CHAPTER FOUR

Are We on Target With Our Pediatric Hearing Aid Fittings?

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Abstract

Children who are hard of hearing rely on amplification to provide audibility that supports positive developmental outcomes. Previous investigations have used milestones such as age of identification with hearing loss or age at which amplification was received to quantify the impact of amplification on development. However, these milestones do not adequately reflect the variability in cumulative auditory experience that may occur related to differences in aided audibility of speech or the amount of hearing aid use either across children or over time. The impact of aided audibility of speech and hearing aid use on developmental outcomes is presented. Clinical suggestions for maximizing audibility and hearing aid use for children who are hard-of-hearing are also discussed.

Children with permanent hearing loss either at birth or during childhood have historically experienced delays in speech and language development, diminished social opportunities and limited academic achievement. Prior to the adoption of universal newborn hearing screening programs and early hearing detection and intervention programs in the United States, the age of identification for children with hearing loss was often not until 18-24 months of age (Moeller, 2000). Many early studies of developmental outcomes in children with hearing loss revealed substantial delays in development (Davis et al. 1986). Hearing loss not only limits immediate access to the acoustic cues needed for communication, but also alters the cumulative auditory experience of children. For this reason, hearing aids must not only restore audibility, but be used consistently during early childhood in order to minimize the likelihood of developmental delays. Previous studies regarding the development of children with hearing loss who use amplification have not routinely described how much audibility was provided by the fitting and how much children used their hearing aids. The goals of this article are to review what is known about aided audibility of speech and hearing aid use among children with hearing loss, and provide clinicians with practical strategies for maximizing these positive predictors of developmental outcomes.

Speech Audibility

Audibility describes how much of the speech signal can be heard. The speech intelligibility index (SII; ANSI S3.5-1997) is a standardized method of quantifying audibility. The SII is expressed as a proportion (between 0 and 1) or percentage (between 0% and 100%), where higher values represent greater audibility of the speech signal. The primary purpose of the SII with children with hearing loss is to quantify the amount of speech information that is audible to the child with and without their hearing aids. Unaided audibility is often used to quantify the effects of hearing loss or noise on the audibility of speech without amplification. Aided audibility describes how much of the speech signal is audible when the speech spectrum is amplified. Both measures should be documented as part of the hearing aid verification process. Speech audibility can be graphically estimated using an SPL-o-gram. The SPL-o-gram plots dB sound pressure level (SPL) as a function of frequency in Hertz. The speech spectrum is represented on the SPL-o-gram using the long-term average speech spectrum (LTASS). The LTASS represents the frequency range and level for a speech signal averaged over time and is plotted relative to the hearing thresholds in SPL. The proportion of the LTASS that is above the hearing thresholds represents the audible portion of the speech spectrum. The LTASS is usually referenced to an average conversational level

for speech from 1 meter away, which is usually equivalent to an overall level of 60 or 65 dB SPL, but can also be used to represent speech at other levels (soft at 50 dB SPL and loud at 75 dB SPL).

The impact of aided audibility on outcomes has recently been highlighted by several studies of speech and language development in children who are hard of hearing. Development of vocabulary (Stiles et al. 2012) and the structural aspects of language, including morphology and syntax (Koehlinger, Van Horne, & Moeller, 2013), have been shown to be higher in children with higher aided audibility than for peers who wear hearing aids that provide less aided audibility. The amount of the speech signal that is audible to children with amplification can directly impact auditory access and subsequent speech and language outcomes and is thus, a key component in the clinical assessment of amplification. However, previous longitudinal studies of outcomes have often used other variables to represent the impact of amplification on developmental outcomes, including age of identification of hearing loss (Moeller, 2000; Yoshinaga-Itano, 2003; Kennedy et al. 2006), age of fitting with amplification (Wake et al. 2004; Ching et al. 2013; Sininger et al. 2010) and pure tone average (Ching et al. 2013; Sininger et al. 2010). While these variables may indirectly reflect the duration or amount of cumulative auditory experience children have with amplification, each also has specific limitations as an indicator of cumulative auditory exposure.

