DOCUMENT RESUME

ED 373 493 EC 303 262

AUTHOR	Beauchaine, Kathryn L.
TITLE	Approaches to Selection and Fitting of Amplification for Infants and Toddlers.
PUB DATE	May 92
NOTE	8p.; In: Cherwo, Evelyn, Ed. Proceedings of the ASHA Audiology Superconference. ASHA Reports Number 21, p63-69, May 1992.
PUB TYPE	Speeches/Conference Papers (150) -- Guides - Non-Classroom Use (055)
EDRS PRICE	MF01/PC01 Plus Postage.
DESCRIPTORS	*Audiology; *Auditory Evaluation; Clinical Diagnosis; Early Intervention; *Evaluation Methods; *Hearing Aids; *Hearing Impairments; Infants; Partial Hearing; Toddlers

ABSTRACT

This paper addresses three areas related to amplification for infants and toddlers with hearing impairments: (1) identification issues as they relate to early amplification; (2) selection of amplification; and (3) assessment of aided function. Identification issues discussed include the goal of early identification of hearing loss and the impact of technology. The paper addresses the following aspects of selection and fitting of amplification systems: formula approaches for fitting gain and output; facilitating adjustment to amplification; and recent expansions in fitting amplification. Finally, behavioral and objective methods of assessing aided hearing performance are described. The paper stresses that early intervention is now feasible on almost any patient given current technology and that the involvement of parents or caregivers at all stages is essential to the success of assessment and amplification selection and fitting. Contains 60 references. (DB)

Chapter 11

APPROACHES TO SELECTION AND FITTING OF AMPLIFICATION FOR INFANTS AND TODDLERS

KATHRYN L. BEAUCHAINE

Boys Town National Research Hospital
Omaha, NE

Implicit in the goal of early identification of hearing loss is the early initiation of habilitation and amplification. The focus of this paper is to address three areas related to amplification of hearing-impaired infants and toddlers (birth to 18 months): identification issues as they relate to early amplification, selection of amplification, and assessment of aided function.

IDENTIFICATION ISSUES

The Goal of Early Identification of Hearing Loss

The Joint Committee on Infant Hearing (JCIH) supports the early identification of hearing loss and initiation of early intervention services (ASHA, 1991). The current recommendation is to screen the hearing of at-risk neonates (birth to 28 days) by 3 months of age and to have diagnostic ABR testing completed no more than 6 months later. Infants (29 days to 2 years) who are found to have a risk factor should be tested as soon as possible after the identification of the risk factor, or at least within 3 months after the factor has been identified.

The justification for early identification of hearing loss is two-fold. First, the notion of critical periods for language acquisition is well accepted. Second, animal studies support the notion that lack of input to the auditory system may result in physiological and/or pathological changes in the auditory nervous system (for a review, see Ross & Seewald, 1988).

The statistics on early identification of hearing loss show variable results, and, in general, suggest that we have not fulfilled our goal. Reports over the past 5 years suggest that the average age of identification varies from 7.6 months to 19.0 months of age (Elssmann, Matkin, & Sabo, 1987; Mace, Wallace, Whan, & Stelmachowicz, in press; Mahoney & Eichwald, 1986; Stein, Jabaley, Spitz, Stoakley, & McGee, 1990). Mace et al. (in press) reported a wide age range for identification of hearing loss depending on the degree of loss. In general, children with moderate losses or greater were identified before 2 years of age. Thus, most of the infants and toddlers currently fit with amplification will have at least a moderate hearing loss.

The definition of educationally significant hearing loss has expanded in the past 10 years to include those with mild and unilateral hearing loss (Bess, 1985; Bess & Tharpe, 1986; Blair, Peterson, & Viehweg, 1985; Oyler, Oyler, & Matkin, 1987). Recent data suggest that these children typically are not identified until they are older than 4 years of age (Mace et al., in press), well beyond the infant and toddler years.

Impact of Technology

Technological advances have affected early fitting of amplification on two levels: testing options and amplification devices. The effect on testing options will be discussed first.

Current technology has affected both our ability to identify hearing loss and to measure aided status. For example, the use of auditory brainstem response (ABR) testing in the intensive care nursery has enhanced our ability to provide early diagnosis of hearing loss. Also, there is some promise in the use of evoked otoacoustic emissions (OAE) for use in the identification of hearing loss (Bray & Kemp, 1987). Aided testing with probe-tube microphone systems has furthered our ability to provide reliable measures of insertion and in situ gain and real-ear estimates of SSPL90.

