention after the diagnosis of HL, infants typically complete a "hearing aid trial" meant to determine whether the HA is providing sufficient benefits, or whether a CI is necessary (Tye-Murray, 2014; Uhler & Gifford, 2014).

Although CIs have become a successful intervention for treating pediatric deafness, not all children who are implanted achieve desirable linguistic outcomes. In fact, many CI users have fewer words in their vocabularies than typically hearing children by the time they start preschool (Lederberg et al., 2013; Prezbindowski & Lederberg, 2003). DHH children are also at greater risk for serious reading deficiencies (Carney & Moeller, 1998). In addition, only about 50% of children who receive a CI are successful at acquiring spoken-language skills that match those of their typically hearing peers (Beer, Peters, & Pisoni, 2014; Geers, Nicholas, Tobey, & Davidson, 2015; Houston, Ying, Pisoni, & Kirk, 2001). What is the reason for this large amount of variability?

Unfortunately, there are serious limitations associated with current clinical practices. First, the audiograms used for diagnosis and patient classification only provide information about hearing *thresholds* (Fowler, 1930), and do not measure infants' ability to actually *perceive and process* speech. In the absence of better diagnostic tools, clinicians miss a considerable amount of detail about the child's auditory processing abilities. Whether children will profit from HAs is particularly unclear for DHH children who fall in the moderate-to-severe range, given that the devices might simply be amplifying sounds that remain distorted and meaningless to the child. And these are not the only children with hearing problems who are affected by present clinical practices. Auditory neuropathy spectrum disorder (ANSD) is a condition in which patients show a great deal of unexplained variability in terms of hearing thresholds and actual linguistic outcomes (Rance, Cone-Wesson, Wunderlich, & Dowell, 2002; Zeng, Oba, Garde, Sininger, & Starr, 1999). Some infants with ANSD have little to no sound awareness, whereas others appear to have normal hearing with the exception of difficulty hearing in noisy environments (Kraus et al., 2000; Rance et al., 2012; Sininger & Starr, 2001). The majority of ANSD patients, however, have inconsistent auditory responses: The hearing levels on the audiogram for an individual can range from normal hearing to a profound HL (Berlin, Morlet, & Hood, 2003), and these thresholds are usually out of proportion with what is observed during behavioral audiograms (i.e., when patients are asked to provide an answer based on what they can hear; Berlin et al., 2003).

Second, HA trials can be lengthy and assessment of children's progress during this period is limited. The duration of the trial period typically varies depending on the degree of HL, making it difficult to know if the child is not succeeding with the HA and needs a CI. Research tells us that profoundly deaf infants should receive CIs as early as possible (Cole, & Flexer, 2007; Svirsky, Teoh, & Neuburger, 2004). But for those 41% who fall into the moderate-to-severe gray area, it is often not until they are 18 months or older and still not showing any clear language understanding with HAs, that CIs become an option (Fitzpatrick et al., 2009). Although the audiologic criteria for cochlear implantation have evolved over the years, from bilateral total deafness (>110 dB HL) in the early 1980s, to severe HL (>70 dB HL) in the 1990s, to now include suprathreshold speech-based criteria (<50% open-set sentence recognition with properly fitted HAs) in postlingual individuals (Zeng, 2004), as of today, there are still no accepted guidelines for best clinical practices (Sorkin, 2013). As implantation is expensive and irreversible, clinicians currently wait to make sure that the child is not progressing with the HA before recommending a CI. Unfortunately, what this means for a large number of children with moderate-to-severe HL is that they fall behind in language development while they wait to be identified as needing a CI.

Combining speech-perception measures with audiological ones for assessment during the trial period has been a goal for more than 10 years (Vaughan, 2005). However, in most clinics, the benefit of the amplification is still determined based primarily on parental reports and basic auditory testing (Uhler & Gifford, 2014). That is, standard clinical procedures always include the search for auditory thresholds (audibility), but less often, the assessment of speech perception, with and without HAs, at least in preverbal infants. It is often reported in clinical publications that obtaining speech-perception measures in young infants is "hindered" due to the limited cooperation and limited linguistic skills that are present at earlier ages (e.g., Ben-Itzhak, Greenstein, & Kishon-Rabin, 2014). This observation emphasizes the fact that diagnosis and treatment for DHH individuals has, for the most part, relied on behavioral responses from infants who do not respond on command. A disconnect between research in the field of infant speech perception and DHH diagnosis has deprived clinical practices of methodologies that have been in place for decades in the research world, and that would be invaluable for guiding diagnosis and intervention of DHH infants. Researchers have masterfully designed and implemented tools that overcome infants' limited linguistic and behavioral skills. However, without clinical goals in mind, researchers who study typically developing infants have not established the reliability and predictive validity of these measures, which are needed for expanding their application to clinical settings.

