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Influence of auditory experience on the outcomes of children with hearing aids: ACCESS matters

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Abstract

In an era of early identification of infants who are hard of hearing, we expect to see improving linguistic outcomes for this population. Only recently have researchers begun to ask if we are accomplishing this goal, and, if not, what factors account for variability in outcomes. This paper examines both questions by synthesizing evidence from a multi-site longitudinal study, called Outcomes of Children with Hearing Loss (OCHL). Emphasis is placed on the importance of optimizing children's access to linguistic input and cumulative auditory experience in order to foster positive outcomes.

Introduction

Beginning in infancy, typical language learners tune in to the linguistic exposure provided in the environment. This exposure to linguistic input and engagement in social interactions are foundational to children's language development. Children who are exposed to more words have more advanced vocabulary (Hart & Risley, 1995; Huttenlocher, Haight, Bryk, Seltzer, & Lyons, 1991) and increased processing efficiency (Hurtado, Marchman, & Fernald, 2008) compared to children exposed to fewer words. Infants are active learners who are believed to rely on statistical learning processes (Elman, 1990; Saffran, 2003) to detect regular patterns in the input, supporting their identification of word boundaries, word classes, and grammatical learning (Farmer, Christiansen, & Monaghan, 2006). This language learning process requires access to acoustic-phonetic properties in the input signal, which can be altered in consistency and/or quality when the learner has hearing loss. In this paper, we explore factors that serve to support or constrain children's access to input. We will also consider factors that influence access and cumulative auditory experience, based on a synthesis of results from the Outcomes of Children with Hearing Loss (OCHL) project. An overarching theme is why access to language experience matters for children who are hard of hearing.

Background: the OCHL study

Prior to the implementation of newborn hearing screening (NHS), children who were hard of hearing (CHH) were typically late-identified (20 months of age or older) by today's standards. As a result, studies exploring the impact of mild to moderately-severe hearing loss on infants' early access to linguistic input were not possible. To compound matters, CHH have historically been overlooked in the research literature. Earlier generation studies typically included small samples of school-age children and rarely assessed the contribution of aided hearing to children's outcomes (Moeller, Tomblin, Yoshinaga-Itano, Connor, & Jerger, 2007). There was a critical need to determine if early service provision following NHS was successful in preventing or minimizing language delays often associated with untreated hearing loss, but only in recent years have studies begun to focus specifically on early-identified children who are fit with hearing aids (HAs). The National Institute on Deafness and Other Communication Disorders funded the OCHL study, among others, to address this research question. The OCHL project is a multi-site, longitudinal study that is a collaborative effort of researchers at the University of Iowa, Boys Town National Research Hospital, and the University of North Carolina at Chapel Hill.

At the outset of this study, we recognized that a large and diverse sample was needed to gain a clear understanding of factors that contribute to risk or resilience in communicative development for individual CHH (Tomblin & Hebbeler, 2007). To achieve this goal, we recruited from a broad catchment area surrounding our three investigative sites, and we implemented an accelerated longitudinal design (see Tomblin et al., 2015). Eligible children were enrolled at any age between 6 months and 6 years, 11 months and then were followed prospectively from their ages at entry for a period of at least 3 years. Thus, the OCHL design involved multiple cross-sectional age cohorts with sufficient overlap to conduct longitudinal analyses. Children met study criteria if they had bilateral, mild to moderately-severe hearing loss, used spoken English in the home, did not have cochlear implants, and did not present with major secondary disabilities. The OCHL team followed 317 CHH and a control group of 117 children with normal hearing (CNH), who were matched on socioeconomic status and age (see Table 1). Children were assessed annually (with more frequent assessments for children under 2 years of age) on a comprehensive battery of audiological, language, developmental, and family measures. Extensive methodological details are provided in Tomblin et al. (2015).

	CHH (n = 317)	CNH (n = 117)
Gender		
Male	55% (n = 173)	46% (n = 54)
Female	45% (n =144)	54%(n = 63)
Maternal Education		
Completed high school	17%	23.1%
Limited postsecondary education	31.6%	13.7%
College graduate	25.2%	31.6%
Postgraduate degree	26.2%	31.6%
Hearing Variables	**CHH (n = 290)**	**CNH (n = 117)**
Mean better-ear PTA	48.73 dB HL (SD = 13.48)	< 20 dB HL
Slight/mild	24% (n = 69)	
Moderate	52% (n = 150)	
Moderately-Severe	22% (n = 64)	
No data at baseline visit	2% (n = 7)	
Referred from NHS	75.7% (n = 220)	
Fitted with hearing aids	98% (7 without)	

Note: Groups were not significantly different on maternal education (Wilcoxon $Z(1) = 1.61$, $p = 0.11$), but both groups were more advantaged than a typical U.S. distribution. NHS = newborn hearing screening; PTA = pure tone average.