Inroads also have been made in amplification systems. One of the most visible effects has been a reduction in the size of ear-level instruments, which are the devices most commonly fit on young children (Martin & Gravel, 1989). In small children, this can enhance retention of the device. In some cases, it also may enhance the parent's acceptance of the device. Improvements have been made in the increased flexibility of amplification devices, including hearing aids and auditory trainers. This flexibility is further increased with the availability of the special purpose Etymotic (e.g., low-pass, notch-filtered) and other filtered tone hooks. There also are other options available to improve retention of ear-level devices (e.g., Huggie aids and smaller tone hooks). With the advent of the tamper-proof battery compartment, safety issues have begun to be addressed. Computerized preselection systems have had an effect on adult hearing aid fittings, and by the end of 1991, a computerized preselection system for young children may be commercially available (Seewald, personal communication). Advanced circuitry (e.g., automatic signal processing, other noise-reduction circuits and the Etymotic K-amp) has been employed in some devices with adult patients, but their efficacy for use with infants and toddlers has not been established.

SELECTION AND FITTING OF AMPLIFICATION SYSTEMS

Key Considerations in Pediatric Amplification

When selecting amplification for infants and toddlers, there are both acoustical and practical issues to consider. Because modifications may need to be done as more information about the residual hearing becomes available or if the child experiences fluctuating hearing loss, it is important to choose a device that has flexible electroacoustic characteristics. The device should also be compatible with a variety of tone hooks to further enhance its flexibility.

The additive advantages of directional microphones and binaural fitting have been demonstrated (Hawkins & Yacullo, 1984) and should be considered essential for pediatric fittings. The availability of direct audio input is important given the likelihood that the child will use an auditory training device in the habilitation program. For this same reason, the telecoil strength should be a consideration in the event that the child will use an auditory trai ith a neck loop.

On a practical level, tamper-resistant battery compartments can improve the safety of the fitting in this age group. Regardless of whether this safety device is used, the parents should be provided with hearing aid battery precautions and the National Battery Ingestion Hotline number. Volume control covers can be used to ensure that the recommended setting is maintained. Loss and damage warranties should be considered, and the parents should be encouraged to insure the devices after the manufacturer's warranty expires.

Formula Approaches for Fitting Gain and Output

For young children, the use of formula or prescriptive approaches for fitting gain and output is essential. In most cases, the goal is to ensure that speech is audible within the patient's dynamic range (Skinner, 1988; Skinner, Pascoe, Miller, & Popelka, 1982). A critical consideration in using any formula approach is to keep the fitting goal in mind. The long-term speech spectrum used to define average conversational speech affects the extent to which a fitting is viewed as successful. Variations in the speech spectrum are accounted for by gender, age, distance, how the measurement is made, and what stimulus is used to generate the speech signal (Cox & Moore, 1989; Olsen, Hawkins, & Van Tasell, 1987). Cornelisse, Gagne, & Seewald (1991) evaluated the speech spectrum of various talkers at a reference position (30 cm and 0° from the mouth) and at the tragus of the talker. They observed that at the tragus, more low frequencies and fewer high frequencies were measured than at the reference position. They suggested that we must remember that the speech spectrum delivered to the ear is different if the patient is a listener versus a talker and that we need to think of the patient as a communicator as well as a listener. The talker's ability to monitor his or her own speech also must be considered as critical.

Various speech spectra have been characterized on dB SPL and dB HL audiograms (Olsen et al., 1987; Skinner, 1988). Recently, Mueller & Killion (1990) proposed using a simplified method to calculate an Articulation Index (AI), shown in Figure 1, that can be used for decision-making and for patient counseling. The AI has been used to predict the intelligibility of speech (e.g., Dirks, Bell, Rossman, & Kincaid, 1986; Pavlovic, 1988, 1989).

Humes & Hackett (1990) and Sullivan, Levitt, Hwang, and Hennessey (1988) have shown that comparisons between adult prescriptive approaches suggest no major differences in aided speech scores. Thus, to date, no adult formula approach clearly has been shown to be superior.