What Developmental Psychology Can Offer: Advancing Our Knowledge about Language Acquisition and the Importance of Early Access to Sound

A fundamental question in the study of language acquisition is the role of experience. Over the years, studies have provided information about the importance of hearing language to shape perception and reach proficiency (Houston, 2016; Houston et al., 2012; Nicholas & Geers, 2013; Soderstrom, 2007; Tomblin et al., 2007; Werker & Hensch, 2015). For typically hearing children, listening experience is particularly important early in life, well before infants can produce language. Even newborns and 2-month-olds display preferences for speech over nonspeech analogues of the same words (Vouloumanos & Werker, 2004, 2007) and quickly become experts at identifying and discriminating the sounds, words, and sentences that make up speech (Berko Gleason & Bernstein Ratner, 2016). Early interest in speech input over nonlinguistic sounds is crucial for categorizing the linguistic information infants encounter (Jusczyk & Bertoncini, 1988; Vouloumanos, Hauser, Werker, & Martin, 2010). For example, by 2 months, infants make accurate phonetic distinctions between sounds, even for languages to which they have not been exposed (Conboy, Rivera-Gaxiola, Klarman, Aksoylu, & Kuhl, 2005). By 3 months, children prefer speech sounds over rhesus monkey vocalizations (Vouloumanos et al., 2010), and by 4 months, children attend more to fluent speech than to silence or white noise (Colombo & Bundy, 1981).

But to acquire a complete linguistic system infants must go beyond simply showing preference for speech over auditory analogues. They must learn a great deal of information about sound combinations and how they signal word boundaries in fluent speech (Saffran, Werker, & Werner, 2006). By the time typically hearing infants turn 6–7 months, they can rely on statistical cues such as tracking how frequently syllables appear one after another to segment words in their language (Saffran, 2014; Thiessen & Saffran, 2007). For example, hearing the phrase "pretty baby" allows infants to note that the first syllable of baby—"ba" is often followed by "by," but the last syllable in "pretty"—"ty" is not as often followed by the "ba" in baby. This is because many words can follow the adjective pretty, as in pretty tie, pretty shirt, etc.; that is, the "ty" in pretty precedes many different syllables. By 6 months, children can understand words they hear frequently, such as "mommy" and "daddy" (Tincoff & Jusczyk, 1999), as well as several other common nouns corresponding to body parts and food items (Bergelson & Swingley, 2012; Tincoff & Jusczyk, 2012). Furthermore, individual differences in word recognition during the first and second year of life are linked to vocabulary development, with more rapid language comprehension associated with faster word learning (Fernald, Perfors, & Marchman, 2006). Even though the rate and the timing of vocabulary growth varies considerably in infants with normal hearing, by their third birthday many children can understand hundreds of words (Fenson et al., 1994). In addition, during the first and second year of life, infants are sensitive to the sentence structure of their language (e.g., the idea that in English, the determiner "these" is used with plural nouns; Gómez & Gerken, 1999; Santelmann & Jusczyk, 1998). As early as 8 months, infants prefer the word-order patterns found in their language

(Gervain, Nespor, Mazuka, Horie, & Mehler, 2008) and when they have as few as two words in their vocabulary (at 16 months), they can comprehend lengthy sentences like, "Big Bird is tickling Cookie Monster" (Hirsh-Pasek & Golinkoff, 1991). This means that many months before infants themselves start combining words, they have already mastered most of the key aspects of language.

Although the ability to hear early in life is necessary for language acquisition, there is a reciprocal effect, in that hearing language plays a significant role in auditory neural development. Access to sound is necessary for the stimulation and organization of the auditory centers and pathways of the brain (Berlin & Weyand, 2003; Gordon et al., 2011; Shepherd & Hardie, 2001). Children who are born DHH and for whom speech signals are degraded or absent altogether are missing critical windows for the development of these key systems. Cochlear implantation stimulates the auditory brainstem and leads to developmental plasticity in this area of the brain—even after prolonged deafness in early childhood (Gordon, Papsin, & Harrison, 2003, 2006). However, the same is not true for other neural regions that are fundamental for processing acoustic information; work by Gordon et al. (2011) suggested that failure to receive adequate auditory input in early infancy may result in irreversible stunting of areas in the brain associated with speech processing and language development, such as the auditory cortex. In short, whereas areas like the brainstem remain more "flexible" and can be stimulated by a CI, the auditory cortex appears not to recover. Can anything be done to improve current practices and give DHH children a better chance to successfully acquire a spoken language?