Table 1. Selected characteristics of the full Outcomes of Children with Hearing Loss (OCHL) sample.

Model of factors explaining individual differences

As practitioners, we have all seen children with nearly the same audiograms who have quite different communicative outcomes. These cases help us recognize that unaided hearing does not operate alone to influence children's language development; other child-, intervention-, and family-specific factors are likely to interact and play a synergistic role. The OCHL team hypothesized that factors that limit children's access to linguistic input would also lead to reductions in auditory-linguistic experience over time, with consequences for language development. Factors related to the hearing loss itself or the amplification (e.g., audibility, spectral degradation, low pass filtering), and/or environmental factors (e.g., distance, noise, and reverberation) can all serve as barriers to access, alone or in combination. We reasoned that variations in children's access to input and the cumulative impact on auditory-linguistic experience may underlie individual differences in outcomes (see Moeller & Tomblin, 2015). We identified three specific factors predicted to influence access (see Figure 1) including 1) audibility with HAs, 2) duration and consistency of HA use, and 3) language input provided in the environment.

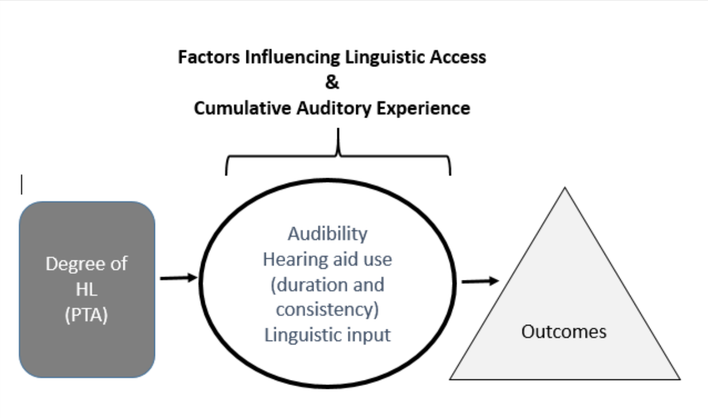

Figure 1. Simplified model of factors influencing children's cumulative auditory experience (see Moeller & Tomblin, 2015).

In the sections that follow, we synthesize evidence from several OCHL studies, including a set of studies that tested the access model (Figure 1) and was published in an *Ear and Hearing* supplement (see www.ochlstudy.org). Given the nature of the current proceedings article, only highlights of the work can be shared, and the reader is encouraged to look to the original manuscripts for rich details and additional findings. In the current paper, we will consider the model of cumulative auditory-linguistic experience in the context of six audiological service-related factors predicted to matter for children's development. These are presented as an acrostic (ACCESS) in Figure 2. We examine evidence we garnered related to each factor and suggest implications for clinical practice and research.

A	Audibility.
C	Carefully fit and closely monitored devices.
C	Consistently worn devices from early infancy.
E	Environment is conducive to language learning.
S	Selected aspects of language considered "at risk" receive attention.
S	Service provision is optimized.

Figure 2. ACCESS: Service-related factors predicted to matter in terms of developmental outcomes for young CHH.

Service-related factors predicted to matter and research findings

Audibility

The first study to examine aided audibility in relation to language outcomes in CHH was conducted by Stiles, Bentler, and McGregor (2012). They found that individual differences in children's language outcomes were explained by the aided Speech Intelligibility Index (SII), which is a weighted proportion of the amount of the speech spectrum that is available to a listener wearing HAs. Values of the SII can range from 0 (none of the speech spectrum is audible) to 1 (the full speech spectrum is audible). Stiles and colleagues concluded that aided SII values greater than 0.65 were associated with better language outcomes than values below 0.65, and that the aided SII might provide a more valid estimate of a child's access to auditory input available for uptake and language learning than unaided hearing. The OCHL study sought to document the aided audibility of a large group of preschool-aged children and determine the relationships between SII and language outcomes for this group. Thus, methods included use of probe microphone measures to verify speech audibility (unaided and aided SII) and maximum output at each study visit. McCreery and colleagues (2013) found that most of the children in the OCHL study had aided audibility that exceeded 0.65. However, approximately 26% of the children in the study fell below this threshold, indicating less than ideal aided audibility levels that may play a role in individual differences in outcomes.