There is some question that these adult formulas cannot simply be applied to infants and toddlers because of the many differences between these two groups. Perhaps the primary difference is that infants and toddlers are learning speech and language and may require a better signal-to-noise ratio or greater input than an adventitiously hearing-impaired adult. Further, the substantially smaller ear-canal

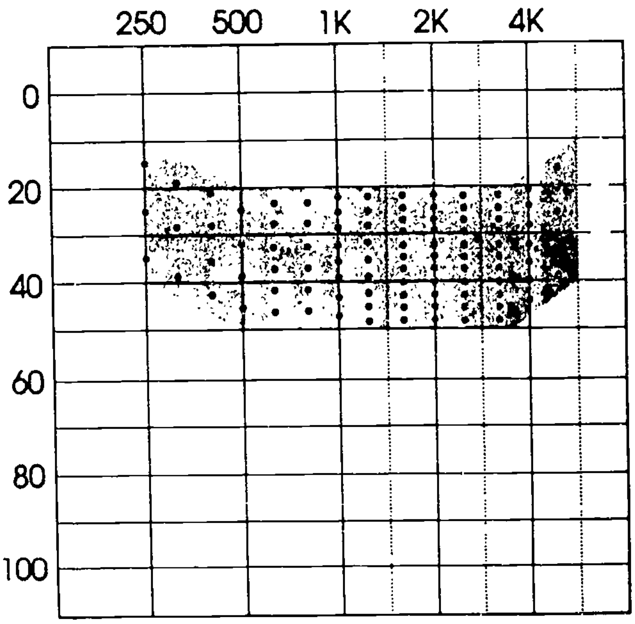

FIGURE 1. The count-the-dot audiogram for calculation of an Articulation Index (AI) (Mueller & Killion, 1990).

size has several ramifications. First, it may affect the SPL delivered to the ear (Feigin, Kopun, Stelmachowicz, & Gorga, 1989). Secondly, it has been shown that the resonance frequency of the ear canal in children below 2 years of age is higher than in an adult (Kruger, 1987). Further, the size of the infant/toddler ear also can affect the earmold fitting such that on the smallest ears, even a tube fitting may actually occlude the entire canal. Thus, most modifications in this population must be made electroacoustically rather than with earmold modifications. In this age group, we often have less threshold information and little, if any, speech recognition information. It is not possible to measure most comfortable loudness (MCL) or loudness discomfort levels (LDL), thus, fittings must be based on threshold data alone. Infants and toddlers have limited abilities for communicating their reactions to amplification. Consequently, we must be able to troubleshoot systematically their reactions to amplification. We must step through possible problems, from fit and comfort of the earmolds to the fit or function of the hearing aids.

Two threshold-based approaches for fitting amplification that are specific to children will be discussed next. The first is the optimal aided audiogram that has been popularized by Matkin (1987). The target aided thresholds are shown in Table 1. The rationale for these targets is to provide aided thresholds within the average conversational speech spectrum, with 5 dB of reserve gain. It should be noted that these targets are not intended for profound losses, where the goal may be altered to the detection of speech.

The second pediatric approach is the desired sensation level (DSL) approach, proposed by Seewald, Ross and colleagues (Ross & Seewald, 1988; Seewald, 1988; Seewald, Ross, & Spiro, 1985; Seewald, Ross, & Stelmachowicz, 1987; Stelmachowicz & Seewald, 1991). The goal of this fitting procedure is to deliver an amplified speech signal to the child that maximizes residual hearing across frequency (Ross & Seewald, 1988). The recommendations for the amplified desired sensation level of speech are shown in Figure 2. Note that the desired sensation level varies as a function of degree of hearing loss on a frequency-by-frequency basis. This approach provides targets to accommodate any given hearing loss.

Both of these pediatric approaches have recommendations for SSPL90 that vary with the degree of hearing loss and are based on average expectations. Previous research has shown that LDLs vary with frequency and cannot be predicted from threshold (Hawkins, Walden, Montgomery, & Prosek, 1987; Kawell, Kopun, & Stelmachowicz, 1988). Work with children has provided reliable methods to estimate LDLs in children as young as 5 years mental age (Macpherson, Elfenbein, Schum, & Bentler, in press). There are no proven solutions, however, for obtaining LDLs in children younger than 5 years of age. If we are unable to make real-ear measures, we must depend on average values for real-ear to coupler differences, and to use these values to estimate and select real-ear SPL (Feigin et al., 1989). Careful observation of the child's behavior for loudness intolerance is critical, and thresholds must be monitored for possible changes.

TABLE 1. Optimal aided thresholds (Matkin, 1987).

