

Chapter 5

Current Issues in Hearing Aid Fitting

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Abstract

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Summary

This chapter provides an overview of current approaches to hearing aid fitting. The role of each of the four sequential stages that comprise the hearing aid fitting process including assessment, selection, verification, and evaluation is considered within the general structure of a comprehensive rehabilitation program. In addition, clinical practices/procedures that are presently employed for this purpose as well as several innovative approaches to hearing aid fitting that have been reported recently are described. Finally, both theoretical and methodological issues that will require further investigation are identified and discussed.

Historically, hearing aid fitting has been described as a clinical process comprised of a series of well-integrated and systematic stages imbedded within a comprehensive program of audiological rehabilitation (Carhart, 1946). In routine clinical practice, however, this process is often performed as a discrete component of audiological service delivery and represents both the beginning and the end of audiological intervention. As such, the fitting of a hearing aid is presented as *the solution* to the full-range of difficulties that are encountered by hearing-impaired individuals. The issues to be discussed in this chapter relate primarily

to the clinical process of hearing aid fitting in adults. Throughout this chapter it is assumed, however, that this process is thoughtfully integrated into a relevant and comprehensive program of audiological rehabilitation.

Despite several notable attempts to characterize the hearing aid fitting process (e.g., Byrne, 1982; Skinner, 1988), the field has yet to reach agreement regarding how to define and to communicate with each other about this component of audiological rehabilitation. Consequently, we have an ever-growing list of concepts and terms associated with clinical hearing aid-related work that includes, for example: assessment, evaluation, verification, validation, selection, preselection, fitting, prescription, orientation, counselling, and follow-up.

To a certain extent, the conceptual and communicative difficulties we have related to this process are historical in nature. While many of the concepts and terms that Raymond Carhart and his colleagues used during the 1940s to describe the activities associated with hearing aid fitting remain in common use today, the nature of the process, as presently implemented in most clinical settings, has undergone substantial modification.

The general framework that has been developed for this discussion is schematically represented in Figure 1. This figure illustrates that the hearing aid fitting process is comprised of a series of sequential stages that are systematically imbedded within the matrix of activities associated with audiological rehabilitation. From this figure, it can be observed that the rehabilitation program is initiated with a general assessment. During this assessment, the problems and needs are defined both from the client's and the clinician's perspective. On the basis of the findings obtained, a preliminary plan for intervention is designed. The intervention strategies that are selected from the available options (see Figure 1) relate naturally to the unique set of problems and needs that are identified and defined for the client. For those individuals for whom the use of a hearing aid has been incorporated into the rehabilitation plan, the hearing aid fitting process is subsequently initiated at the appropriate time.

As shown in Figure 1, the hearing aid fitting process is initiated with a set of assessment procedures specifically designed for the purposes of hearing aid fitting. Also shown in this figure are the three subsequent stages of the hearing aid fitting process. The dotted arrows have been included to illustrate the inter-related nature of these four stages. For example, if the results obtained during the verification stage indicate that the instrument that has been fitted to the client does not display the desired electroacoustic characteristics, it will be necessary to return to the selection stage where alternative instruments and/or fitting strategies can be considered. Finally, once the evaluation of aided benefit has been successfully completed, the client continues on through all necessary components of the rehabilitation program. To a certain extent, the benefit that is derived from the use of hearing aids will determine the need for additional intervention strategies. In the following discussion, attention is focused primarily on the four sequential stages that comprise the hearing aid fitting process that include: (a) assessment for hearing aid fitting, (b) hearing aid selection, (c) veri-

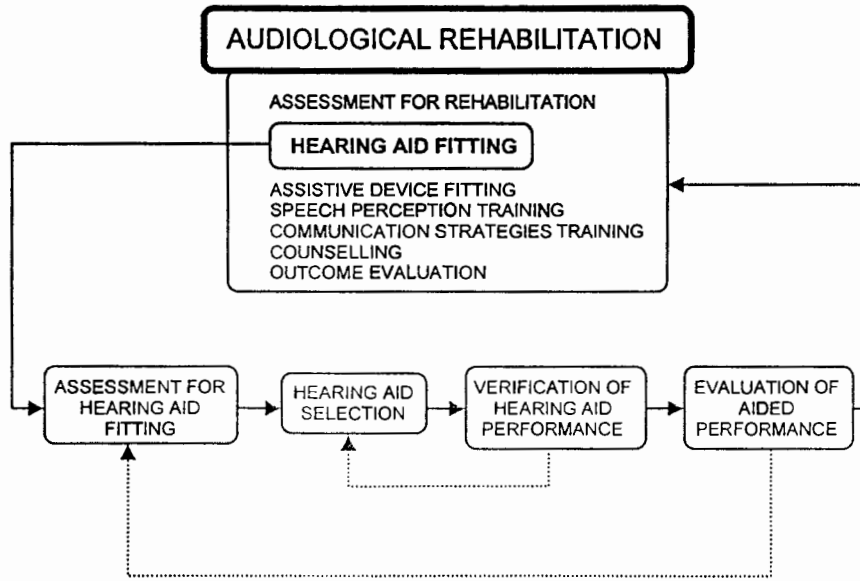


Figure 1. Schematic representation of the hearing aid fitting process shown in relation to a comprehensive program of audiological rehabilitation.

fication of hearing aid performance, and (d) evaluation of aided performance.

