12

A Sound Foundation Through Early Amplification

Proceedings of the 7th International Conference 2016

Establishing a sound foundation through electroacoustic verification

Marlene P. Bagatto, Au.D., Ph.D.

Abstract

Within Early Hearing Detection and Intervention (EHDI) programs, timely and accurate hearing assessment establishes the groundwork for early and optimal intervention for infants with permanent hearing loss. Many families choose personal hearing aids as part of a comprehensive intervention program for their child with hearing loss. Audiologists who provide hearing aids to the pediatric population have a responsibility to provide safe, accurate, and suitable hearing aids to their patients. The appropriateness of the hearing aid fitting is a critical component to achieving successful outcomes for children with hearing loss.

This paper describes current, evidence-based strategies for the fitting of hearing aids to the pediatric population. Recent guidelines and protocols will be reviewed with a goal to highlight relevant clinical procedures. The importance of measuring the real-ear-to-coupler difference (RECD) and how it is applied in the pediatric hearing aid fitting process will be examined. Simulated (coupler-based) real-ear verification will also be described to support the evaluation of hearing aid performance in relation to individualized prescriptive targets. These components provide a solid foundation for optimal communication development opportunities for infants and young children who wear hearing aids.

Introduction

For decades, infants and young children have had access to early hearing aid fittings from skilled and knowledgeable pediatric audiologists. Evidence-based guidelines and protocols applied with modern technologies within hearing aids and hearing aid test systems allow clinicians to provide optimal and safe speech access to pre-lingually hearing impaired infants and children with confidence. Throughout the pediatric hearing aid fitting process, key elements are considered and re-considered as the infant develops and hearing loss management needs change. The importance of verifying the electroacoustic performance of hearing aids for the pediatric population cannot be overstated. Because we cannot rely on infants to participate in the verification process and their development of speech and language skills depends on the appropriateness of the sounds delivered through the hearing aids, audiologists must apply evidence-based procedures to manage infants with hearing loss. We are fortunate to have the contributions of researchers, clinicians, and industry to provide high-quality research and technology to support the work that we do with infants and young children with hearing loss. The application of these strategies ensures that the initial hearing aid fitting is done systematically and effectively. The impact of the hearing aid fitting can then be evaluated using outcome measures to determine the overall progress of the infant.

The availability of evidence-based pediatric hearing aid fitting guidelines and protocols facilitates large-scale outcomes studies of infants and children who wear hearing aids (e.g., Dillon, Cowan & Ching, 2013; Tomblin, Oleson, Ambrose, Walker & Moeller, 2014) as well as clinic or patient-based outcomes to monitor progress with hearing aids (e.g., Bagatto et al., 2011; 2016). Additionally, as new hearing aid technologies are constantly emerging, establishing a good base hearing aid fitting, without the additional technologies activated, guides the decision about whether additional technologies are necessary. If activated and verified systematically, outcomes can be further evaluated. Therefore, this paper addresses the key elements to establishing a sound foundation through electroacoustic verification.

Provision of hearing aids

Within the pediatric hearing aid fitting process, information is gathered from the infant, caregivers, and/or hearing aids at each stage. During this process, the stages are revisited over time and the evolution of the child's physical, communication, and social development are considered. The stages of the pediatric hearing aid fitting process are:

1) Assessment: Gather hearing thresholds through electrophysiological measures (dB nHL or dB eHL) or behavioral measures (dB HL) and measure the ear canal acoustics (RECD). Both items are required to provide a thorough description of the infant's hearing levels (dB SPL) for use in the next steps of the process.
2) Prescription and Selection: Apply an evidence-based prescriptive formula. Most pediatric audiologists apply the DSL Method (v5.0; Moodie et al., 2016b; Scollie et al., 2005); however, NAL-NL2 is also available for this purpose (Keidser, Dillon, Carter & O'Brien, 2012). DSL prescriptive targets are calculated from the dB SPL thresholds generated in the assessment stage. This approach accurately defines the levels of sound that are needed for the infant or young child with hearing loss to access the speech signal effectively and safely. It also supports suitable selection of hearing aids that will be capable of achieving the prescribed targets, which is often reported by clinicians (Jones & Feilner, 2014; Moodie et al., 2016b).
3) Verification: Ensure that the output levels of the hearing aids for a variety of speech levels and maximum signals approximate the DSL v5.0 prescriptive targets using electroacoustic measurements compatible with the pediatric population.
4) Evaluation/Validation: Also known as outcome measurement, assess the impact of the verified hearing aids for the infant with hearing loss. Questionnaires completed by caregivers and/or listening tasks conducted in the clinic are suitable for this purpose.