	Frequency (Hz)				
	250	500	1000	2000	4000
dB HL	30	30	25	20	20

For infants and toddlers, decisions about electroacoustic characteristics often must be made with minimal information. Limited behavioral test data must be supplemented with the behavioral observations of parents and teachers and with evoked potential test findings. ABR testing with clicks alone is not a solution to the problem of limited threshold information because the click-evoked ABR estimates only a limited frequency region. For this reason, click-evoked ABRs should be supplemented with tone-evoked ABRs (Gorga, Kaminski, Beauchaine, & Jesteadt, 1988; Stapells, Picton, Perez-Abalo, Read, & Smith, 1985). These tone-evoked ABR thresholds can be used to estimate behavioral thresholds.

Facilitating Adjustment to Amplification

One aspect of facilitating adjustment to amplification is addressed through communication with the parents, caregivers, and therapists. They should be trained to troubleshoot and care for the devices. To do so effectively, they should be provided with the necessary information and tools (e.g., a listening tube or stethoscope, a battery tester, an earmold blower, extra batteries, and a moisture-reduction device). Close contact with the parents, caregivers, and therapists during the initial phases of fitting assists in monitoring progress, and encouragement can be provided. With this close communication, fitting expectations can be compared with the child's performance, questions and issues addressed, and intervention strategies that enhance auditory skill development can be developed.

Audiologic follow-up visits are planned at frequent intervals to monitor thresholds, to ensure adequate adjustment to amplification, and to change settings on the hearing aid as new information is acquired. Some investigators have suggested that infants and toddlers be seen at least every 3 months for audiological assessment (Matkin, 1987; Stelmachowicz, Larson, Johnson, & Moeller, 1985).

Recent Expansions

Two recent expansions in fitting amplification have been in the areas of fitting children with unilateral hearing loss and the home use of auditory trainers. Because the focus of this discussion is on infants and toddlers, we will not discuss unilateral hearing losses because, as noted above, these are not often identified prior to 4 years of age (Mace et al., in press).

Infants and toddlers may be candidates for the home use of auditory trainers. Some centers have used auditory trainers in this application as the primary and initial device

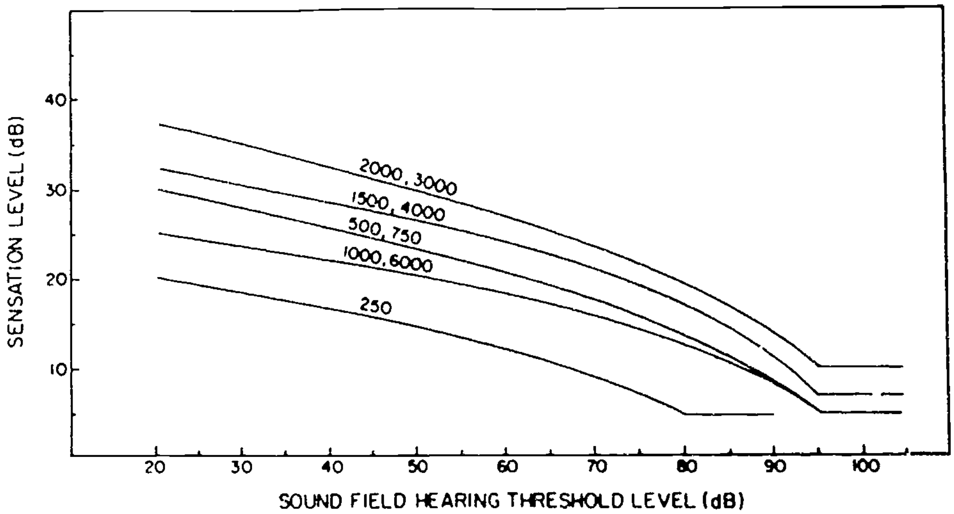

FIGURE 2. The desired sensation levels (DSL) for the amplified long-term speech spectrum. Levels are plotted as a function of sound field thresholds and frequency (Seewald & Ross, 1988).

for children with severe to profound losses. Benoit (1989) reported on a group of 1- to 4-year-olds with severe, profound hearing loss who were fit with auditory trainers for home use. The parents in that study reported that use of the device increased the amount that they talked to their child. They also reported that the microphone-transmitter acted as a reminder to talk to their child. However, there was no actual testing done on the children in this study to evaluate changes in their speech, language, or auditory skills. More research in this area is necessary to delineate further the efficacy of home use of these devices.