ASSESSMENT FOR HEARING AID FITTING

One of the primary purposes of audiological assessment is to describe the nature of an auditory impairment and its consequences in a manner which will facilitate appropriate audiological and/or otologic intervention. A second and equally important purpose is to establish a pretreatment performance baseline against which the outcome of intervention can be assessed. By viewing assessment in this way, the clinician needs to: (a) determine the type of information that will be required for the purpose of informed clinical decision making, (b) consider the array of available measurement options, and (c) develop a set of audiological assessment protocols accordingly. The extent to which this general orientation to assessment is reflected in routine clinical practice, for the purposes of hearing aid fitting, varies substantially across clinicians.

Before audiological assessment practices for hearing aid fitting are discussed, it may be useful to consider how the assessment findings will be applied during the subsequent stages of the fitting process. Once it has been determined that the individual is a candidate for hearing aid use, a series of hearing aid selection-related decisions will need to be made. These decisions relate to both the physical and electroacoustic performance characteristics of the instrument(s) that will be prescribed. With regard to the physical characteristics of the hearing aid, for example, the clinician will need to select the hearing aid type and choose from

among a variety of hardware options (e.g., telecoil, direct audio-input, microphone type).

The clinician will also be required to make a number of decisions that relate to the gain, frequency response, and output limiting characteristics of the hearing aid. Furthermore, there is a need to decide if acoustic venting or other earmold/shell modifications will be required. Finally, decisions regarding the need for one of several alternative forms of compression amplification may be necessary. With the new generation hearing aids (e.g., programmable multi-band compression instruments), the number of parameters that require adjustment increases the complexity of electroacoustic selection several-fold. For example, several of the hearing aids that have been recently introduced require adjustment of the cut-off frequencies between two or more bands, the attack and recovery times within each band as well as band-dependent compression thresholds and compression ratios. Technical decisions such as these cannot be made in an informational vacuum. However, by identifying the issues that will require consideration throughout the process the clinician can structure the assessment protocol in a manner that will facilitate informed decision making.

Audiometric Assessment Measures

Undoubtedly, the most common approach to audiological assessment for the purposes of hearing aid fitting is to utilize the test findings that were obtained using conventional audiometric procedures. The results of a recent survey reported by Bratt and Sammeth (1991) revealed, for example, that between 80-95% of orders received by manufacturers of custom hearing aids were accompanied by a pure tone audiogram only. The assumption associated with this approach to assessment for hearing aid fitting is that these conventional audiometric procedures (in particular pure tone threshold measures) provide both sufficient and valid data upon which to base all decisions that relate to hearing aid selection. The validity of this assumption can be questioned for several reasons.

With regard to the adequacy of audiometric threshold data for hearing aid selection purposes there are, at present, no data which support the position that the growth of loudness or degree of loudness summation in listeners with sensorineural hearing impairment can be predicted accurately from pure tone thresholds. In fact, all available data sets concerning the relationship between pure tone thresholds and supra-threshold loudness measures in listeners with sensorineural hearing impairment suggest that these variables are only slightly related (e.g., Kamm, Dirks, & Mickey, 1978; Pascoe, 1988). For this reason, some supra-threshold audiometric assessment procedures have been developed for the purposes of hearing aid fitting specifically. They include: (a) frequency-specific comfortable listening level measures (Allen & Jeng, 1990; Cox, 1983, 1985; Pascoe, 1986) and (b) frequency-specific loudness discomfort level (LDL) measures (Cox, 1981; Gagné, Seewald, Zelisko, & Hudson, 1991; Hawkins, 1980; Hawkins, Walden, Montgomery, & Prosek, 1987; Kawell, Kopun, & Stelmachowicz, 1988; Pascoe, 1986).

It is relevant to this discussion to note that the recently published Vanderbilt/VA Hearing Aid Conference Consensus Statement regarding the recommended components of a hearing aid selection procedure for adults states that, "Some accepted type of supra-threshold judgement (e.g., loudness discomfort levels, uncomfortable loudness levels, or highest comfortable loudness levels) should be used to determine an appropriate maximum output of a hearing aid" (Hawkins, Beck, Bratt, Fabry, Mueller, & Stelmachowicz, 1991, p. 321). Nonetheless, clinician acceptance of the need for supra-threshold loudness measurements for the purposes of hearing aid fitting remains an unresolved and somewhat controversial issue in this field (Hawkins & Schum, 1991). This on-going controversy is particularly interesting in light of the fact that similar measurements are considered to be essential and are performed routinely in the fitting of cochlear implant systems.

It can be anticipated that some of the uncertainty surrounding supra-threshold measures may be resolved within the near future as a result of emerging hearing aid technologies. It is difficult to imagine, for example, how the compression ratios of individual frequency bands incorporated into multiple band hearing aids can be appropriately selected without having first carefully defined a listener's auditory area (i.e., thresholds, comfortable listening levels, loudness discomfort levels) across frequencies. Clearly, without sufficient problem definition appropriate intervention with amplification cannot be easily accomplished.