This paper will discuss the details included within stage three of the pediatric hearing aid fitting process: electroacoustic verification.

Evidence-based electroacoustic verification

The availability of systematic, evidence-based guidelines and protocols for verifying hearing aids for children is substantial (e.g., American Academy of Audiology [AAA], 2013; Ontario Infant Hearing Program [OIHP], 2014). With good agreement among main elements of these guidelines and protocols, even across jurisdictions and clinical contexts, electroacoustic verification is documented as the main strategy for the verification of hearing aid performance for children (AAA, 2013; Bagatto, Scollie, Hyde, Seewald, 2010; Bagatto et al., 2016; King et al., 2010; OIHP, 2014). Recently, the American Academy of Audiology updated their guideline for the provision of hearing aids to children (AAA, 2013). In addition to addressing each stage of the hearing aid fitting process described above, it provides further detail to support the evolution of hearing aid technology, clinical practice, and outcomes of children with hearing loss. For example, in the verification stage, probe microphone measures using speech signals are recommended for the base fitting as well as after each additional hearing aid feature is activated. The AAA Guideline also recommends using validation measures routinely for each child fitted with a hearing aid to determine if hearing loss management goals are met or if an additional hearing aid feature is providing benefit or detriment (AAA, 2013). The document suggests particular outcome measurement tools that would be suitable for a child based on their developmental age.

In addition to a guideline, which provides recommendations based on different levels of evidence, a protocol operationalizes the recommendations from within guidelines, also by applying the best available evidence. An example is the Ontario Infant Hearing Program's (IHP) Protocol for the Provision of Amplification (OIHP, 2014; Bagatto et al., 2016). The current iteration of this protocol includes new procedures to support the application and verification of noise management and frequency lowering technologies, as well as clinical decision support for managing infants and young children who have been identified with mild bilateral hearing loss (MBHL) or unilateral hearing loss (UHL) within the Ontario IHP. Updates to evidence are intended to support current clinical practice both within and outside the Ontario IHP. The IHP Protocol aligns with the AAA Guideline due to the robustness and current applicability of the research from which it was based. Evidence continues to be accrued and will be applied in future versions of both documents.

The relevance of establishing a sound foundation through early amplification is highlighted in the results of a large scale study, Outcomes of Children with Hearing Loss (OCHL), conducted in the United States (Moeller & Tomblin, 2015). The main predictors of positive outcomes of children who wear hearing aids are: 1) the quality and quantity of linguistic input a child receives (Ambrose, Walker, Unflat-Berry, Oleson & Moeller, 2015); 2) the consistency with which a child wears his/her hearing aids (at least 10 hours per day; Walker et al., 2015a; 2015b); and 3) the amount of speech audibility provided from the hearing aids (McCreery et al., 2015b). The quality of the hearing aid fitting, as indexed by speech access and comfort level, is vital to supporting good outcomes for the children who wear the hearing aids. Without appropriate audibility provided from the hearing aids, the amount of daily hearing aid use or access to good quality linguistic input is not supported. Therefore, the significance of using an evidence-based, systematic protocol for verifying hearing aids for infants and young children cannot be overstated.

Supporting appropriate audibility in pediatric hearing aid fitting

Infants born with permanent hearing loss require support from hearing aids within the first six months of life if they are to acquire spoken language skills on par with their normal hearing peers (Joint Committee on Infant Hearing, 2007). To do this effectively, hearing levels as well as small ears with changing ear canal acoustics must be accounted for throughout the hearing aid fitting process. As children depend on caregivers to sustain the early years of hearing aid use (e.g., changing batteries, putting the hearing aids on), it is the pediatric audiologist's role to ensure the electroacoustic performance of the hearing aids is optimal.