In order to examine audibility (SII) in relation to outcomes, we were particularly interested in isolating the boost in audibility provided by HAs and its effect on language over time. However, it was necessary to first consider that the amount to which HAs can improve the SII is limited by the child's degree of hearing loss. A child with a moderately-severe hearing loss might receive a large boost in audibility with amplification relative to their unaided hearing, yet still have restricted overall audibility (e.g., SII < 0.65). In contrast, a child with a mild loss needs only a small amount of gain to reach high levels of audibility. To examine the unique contribution of aided hearing to outcomes, Tomblin and Oleson (see Tomblin, Oleson, Ambrose, Walker, & Moeller, 2014) developed a measure called residualized SII (rSII) that essentially leveled the playing field across children with varying degrees of loss by controlling for unaided hearing in regression analyses. The rSII represents aided benefit or boost in audibility after controlling for degree of hearing loss. The rSII was examined in a cross-sectional analysis of outcomes for 180 3- and 5-year old CHH. Results revealed that the boost in audibility (rSII) provided by HAs was significantly correlated with both speech production and language outcomes for these children. Importantly, the benefit of improved audibility from HAs was realized for children with all levels of hearing loss, including mild (Tomblin et al., 2014).

In a second study, the research team examined the contribution of rSII to language growth over time, as reflected in composite measures of language ability from ages 2 to 6 years, while controlling for maternal education. Results are illustrated in Figure 3, where predicted language scores (growth curves) are plotted as a function of age for four subgroups, representing quartiles from lowest to highest rSII. Although audibility did not have an overall effect on language ability, it was significantly related to differential rates of language growth. Notice in Figure 3 that the children in all of the quartiles had similar language abilities at age 2 years, but after this age, their trajectories show considerable divergence. The children with the highest benefit from HAs demonstrated a positive pattern of growth in language, while those with the most limited benefit show no evidence of change in language level from 2 to 6 years. By age 6 years, the difference between these highest- and lowest-benefit groups was two-thirds of a standard deviation, showing a large cumulative effect of aided audibility on language growth (Tomblin et al., 2015). This study provides strong evidence that benefit or boost in audibility provided by HAs promotes language growth over time.

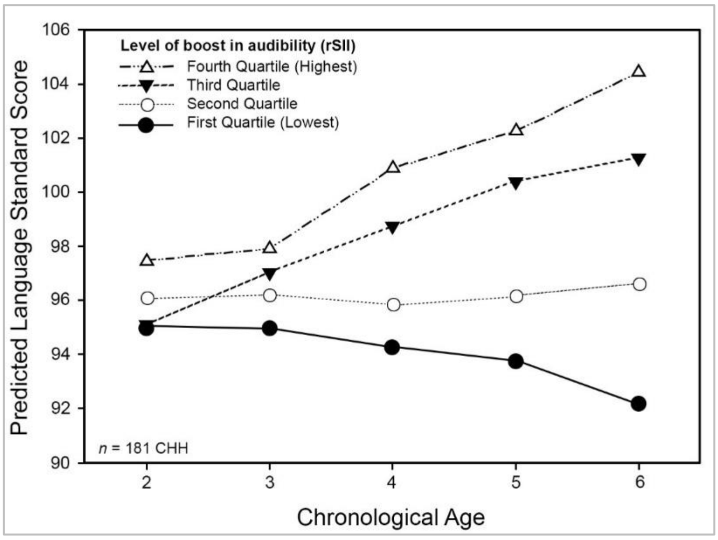

Figure 3. Average predicted language scores for CHH based on longitudinal mixed modelling across the ages 2 to 6 years. Quartiles represent levels of gain in audibility as measured by the residualized SII (rSII) (from Tomblin, Harrison, et al., 2015).

Note: rSII = residualized speech intelligibility index; CHH = children who are hard of hearing.

A final study that speaks to the contribution of aided audibility to outcomes explored the accurate use of s-related morphemes in spontaneous language samples collected from 51 3-year old. CHH (Koehlinger et al., 2015). Results showed that, in addition to other factors, children's aided sensation level, or amount of gain provided above the hearing threshold, at 4-kHz was a significant predictor of accurate morpheme use. This finding adds to the evidence indicating a contribution of aided hearing in the high frequencies to children's grammatical development. Taken together, these three studies provide evidence for the view that optimized aided audibility benefits language development in CHH.

Carefully fit and closely monitored devices.