Skinner (1988) has described a number of factors that, either alone or in combination, can compromise the validity of audiometric data that are obtained for the purposes of hearing aid fitting. While it is not within the scope of this chapter to examine all potential threats to the validity of audiometric data, one such factor will be used to illustrate the need to critically evaluate current approaches to audiometric assessment for this purpose.

According to Skinner (1988) one potential threat to the validity of audiometric data that are collected for hearing aid fitting purposes relates to the manner in which the audiometric test signals are delivered to the listener. By convention, most audiometric data are obtained using the TDH-series supra-aural earphone. While it is convenient to use the same signal transducer for a variety of purposes in audiometric data collection, there are several potential problems and limitations associated with this approach for hearing aid fitting purposes (Gauthier & Rapisardi, 1992; Seewald, Moodie, & Zelisko, 1993; Skinner, 1988).

As we have observed elsewhere (Seewald et al., 1993), there are certain advantages to specifying audiometric data in dB sound pressure level (SPL) as measured in a 2-cm³ coupler or in the real-ear of the listener for the purposes of hearing aid fitting (Cox, 1981; Erber, 1973; Hawkins, 1980; Libby, 1985; Seewald, 1991; Skinner, 1988). By specifying audiometric data in terms of the SPL developed in a 2-cm³ coupler, the metric is the same as that used to characterize the electroacoustic performance of hearing aids. Thus, direct comparisons can be made between hearing aid performance and the auditory characteristics of the listener. Unfortunately, the conventional audiometric earphone is cali-

brated in a 6-cm³ coupler. Therefore, when clinicians manipulate audiometric and electroacoustic data simultaneously in routine practice, they are dealing with a quintessential "apples and oranges" problem. There are several ways that audiometric data can be collected so that they are more compatible with hearing aid fitting. The first option is to use a probe-tube microphone to measure the SPL of the test signal within the ear canal at threshold or at the listener's loudness discomfort level (Gagné et al., 1991; Hawkins & Schum, 1991; Stelmachowicz, 1991; Stuart, Durieux-Smith, & Stenstrom, 1991). With this approach, the manner in which the auditory characteristics are defined (i.e., ear canal sound pressure level) will be the same as that which is subsequently applied in quantifying the levels of the measured hearing aid performance characteristics. Alternatively, it has been suggested that a listener's auditory characteristics can be defined in reference to the SPL developed in a 2-cm³ coupler (Cox, 1981; Erber, 1973; Hawkins, 1980; Hawkins et al., 1987). Although somewhat less precise, a third option is to predict the ear canal SPL associated with audiometric measures by using a set of average transformation values (e.g., Bentler & Pavlovic, 1989, 1992; Cox, 1986).

With regard to the option of predicting the ear canal levels from audiometric data collected using the TDH-series earphone, Skinner (1988) has concluded that average 6-cm³ coupler to tympanic membrane transformation values can be used to predict the SPL at the eardrum with a reasonable degree of accuracy for frequencies between 750 and 2000 Hz, but not at higher and lower frequencies. Furthermore, on the basis of her findings, Cox (1986) concluded that an average 6-cm³ coupler to tympanic membrane transformation could be used to predict the SPL at the eardrum to within ± 6 dB between 250 and 2000 Hz and to within only ± 12 dB at frequencies above 2000 Hz for 95% of the adult subjects in her study.

The following example is presented to illustrate the importance of signal-transducer considerations as they relate to audiometric assessment for hearing aid fitting. Assume that a listener's LDL, that has been measured using a conventional supra-aural audiometric earphone, is 100 dB HL at 4000 Hz. Having obtained this finding, the question is: what should the maximum output of the hearing aid be within the listener's ear canal so that comfortable listening can be ensured? If the clinician were to apply an average 6-cm³ coupler to eardrum transformation, it would be predicted that the ear canal level at this listener's LDL would be 115 dB SPL. Thus, the clinician might adjust the maximum hearing aid output to some level below 115 dB SPL (ear canal level). Unfortunately, because of the degree of inaccuracy associated with this prediction, the clinician can only be certain (95 times in 100) that the actual ear canal level associated with this listener's LDL at 4000 Hz falls somewhere between 103-127 dB SPL! Clearly, this degree of accuracy in predicting the quantity of primary interest (i.e., ear canal SPL) is inadequate for the purposes of electroacoustic fitting.

The preceding discussion has identified issues that are specifically related to

the signal transducer used in audiometric assessment. As noted earlier, this is only one of several procedural issues that need to be investigated further if our clinical approaches to hearing aid fitting are to evolve. Additional procedure-related issues that require further consideration with regard to assessment for the hearing aid fitting process include: (a) test signal characteristics and (b) psychophysical measurement procedures and instructional set characteristics for supra-threshold measures. Above all, it is important to remain cognizant of the fact that regardless of which approach is taken to audiometric assessment, the appropriateness of a hearing aid (and ultimately the benefit that can be derived from amplification) will depend in part on the validity of the audiometric data that are applied during the fitting process.