In the assessment stage, a smooth transition from electrophysiologic hearing assessment (frequency-specific auditory brainstem response [ABR] to air- and bone- conducted stimuli) to early hearing aid fitting is necessary so that intervention is not delayed. To ensure accuracy in the calculation of prescriptive targets, a correction is applied to dB nHL thresholds to predict behavioral thresholds (dB eHL) for generating DSL prescriptive targets (Bagatto et al., 2005; McCreery et al., 2015a). The corrections are based on equipment type and ABR collection parameters. Also in this stage, the real-ear-to-coupler difference (RECD) is obtained to measure the individual ear canal acoustics that are applied within two stages of this process. The RECD values are first used to convert dB HL thresholds to dB SPL (Scollie, Seewald, Cornelisse & Jenstad, 1998). The SPL values are then used to calculate the DSL prescriptive targets. Pediatric hearing aid fitting guidelines and protocols support verification of hearing aid performance with the hearing aid test system's coupler placed in the test box. The RECD values are used a second time to allow for accurate electroacoustic verification of hearing aids in a controlled test box environment, which is more compatible with the pediatric population and suitable when the fitting applies little or no venting (Seewald, Moodie, Sinclair, Scollie, 1999; see Figure 1). Using the child's personal earmolds for both audiometry and the RECD measurement accounts for the earmold acoustics in the fitting process (Moodie et al, 2016a).

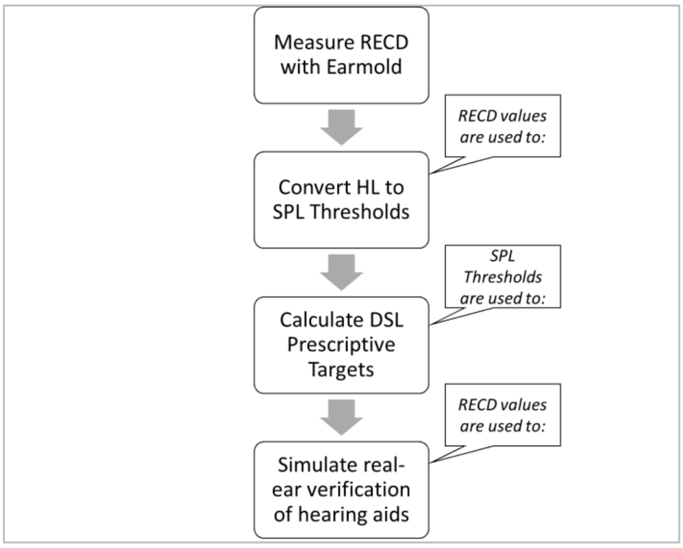

Figure 1: Application of RECD values in the pediatric hearing aid fitting process.

If the child is cooperative and the clinical environment is appropriately quiet to execute on-ear verification accurately, the measured RECD is still required for the HL to SPL conversion and subsequent prescriptive target calculation. If on-ear verification is conducted with the child instead of coupler or test box verification, then the RECD values will not be used a second time for the on-ear verification stage of the fitting process. For either verification strategy (on-ear or coupler), the SPL threshold values allow for a true depiction of the child's hearing levels and subsequent target generation that is plotted along with hearing aid output measurements on an SPL-o-gram. The SPL-o-gram provides the visual basis with which we assess the performance of hearing aids for our patients, in dB SPL at the ear canal (Gagné, Seewald, Zelisko & Hudson, 1991; Munro & Hatton, 2000; Munro & Davis, 2003; Revit, 1997; Scollie et al., 1998).

