Evolution of Prescriptive Fitting Approaches

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The development of the modern-day electronic hearing aid can be traced back to early vacuum-tube designs in the 1920s. From their inception, hearing aid companies and their representatives in the field were concerned with how to fit these devices to the prospective hearing aid wearer. Methods such as mirroring the audiogram (Knudsen & Jones, 1935), in which every decibel of hearing loss was compensated by a decibel of hearing aid gain, and the still-popular half-gain rule (Lybarger, 1944), in which 1/2 dB of gain was provided for every decibel of hearing loss, were two such methods that emerged early in the evolution of hearing-aid fitting strategies. The basic assumption underlying both of these methods, and any prescriptive rationale, is that there is an interaction between the individual’s hearing loss, or some other audiologic characteristic, and the parameters of the most appropriate electronic circuit for the hearing aid. Otherwise, if one response works well for everyone (“one size fits all”), then there is no need to “prescribe” the best circuit for an individual wearer.

The 1940s was a period of radical change for our profession. Many people consider that audiology was born as a profession in this decade. Regarding hearing aid selection, it appears that the publication of two reports on hearing aid fitting, the Harvard Report (Davis et al., 1946) and the MedResCo Report (Radley et al., 1947), had a profound influence on the way in which the newborn profession of audiology would select hearing aids for their patients over the next several decades. Generally, both reports were interpreted (erroneously) as supporting a general “one size fits all” philosophy. It was believed that the data in these reports supported the use of hearing aids with frequency responses rising at a rate of +6 dB/octave for all potential hearing aid wearers, regardless of audiometric configuration.

Under this basic assumption, the hearing aid “selection” process involved selecting the appropriate instrument from the clinic stock of hearing aids having very similar frequency responses. The primary approach developed by audiologists during this time was described in detail by Carhart (1946) and has been referred to since then as the “comparative approach” to hearing aid selection. In this approach, the audiologist would select 3–4 electroacoustically similar hearing aids and evaluate them on the prospective wearer using a battery of tests. The actual test battery described by Carhart (1946) was really quite extensive and measured functional gain for speech (at two different volume-control settings), speech recognition threshold in noise with and without the hearing aid [not unlike procedures advocated much later by Plomp and colleagues (Plomp, 1978; Plomp, 1986)], speech-recognition scores using monosyllabic words at moderate levels, and tests of tolerance for loud sounds.

It is important to note that the development of the comparative procedure and its advocacy by audiologists had a tremendous impact on the way audiologists went about selecting hearing aids for the prospective wearer. It did not, however, have much bearing on the dispensing of hearing aids in this country. Until the mid to late 1970s, audiologists did not dispense hearing aids in the United States. Most hearing aids during this time period were dispensed by hearing instrument specialists working for a particular manufacturer. Although it is not certain what particular procedures were used by the majority of hearing instrument specialists to dispense hearing aids, it is doubtful that any used the comparative approach and likely that the majority used one of the prescriptive procedures developed in the 1930s and 1940s, or one of their variants.

This paper, along with the two papers that follow, is based on a presentation at the session on contemporary approaches to hearing aid fitting held at ASHA’s 1994 Annual Convention in New Orleans, LA.
Among audiologists, it is clear from periodic published surveys of audiologic practices (Burney, 1972; Martin & Morris, 1989; Smaldino & Hoene, 1981) that the comparative procedure continued to be the method of choice for most audiologists until the mid to late 1980s (Figure 1). It is also clear from these surveys, however, that the “comparative” approach used was a much abbreviated version of the original that typically involved measures of functional gain for SRT, word recognition in quiet, and, occasionally, word recognition in noise.

Fundamental problems with the comparative approach to hearing aid selection began to emerge as early as 1960 (Shore, Bilger, & Hirsh, 1960), but its death knell was sounded clearly in 1983 with the publication of a critique of the approach by Walden, Schwartz, Williams, Holum-Hardegen, and Crowley (1983). These investigators clearly stated five key assumptions underlying the comparative approach and then systematically evaluated each assumption. The evaluation of underlying assumptions was conducted for both a set of electroacoustically similar hearing aids, representative of a typical set of hearing aids evaluated with this approach by audiologists, and a set of electroacoustically dissimilar instruments. Briefly, the assumptions underlying the approach were shown to be invalid, especially for the set of electroacoustically similar devices, the set of instruments representative of those evaluated in typical audiologic practice prevailing at the time.