Age of identification with hearing loss or age of fitting with amplification have been the most frequently identified factors used to predict outcomes in children with hearing loss. Prior to universal newborn hearing screening, the age of identification or hearing aid fitting was often used to reflect the duration of auditory deprivation that children experienced prior to amplification. Children with later ages of identification or fitting would be expected to have limited access to sound during sensitive developmental periods and also be predicted to have poorer outcomes. Age of identification (Moeller, 2000; Yoshinaga-Itano, 2003; Kennedy et al. 2006) was an influential predictor of developmental outcomes prior to newborn hearing screening, primarily because the ages at which children were identified with hearing loss and enrolled in intervention varied considerably. For example, Moeller (2000) reported data from a sample that included both early- and later-identified children with hearing loss and found a range of age of identification from birth to 4.5 years. As newborn hearing screening has become more widely available, the age of identification of hearing loss has decreased and become more uniform among states (Holte et al. 2012). While the decreasing age of identification has undoubtedly had a positive impact on outcomes, greater uniformity in age of identification and the related milestone of age of hearing aid fitting have made these variables less able to predict variability in outcomes. Age of hearing aid fitting, for example, has been positively related to some speech and language outcomes in one investigation (Sininger et al. 2010), but has not been predictive of outcomes in others (Wake et al. 2004; Ching et al. 2013).

Another limitation of age of identification or amplification as a predictor of outcomes is that these variables assume that audibility for children with hearing loss is binary. Specifically, these variables assume that the period of time prior to intervention had little or no contribution to the child's development and also that once the child is diagnosed with hearing loss, the benefits of amplification are fully activated and constant thereafter. While this may reflect the experience of children with profound hearing loss prior to amplification, the amount of audibility received by children with mild to severe hearing loss, with and without amplification depends on their degree of hearing loss and how well their hearing aids are fit. Some studies have attempted to take this variability into account by using the pure tone average as a predictor of audiological outcomes. The pure tone average is an average of either three or four mid-frequency audiometric frequencies. The most common frequencies used to calculate pure tone average are 500, 1000 and 2000 Hz or those three frequencies plus 4000 Hz.

However, pure tone average has had mixed results predicting variability in outcomes with some studies finding greater pure tone averages associated with poorer outcomes (Sininger et al. 2010) and other studies finding no relationship (Moeller, 2000) or only a relationship with specific developmental outcomes (Ching et al. 2013). Although pure tone average provides a single numerical estimate of the degree of hearing loss, this variable does not represent how much the child is able to hear with amplification, particularly since children with the same pure tone average may have varying degrees of aided audibility through their hearing aids depending on how closely the hearing aids are fit to prescriptive targets (McCreery et al. 2013). Interestingly, one recent study that found a correspondence between pure tone average and language outcomes was a study where all of the children were fit with amplification that was verified to provide optimal audibility (Sininger et al. 2010); thus,

the relationship between pure tone average and aided audibility was so consistent that aided audibility had to be excluded from statistical models. Other investigations have shown that the children with hearing loss in clinical populations do not have consistent aided audibility (Strauss & van Dijk, 2008; McCreery et al. 2013). Therefore, the amount of aided audibility depends not only on the degree of hearing loss, but also on whether or not amplification is programmed and verified to provide adequate audibility. Children with higher aided audibility and well-fit amplification are predicted to have a more optimal auditory experience, which should help to mitigate the negative effects of hearing loss on development.

Hearing Aid Use

As described above, recent studies suggest that increased aided audibility with hearing aids influences language outcomes (Koehlinger, Van Horne, & Moeller, 2013; Stiles, Bentler, & McGregor, 2012). Presumably, however, the advantages of appropriately-fit hearing aids will only occur if children wear their devices on a consistent basis. There are two clinically-useful objective and subjective strategies for determining how frequently children wear their devices: data logging and parent report measures. Investigations utilizing these methods demonstrate that there is variability in hearing aid use time in young children (Jones & Launer, 2011; Moeller, Hoover, Peterson, & Stelmachowicz, 2009; Walker et al., 2013). These methods may also be appropriate when counseling parents on how to achieve consistent hearing aid use over time.

Data Logging

Many current hearing aid models now have data logging, an automatic feature built into the hearing aid which records information about the hearing aids over time, including average hours of daily use. Investigations using data logging features have shed new light on everyday practices for children with hearing aids. Walker et al. (2013) collected data logging information on 133 children, ranging in age from 8 months to 8 years. On average, data logging indicated that children wore hearing aids 8.3 hours per day, but usage varied across participants from 0 to 16 hours. Nineteen percent wore hearing aids for 4 hours or less per day and 12% were "full-time hearing aid users" (more than 12 hours per day). In a separate study, Jones and Launer (2011) obtained data logging on approximately 5000 children, ages birth to 19 years. The average use time for the entire sample was 5.5 hours per day, with wide variation across participants. Forty percent wore hearing aids for 4 hours or less, and 10% were full-time hearing aid users (more than 12 hours per day). Results for both of these studies lend support for the notion that there are individual differences in the amount of daily hearing aid use in children with hearing loss, and a number of children are not achieving full-time use with hearing aids.