Considerations for RECD measurement

In a recent paper from Moodie and colleagues (2016a), RECDs were measured in 36 children with their own earmolds (average tubing length = 36 mm) and standard foam eartips (tubing length = 25 mm). As described elsewhere (Bagatto, 2001), RECDs measured with personal earmolds with tubing longer than a standard foam eartip will demonstrate reduced values in the high frequency region (see Figure 2). This natural acoustic consequence of increased tubing length in the earmold must be considered in the hearing aid fitting process. This can be accomplished by using the earmold as the *coupling type* to the child's ear for both audiometry and the RECD. The same set of earmold RECD values will then be used to convert HL to SPL and predict the real-ear hearing aid response in the coupler.

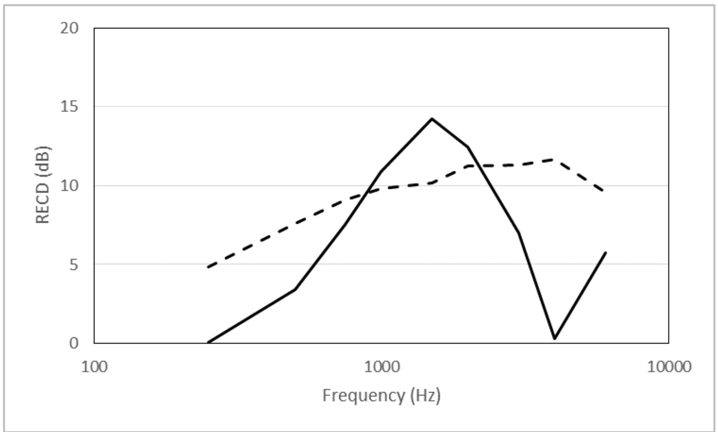

Figure 2: RECD values using standard foam eartips (dashed line) compared to unvented personal earmolds (solid line). Adapted from Moodie et al., 2016a.

Current protocols indicate that subsequent behavioral hearing assessments (visual reinforcement audiometry, conditioned play audiometry) be conducted with the child's personal earmolds connected to the insert earphone transducers (AAA, 2013; OIHP, 2014; Moodie et al., 2016a).

Audiometry with earmolds is vital in this process because it supports:

1) better acceptance of the coupling to the ear by the child compared to a standard foam eartip;
2) more accurate hearing aid fitting by capturing earmold tubing properties in audiometry for conversion to SPL by an earmold RECD measurement; and
3) cost effectiveness because foam eartips are used less.

For some clinical scenarios, the earmold might not be available or appropriate for audiometry and a foam eartip is used. This is followed by an earmold RECD measurement, as per recommended guidelines (e.g., AAA, 2013; OIHP, 2014; Moodie et al., 2016a). In some cases, this mismatch is addressed in hearing aid test systems by implementing DSL v5.0 age-dependent RECD predictions for foam tip or earmold coupling (Bagatto, Scollie, Seewald, Moodie, & Hoover, 2002) at the appropriate stage (assessment or verification). Some test systems have implemented the ANSI RECD standard (ANSI S3.46, 2013) that manages the mismatch by offering a predicted earmold RECD based on the child's measured foam eartip RECD. Preliminary data suggest this conversion to be suitable within the fitting process (Moodie et al., 2016a).
As previously stated, the ideal pediatric hearing aid fitting protocol is historical and relies on matching the coupling type to the ear for audiometry and the RECD to achieve ultimate accuracy within the process. A matched protocol includes:

1) audiometry with insert earphones connected to personal earmolds;
2) measurement of the RECD with personal earmold; and
3) verification of behind-the-ear hearing aid(s) in the HA-2 coupler.

For clinical scenarios where coupling mis-matches occur, the protocol includes:

1) audiometry with insert earphones coupled to standard foam eartips;
2) measurement of the RECD with personal earmold; and
3) verification behind-the-ear hearing aid(s) in the HA-2 coupler.

To support these different clinical protocols, some hearing aid test systems allow you to label the coupling type (earmold or foam eartip) and coupler type (HA-1 or HA-2) and will provide the necessary conversions to comply with the ANSI standard and support clinical practice (Moodie et al., 2016a). The ANSI standard references the coupler-based fitting to the

HA-1 coupler instead of the HA-2 coupler (see ANSI ref for more information). Because coupling a soft pediatric earmold to an HA-1 coupler is not stable or hygienic, standard conversions between HA-1 and HA-2 couplers are automatically applied within the hearing aid test system. As such, clinical practice for coupling the hearing aid directly to the HA-2 coupler (without the earmold attached) for verification remains common practice. To satisfy the ANSI standard, the HA-1 RECD is constructed and reported in the hearing aid test system even though it was not measured that way. This is because the goal is to comply with the ANSI standard but also support a wide range of clinical practice. For further details, please refer to an online course provided by Scollie (2015).