ASSESSMENT OF AIDED PERFORMANCE

Behavioral Methods

Behavioral and objective methods for assessment of aided performance will be discussed next. In the area of behavioral methods, functional gain has been used to estimate insertion gain. The reliability of aided sound field thresholds and functional gain has been addressed in adults (Hawkins, Montgomery, Prosek, & Walden, 1987; Humes & Kirn, 1990) and children as young as age 5 years (Stuart, Durieux-Smith, & Stenstrom, 1990); however, the reliability of aided sound field thresholds for infants and toddlers has not been studied. Functional gain or aided sound field thresholds can be used in cases when probe-tube microphone measures are not possible, for example, when there is limited cooperation for probe-tube microphone measures, when there is wax or slight drainage in the ear canal, in cases of atresia or stenosis, in the assessment of a bone-conduction device, and if there is limited access to probe-tube microphone equipment. The limitations of functional gain as compared to probe-tube microphone measures include the fact that measures are not valid if there are regions of normal sensitivity (Rines, Stelmachowicz, & Gorga, 1984). Behavioral methods are more time-consuming and provide only threshold information, with no estimate of aided performance for speech-level inputs or hearing aid maximum output.

Objective Methods

Two objective methods will be discussed: probe-tube microphone measures and ABR measures. Probe-tube microphone measures provide objective real-ear estimates of in situ and insertion gain and SSPL90. One advantage the measures have over functional gain is that they can reflect aided performance for average speech inputs. Other advantages are (a) they account for the impedance, resonance, earmold, and insertion loss on an individual; (b) they are fast, so many comparisons can be obtained in a short time; (c) they provide good frequency resolution; (d) estimates of gain can be obtained in regions of normal hearing; and (e) real-ear SSPL90 can be documented.

The limitations of using probe-tube measures with the pediatric population are that some ear canals may prove to be too small for placement of the probe and earmold without feedback, especially in cases of severe to profound hearing loss, and some children simply may not tolerate the procedure.

Real-ear measures, however, are especially useful because of the demonstrated range of variability of real-ear to coupler differences between subjects. Feigin et al. (1989) evaluated and compared these differences in children from 4 weeks to 5 years of age and in a group of adults. For the children, mean real-ear to coupler differences were greater than that observed for adults at all frequencies. The children showed a larger difference than adults, but with the same pattern, that is, greater real-ear to coupler differences with increasingly higher frequencies. For children, 10% of the time this difference exceeded 14 dB, whereas, in adults, 10% of the time this difference exceeded only 8 dB. The authors concluded that there was a greater risk of overamplification with children if 2cm³ coupler values were used to estimate SSPL90. Unfortunately, ear canal volume alone was not a useful predictor of this difference.

Consideration should be given also to situations in which insertion gain and functional gain do not agree. Some of these instances have been described by Stelmachowicz and Lewis (1988) and will be reviewed briefly here. As previously stated, when there are regions of normal hearing, functional gain is not an accurate estimate of the SPL developed in the ear because internal hearing aid noise can mask aided thresholds. Thus, functional gain would underestimate insertion gain in those cases. Also, if a hearing aid is set with high gain and low output, functional gain overestimates actual gain for average speech inputs. Also, in some patients with profound hearing loss, "thresholds" may be vibrotactile rather than auditory responses and insertion gain may overestimate functional gain.

Another objective approach to amplification is through the use of evoked potentials. The ABR has been proposed for use in hearing aid selection and assessment (for a review, see Beauchaine & Gorga, 1988; and Mahoney, 1985). Parameters that have been evaluated include comparisons of aided and unaided responses for (a) latency shifts (Cox & Metz, 1980; McPherson & Clark, 1983), (b) thresholds shifts (Beauchaine, Gorga, Reiland, & Larson, 1986; Kileny, 1982), and (c) changes in the slope of latency-intensity function (Hecox, 1983). Others have proposed using amplitude to estimate loudness (Davidson, Wall, & Goodman, 1990) and to prescribe maximum output and/or the need for compression (Keissling, 1982; 1983). To date, conflicting results have been reported about the relationship between ABR amplitude and loudness (Darling & Prince, 1990; Davidson et al., 1990). Thornton, Yardley, and Farrell (1987) and Thornton, Farrell, and McSporran (1989) have postulated using the slope of the latency-intensity function to estimate LDL.