Applications for Clinical Practice From Developmental Psychology

Developmental researchers in the area of language acquisition have established procedures to examine how infants process speech and begin to develop linguistic skills in the first years of life. These paradigms do not demand overt responses from preverbal children, and instead measure either the speed and/or accuracy of behavioral responses (e.g., eye-gaze, head-turning) or the presence of neural responses—both of which are present from a very early age. This means that researchers have developed techniques to work around the "limited cooperation and limited linguistic skills" present during infancy. Each of these methods provides a different view of the phenomenon at hand, and makes it possible to examine what children know about language as their linguistic skills advance (e.g., Golinkoff, Ma, Song, & Hirsh-Pasek, 2013; Hoff, 2012).

Some specific examples of behavioral procedures include the head-turn preference procedure (HPP; Nelson et al., 1995) and the intermodal preferential looking paradigm (IPLP; Golinkoff et al., 2013). These classic behavioral methods rely on infants' preference for either an auditory (HPP) or a visual (IPLP) stimulus. During the HPP, the child is seated inside a three-sided booth with a flashing light in the middle, and a light on each side (see Figure 1). After the infants' attention is drawn to the center blinking light, one of the side lights blinks while a speaker near the light plays an auditory stimulus. The dependent variable is visual fixation time, i.e., how long the infant remains oriented to the auditory stimulus. Using the HPP, researchers have familiarized and tested children with both words (e.g., Mandel, Jusczyk, & Pisoni, 1995) and passages (e.g., Bortfeld, Morgan, Golinkoff, & Rathbun, 2005) to

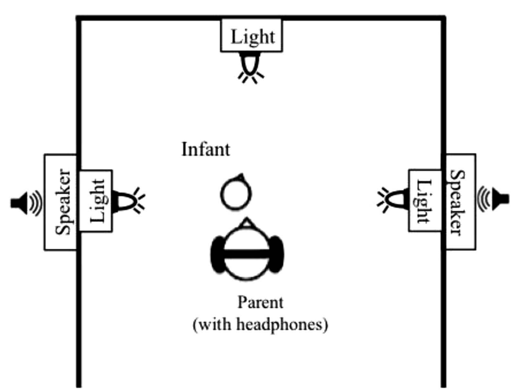

Figure 1. General setup for head-turn-preference procedure (HPP). During this paradigm, the infant is seated inside a three-sided booth with a flashing light in the middle, and a light on each side. After the infants' attention is drawn to the center blinking light, one of the side lights blinks while a speaker near the light plays an auditory stimulus. The dependent variable is visual fixation time, i.e., how long the infant remains oriented to the auditory stimulus.

probe their recognition or identification of acoustic properties of the linguistic input. In the IPLP, children are presented with pairs of images on a single screen accompanied by an auditory stimulus that matches only one of the images (see Figure 2). In the simplest case, the child might see a car and a dog and be asked to, "Look at the dog!" The dependent variable is how long the child looks toward the image that matches what they are hearing (in this case, the dog), versus the nonmatching image (the car).

Developmental psychologists and linguists have relied on these behavioral paradigms for several decades to measure a variety of infants' language-related skills, including the acquisition of the sound structure of their language (e.g., Jusczyk & Aslin, 1995; Mattys, Jusczyk, Luce, & Morgan, 1999; Zamuner, 2006); word-learning and processing speed (e.g., Fernald, Swingley, & Pinto, 2001; Halberda, 2003; Hollich et al., 2000; Swingley & Aslin, 2002); and syntactic acquisition (Fisher & Gleitman, 2002; Hirsh-Pasek & Golinkoff, 1996). To date, these measures have primarily been implemented with typically hearing infants. However, a few studies have successfully used these methodologies to investigate speech perception and early language skills in groups of infants and toddlers with HL (e.g., Houston et al., 2001, 2012; Martinez, Eisenberg, Boothroyd, & Visser-Dumont, 2008).