During this period of gradual demise of the comparative approach to hearing aid selection from roughly 1960 to 1985, renewed interest had developed in prescriptive procedures. They emerged, in large part, because of the increasing number of studies had demonstrated that “one size did not fit all.” That is, so-called selective prescriptive procedures continued to be the method of choice for most audiologists until the mid to late 1980s (Figure 1). It is during this same time that dispensing audiology in private practice emerged as a bona fide career opportunity in the profession.

Since the late 1980s, the focus has been on which of several competing prescriptive procedures is the most appropriate or “best” to use. Consequently, several studies have been published in which the comparison of prescriptive methods was the focus. An important issue here is the manner in which the studies should be compared. Certainly, we could group methods by the audiologic characteristics required for the prescription (thresholds only, threshold plus loudness measures, loudness measures only, etc.), but this is not very informative regarding similarities or differences in the outcome of the methods (i.e., the prescribed responses).

Another, more informative, basis for classifying prescriptive procedures would be in terms of the electroacoustic output characteristics prescribed by each method. Here too, however, one is confronted with several choices. For example, do we group hearing aids by their average absolute gain or their relative gain characteristics (frequency response)? Given that a large range of absolute gain characteristics can be accommodated by the 35–40 dB operating range of a hearing-aid volume control, most such comparisons have opted to compare the relative gain or frequency responses prescribed by various approaches. Several such comparisons have been published for both threshold-based prescriptions (Byrne, 1987; Humes, 1991) and suprathreshold-based approaches (Humes & Halling, 1993). In all cases, these comparisons have revealed that there is considerable overlap in prescribed frequency response among the many prescriptive procedures examined for a given set of audiologic characteristics (thresholds and/or loudness measures). In most cases, however,
some statistically significant differences were observed among a subset of methods and for a subset of audiologic profiles.

Statistical significance of the frequency-response differences between prescriptive methods, however, may not always translate into differences of practical significance. For example, if the differences among prescribed frequency responses were confined to the region above 2000 Hz, these differences may be of little or no practical significance because of the difficulty in attaining the prescribed amount of gain in the high frequencies. In addition, if one is using the prescribed gain characteristics to select a BTE from a database or clinic stock or to select an ITE response from the manufacturer’s matrix of such responses, statistically significant differences among prescriptions may not result in the selection of different hearing aids or hearing aid circuits. Figure 2, for example, shows two significantly different frequency responses prescribed by two different prescriptive approaches. Also shown is the most closely matching frequency response for each prescription. Notice that the same hearing aid or hearing aid circuit was the closest match to both prescriptions. Thus, even though statistical differences may exist between prescriptive procedures, it is not always the case that practical differences resulting in different hearing aids or hearing aid circuits being recommended for the prospective wearer will always follow.

In one study, this issue was directly addressed (Humes, 1986). Ten different prescriptive methods were applied to nine sets of audiologic profiles (3 sloping configurations, 3 flat configurations, and 3 rising configurations). For each configuration, ten sets of frequency-gain characteristics were generated and a large database of over 400 instrument responses and 20 earmold/coupling configurations was examined for a match. For each prescription, the four most closely matching instrument/earmold combinations were identified. If all ten procedures resulted in the identification of four unique hearing aid/earmold combinations for a particular hearing loss, then a total of 40 unique hearing aid/earmold combinations would result. On the other hand, if all of the methods converged on the same four hearing aids, then only four hearing aid/earmold combinations would be identified. The results of that study indicated that, despite the enormous database of thousands of possible hearing aid/earmold combinations, there was quite a bit of overlap in the hearing aids selected as the four most closely matching each prescription. Thus, it is often the case that reported statistical differences among prescriptive procedures may be of little practical significance given the range of instruments and circuits from which the dispenser has to choose.

More recently, Bratt and Sammeth (1991) have made this same point for ITEs by comparing the size of error in achieving insertion-gain target to the size of between-method differences in prescribed insertion gain. In general, the between-method differences in prescribed gain are comparable in size to the average magnitude of error in achieving target gain. Thus, the differences among many prescriptive methods are of little practical significance given that the aid can’t be fine-tuned enough to precisely match the various targets so as to actually realize the difference between prescriptive methods.

Let’s assume that we are no longer restricted to a set of hearing aid responses or circuits and that any prescribed response can be achieved on the prospective wearer. Under this assumption, is there a response that is “best” for the prospective wearer in terms of speech-understanding ability? Several studies conducted in the past decade have attempted to address this question. Byrne (1986), for example, compared the performance of six different prescribed responses (one threshold-based, one LDL-based, and four MCL-based) on each of 14 ears. Despite his best efforts to generate 84 unique responses (6 for each of 14 subjects), several responses for a given subject were considered to be virtually identical and the total evaluated was just 44 (just over half!). This is consistent with the redundancy among methods noted previously despite the investigator’s best efforts to use different prescriptive approaches and the ability to closely match them with a 1/3-octave multfilter. Moreover, in several cases, many of the remaining responses considered to be different or unique, in fact, differed 8 dB or less across the entire frequency range. Mean nonsense-syllable identification scores obtained for the six prescribed responses were found not to differ significantly. Moreover, only 10 of the 60 possible comparisons within individual subjects were found to yield significant differences in speech recognition.