Although promising, many problems have been identified in using the ABR for hearing aid evaluation and assessment. Each hearing aid introduces changes in the stimulus because it acts as a filter. Kileny (1982) demonstrated that the hearing aid can ring after a transient is introduced, affecting the response. Temporal delays introduced by the hearing aid are not predictable (Beauchaine et al., 1986). Unless measured and accounted for individually, the temporal delays may affect the supposed success of a fitting suggested by latency shifts. Compression circuits cannot be assessed with the ABR because the stimuli necessary to elicit the ABR are shorter than the compression times in the aids and the attack time of the hearing aid cannot follow the transient stimuli; yet even this relationship is not predictable (Gorga, Beauchaine, & Reiland, 1987). Most of the ABR-hearing aid work has been done with clicks, and this stimulus typically estimates high-frequency sensitivity (Coats & Martin, 1977; Jerger & Mauldin, 1978; Gorga, Worthington, Reiland, Beauchaine, & Goldgar, 1985). For profound losses, predictions of gain cannot be made from ABR data because there is no baseline for comparison. Finally, the relationship between loudness and amplitude and slope is not clearly established.

Given these precautions and problems with using the ABR to fit and evaluate hearing aids, a recommended protocol for patients on whom we cannot obtain behavioral thresholds might be to obtain frequency-specific ABR thresholds for a range of frequencies to estimate behavioral thresholds. Next, preselect a hearing aid or device using a method with a goal to make speech audible. Gain and output should be assessed in a coupler for estimates of these parameters, with average real-ear to coupler differences applied, and individual probe-tube microphone assessments should be used when possible. The child should be monitored with continued attempts at behavioral thresholds in the unaided condition, and adjustments made in the amplification as new information is obtained.

SUMMARY

In summary, early intervention is feasible on almost any patient given current technology. Technological advances have influenced early identification and amplification. Advantages in speech intelligibility have been demonstrated for improving signal-to-noise ratios. Research has delineated similarities and differences between children and adults. Although much progress has been made, many questions remain when fitting infants and toddlers, especially in the area of validation of the device of choice. A focus of the fitting scheme should include the parents or caregivers as key figures in the success of amplification selection and fitting. Without their support, acceptance, cooperation, and enthusiasm, the child will not succeed with use of amplification no matter what selection and assessment procedures are used.

ACKNOWLEDGMENTS

I would like to acknowledge Michael Gorga and Pat Stelmachowicz for their review of this manuscript and their many helpful editorial comments, and Betsy From for her assistance in the preparation of the manuscript.

REFERENCES

American Speech-Language Hearing Association, (ASHA). Joint Committee on Infant Hearing. (1991). 1990 Position Statement. *Asha* (Suppl. 5), 33, 3–6.

Beauchaine, K.A., & Gorga, M.P. (1988). Applications of the auditory brainstem response to pediatric hearing aid selection. *Seminars in Hearing*, 61, 7 4.

Beauchaine, K.A., Gorga, M.P., Reiland, J.K., & Larson, L.L. (1986). Application of ABRs to the hearing-aid selection process: Preliminary data. *Journal of Speech and Hearing Research*, 29, 120–128.

Benoit, R. (1989). Home use of FM amplification systems during the early childhood years. *Hearing Instruments*, 40, 8–12.

Bess, F.H. (1985). The minimally hearing-impaired child. *Ear and Hearing*, 6, 43–47.

Bess, F.H., & Tharpe, A.M. (1986). Case history data on unilaterally hearing-impaired children. *Ear and Hearing*, 7, 14–19.

Blair, J.C., Peterson, M.E., & Viehweg, S.H. (1985). The effects of mild hearing loss on academic performance of young school-age children. *The Volta Review*, 87, 87-93.

Bray, P., & Kemp, D. (1987). An advanced cochlear technique suitable for infant screening. *British Journal of Audiology*, 21, 191-204.

Coats, A.C., & Martin, J.L. (1977). Human auditory nerve action potentials and brainstem evoked responses: Effects of audiogram shape and lesion location. *Archives of Otolaryngology*, 103, 605-622.

Cornelisse, L.E., Gagne, J.P., & Seewald, R.C. (1991). Ear level recordings of the long-term average spectrum of speech. *Ear and Hearing*, 12, 47-54.

Cox, L., & Metz, D.A. (1980). ABER in the prescription of hearing aids. *Hearing Instruments*, 31, 12-15.

Cox, R.M., & Moore, J.N. (1989). Composite speech spectrum for hearing aid gain prescriptions. *Journal of Speech and Hearing Research*, 31, 102-107.

Darling, R.M., & Price, L.L. (1990). Loudness and auditory brainstem evoked response. *Ear and Hearing*, 4, 289-295.

Davidson, S.A., Wall, L.G., & Goodman, C.M. (1990). Preliminary studies on the use of an ABR amplitude projection procedure for hearing aid selection. *Ear and Hearing*, 11, 332-339.