Self-Report Measures

To this point in the discussion, emphasis has been placed on the application of audiometric measures in the fitting of hearing aids. When this approach to assessment is used exclusively, the problems that clients bring with them are largely defined from the clinician's perspective. Although well-intentioned, this clinician-centered approach to problem definition can all too easily lead to inappropriate and/or ineffective treatment.

In recent years, a number of self-report measures have been developed for the purpose of describing the nature of the problems associated with impaired auditory function from the client's perspective (e.g., Demorest & Erdman, 1986; Giolas, Owens, Lamb, & Schubert, 1979; Ventry & Weinstein, 1983a). One potential application of such measures can be derived from the findings of a study recently reported by Fino, Bess, Lichtenstein, and Logan (1992).

This retrospective study was designed to identify factors that led to successful hearing aid use by elderly listeners. In addition to routine audiometric procedures, each individual's self-perceived handicap was measured using the screening version of the Hearing Handicap Inventory for the Elderly (HHIE-S; Ventry & Weinstein, 1983b). The HHIE-S is a 10-item questionnaire that was developed to measure self-perceived communicative and emotional problems among the elderly which can result from impaired hearing. One finding of particular relevance to the present discussion is that, regardless of the degree of hearing loss, the elderly subjects who failed to comply with a recommendation for hearing aid use perceived themselves to be significantly less handicapped relative to the individuals who ultimately chose to use a hearing aid. This finding highlights the importance of incorporating the client's own perceptions of their needs and difficulties into the decision-making process for determining candidacy for a particular form of audiological intervention. The potential application of self-report measures for the important purpose of predicting the success of our rehabilitative efforts warrants further study.

It should be recalled that one additional purpose in performing the assessment prior to the fitting of a hearing aid is to establish a pretreatment performance baseline against which the outcome of the intervention can be evaluated. Several

innovative approaches to quantifying outcome, using self-report measures, have been reviewed in the recent literature (e.g., Cox, Alexander, & Gilmore, 1991; McCarthy, 1991). Because the findings that are obtained from such measures are primarily used for the purpose of measuring outcome, their application in hearing aid fitting process will be discussed within the section devoted to the evaluation of aided performance.

As illustrated in Figure 1, once the assessment protocol for hearing aid fitting has been completed, the information obtained is subsequently applied within the selection stage. The following section provides a description of several current approaches to selection along with a discussion of several hearing aid selection-related issues that will require further consideration.

HEARING AID SELECTION

During the selection stage, the clinician engages in a complex decision-making process. The outcome of this decision-making process is a hearing aid configuration that embodies the physical and electroacoustic characteristics which, in theory, are most likely to meet the unique requirements of the client under consideration. As Byrne (1982) has observed, the fundamental problem at this stage is in knowing how to choose the particular combination of amplification characteristics (e.g., gain, frequency response, output limiting, compression ratios) that will be most appropriate for a particular individual given their own unique set of auditory characteristics and communicative requirements (e.g., hearing sensitivity across frequencies, growth of loudness, environmental factors). In view of the vast number of potentially relevant variables that need to be considered, the task of selecting an appropriate hearing aid is one that is inherently complex. To a certain extent, the approach that is taken at the selection stage will depend on the type of hearing aid that is to be prescribed as well as the availability of particular instrumentation systems. However, regardless of the particular conditions under which the characteristics of hearing aids are selected, the theoretical rationale that is applied at this stage of the process should be defensible on the basis of current scientific knowledge.

Presently, one approach that is relatively popular (Bratt & Sammeth, 1991) might be described as the minimalist approach to selection. Briefly, the clinician submits the audiometric data they have collected for a particular client, along with an ear impression, to a manufacturer of "custom" in-the-ear (ITE) or in-the-canal (ITC) instruments. On some basis, the manufacturer fabricates an instrument that is subsequently fitted to the client. There are several advantages associated with this approach that relate primarily to efficiency. First, the only selection-related decisions the clinician is required to make pertain to the type of instrument (e.g., ITE, ITC) that is to be recommended and which manufacturer to employ. Second, the verification stage of the fitting process can be virtually eliminated. This is because, when a set of electroacoustic performance criteria have not been developed at the selection stage, there exists no basis upon

which the adequacy of the electroacoustic fit can be evaluated.

Unfortunately, even if the manufacturer applies a theoretically defensible approach to the selection of electroacoustic characteristics, there are several sources of variability that are associated with this general approach. Specifically, because there are "missing data" for relevant variables (e.g., Real Ear Unaided Response, Real Ear to Coupler Differences), the manufacturer is forced to apply average values in developing a set of appropriate 2-cm³ coupler performance characteristics. The extent to which these coupler-based characteristics translate into a reasonable set of real-ear performance characteristics cannot be known.