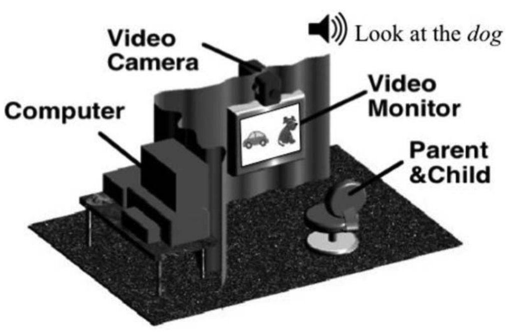

Figure 2. General setup for intermodal preferential looking paradigm (IPLP). In this paradigm, children are seated in front of a video monitor and presented with pairs of images that are accompanied by an auditory stimulus that matches only one of the images. The child might see a car and a dog and be asked to, "look at the dog." A video camera records children's eye movements. The dependent variable is how long the child looks at the image that matches the target word (in this case, the dog) versus the nonmatching image (the car).

Houston and colleagues (Houston et al., 2001, 2012) explored the effectiveness of early cochlear implantation by evaluating DHH children's performance on fundamental linguistic tasks such as word learning. Using the IPLP, congenitally deaf infants with CIs were tested on establishing associations between speech sounds and novel objects that appeared on a screen. Infants who were implanted earlier (between 7 and 15 months of age) and who had 2–6 months of CI experience showed similar patterns of performance to typically hearing infants. On the other hand, DHH infants who were implanted later (between 16 and 25 months of age) were unable to learn word–object mappings (Houston et al., 2001). In addition, follow-up work identified a significant correlation between DHH children's scores on a standardized measure of vocabulary outcome—the Peabody Picture Vocabulary Test (PPVT; Dunn & Dunn, 2007), as well as performance on the IPLP word-learning task (Houston et al., 2012).

Similar behavioral measures have also been adapted to examine DHH infants' discrimination and attention to speech, as these skills are thought to possibly impact various aspects of speech-perception and spoken-language development (Houston, Pisoni, Kirk, Ying, & Miyamoto, 2003). In that study, typical and DHH infants' looking times were compared across trials in which a visual display was either paired with a repeating speech sound or presented in silence. Before receiving a CI, DHH infants showed no difference in looking times across the two types of trials. In contrast, after implantation, CI children showed longer looking times during sound trials than during silent ones. Although this result indicated that CI children were now capable of discriminating speech from silence, the difference between trial types was significantly smaller than that obtained with typically hearing infants.

Taken together, these findings suggest that early sound exposure, and specifically, exposure to speech, plays an important role in the development of speech-discrimination abilities and vocabulary growth. Most importantly, this work raises the possibility that behavioral techniques from developmental psychology can provide early predictive measures of vocabulary outcomes and language performance. Findings with both typically hearing and DHH infants can be used to create guidelines to enable us to better understand the relationships between hearing thresholds, speech-processing skills, and later linguistic skills. We contend that these processing measures will be even more predictive of language outcomes than an audiogram, particularly for children who fall in the gray area of HL. Given that these methods are inexpensive and informative and can be used in the clinic, administering a battery of such tests to infants with a hearing impairment is possible. Further research may indicate that this additional information is valuable for guiding interventions and identifying DHH infants earlier, especially those who are at risk for difficulties in language development.

There are, however, some challenges to overcome. The majority of research using infant-language paradigms has focused on evaluating group effects, not individual differences. There is still a need to further explore how reliable these measures are in individual, typically hearing children (Cristia, Seidl, Singh, & Houston, 2016), as well as across laboratories. Establishing the reliability of the methods used with typically hearing children is fundamental for translating these methodologies for use with largely heterogeneous populations, such as DHH infants, who typically differ with respect to the etiology and the degree of their HL (Houston, Horn, Qi, Ting, & Gao, 2007).

Beyond these behavioral techniques, there have been methodological advances that enable the investigation of language development from a different perspective. Specifically, the areas of electrophysiology and neuroimaging have provided researchers with alternative methods for measuring infant-speech processing (Kuhl, 2010). Nevertheless, before these techniques can be used as clinical tools for assessing speech discrimination in *individual* infants, additional work is needed to cross-validate these methods with behavioral ones in the same babies (Purdy et al., 2004).

The process of translating laboratory-based measures of infants' speech processing as viable clinical tools in the management of DHH infants has some clear but fordable challenges. Establishing the long-term predictive validity of speech-perception tests for later language learning is crucial, as is identifying which language-related skills are most predictive of later success. Determining if children are progressing as they should with a HA, or if they should receive further intervention in the form of a CI, is essential if we are to reduce the wide variability in language outcomes for DHH children. In typically hearing infants, this longitudinal research is just beginning, but early findings suggest that there is indeed a link between speech-processing skills in infancy and their relation to language development many months later (Kuhl, 2008; Kuhl, Conboy, Padden, Nelson, & Pruitt, 2005; Werker & Fennell, 2008). It is time to explore these links in DHH children.