Given that the evidence confirms that audibility provided by HAs benefits children's linguistic development, it is essential for us to determine if HAs are fit in a way that **does** optimize audibility. Best-practice HA verification protocols include the use of probe microphone measures to estimate the audibility of speech (Bagatto, Scollie, Hyde, & Seewald, 2010). Prescriptive formulae are used to derive target values for selecting appropriate gain across speech frequencies in order to maximize speech audibility. One measure for determining HA fitting adequacy involves comparing the goodness-of-fit of actual gain to the prescribed target. Deviations from targets at 500, 1000, 2000, and 4000 Hz are represented as average root-mean-square (RMS) error. McCreery and colleagues (2013) examined the appropriateness of fit-to-target using HA fitting data from 195 CHH enrolled in the OCHL project compared to Desired Sensation Level targets (Scollie et al., 2005). A benchmark of less than 5 dB RMS error was considered to be appropriate fit-to-target. Results showed that proximity to target averaged 6.6 dB across all fittings, which exceeded the 5 dB criterion. Furthermore, 55% of the children in the study had HAs that exceeded 5 dB RMS error in at least one ear. Critically, RMS error was a significant predictor of audibility. A follow-up study confirmed these results by examining longitudinal data from 288 CHH in the OCHL study (McCreery et al., 2015). The findings indicated that over half of the children's HAs had RMS error deviation from prescribed targets that was greater than 5 dB at each of their first four study visits. Approximately 35% of the children had aided audibility values that fell below normative expectations (from Bagatto et al., 2011). Further analysis of longitudinal patterns of audibility showed that children who experience limited aided audibility due to decreasing (worsening) hearing thresholds or HA fittings with poor match-to-target or a combination of these factors might be at particular risk for language delays (McCreery et al., 2015). Our best line of defense in preventing such delays includes careful fitting and ongoing verification of HAs following recommended practice protocols (Bagatto et al., 2010).

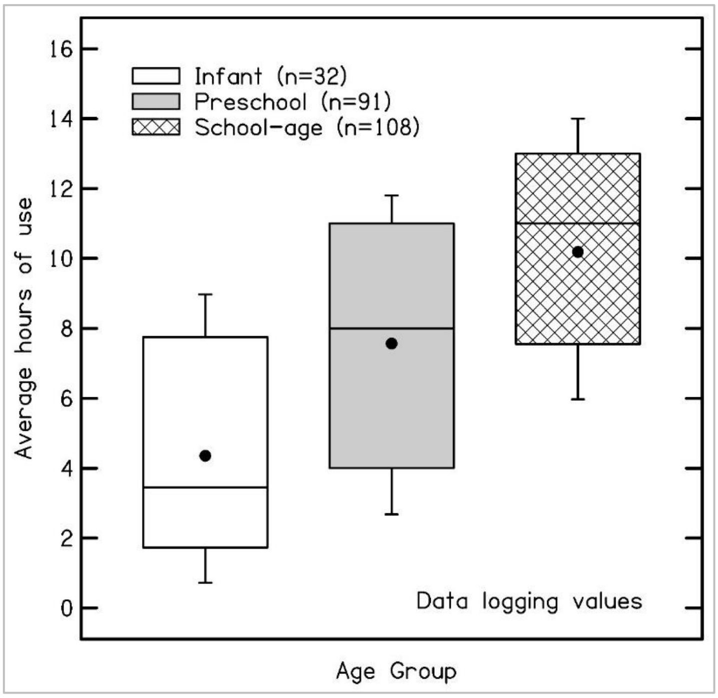

Figure 4. Box plots representing average hours of daily use based on data logging values for three age groups. Black dots are means, with central lines representing median values. Box limits represent 25th and 75th percentiles (fences extend to 10th and 90th percentiles).

Consistently worn devices from early infancy.

We can fit HAs to provide optimal audibility, but if the infant or young child does not wear them, benefits for language learning might not be realized. Walker and colleagues (2013) documented variability in amount of HA use in young CHH and determined that age, maternal education, and degree of hearing loss were significant predictors of use time. Younger children, children from families with lower education levels, and children with milder degrees of hearing loss were the least regular HA users.

In a follow-up study, Walker and colleagues (2015) examined HA use over time in 290 CHH who participated in the OCHL project. A key finding from this study is highlighted in Figure 4. Based on data logging values, HA use increased across the three age groups represented. Notably, the average data logging values for infants was approximately 4.2 hours, which is well below the ideal goal of use during all waking hours. Given that infants are in a particularly sensitive period of language development, the important implication is the need to provide additional supports to families of young infants who are experiencing challenges in regard to HA use consistency. This second study confirmed that families with less education are particularly at risk for HA use challenges and may require unique supports.