Dirks, D.D., Bell, T.S., Rossman, R.N., & Kincaid, G.E. (1986). Articulation index predictions of contextually dependent works. *Journal of the Acoustical Society of America*, 80, 82-92.

Elssmann, S.F., Matkin, N.D., & Sabo, M. (1987). Early identification of congenital sensorineural hearing impairment. *The Hearing Journal*, 40, 13-17.

Feigin, J.A., Kopun, J.G., Stelmachowicz, P.G., & Gorga, M.P. (1989). Probe microphone measures of ear-canal sound pressure levels in infants and children. *Ear and Hearing*, 10, 254-258.

Gorga, M.P., Beauchaine, K.A., & Reiland, J.K. (1987). Comparison of onset and steady state responses of hearing aids: Implications for use of the auditory brainstem response in the selection of hearing aids. *Journal of Speech and Hearing Research*, 30, 130-136.

Gorga, M.P., Kaminski, J.R., Beauchaine, K.A., & Jesteadt, W. (1988). Auditory brainstem responses to tone bursts in normally hearing subjects. *Journal of Speech and Hearing Research*, 31, 87-97.

Gorga, M.P., Worthington, D.W., Reiland, J.K., Beauchaine, K.A., & Goldgar, D.E. (1985). Some comparisons between auditory brain stem response thresholds, latencies, and the pure-tone audiogram. *Ear and Hearing*, 6, 105-112.

Hawkins, D.B., & Yacullo, W.S. (1984). Signal-to-noise advantage of binaural hearing aids and directional microphones under different levels of reverberation. *Journal of Speech and Hearing Disorders*, 49, 278-286.

Hawkins, D.B., Montgomery, A.A., Prosek, R.A., & Walden, B.E. (1987). Examination of two issues concerning functional gain measurements. *Journal of Speech and Hearing Disorders*, 52, 56-63.

Hawkins, D.B., Walden, B.E., Montgomery, A., & Prosek, R.A. (1987). Description and validation of an LDL procedure designed to select SSPL90. *Ear and Hearing*, 8, 162-169.

Hecox, K.E. (1983). Role of auditory brainstem responses in the selection of hearing aids. *Ear and Hearing*, 4, 51-55.

Humes, L.E., & Hackett, T. (1990). Comparison of frequency response and aided speech-recognition performance for hearing aids selected by three different prescriptive methods. *Journal of the American Academy of Audiology*, 1, 101-108.

Humes, L.E., & Kirn, E.U. (1990). The reliability of functional gain. *Journal of Speech and Hearing Disorders*, 55, 193-197.

Jerger, J., & Mauldin, L. (1978). Prediction of sensorineural hearing level from the brainstem evoked response. *Archives of Otolaryngology*, 104, 456-461.

Kawell, M.E., Kopun, J.G., & Stelmachowicz, P.G. (1988). Loudness discomfort levels in children. *Ear and Hearing*, 9, 133-137.

Kiessling, J. (1982). Hearing-aid selection by brainstem audiometry. *Scandinavian Audiology*, 11, 269-273.

Kiessling, J. (1983). Clinical experience in hearing aid adjustment by means of BER amplitudes. *Archives of Otolaryngology*, 238, 233-240.

Kileny, P. (1982). Auditory brainstem responses as indicators of hearing aid performance. *Annals of Otology, Rhinology and Laryngology*, 238, 233-240.

Kruger, B. (1987). An update on the external ear resonance in infants and young children. *Ear and Hearing*, 8, 333-336.

Mace, A.L., Wallace, K.L., Whan, M.Q., & Stelmachowicz, P.G. (in press). Relevant factors in the identification of hearing loss. *Ear and Hearing*.

Macpherson, B.J., Elfenbein, J.L., Schum, R.L., & Bentler, R.A. (in press). Thresholds of discomfort in children. *Ear and Hearing*.

Mahoney, T.M. (1985). Auditory brainstem response hearing aid applications. In J.T. Jacobson (Ed.), *The auditory brainstem response* (pp. 349-380). San Diego, College-Hill Press.

Mahoney, T.M., & Eichward, J.G. (1986). Model program V: A high-risk register by computerized search of birth certificates. In E.T. Swigart (Ed.), *Neonatal hearing screening*. San Diego: College-Hill Press.

Martin, F.N., & Gravel, K.L. (1989). Pediatric audiologic practices in the United States. *The Hearing Journal*, 42, 33-48.

Matkin, N.D. (1987). Hearing instruments for children: Premises for selecting and fitting. *Hearing Instruments*, 38, 14-16.