There are, of course, a variety of options that are presently available to clinicians beyond the minimalist approach. However, they require the clinician to take a more active role in selection-related decisions. During the past 15 years a number of hearing aid selection methods have been developed that can be used by clinicians to select the electroacoustic characteristics of hearing aids for their clients (Berger, Hagberg, & Rane, 1984; Byrne & Dillon, 1986; Cox, 1983, 1985, 1988; Hawkins et al., 1987; McCandless & Lyregaard, 1983; Schwartz, Lyregaard, & Lundh, 1988; Seewald, 1992; Skinner, Pascoe, Miller, & Popelka, 1982). For specific details related to these formal hearing aid selection methods, the interested reader is referred to Byrne (1993); Byrne, Parkinson, and Newall (1991); Hawkins (1992); Humes (1991); and Skinner (1988, 1993).

The extent to which any of these hearing aid selection methods lead to a greater degree of long-term benefit for the client on a consistent basis is presently unknown. Nonetheless, there would appear to be several advantages to the application of one of these formal selection methods relative to the approach that was described earlier. This position is reflected in the recently published Vanderbilt/VA Conference Consensus Statement regarding the recommended components of a hearing aid selection procedure for adults. Specifically, it is stated, "Two-cm³ gain should be determined which will yield desired real-ear performance as specified by a published gain/frequency response selection procedure" (Hawkins et al., 1991, p. 322). Furthermore, it was recommended in this Consensus Statement that, in those circumstances where a client is unable to make reliable supra-threshold judgements of loudness, a data-based prediction method (e.g., Cox, 1988; Seewald, 1992; Skinner, 1988) should be used to determine the maximum output limiting characteristics of the selected instrument.

A major advantage associated with using one of the formal hearing aid selection methods is that, in doing so, the clinician participates more actively in deciding how a hearing aid should perform for a given individual. As a result, a set of performance criteria is developed against which the actual real-ear performance can be compared. Although none of the currently available methods come with a built-in guarantee for perfect fitting in all cases, it is only through the application of these more systematic approaches that we can accumulate the type of data that is required for the natural evolutionary process to proceed toward more beneficial fitting for each individual hearing-impaired listener.

One selection-related issue that will require consideration within the near fu-

ture relates to the manner in which the electroacoustic performance criteria are specified. Prior to the availability of clinical probe-tube microphone systems, most of the hearing aid selection methods expressed the electroacoustic performance criteria in terms of target sound field aided thresholds (Berger et al., 1984; Byrne & Tonnison, 1976; Cox, 1983; Seewald & Ross, 1988). These target threshold values were derived by subtracting the prescribed real-ear gain for a given degree of hearing loss from the unaided thresholds. Thus, if a client was provided with the prescribed amount of real-ear gain across frequencies, the measured sound field aided thresholds would, at least in theory, be equal to the target values. With the development of clinical probe-tube microphone systems, it was only natural to retain the concept of desired real-ear gain, but to specify the performance criteria in terms of the desired insertion gain rather than as target sound field aided thresholds.

In the development of most of the current hearing aid selection methods it has been assumed that the amount of real-ear gain that is measured within the clinical setting (using either sound field aided thresholds or probe-tube microphone measures) will be the same as that which is available under the conditions of everyday communication. This assumption holds true for most linear hearing aids provided that the output limiting levels of the hearing aid are adjusted such that linearity in output is maintained for input signal levels that are associated with conversation speech. Unfortunately, with the newer generation of automatic signal processing (ASP) instruments where, for example, both the gain and the frequency response vary as a function of the input signal level, this assumption is no longer valid. Thus, it cannot be assumed that, by adjusting the response of a hearing aid to match a set of target insertion gain values within the clinical environment, the listener will be provided with the desired performance under real-world communicative conditions. This is one of the hearing aid fitting-related problems that calls for immediate attention.

Assuming that the clinician has developed a set of electroacoustic performance criteria for the client, the next step is to construct or have a hearing aid/coupling arrangement constructed that should, at least in theory, provide a good approximation to the criteria that were developed within the selection stage. As observed earlier, one weak-link in the process of selecting/ordering custom ITE and ITC hearing aids pertains to the absence of data for several relevant variables. The problem that this creates for the manufacturer is that, without having the necessary information regarding the unique acoustical properties of the ear(s) to be fitted, a set of average values must be applied during the "customization" process. One innovative approach to this missing data problem has been described in the recent literature (Fikret-Pasa & Revit, 1992; Mueller, 1989, 1992; Punch, Chi, & Patterson, 1990) and is as follows. First, the clinician applies one of the formal electroacoustic selection strategies to derive a set of target real-ear insertion response values for the listener. Second, the clinician obtains a measurement of the real-ear unaided response and real-ear to coupler difference values for that listener. Finally, the real-ear insertion response, real-ear unaided

response, and real-ear to coupler difference values are combined (along with a constant for reserve gain) to develop a prescription for the desired full-on 2-cm³ coupler gain. Similarly, a prescription for SSPL90/frequency can be derived by combining the desired real-ear saturation response target values and the real-ear to coupler differences/frequency for the client under consideration.

By individualizing the selection/ordering process in this way, electroacoustic fitting can be more precise and thereby possibly reduce the number of returns to the manufacturer for instrument remakes. It should also be noted that this entire problem can be eliminated through the use of digitally programmable hearing aids where the selection/fitting process (with the exception of hearing aid shell fabrication) occurs within the clinical environment.