A Call to Action: Time to Take More Steps in the Right Direction

The good news is that some researchers are already aware of the above challenges, and are focusing efforts on identifying which measures are best for examining individual variability in typical and DHH infants (e.g., Cristia et al., 2016; Houston et al., 2007). There is also an ongoing effort to replicate a fundamental phenomenon across labs—infants' preference for infant-directed speech over adult-directed speech (Frank, 2015). However, more developmental researchers need to join "the search for reliable infant speech perception tasks" (Cristia et al., 2016, p. 649). This is a crucial first step in bringing methodologies from psychological science to a level where they can be given practical applications outside of the lab. As Cristia and colleagues emphasized, one way to achieve this is through "cross-laboratory collaboration, and potentially even large-scale crowd sourcing," an approach that has proven successful in other areas. For example, a "many labs" initiative by Klein et al. (2014) assessed the replicability of 13 specific effects in the social sciences. By implementing a similar approach in the language sciences, we have the potential to greatly advance our understanding of the test–retest reliability and predictive validity of commonly used linguistic measures. Following this approach, collaborators across labs would identify, test, and retest specific speech-perception tasks (e.g., sound discrimination, word recognition) with typically hearing and DHH infants. Labs would then contribute to a large dataset that would be used to capture the range of performance on these measures and their relationship to language outcomes. These findings would greatly assist in interpreting results in clinical settings. For example, an infant in the gray area of HL who falls within the typical range of performance on multiple speech-perception tasks would require a different intervention than a child who shows no evidence of the speech-processing abilities these tasks reveal. This information would complement what is known about the child's audiological thresholds, making it possible to tailor interventions based on individual needs.

There are some important factors to keep in mind as we take these steps. First, collaborations are necessary between specialists in language development, hearing scientists, and clinicians involved in the care of children with HL (e.g., audiologists, speech-language pathologists, ear–nose–throat specialists). Second, having multiple labs simultaneously conducting analyses and sharing data that examine individual variability will speed up this much-needed process. Lastly, having test–retest reliability information and norms from typically hearing infants would be an important and informative accomplishment. But the work cannot stop with typically hearing infants. Collecting data from DHH infants with a range of HL is crucial to tracing the development of language and for making medical decisions.

Taken together, the field of developmental psychology is in a position to offer valuable tools for the management of pediatric HL. Adapting research approaches to the management process that DHH infants undergo can provide more detailed information about children's auditory processing profiles, which might make it possible for appropriate interventions to be identified more timely and efficiently—especially for those infants in the gray area who are in the HA trial. It is important to note that such practices could help determine the degree to which auditory thresholds are related to the development of different speech-processing skills. DHH children for whom a HA is the appropriate intervention might show similar patterns to the ones identified in typically hearing children; insufficient HA benefits might lead to divergent results. We are in a position to conduct translational science to answer these questions and potentially improve language outcomes for DHH children.

Implications for DHH Infants, Caregivers, Educators, and Society

The implementation of this translational approach has significant implications for the language outcomes of DHH children because it might shorten the time infants remain in an HA trial if they actually require a CI. It is now well-established that cochlear implantation by the age of 12 months is highly desirable (Dowell, Dettman, Blamey, Barker, & Clark, 2002; Houston et al., 2012), and allows for better development of auditory, language, and cognitive abilities than implantation after the first year (Colletti, 2009; Dettman, Pinder, Briggs, Dowell, & Leigh, 2007; Holt & Svirsky, 2008; Nicholas & Geers, 2006). Implantation by 12 months allows the majority of children to reach age-appropriate speech and language skills by 24 months (Holman et al., 2013), whereas children who are implanted later experience delays in speech perception, speech production, and overall linguistic development (Colletti, 2009; Dettman et al., 2007; Holt & Svirsky, 2008; Robbins, Koch, Osberger, Zimmerman-Phillips, & Kishon-Rabin, 2004; Schauwers et al., 2004; Schauwers, Gillis, Daemers, De Beukelaer, & Govaerts, 2004; Waltzman & Cohen, 1998). Some research further suggests that DHH infants must be identified and receive appropriate intervention before 6 months of age (Yoshinaga-Itano, Sedey, Coulter, & Mehl, 1998) if they are to acquire language skills comparable to those of typically hearing children. Hence, reducing the length of time a DHH child remains in an unsuccessful HA trial is crucial for allowing DHH children to acquire linguistic skills in a timely fashion. Furthermore, DHH children's linguistic outcomes have critical implications for society. Language is *the* core ability that children rely on to succeed in school, as it allows them to understand teachers and peers, engage in conversation, learn to read, and even acquire mathematical skills (Harris, Golinkoff, & Hirsh-Pasek, 2011). Without the early linguistic input necessary for the development of language, DHH children, their families, and educators are likely to experience long-lasting struggles. Special education for a child with HL who fails to receive the appropriate early intervention costs schools an additional $420,000, with a lifetime cost of $1 million per individual (Johnson et al., 1993).