More research is needed to determine what family counseling practices are most effective in addressing individual barriers and challenges to HA use. Three key findings from the OCHL team could be shared with families to support their understanding of the benefits of HA use. The first is the result showing that children who used their HAs more than 10 hours daily had stronger language learning rates than children using HAs less than 10 hours daily (see Figure 5; Tomblin, Harrison, et al., 2015). The second result relates to the duration of HA use during the preschool years. Our findings suggest a developmental advantage for HA fittings in infancy. The language growth trajectories of early-fit children showed that they were protected from delays or caught up to CNH by 2 years of age. However, later-fit children showed accelerated growth once aided, and had language skills comparable to early-fit children by 6 years of age (Tomblin, Harrison, et al., 2015). These results can provide encouragement to families who are concerned about their later-fit children; there is opportunity for catching up with peers once HAs are fit and used regularly. Obviously, the results are also encouraging for families of early-fit children, suggesting that our goals of preventing delays are being met for some children. Finally, readers are referred to an important finding from Walker and colleagues (Walker, Holte, et al., 2015), demonstrating better vocabulary and grammatical development outcomes for children with mild hearing loss who used HAs compared to those who did not. Given the uncertainty parents might face regarding the need for amplification for children with mild hearing loss, this evidence is particularly germane to the counseling context.

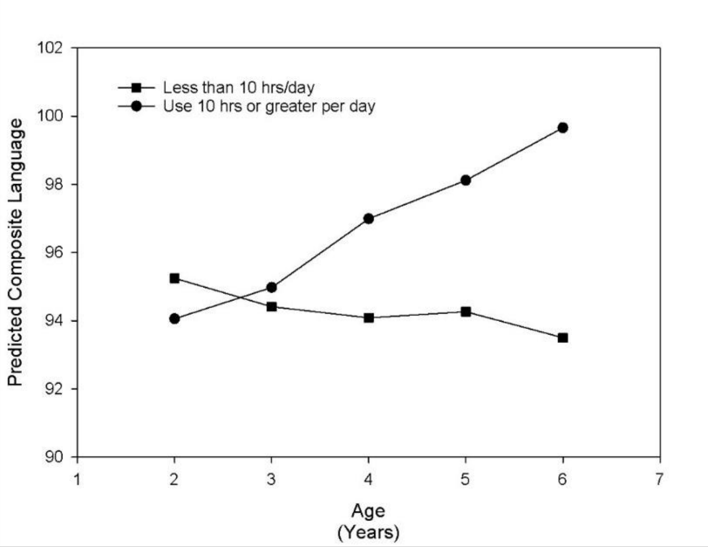

Figure 5. Average predicted composite language standard scores based on a mixed model across ages 2 to 6 years for children who are hard of hearing with 10 or more hours of daily hearing aid use compared to less than 10 hours (Tomblin, Harrison et al., 2015).

Environment is conducive to language learning.

We have argued in this paper that CHH miss opportunities for language exposure due to access barriers that reduce their cumulative auditory-linguistic experience, consequently leading to language delays. Increasing the quality and quantity of language interactions in the environment, a primary goal of early intervention providers, is one way to protect against access barriers. However, little is known about how successful families are at optimizing language environments for young CHH and what impact this has on children's language outcomes. These questions were explored by comparing language input directed by caregivers to CNH and CHH at 18 and 36 months of age within the OCHL study (Ambrose, Walker, Unflat-Berry, Oleson, & Moeller, 2015). Caregivers and children were video-recorded in 5-minute semi-structured interactions. Transcripts were prepared from these interactions for 50 dyads with CNH and 156 dyads with CHH and were coded to characterize a number of quality and quantity features of the caregivers' input. Specifically, utterances that were high-level vs. directive were analyzed.[1]

Results indicated differences in the quality of input directed to CNH and CHH that were especially evident at 36 months of age. The CHH were exposed to fewer different words, shorter utterances, lower proportions of high-level facilitative utterances, and greater proportions of directives than the CNH. Notably, caregiver directiveness was linked to poorer child language outcomes. This work provided evidence that features of the linguistic environment contribute to individual differences in the language outcomes of CHH. Some families of CHH need to be encouraged to adopt responsive rather than directive styles in their interactions, and some might need to be supported to increase the complexity of their talk, if developmentally appropriate for their children.