Coupler-based electroacoustic verification

Best practice indicates that the key components of verifying hearing aids for children are: 1) audibility of the long-term levels of average conversational speech; and 2) limiting the maximum output of loud sounds to the hearing aids, across a broad frequency range of hearing. This can only be accomplished through presenting calibrated stimuli to the hearing aids and measuring the output of the devices compared to the prescribed targets in dB SPL. Meaningful SPL-o-gram displays allow clinicians to compare the output of the hearing aids to the child's thresholds (in dB SPL) and upper limits of comfort. In addition, for infants we see through Early Hearing Detection and Intervention (EHDI) programs, there should not be a requirement to sit up or respond behaviorally in order for hearing aid verification to be accomplished. Electrophysiological measures of hearing threshold estimation are used in early infancy because we cannot rely on this population to provide reliable behavioral information until approximately six months developmental age. *Electroacoustic* verification of the performance of the hearing aids is the only strategy in which optimal hearing aid fitting can be accomplished.

Behavioral strategies (e.g., functional gain, aided audiograms) for measuring hearing aid function are not suitable for assuring the devices are meeting the prescribed targets for gain and maximum output. They might be useful for evaluating the impact of the hearing aids in mitigating the hearing loss, but this occurs as part of the *validation* stage of the hearing aid fitting process. Aided behavioral strategies are not efficient, reliable, or valid for verifying hearing aid performance in children being provided with modern hearing aids. Aided audiograms do not provide the necessary verification information about how the hearing aid processes speech at various levels or the levels at which the hearing aids' output is limited. In addition, the stimuli necessary for the verification of modern hearing aids cannot be examined appropriately in a sound booth condition. Complex speech at various levels as well as high level narrow band stimuli must be compared to prescribed targets across a broad frequency range to achieve the goals of speech audibility and comfort for loud sounds. These goals are best achieved using simulated real-ear measurements in a controlled test box environment, without having to rely on the behavior or comfort level of the infant. Current outcomes research indicates that the quality of the hearing aid fitting is critical, in addition to an early fitting (McCreery, Bentler & Roush, 2013; Bagatto et al., 2011; 2016; Stiles, Bentler & McGregor, 2012). We have the technology and protocols to accomplish both for the children with whom we work.

Coupler-based hearing aid measures applying measured RECD values allow accurate and reliable predication of real-ear hearing aid performance across frequencies and ages. Electroacoustic verification reduces the time and cooperation needed from the child; one RECD measurement is all that is required following the audiometric assessment. Initial fitting within hearing aid software is a useful starting place, but only provides a simulation of what the hearing aid is doing. It is the responsibility of the audiologist to measure the output of sound to a variety of inputs and adjust according to evidence-based prescriptive targets (e.g., DSL, NAL). Using speech-like signals for soft (55 dB), average (65 dB), and loud (75 dB) levels as well as maximum power output (MPO; narrowband at 90 or 100 dB) satisfy the goals for hearing aid verification using the real-ear aided response (REAR). Fine-tuning the device while comparing to targets in an SPL-ogram format is best for interpretation.

Other analyses include the speech intelligibility index (SII; ANSI S3.5 1997 [R2012]) that describes the audibility provided by the hearing aid based on the listener's hearing levels. The SII values are provided based on importance-weighted speech at different levels and are automatically calculated in many hearing aid test systems. For clinical interpretation, normative values are available for DSL Child Targets to assess the overall suitability of the hearing aid fitting following electroacoustic verification (Bagatto et al., 2011; Moodie et al., in press) and are an integral part of an outcome measurement protocol known as the University of Western Ontario Pediatric Monitoring Protocol (Bagatto et al., 2011; 2016).