Parent Report Measures

Moeller, Hoover, Peterson, and Stelmachowicz (2009) were among the first to explore individual variations in parent-report for pediatric hearing aid compliance. They conducted longitudinal interviews with mothers of seven early-identified infants with mild to moderate hearing loss (age range = 11 to 28.5 months). Rather than asking mothers to estimate average daily hearing aid use, the researchers evaluated hearing aid use with a Likert scale for different situations (e.g., in the car, book sharing, at the playground, etc.). Results showed that the infants were inconsistent hearing aid users for most situations prior to two years of age. Only two out of the seven parents were able to establish early, consistent usage across all contexts. Over time, consistency of use increased, although even at 28 months, there were still some unsupervised situations that parents found problematic, such as riding in the car.

Walker et al. (2013) used a similar parent-report rating scale with a larger number of participants (n = 272) and wider age range (5 months to 7 years, 3 months). Results were consistent with the findings from Moeller et al. (2009); amount of hearing aid use increased with chronological age and unsupervised situations were more challenging than supervised situations. In addition, children with more severe hearing loss (greater than 50 dB HL) were reported to wear hearing aids more consistently across different contexts than children with milder hearing loss (less than 50 dB HL). The use of parent-report consistency ratings across different listening situations provides insight into circumstances that were challenging for families. These rating scales may be useful as a counseling tool, in conjunction with data logging measures, to help parents become more aware of situations in which consistent hearing aid use is difficult to achieve. This awareness, in turn, could help parents be better prepared to cope with problematic contexts and increase consistent usage in these contexts.

Predictors of Variation in Hearing Aid Use

Both the Jones and Launer (2011) and Moeller et al. (2009) studies were limited in that they could not identify child- or family-specific factors that influenced individual differences in average daily hearing aid use. Such information has clinical value, because it could help direct audiological counseling practices. Walker et al. (2013) addressed the question of predictors of average daily hearing aid use with a cross-sectional sample of 272 children who were hard of hearing, between the ages of 5 months to 7 years, 3 months. Results from a multiple regression analysis showed that longer daily hearing aid use (based on subjective parent report) was related to older age, poorer hearing, and higher maternal education level. These results suggest a possible need for more counseling with families of pediatric hearing aid recipients, particularly children with milder hearing loss and families with lower education levels.

Both aided audibility and the amount of hearing aid use are predicted to reflect cumulative auditory experience in children with hearing loss. Children who use hearing aids that provide adequate audibility on a consistent basis are likely to experience better developmental outcomes than children who either have poor aided audibility or do not consistently use amplification. Speech recognition in noise data from the Outcomes for Children with Hearing Loss study are presented as an example of how audibility and hearing aid use may impact outcomes. Figure 1 shows aided and unaided word and phoneme recognition in steady-state noise from the Computer-Aided Speech Perception Assessment (CASPA) collected on a group of 7 year-old children who wear hearing aids compared to a group of age-matched children with normal hearing. Figure 2 shows the relationship between aided audibility and word recognition and average hours of hearing aid use per day and word recognition. Linear regression was used to predict word recognition using aided audibility and hearing aid use, while controlling for degree of hearing loss. Aided audibility was a significant predictor of word recognition in noise; however, average amount of hearing aid use was not found to predict word recognition after controlling for degree of hearing loss.

The example highlights the challenges of using hearing aid use to predict complex outcomes like speech recognition. Hearing aid use and degree of hearing loss are positively associated; children who have greater degrees of hearing loss use their hearing aids more hours per day on average than children with less hearing loss. Additionally, the majority of the children in the sample were consistent hearing aid users by age 7, which means that the amount of hearing aid use in the sample may have been sufficient to support the skills needed to develop speech recognition in noise. Further analyses of these data will attempt to use longitudinal models to predict how audibility and hearing aid use earlier in childhood might impact outcomes in school-age children who wear hearing aids.

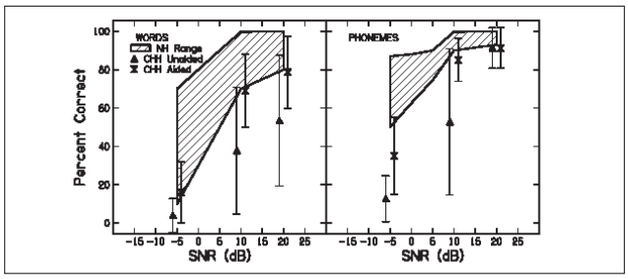

Figure 1. Word (Left panel) and Phoneme (Right panel) recognition for 7 year-old children at -5 dB, 10 dB and 20 dB signal-to-noise ratios (SNR). Triangles represent the means for unaided conditions for children who are hard of hearing (CHH) and hourglasses represent the means for aided conditions. Error bars represent +/- one standard deviation. The cross-hatched area represents the range of performance for children with normal hearing.