To explore other aspects of the language environment, the OCHL team collected full-day recordings from 28 CHH who were about 2-years of age using Language Environment Analysis (LENA) technology (Ambrose, VanDam, & Moeller, 2014). Of particular interest to pediatric audiologists is the finding that, on average, 8% of each recording (or about 58 minutes of a 12 hour recording) was classified by the software as electronic media (e.g., television, radio), and for some recordings, the percent of the recording was as high as 18%. Importantly, results showed electronic media was negatively correlated with children's receptive language. However, further analysis revealed that this finding was mediated by adult-child conversational turns. Children who were exposed to high rates of electronic media also experienced fewer conversational turns, which led to weaker receptive language abilities. Parents should be counseled to reduce noise sources like electronic media, with an additional caution about the impact of media distractions on opportunities for conversational interactions that promote child language.

Selected aspects of language considered "at risk" receive attention. The OCHL team hypothesized that CHH may be at differential risk for delays in language domains that are especially dependent on perceptual access to phonetic details in the input. Hearing loss, we proposed, reduces opportunities for perceiving elements that are perceptually subtle, which results in less exposure overall. An example from grammar makes this point. In a sentence like, "She wants more cookies," CHH might be challenged to regularly hear the /s/ on the verb *wants* or the /s/ that makes the word *cookie* plural. Reasons include the fact that many morphemes in English are conveyed by high-pitched fricative sounds (s, z), and the limited bandwidth of HAs can render them inaudible, especially when spoken by females (Stelmachowicz, Pittman, Hoover, & Lewis, 2002). Noise and reverberation can exacerbate access barriers for perceptually subtle features like these morphological endings. This led the OCHL team to predict that CHH might be at greater risk for delays in grammar (e.g., morphology) than in semantic domains, like vocabulary or concept words, which are often in contexts that include redundant language cues.

[1] High-level facilitative utterances were those that elicited conversation and/or talk outside the immediate context, included thinking (know, remember) or feeling (sad) words, or were sincere requests for information or opinions ("Why do you think that?). Directive utterance served to direct the child's actions, attention, or behavior ("sit down," "say ball," "don't touch").

To explore this hypothesis, we tested 154 CHH and 69 CNH at 4 years of age on semantic measures such as basic concepts and vocabulary, and on a morphology task that was designed to elicit production of a variety of word endings. We found that scores for both measures (semantic, morphology) dropped systematically relative to the CNH with increasing severity of hearing loss. However, the morphology scores for the CHH were more depressed relative to the CNH (-1 to -2 standard deviations below) than semantic scores (-0.5 to -1 standard deviations below) as severity of hearing loss increased. Regression analysis showed that morphology was significantly associated with degree of hearing loss after accounting for semantic skills, but degree of hearing loss was not associated with semantic skills after accounting for morphology. This indicates that morphology has a specific relationship with hearing beyond what we found for the semantic measures (Tomblin, Harrison, et al., 2015). Overall, the results confirm that perceptually subtle aspects of language development are especially vulnerable in CHH. Further research is needed to determine the scope of vulnerable domains and to explore whether interventions that provide massed exposure (auditory bombardment) might facilitate language learning in vulnerable domains (Encinas & Plante, 2016).

Service provision is optimized. Service provision is addressed with both a caveat and a cautionary tale. First, the caveat. We have much more to learn about efficacy and effectiveness of early intervention practices for CHH (including home-based services). Detailed discussion of this issue is beyond the scope of this paper, but suffice it to say that well-designed and controlled intervention studies are sorely needed if we are to optimize and tailor early intervention practices for infants who are hard of hearing. And now the cautionary tale. Results of the OCHL study demonstrated that the language abilities of CHH differed significantly from CNH who were matched on age and socioeconomic status across the preschool years (see Figure 6). By 5 to 6 years of age, the difference between groups was large – nearly one standard deviation. This suggests CHH are at risk for depressed language development even when identified and fit with HAs early. Some might argue when looking at the figure that there is no cause for concern, because the means for the CHH fall within the average to low average range compared to the test standardization sample. It is important to recognize that most of the OCHL children had early access to HAs and early intervention services, which were likely to influence these outcomes. In spite of early service provision, however, their outcomes lagged behind those of well-matched CNH. We believe that the effect of HL on language is better reflected by comparison to our matched controls, the children with whom they are competing in school, than to the standardization sample. The cautionary tale is that we might perpetuate the historical practice of underestimating the needs of CHH if we rely only on standardized test norms to judge their performance.