Once the hearing aid has been fitted to the client, the next question the clinician confronts relates to how well the measured real-ear hearing aid performance approximates the target values. This leads to the verification stage of the fitting process.

VERIFICATION OF HEARING AID PERFORMANCE

The fundamental question to be addressed at the verification stage is: to what extent does the measured performance of a hearing aid meet the theoretical set of criteria that were developed for a given client? To answer this question, two requirements must be met. First, a set of electroacoustic performance criteria must exist for the client under consideration. Otherwise, there is simply no basis upon which the adequacy of the fitting can be evaluated. Second, the type of measurement that is employed at the verification stage must provide the clinician with a valid answer to the question that is being asked. Naturally, the type of measurement procedure that is employed during verification will depend on the manner in which the selection criteria have been stated. Thus, a clear and logical interrelationship exists between the selection and verification stages of this process. This interrelationship has been illustrated by the feedback loop (dotted arrow) shown in Figure 1. If, for example, the instrument that has been fitted to the individual does not provide the desired response characteristics, it may be necessary to recycle through the selection stage so that a more adequate instrument can be chosen.

Presently, clinicians have an ever-growing number of options that can be used to assess the adequacy of a hearing aid fitting. Prior to the introduction of clinical probe-tube microphone systems, the measurement option that was used primarily for this purpose was the sound field aided audiogram. Over the years, sound field aided thresholds have been applied in a variety of ways and include, for example: (a) comparing the sound field aided thresholds to audiometric zero, (b) comparing the sound field aided thresholds to some representation of the long-term spectrum of conversational speech (e.g., Ling & Ling, 1978; Matkin, 1986; Olsen, Hawkins, & Van Tasell, 1987), and (c) comparing the sound field aided thresholds against a set of target threshold values that were derived for a

client using a formal selection strategy (e.g., Berger et al., 1984; Byrne & Tonison, 1976) or that were developed by the individual clinician on the basis of their clinical experience.

In some audiological settings, sound field aided thresholds continue to be used as the primary means for evaluating the adequacy of hearing aid fittings despite the various problems and limitations that are known to be associated with this approach (e.g., Erber, 1973; Hawkins, 1985; Seewald, Hudson, Gagné, & Zelisko, 1992; Stelmachowicz & Lewis, 1988). For example, in a recent survey of audiologists (Bratt & Sammeth, 1991), it was reported that 40% of the clinicians always used sound field aided threshold measures to evaluate real-ear hearing aid performance. In contrast, only 27% of the respondents reported using probe-tube microphone measurements for this purpose. Perhaps the most discouraging finding of all was that one-third of the audiologists surveyed reported that they did not routinely measure the real-ear hearing aid performance with either sound field aided threshold testing or probe-tube microphone measurements at the time of the fitting. Clearly, there is a need to better understand the reasons that underlie this set of findings.

Despite an apparent reluctance on the part of clinicians to employ this new technology, clinical probe-tube microphone systems do offer several advantages, relative to sound field aided threshold measures, for assessing the real-ear performance of hearing aids. First, probe-tube microphone measures provide the clinician with a description of electroacoustic performance across the complete frequency range of interest and not at discrete frequencies only. Second, the signal types and signal levels that are available with these systems provide a better approximation to the real-world signal that is of primary interest (i.e., conversational speech). Third, probe-tube microphone systems allow the clinician to measure both the gain/frequency and the output limiting/frequency characteristics of hearing aids. Finally, these measurements are relatively time-efficient and require only passive cooperation from the client.

Despite the relative advantages of probe-tube microphone measurements for electroacoustic verification, clinicians who wish to use these systems need to develop a thorough understanding of the various sources of variability that are associated with the measurements. During the past several years, a number of studies have been performed to identify and isolate these sources of variability. Collectively, the results of these studies have helped us to understand how variables such as loudspeaker azimuth, probe-tube insertion depth, reference microphone position, signal level, signal type, and sound field calibration method, among others, can affect the reliability and validity of the data that result from these measures. Excellent reviews of this work are provided in two recent publications by Hawkins (1991) and Hawkins and Mueller (1992).

The work that has provided us with an understanding of the various sources of variability associated with clinical probe-tube microphone measurements has been both necessary and informative. It may be time, however, to address several more challenging issues that relate to the clinical application of these sys-

tems. At the present time, all of the commercially available probe-tube microphone systems provide clinicians with a variety of options, both in terms of the type of measurement that can be performed (e.g., real-ear insertion response, real-ear aided response, real-ear saturation response) and the type of signals that can be employed (e.g., frequency-modulated tone, narrow-band noise, broadband noise). As a profession, we have yet to determine which of the available options, when applied under particular circumstances, provide the most valid characterization of electroacoustic performance for the purposes of clinical hearing aid fitting. Unfortunately, these are not issues that will be resolved easily. They are issues that are complex in nature and will require substantial thought and systematic investigation.