For additional technologies that might be activated within the hearing aid, specific protocols are available for noise management and frequency lowering (Scollie et al., 2016a; 2016b). Current guidelines and protocols support the consideration of these technologies on a case-by-case basis (AAA, 2013; OIHP, 2014; Scollie et al., 2016a; 2016b). The current Ontario IHP protocol offers candidacy factors for each type of technology and, if activated, specific protocols for verifying the characteristics and impact of the technology on the audibility of speech (Scollie et al., 2016a; 2016b). These additional protocols are applied following the electroacoustic verification described here for the base hearing aid fitting. When the hearing aid performance is optimal, the audiologist applies suitable outcome measures to determine the effectiveness of the technology. Examples of appropriate tools include Ling 6-HL (Scollie et al., 2012), UWO Plurals (Glista & Scollie, 2012), LittlEARS Auditory Questionnaire (Tsiakpini et al., 2004), and Parents' Evaluation of Aural/Oral Performance of Children (PEACH; Ching & Hill, 2007).

Conclusion

Fitting hearing aids to children requires the application of evidence-based, systematic procedures that are suitable for the capabilities of infants and children. The unique characteristics of this population require careful consideration of small and changing ear canals, the impact of the hearing loss on the developing brain, and the reliance on caregivers to apply the hearing aids routinely. The internal workings of the hearing aid must be such that access to speech is optimal and safe. This can be accomplished by pediatric audiologists executing the protocols and technology available to support electroacoustic verification of hearing aid performance. Key elements of the process discussed here include:

- RECD values are used to convert HL to SPL *and* allow for coupler-based verification.
- Both audiometry and RECD measures using the child's personal earmold are used to achieve the best accuracy in the fitting process.
- Hearing aid performance in infants and children is assessed using electroacoustic verification (simulated real-ear aided responses is a valid and reliable way).
- Additional hearing aid technologies are considered on a case-by-case basis, using careful reasoning and analysis of the technology.
- If additional technologies are activated within the hearing aids, characteristics, the impact on speech audibility, and benefit (or detriment) to the child are verified.

It is the responsibility of pediatric audiologists to ensure appropriate and optimal speech audibility is achieved within the hearing aids provided to the infants and young children with whom they work. The implications for development are simply too important.

References

Ambrose, S., Walker, E., Unflat-Berry, L., Oleson, 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 and Hearing, 36, 48S-59S.

American Academy of Audiology. (2013). American Academy of Audiology Pediatric Amplification Guidelines. Retrieved from http://audiology-web.s3.amazonaws.com/migrated/PediatricAmplificationGuidelines.pdf_539975b3e7e9f1.74471798.pdf

American National Standards Institute. (1997). Methods of measurement of real-ear performance characteristics of hearing aids. ANSI S3.46-1997 (R 2013). New York, NY: Acoustical Society of America.

Bagatto, M. (2001). Optimizing your RECD measurements. Hearing Journal, 54(5), 32-36.

Bagatto, M., Moodie, S., Brown, C., Malandrino, A., Richert, F., Clench, D., Scollie, S.D. (2016). Prescribing and verifying hearing aids applying the American Academy of Audiology Pediatric Amplification Guideline: Protocols and outcomes from the Ontario Infant Hearing Program. Journal of the American Academy of Audiology, 27(3), 188-203.

Bagatto, M., Moodie, S., Malandrino, A., Richert, F., Clench, D., Scollie, S.D. (2011). The University of Western Ontario Pediatric Audiological Monitoring Protocol (UWO PedAMP). Trends in Amplification, 15(1), 57-76.

Bagatto, M. P., Moodie, S. T., Scollie, S., Seewald, R. C., Moodie, S., Pumford, J., & Liu, K. P. R. (2005). Clinical protocols for hearing instrument fitting in the Desired Sensation Level Method. Trends in Amplification, 9(4), 199–226.

Bagatto, M., Scollie, S., Hyde, M., Seewald, R. (2010). Protocol for the provision of amplification within the Ontario Infant Hearing Program. International Journal of Audiology, 49, S70-S79.