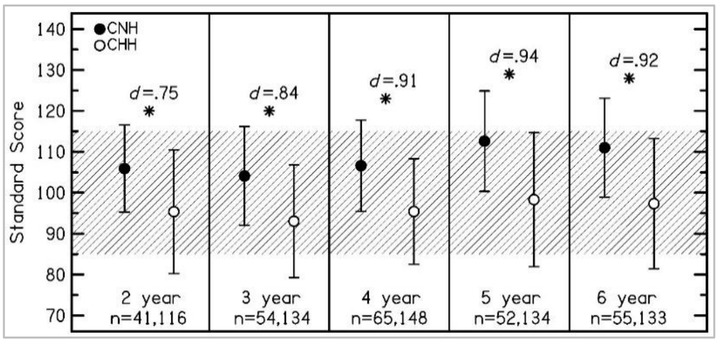

Figure 6. Mean language composite standard scores for the children with normal hearing and children who are hard of hearing across the waves of assessment (2 years to 6 years).

Note: Shaded area represents the average range compared to test standardization samples; n = signifies the number of CNH and CHH respectively who contributed at each assessment wave; d = effect sizes (Cohen's d) (Tomblin, Harrison et al., 2015).

Conclusion

By way of summary, we revisit the ACCESS factors presented in Figure 1 by considering evidence-based implications for practice in Figure 7.

A	Audibility influences language growth rates.
C	Carefully fit HAs that are verified with real-ear, probe microphone verification measures to match prescribed targets are needed to optimize audibility.
C	Consistently worn devices from early infancy place children in developmentally favorable circumstances, but later-fit children make promising gains once provided with hearing aids.
E	Environments are conducive to language learning when parents adopt a responsive style, engage the child in conversations, avoid being overly directive, and reduce sources of electronic media.
S	Selected areas of language, such as morphology, are at differential risk in CHH and deserve additional emphasis in intervention. Intervention research is needed in this area.
S	Service provision research is a priority for CHH; comparison to standardized test norms may lead to perpetuation of the tendency to underestimate the needs of this group of children.

Figure 7. ACCESS: Summary of best practice implications derived from the evidence on children's outcomes from the OCHL study.

In essence,

- Our findings that audibility influences language growth rates provide strong justification for vigilance in HA fitting and verification practices to optimize audibility.
- Our work also verifies the benefits of early and consistent HA use to promote positive developmental outcomes.
- We have also shown that developmental protection results from provision of language environments that are responsive rather than directive and in which children are

able to engage in frequent conversations as a result of caregiver efforts and limited distractions from electronic media.

- We have demonstrated that selected aspects of language might need additional emphasis in intervention for CHH.
- Additionally, we have suggested the need for further research into intervention practices and the importance of avoiding the tendency to underestimate the needs of CHH.

Pediatric audiologists are in a strong position to partner with families to provide young CHH with the best possible access to input and language experience so that they will achieve optimal outcomes.

References

Ambrose, S. E., VanDam, M., & Moeller, M. P. (2014). Linguistic input, electronic media, and communication outcomes of toddlers with hearing loss. Ear and Hearing, 35(2), 139–147.

Ambrose, S. E., Walker, E. A., Unflat-Berry, L. M., Oleson, J. J., & Moeller, M. P. (2015). Quantity and quality of caregivers' linguistic Input to 18-month and 3-year-old children who are hard of hearing. Ear & Hearing, 36(Suppl 1), 48–59.

Bagatto, M. P., Moodie, S. T., Malandrino, A. C., Richert, F. M., Clench, D. A., & Scollie, S. D. (2011). The University of Western Ontario pediatric audiological monitoring protocol (UWO PedAMP). Trends in Amplification, 15(1), 57–76.

Bagatto, M., Scollie, S. D., Hyde, M., & Seewald, R. (2010). Protocol for the provision of amplification within the Ontario Infant hearing program. Clinical Protocols International Journal of Audiology, 49, 70–79.

Byrne, D., & Cotton, S. (1988). Evaluation of the National Acoustic Laboratories' new hearing aid selection procedure. Journal of Speech, Language, and Hearing Research, 31(2), 178-86.

Elman, J. L. (1990). Finding structure in time. Cognitive Science, 14(2), 179–211.

Encinas, D., & Plante, E. (2016). Feasibility of a recasting and auditory bombardment treatment With young cochlear implant users. Language Speech and Hearing Services in Schools, 47(2), 157-170.

Farmer, T. A., Christiansen, M. H., & Monaghan, P. (2006). Phonological typicality influences on-line sentence comprehension. Proceedings of the National Academy of Sciences of the United States of America, 103(32), 12203–8.