As a result of the electroacoustic complexities that developing hearing instrument technologies will bring to the clinical fitting process, it can be anticipated that we will soon need to revise the manner in which electroacoustic performance criteria (e.g., real-ear insertion response targets) are stated. Consequently, the manner in which hearing aid performance is verified at the time of the fitting will also require some revision. In the meantime, it is critical that clinicians inform themselves about the relative strengths and limitations of the electroacoustic measurement options that are presently available (Burnett, 1991; Hawkins, 1991; Humes, 1992; Kates, 1991; Seewald et al., 1992; Stelmachowicz, 1991). Regardless of the specific approach to verification that has been employed, once the clinician has determined, by some means, that the hearing aid fitting provides the listener with both physical comfort and appropriate electroacoustic performance, the final stage of the hearing aid fitting process can be initiated.

EVALUATION OF AIDED PERFORMANCE

The hearing aid fitting process is not complete until it has been determined that the client has derived the anticipated benefit from this form of audiological intervention. It is unlikely that the fitting of a hearing aid will provide a complete solution to the variety of problems the client experiences as a result of their hearing impairment. Nonetheless, if we can assume that the individual was a reasonable candidate for acoustic amplification to begin with and that both knowledge and care have been applied throughout the fitting process, some improvement in the client's auditory performance with amplification can be expected. However, there is an important difference between assuming that change has occurred and determining, in a systematic fashion, that change has taken place.

Generally, two different approaches can be taken to evaluate aided performance. The traditional approach has been to obtain clinical laboratory-based measures of speech perception in the aided condition. A second approach to the problem of measuring aided performance incorporates the use of one of the self-report instruments referred to in a previous section. These two approaches are briefly reviewed below.

Audiometric-Based Procedures

The history of using speech perception measures for the purposes of hearing aid selection and fitting has been both long and interesting. In general, the most common approach that was taken until the mid 1980s included the measurement of monosyllabic word recognition performance, in quiet, with several different hearing aids. On the basis of the test findings, the hearing aid with which the client obtained the "highest" word recognition performance score was ultimately selected.

It is worth noting that by design, the procedures employed by Carhart and his colleagues during the post-war years extended beyond the simple administration of monosyllabic speech discrimination testing in quiet. First, the recommended protocol incorporated several different measures of speech perception including measurements that were performed in a background of noise. Second, and perhaps more importantly, the evaluation stage was systematically integrated into an intensive program of audiological rehabilitation. Thus, the evaluation stage was not a single event in time, but one that allowed the client to experience amplified sound, provided by several different instruments, under everyday listening conditions. As Carhart (1975) later explained, "the formal tests were merely the last stage in a long procedure of winnowing out undesirable aids and of habituating the patient to wearable amplification" (p. xxxi). Thus, it was on the basis of this long-term evaluation, and not the results of a single test session, that a specific instrument was selected for the client.

The goal of any clinically-based measure of speech perception, obtained with an amplification system at or around the time of the fitting, is to accurately predict long-term performance within the client's everyday listening environments. There are several reasons why conventional measures of speech perception (e.g., speech reception threshold [SRT] in quiet; monosyllabic word recognition performance in quiet) have failed to assist clinicians in accomplishing this goal. First, it has been demonstrated that the conventional measures of speech perception that have been applied clinically are not sufficiently reliable to identify differences in performance between conditions of interest (e.g., hearing aid A vs. hearing aid B: Walden, Schwartz, Williams, Holum-Hardegen, & Crowley, 1983). Second, the content relevance of these measures (i.e., perception of single words in quiet) is clearly suspect if the goal is to predict the benefit to be derived from amplification in everyday listening (Walden, 1982).

Once the limitations of conventional speech perception measures (i.e., SRT and monosyllabic word recognition) became fully understood, the reaction (over-reaction?) on the part of clinicians was to discontinue the application of speech perception measures entirely in the process of fitting hearing aids. Instead, many clinicians have adopted the strategy of using one of the electroacoustic selection methods and assume that by matching the frequency/gain characteristic to a set of target insertion gain values that the optimal use of residual hearing has been ensured. Fortunately, in recent years, several laboratories have worked toward

developing tests of speech perception that may be more appropriately suited to assessing the potential benefits that can be derived from amplification.

One of the more innovative approaches to this problem is the development of the Connected Speech Test (CST) that has been reported by Cox, Alexander, and Gilmore (1987), and Cox, Alexander, Gilmore, and Pusakulich (1988, 1989). Because the goal of applying speech perception measures is to predict the benefit a client will realize in everyday communication, Cox and her colleagues have proposed that any such instrument should contain the following attributes (Cox et al., 1991): "1) speech produced in a conversational manner; 2) a talker whose intelligibility is average; 3) availability of visual cues; and 4) speech that follows the same topic for several sentences and for which the topic is known to the listener" (p. 202).

With regard to the issue of face validity alone, the recent development of test instruments such as the CST takes our field well beyond the conventional audiometric measures of speech perception. In view of our current need for sensitive and valid outcome measures for application within the hearing aid fitting process, work such as this is most encouraging.

Self-Report Procedures

Ultimately, we need to know at the end of this process if the hearing-impaired individual perceives any improvement in their situation as a result of intervention. Within the general context of the audiological rehabilitation program, we are particularly interested in knowing the amount of benefit that is realized by *the client* as well as the extent and nature of any residual difficulties the client perceives. It is only through the collection of this type of information that we can proceed further with our rehabilitative efforts in a relevant and effective manner. The application of self-report instruments should be particularly appropriate for this purpose.