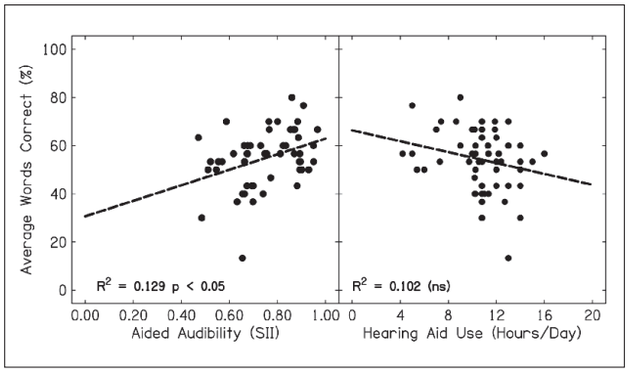

Figure 2. Word recognition as a function of aided audibility (Left panel) and average hours of hearing aid use (Right panel). Regression line represents the bivariate relationship between word recognition and each variable. The R2 values in each panel represent the linear regression model with each variable as a predictor of word recognition, controlling for unaided audibility (SII).

Clinical Implications

Audiologists and early intervention service providers are in a unique position to support parents and convey

how amplification early in life may prevent communication delays. Parents are also in the best position to monitor the consistency of hearing aid use in everyday situations. Service providers can utilize parent ratings of hearing aid use consistency across situations as a tool for encouraging parents to increase overall use as their child grows and develops. The consistency ratings can also be used to point out specific circumstances where the child will potentially benefit from increased access to quality communication. Targeting these situations will help parents focus their efforts on giving their child access to sound that is meaningful to their development. For example, targeting device use at the breakfast table when all family members are engaging in conversation or during a vocabulary-rich book reading session at night may be more beneficial than using the hearing aids in the car where conversation is difficult to overhear and follow. Temperament, behavior, and infant state may be obstacles to consistent hearing aid use early in life. Likewise, there are situations that will not be realistic opportunities for consistent device use due to safety or equipment concerns, such as when unsupervised in the car or outdoors. Providers who understand these obstacles, and can offer coping strategies, will be better able to counsel parents on realistic expectations for device use in these challenging situations. Data logging features may be used in conjunction with parent reports of hearing aid use to make parents more aware of their children's everyday listening environments. In addition to information obtained about the average number of hours of hearing aid use, current hearing aids may also provide environmental classifier information. Environmental classifiers calculate the percentage of time the hearing aid user spends in different listening contexts (e.g, quiet, speech only, speech in noise, and noise only). In the case of pediatric hearing aid users, environmental classifiers could be used to counsel parents about how much time their child spends in quiet or noisy situations. A recent study with the Outcomes for Children with Hearing Loss cohort showed that time spent in background noise (i.e., with the television or radio on) decreases opportunities for parent-child interaction, which has a negative effect on language outcomes for children with hearing loss (Ambrose et al., 2014). Parents may not be cognizant of how often the television or radio is on in the home, simply because it is background noise. Using the environmental classifier feature creates opportunities for discussion with parents and caregivers about minimizing background noise. Further research is needed to validate the accuracy of hearing aid classification schemes.

Additional counseling for families with lower educational levels should be given regarding the direct relationship between consistent hearing aid use, learning, and brain development. The emphasis on learning and brain development may help families better understand that achieving successful communication outcomes at a young age may lead to ease of learning in school and social activities later in life. Another subgroup of children that do not achieve consistent hearing aid use are those who have mild hearing loss. Children with mild hearing loss deserve pointed attention in terms of counseling. Some families (and audiologists) see the child responding to sound and developing speech and thus, feel the child does not need to wear their hearing aids. The evidence base now shows that audibility from hearing aids benefits children with mild hearing loss as much as for children with moderate and severe hearing loss. Thus, along with well-fit amplification, consistent use is vital to prevent delays in their development, just as it is for children with moderate and severe degrees of hearing loss.

Summary

Speech and language delays may be ameliorated with well-fit, consistently worn hearing aids. Children who are hard of hearing receive the most benefit from their hearing aids when audibility is optimally fit. Audiologists need to remain vigilant regarding developmental changes of their pediatric patients by consistently applying RECD measurements to programming gain adjustments. By verifying audibility at several levels of input with speech mapping and comparing to normative audibility data (Bagatto et al. 2011), audiologists can further ensure that soft and conversational speech are able to be heard. Furthermore, audiologists have several tools at their disposal to confirm that children are wearing hearing aids on a consistent basis. By using data logging and asking specific questions about the situations where hearing aid use is most beneficial and also most challenging, audiologists can help to support families in establishing consistent hearing aid use for their children.

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