Hart, B., & Risley, T. R. (1995). Meaningful differences in the everyday experience of young American children. Baltimore, MD: Paul H. Brookes Publishing

Hurtado, N., Marchman, V. A., & Fernald, A. (2008). Does input influence uptake? Links between maternal talk, processing speed and vocabulary size in Spanish-learning children. Developmental Science, 11(6), F31–F39.

Huttenlocher, J., Haight, W., Bryk, A., Seltzer, M., & Lyons, T. (1991). Early vocabulary growth: Relation to language input and gender. Developmental Psychology, 27(2), 236-248.

Koehlinger, K., Van Horne, A. O., Oleson, J., McCreery, R., Moeller, M. P., J., B., ... B., T. J. (2015). The role of sentence position, allomorph, and morpheme type on accurate use of s-related morphemes by children who are hard of hearing. Journal of Speech, Language, and Hearing Research, 58(2), 396-409.

McCreery, R. W., Bentler, R. A., & Roush, P. A. (2013). Characteristics of hearing aid fittings in infants and young children. Ear and Hearing, 34(6), 701-710.

McCreery, R. W., Walker, E. A., Spratford, M., Bentler, R., Holte, L., Roush, P., ... Moeller, M. P. (2015). Longitudinal predictors of aided speech audibility in infants and children. Ear and Hearing, 36(Suppl. 1), 24–37.

Moeller, M. P., & Tomblin, J. B. (2015). An introduction to the Outcomes of Children with Hearing Loss study. Ear and Hearing, 36(Suppl. 1), 4–13.

Moeller, M. P., Tomblin, J. B., Yoshinaga-Itano, C., Connor, C. M., & Jerger, S. (2007). Current state of knowledge: Language and literacy of children with hearing impairment. Ear and Hearing, 28(6), 740–753.

Saffran, J. R. (2003). Statistical language learning: Mechanisms and constraints. Current Directions in Psychological Science, 12(4), 110–114.

Scollie, S., Seewald, R., Cornelisse, L., Moodie, S., Bagatto, M., Laurnagaray, D., ... Pumford, J. (2005). The Desired Sensation Level multistage input/output algorithm. Trends in Amplification, 9(4), 159–197.

Stelmachowicz, P. G., Pittman, A., Hoover, B., & Lewis, D. (2002). Aided perception of /s/ and /z/ by hearing-impaired children. Ear and Hearing, 23(4), 316–324.

Stiles, D. J., Bentler, R. A., & McGregor, K. K. (2012). The speech intelligibility index and the pure-tone average as predictors of lexical ability in children fit with hearing aids. Journal of Speech, Language, and Hearing Research, 55(3), 764-778.

Tomblin, J. B., Harrison, M., Ambrose, S. E., Walker, E. A., Oleson, J. J., & Moeller, M. P. (2015). Language outcomes in young children with mild to severe hearing loss. Ear and Hearing, 36(Suppl. 1), 76–91. Tomblin, J. B., & Hebbeler, K. (2007). Current state of knowledge: Outcomes research in children with mild to severe hearing impairment-Approaches and methodological considerations. Ear and Hearing, 28(6), 715–728.

Tomblin, J. B., Oleson, J., Ambrose, S. E., Walker, E. A., & Moeller, M. P. (2014). The influence of hearing aids on speech and language development in children with hearing loss. JAMA Otolaryngology, 140(5), 403–409.

Tomblin, J. B., Walker, E. A., McCreery, R. W., Arenas, R. M., Harrison, M., & Moeller, M. P. (2015). Outcomes of children with hearing loss: Data collection and methods. Ear and Hearing, 36(Suppl. 1), 14–23.

Walker, E. A., Holte, L., McCreery, R. W., Spratford, M., Page, T., Moeller, M. P., ... C., Y.-I. (2015). The influence of hearing aid use on outcomes of children with mild hearing loss. Journal of Speech, Language, and Hearing Research, 58(5), 1611-1625.

Walker, E. A., McCreery, R. W., Spratford, M., Oleson, J. J., Van Buren, J., Bentler, R., ... Moeller, M. P. (2015). Trends and predictors of longitudinal hearing aid use for children who are hard of hearing. Ear and Hearing, 36(Suppl. 1), 38–47.

Walker, E. A., Spratford, M., Moeller, M. P., Oleson, J., Ou, H., Roush, P., ... C., Y.-I. (2013). Predictors of hearing aid use time in children with mild-to-severe hearing loss. Language Speech and Hearing Services in Schools, 44(1), 73-88.

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