Bagatto, M., Scollie, S., Seewald, R., Moodie, K., Hoover, B.M. (2002). Real-ear-to-coupler difference predictions as a function of age for two coupling procedures. Journal of the American Academy of Audiology. 13(8), 407-415.

Dillon, H., Cowan, R., Ching, T.Y. (2013). Longitudinal outcomes of children with hearing impairment. International Journal of Audiology, 52, Supplement 2, S2-S3.

Ching, T.Y. & Hill, M. (2007). The Parents' Evaluation of Aural/Oral Performance of Children (PEACH) Scale: Normative data. Journal of the American Academy of Audiology, 18, 220-235.

Gagne, J., Seewald, R., Zelisko, D., Hudson, S. P. (1991). Procedure for defining the auditory area of hearing-impaired adolescents with a severe/profound hearing loss. II: Loudness discomfort levels. Journal of Speech-Language Pathology, 12, 27–32.

Glista, D. & Scollie, S. (2012). English language measure of detection of word-final plurality markers: The University of Western Ontario Plurals Test. American Journal of Audiology, 21, 76-81.

Joint Committee on Infant Hearing (JCIH). (2007). Year 2007 Position Statement: Principles and guidelines for early hearing detection and intervention programs. Pediatrics, 120(4), 898–921.

Jones, C., Feilner, M. (2014). What do we know about the fitting and daily life usage of hearing instruments in pediatrics? In J. Northern (Ed.), A Sound Foundation Through Early Amplification 6th International Conference Proceeding, 97-104. Stafa, Switzerland: Phonak AG.

Keisder, G., Dillon, H., Carter, L., O'Brien, A. (2012). NAL-NL2 empirical adjustments. Trends in Amplification, 4, 211-223.

King, A.M. (2010). The national protocol for paediatric amplification in Australia. International Journal of Audiology, 49, S64-S69.

McCreery, R., Kaminski, J., Beauchaine, K., Lenzen, N., Simms, K., Gorga, M.P. (2015). The Impact of Degree of Hearing Loss on Auditory Brainstem Response Predictions of Behavioral Thresholds. Ear and Hearing, 36, 309-319.

McCreery, R., Walker, E., Spratford, M., Bentler, R., Holte, L., Roush, P., Oleson, J., Van Buren, J., Moeller, M. P. (2015). Longitudinal Predictors of Aided Speech Audibility. Ear and Hearing, 36, S24S-S37.

Ministry of Children and Youth Services Ontario Infant Hearing Program. (2014). Protocol for the Provision of Amplification, Version 2014.01. Eds. M. Bagatto & S. Scollie. Retrieved from https://www.dslio.com/wp-content/uploads/2015/05/DSL5-Pediatric-Protocol.2014.01.pdf

Moeller, M., Tomblin, J. (2015). An introduction to the Outcomes of Children with Hearing Loss study. Ear and Hearing, 36, 4S-12S.

Moodie, S., Pietrobon, J., Rall, E., Lindley, G., Eiten, L., Gordey, D., Davidson, L., Moodie, K., Bagatto, M., Haluschak, M., Folkeard, P., Scollie, S. (2016a). Using the real-ear-to-coupler difference within the American Academy of Audiology Pediatric Amplification Guideline: Protocols for applying and predicting earmold RECDs. Journal of the American Academy

Moodie, S., Rall, E., Eiten, L., Lindley, G., Gordey, D., Davidson, L., Bagatto, M., Scollie, S. (2016b). Pediatric audiology in North America: Current clinical practice and how it relates to the American Academy of Audiology Pediatric Amplification Guideline. Journal of the American Academy of Audiology, 27(3), 166-187.

Moodie, S., The Network of Pediatric Audiologists of Canada, Scollie, S., Bagatto, M., Keene, K. (In press). Fit-to-targets for the DSL v5.0a hearing aid prescription method for children. International Journal of Audiology.

Munro, K. J., & Davis, J. (2003). Deriving the real-ear SPL of audiometric data using the "coupler to dial difference" and the "real ear to coupler difference." Ear and Hearing, 24, 100–110.