There are many instruments that have been developed for the purpose of quantifying the self-perceived handicap that results from hearing-impairment. To select from among the available instruments, it is important to consider the nature of the question that will hopefully be answered through their application. For example, one of the questions that is being asked at this stage of the fitting process is: to what extent has the individual's self-perceived handicap changed as a result of the use of amplification? To answer this question, the clinician will need to have obtained pre- and post-treatment measurements of self-perceived handicap. Furthermore, the psychometric properties of the questionnaire of the instrument must be known, particularly its use for repeated measures testing. Also, it is important to carefully examine the content of the individual items contained in the instrument (i.e., the instrument must be valid for the purpose that it is being used). Thus, it cannot be assumed that all existing self-report measures are equally well-suited to the task of assessing the self-perceived benefit that is derived from amplification. The reader is referred to Chapter 4 for a more thorough discussion on the use of self-assessment instruments

in audiological rehabilitation.

One obvious need, and one that should be high on our list of priorities, is to develop a standard instrument for the purpose of quantifying self-perceived benefit that is derived from the use of amplification. To date, two such instruments have been developed (Cox et al., 1991; Walden, Demorest, & Hepler, 1984) and warrant serious consideration for their potential application in routine clinical practice.

To this point in the discussion, attention has been given primarily to the need for valid measures of aided performance that can be applied efficiently within the context of routine clinical practice. Certainly, it is difficult to see how our approaches to the fitting of hearing aids can evolve in the absence of such measures. One additional issue that will require investigation relates to the question of when such measures should be administered. Related to this question, some findings reported by Gatehouse (1992) would seem to have both important and interesting implications for our approaches to evaluating aided performance.

Briefly, Gatehouse (1992) studied the time course and the magnitude of improvements in aided speech perception that followed the fitting of a hearing aid in four adult listeners. For these subjects, he found that a period of "perceptual acclimatization" was required before the benefits of amplification for speech perception were recognized. Furthermore, it was found that this period of acclimatization required at least a 12 week exposure to amplified sound. On the basis of these findings, Gatehouse concluded that "any evaluation concerning the overall effectiveness of a hearing aid prescription should only be made after the process of acclimatization is substantially complete" (p. 1267). Assuming that the findings reported by Gatehouse will be replicated and subsequently elaborated upon, we may need to reevaluate some of our present approaches to evaluating aided performance that are obtained at the time of the hearing aid fitting. Furthermore, we will in all likelihood, need to examine the validity of research designs in which "the effects" of alternative amplification strategies on aided performance are measured within a single experimental session.

As Figure 1 illustrates, there are two alternative paths that can be taken once the reassessment stage has been concluded. First, if the anticipated degree of benefit from amplification has not been realized, it will be necessary to return to the assessment stage. The purpose of this "recycling" is to attempt to identify any errors that may have been made at the time of the assessment or during the selection and verification stages. In the absence of any obvious errors, the expectations for amplification may require revision. Alternatively, when the benefit that is derived from the use of a hearing aid is considered to be satisfactory, the client will proceed to the remaining components of the rehabilitation program that are required. As noted earlier, the client's success with hearing aids will determine, to some extent, the need for additional intervention strategies.

SUMMARY

This chapter has provided an overview of the hearing aid fitting process. De-

spite the fact that audiologists have been engaged in a range of activities related to the provision of hearing aids for more than 40 years, it should be apparent from the present review that our professional community has yet to reach consensus regarding many aspects of this clinical process. However, a perceived commitment to problem definition and problem solving, as illustrated by several of the innovative approaches that have been described in this chapter, along with the vast array of technological developments that have emerged during the past decade, are both notable and encouraging.

Throughout the chapter, particular emphasis was given to hearing aid fitting-related issues that are presently unresolved. Despite the progress that has been made during the past decade, work will need to continue on most aspects of this clinical problem. In retrospect, perhaps the most limiting factor to work in this area has been the absence of valid outcome measures. For this reason, continued work on the development of valid and efficient outcome measures should be given the highest priority among the various hearing aid-related issues that will require attention.

Finally, it should be of concern to professionals in this field that so many different approaches to this clinical problem presently exist. It should be obvious that the many different approaches that are employed for this purpose cannot be equally valid. It should also be apparent that it is now possible to take a more systematic approach to hearing aid fitting. As a first step, this will likely require some restructuring of clinical priorities.

ACKNOWLEDGEMENTS

Preparation of this manuscript was supported by a grant from the Ontario Ministry of Health to the Hearing Health Care Research Unit (A System-Linked Research Unit funded by the Ontario Ministry of Health). The thoughtful comments provided by Margaret W. Skinner, Nancy Tye-Murray, and by an anonymous reviewer on a draft version of this chapter are gratefully acknowledged. In particular, I express appreciation to J.-P. Gagné with whom I have had several years to engage in serious and stimulating discussion regarding many of the ideas and issues presented in this chapter.

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