McPherson, D.L., & Clark, N.E. (1983). ABR in hearing aid utilization: Simulated deafness. *Hearing Instruments*, 34, 12-15.

Mueller, H.G., & Killion, M.C. (1990). An easy method for calculating the articulation index. *The Hearing Journal*, 43, 14-17.

Olsen, W.O., Hawkins, D.B., & Van Tasell, D.J. (1987). Representations of the long-term spectra of speech. *Ear and Hearing*, 100S-108S.

Oyler, R.F., Oyler, A.L., & Matkin, N.D. (1987). Warning: A unilateral hearing loss may be detrimental to a child's academic career. *The Hearing Journal*, 18, 20-22.

Pavlovic, C.V. (1988). Articulation index predictions of speech intelligibility in hearing aid selection. *Asha*, 32, 63-65.

Pavlovic, C.V. (1989). Speech spectrum considerations and speech intelligibility predictions in hearing aid evaluations. *Journal of Speech and Hearing Disorders*, 54, 3-8.

Rines, D., Stelmachowicz, P.G., & Gorga, M.P. (1984). An alternate method for determining functional gain of hearing aids. *Journal of Speech and Hearing Research*, 27, 627-633.

Ross, M., & Seewald, R.C. (1988). Hearing aid selection and evaluation with young children. In F.H. Bess (Ed.), *Hearing impairment in children* (pp. 190-213). Parkton, Maryland: York Press.

Seewald, R.C., Ross, M., & Stelmachowicz, P.G. (1987). Selecting and verifying hearing aid performance characteristics for young children. *Journal of the Academy of Rehabilitative Audiology*, 20, 25-37.

Seewald, R.C. (1988). The desired sensation level approach for children: Selection and verification. *Hearing Instruments*, 39, 18-22.

Seewald, R.C., Ross, M., & Spiro, M.K. (1985). Selecting amplification characteristics for young hearing-impaired children. *Ear and Hearing*, 6, 48-53.

Skinner, M.W. (1988). *Hearing aid evaluation*. Englewood Cliffs, NJ: Prentice Hall.

Skinner, M.W., Pascoe, D.P., Miller, J.D., & Popelka, G.R. (1982). Measurements to determine the optimal placement of speech energy within the listener's auditory area: A basis for selecting amplification characteristics. In G. A. Studebaker & F.H. Bess (Eds.), *The Vanderbilt hearing-aid report. State of the art-research needs* (pp. 161-169). Upper Darby, PA: Monographs in Contemporary Audiology.

Stapells, D.R., Picton, T.W., Perez Abalo, M., Read, D., & Smith, A. (1985). Frequency specificity in evoked potential audiometry. In J.T. Jacobson (Ed.), *The auditory brainstem response* (pp. 147-177). San Diego, California: College-Hill Press, Inc.

Stein, L.K., Jabaley, T., Spitz, R., Stoakley, D., & McGee, T. (1990). The hearing-impaired infant: Patterns of identification and habilitation revisited. *Ear and Hearing*, 11, 201-205.

Stelmachowicz, P.G., Larson, L.L., Johnson, D.E., & Moeller, M.P. (1985). Clinical model for the audiological management of hearing-impaired children. *Seminars in Hearing*, 6, 223-237.

Stelmachowicz, P.G., & Lewis, D.E. (1988). Some theoretical considerations concerning the relation between functional gain and insertion gain. *Journal of Speech and Hearing Research, 31*, 491–496.

Stelmachowicz, P.G., & Seewald, R. (1991). Probe-tube microphone measures in young children. *Seminars in Hearing, 12*, 62–72.

Stuart, A., Durieux-Smith, A., & Stenstrom, R. (1990). Critical differences in aided sound field thresholds in children. *Journal of Speech and Hearing Research, 33*, 612–615.

Sullivan, J.A., Levitt, H., Hwang, J., & Hennessey, A. (1988). An experimental comparison of four hearing aid prescription methods. *Ear and Hearing, 9*, 22–32.

Thornton, A.R.D., Farrell, G., & McSporran, E.L. (1989). Clinical methods for the objective estimation of loudness discomfort level (LDL) using auditory brainstem responses in patients. *Scandanavian Audiology, 16*, 225–230.

Thornton, A.R.D., Yardley, L., & Farrell, G. (1987). The objective estimation of loudness discomfort level using auditory brainstem evoked responses. *Scandanavian Audiology, 16*, 219–225.