Munro, K. L., & Hatton, N. (2000). Customized acoustic transform functions and their accuracy at predicting rea-lear hearing aid performance. Ear and Hearing, 21(1), 59–69.

Revit, L. (1997). The circle of decibels: Relating the hearing test, to the hearing instrument, to the real-ear response. Hearing Review, 4, 35–38.

Scollie, S. (2016). New RECDs and a new ANSI standard: Revisiting RECD basics and Applications. Audiology Online, Course #26580. Retrieved from http://www.audiologyonline.com/articles/new-recds-and-ansi-standard-16380

Scollie, S., Glista, D., Seto, J., Dunn, A., Schuett, B., Hawkins, M., Pourmand, N, Parsa, V. (2016a). Fitting frequency-lowering signal processing applying the American Academy of Audiology Pediatric Amplification Guideline: Updates and protocols. Journal of the American Academy of Audiology, 27(3), 219-236.

Scollie, S., Glista, D., Tenhaaf, J., Dunn, A., Malandrino, A., Keene, K., & Folkeard, P. (2012). Stimuli and normative data for detection of Ling-6 sounds in hearing level. American Journal of Audiology, 21(2), 232-241.

Scollie, S., Levy, C., Abbasalipour, P., Bagatto, M., Richert, F., Moodie, K., Crukley, J., Parsa, V. (2016b). Fitting noise management signal processing applying the American Academy of Audiology Pediatric Amplification Guideline: Verification protocols. Journal of the American Academy of Audiology, 27(3), 237-251.

Scollie, S., Seewald, R., Cornelisse, L., Jenstad, L. M. (1998). Validity and repeatability of level-dependent HL to SPL transforms. Ear and Hearing, 19(5), 407–413.

Scollie, S. D., Seewald, R. C., Cornelisse, L. C., Moodie, S. T., Bagatto, M. P., Laurnagaray, D., . . . Pumford, J. M. (2005). The Desired Sensation Level Multistage Input/Output Algorithm. Trends in Amplification, 9(4), 159–197.

Seewald, R., Moodie, K., Sinclair, S., Scollie, S. D. (1999). Predictive validity of a procedure for pediatric hearing instrument fitting. American Journal of Audiology, 8(2), 143–152.

Stiles, D., Bentler, R., McGregor, K. (2012). Speech Intelligibiliy index and the puretone average as predictors of lexical ability in children fit with hearing aids. Journal of Speech, Language, and Hearing Research, 55, 764-778.

Tomblin, J. B., Oleson, J. J., Ambrose, S. E., Walker, E., & Moeller, M. P. (2014). The influence of hearing aids on speech and language development of children with hearing loss. Journal of the American Medical Association - Otolaryngology – Head & Neck Surgery, 140(5), 403-409.

Tsiakpini, L., Weichbold, V., Kuehn-Inacker, H., Coninx, F., D'Haese, P., & Almadin, S. (2004). LittlEARS Auditory Questionnaire. MED-EL. Innsbruck, Austria.

Walker, E., Holte, L., McCreery, R., Spratford, M., Page, T.A., R., Moeller, M. P. (2015). The Influence of Hearing Aid Use on Outcomes of Children with Mild Hearing Loss. Journal of Speech, Language, and Hearing Research, 58, 1611-1625.

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

Acknowledgements: I would like to thank all of the pediatric audiologists, researchers, and families who have contributed to the evidence and clinical procedures that we use to help infants with hearing loss.

Author

Marlene P. Bagatto, Au.D., Ph.D.
Research Associate and Adjunct Research Professor
National Centre for Audiology
Western University
London, Ontario, Canada
bagatto@nca.uwo.ca

Editors

Anne Marie Tharpe, Ph.D.
Chair, Phonak Research Advisory Board
Professor and Chair
Department of Hearing & Speech Sciences
Vanderbilt University School of Medicine
Nashville, Tennessee, United States

Marlene Bagatto, Ph.D.
Research Associate and Adjunct Research Professor
National Centre for Audiology
Western University
London, Ontario, Canada