A more efficient method of evaluating DHH infants' speech-processing abilities can therefore offer a variety of benefits. First, it can prevent delays in language and speech acquisition, and associated lags in later academic achievement. Second, it can reduce the costs of special education. Third, it has the potential to result in emotional benefits for caregivers and their DHH children. Some studies suggest that timely identification and treatment of pediatric HL leads to a decrease in parental stress and an increase in parent–child bonding, which in turn results in quicker resolution of parental grief following child diagnosis (Yoshinaga-Itano, 2003; Yoshinaga-Itano & Apuzzo, 1998).

Translational measures can be particularly helpful for infants from racial and socioeconomic minorities as the prevalence of HL is higher in African American, Hispanic, and American Indian children (Schildroth & Hotto, 1995). Furthermore, the linguistic input that children receive varies as a function of socioeconomic status, and this too, influences children's language acquisition (Hoff, Laursen, & Tardif, 2002; Hoff & Naigles, 2002). This means that DHH children from underrepresented groups are at a much higher risk for falling behind in a variety of areas, including linguistic development. It is beyond the scope of this paper to discuss differences in identification and management options for these different groups. However, see (Eyalati, Jafari, Ashayeri, Salehi, & Kamali, 2013; Scott, 2000) for further discussion.

Summary and Conclusion

The means for promoting successful language outcomes in DHH children are still unresolved because of uncertainties in uncovering whether preliminary interventions are working. This problem often leads to long-term delays in children's language and cognitive development. By bridging research and clinical practices, we have the potential to enhance our scientific understanding of DHH children's language development, and to impact current practices. Health-care providers are forced to make recommendations about which interventions are best for DHH children without a clear understanding of how measures of auditory thresholds relate to speech perception. Caregivers must make decisions regarding the type of intervention their DHH children require without sufficient data.

We have learned that audiological measures alone are insufficient for evaluating whether DHH children can process the details in speech that are necessary for acquiring spoken language (Fowler, 1930). Thus, to successfully acquire a language, more than raw perceptual ability is required; a listener's skill in processing speech signals must also be assessed. For example, in some DHH children, the listening thresholds are out of proportion with their ability to actually process speech signals (Berlin et al., 2003).

The field's limited understanding of how DHH infants develop speech-processing skills, and the inability to select appropriate and timely interventions means that many children remain uncertain for long periods of time when they could receive CI and be on the road to language development. We do know that typical infants engage in a considerable amount of linguistic learning early in life—finding the sounds, word boundaries, and argument-structure patterns of their language, long before they even utter a single word. Unfortunately, health-care providers must currently wait until DHH children show clear signs that they are not progressing well, which inherently means they are already falling behind. When children do not receive the appropriate intervention early enough, they are being deprived of vital input during a critical period for neural and linguistic development.

There is a clear need to more thoroughly assess speech-perception skills in DHH infants early in the management process. The good news is that the field of developmental psychology offers powerful tools to measure how babies acquire language. Behavioral techniques such as the HPP and IPLP, as well as electrophysiological and neuroimaging measures, are ripe for use in studies with DHH infants. By translating these long-standing research methods to clinical applications, clinicians might well achieve a more comprehensive and nuanced understanding of DHH children's listening and linguistic abilities. To accomplish this goal, future researchers should examine the test–retest reliability of these measures with typical and DHH infants. Only then can we know how the degree of HL and speech-processing capability influence infants' language acquisition.

Imagine if we could obtain a more complete listening profile for DHH children, thereby providing more hearing-compromised infants with the appropriate treatment at an earlier age. Preventing delays in language and speech development, associated lags in later academic achievement, and ensuing behavioral problems may well be within our reach.

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