Similar findings were also obtained by Sullivan, Levitt, Hwang, and Hennessey (1988). Subjects in that study were evaluated with four different frequency responses, two generated by threshold-based prescriptions, one by an MCL-based prescription, and one by a special adaptive algorithm. A master hearing aid was used to adjust the frequency response to match the prescription.

Finally, Humes and Hackett (1990) reached similar conclusions when using actual BTE hearing aids adjusted to optimize the match to prescribed gain generated by three
different prescriptions. Speech-recognition performance was identical for all three prescribed responses in quiet and in noise (and the obtained and prescribed frequency responses were once again equivalent).

In summary, many different prescriptive formulas have been developed and advocated over the past couple of decades as replacements for the comparative approach to hearing aid selection. Although there clearly are some differences among prescriptions in terms of targeted gain values, these differences are generally small, and most can be accommodated by adjustments in the volume control of linear hearing aids. Moreover, there is not a lot of difference in observed speech-recognition performance across several of the methods, especially when evaluated using a representative (comfortable) volume-control setting. Given the foregoing, the decision as to which prescriptive procedure to use could just as easily rest on the extent to which the approach has been established as a valid and reliable approach (not necessarily the “best” approach). Probably the most rigorously evaluated prescriptive methods to date have been the NAL-R method (Byrne & Dillon, 1986), the MSU approach (Cox, 1983, 1985, 1988), the Berger method (Berger, Hagberg, & Rane, 1977), and POGO (McCandless & Lyregaard, 1983; Schwartz, Lyregaard, & Lundh, 1988). Until it can be demonstrated that one of these methods is, in fact, superior to another, any one of these methods will suffice. A clinician’s preference may well be determined by practical issues as to ease of implementation and the information provided by the approach. The MSU approach, for instance, requires the measurement of threshold and loudness, whereas the other methods only require thresholds as input for their prescriptive formulas. The three threshold-based approaches (NAL-R, Berger, POGO-II), however, base prescriptions of SSPL90 on loudness estimates derived from thresholds, whereas the MSU approach, as noted, makes use of actual loudness measurements from the patient in generating SSPL90 targets.

Finally, it should be noted that all of the prescriptive formulas that have been developed over the past couple of decades as replacements for the comparative approach have been designed to prescribe gain for linear hearing aids with moderate level inputs. As hearing aids that are intentionally nonlinear over most of their operating range, with moderate level inputs. As hearing aids that are have been designed to prescribe gain for linear hearing aids. Moreover, there is not a lot of difference in observed speech-recognition performance across several of the methods, especially when evaluated using a representative (comfortable) volume-control setting. Given the foregoing, the decision as to which prescriptive procedure to use could just as easily rest on the extent to which the approach has been established as a valid and reliable approach (not necessarily the “best” approach). Probably the most rigorously evaluated prescriptive methods to date have been the NAL-R method (Byrne & Dillon, 1986), the MSU approach (Cox, 1983, 1985, 1988), the Berger method (Berger, Hagberg, & Rane, 1977), and POGO (McCandless & Lyregaard, 1983; Schwartz, Lyregaard, & Lundh, 1988). Until it can be demonstrated that one of these methods is, in fact, superior to another, any one of these methods will suffice. A clinician’s preference may well be determined by practical issues as to ease of implementation and the information provided by the approach. The MSU approach, for instance, requires the measurement of threshold and loudness, whereas the other methods only require thresholds as input for their prescriptive formulas. The three threshold-based approaches (NAL-R, Berger, POGO-II), however, base prescriptions of SSPL90 on loudness estimates derived from thresholds, whereas the MSU approach, as noted, makes use of actual loudness measurements from the patient in generating SSPL90 targets.

Finally, it should be noted that all of the prescriptive formulas that have been developed over the past couple of decades as replacements for the comparative approach have been designed to prescribe gain for linear hearing aids with moderate level inputs. As hearing aids that are intentionally nonlinear over most of their operating range, such as instruments with wide dynamic-range compression, become more commonplace, new procedures will need to be developed to select and fit the hearing aid for the patient. Some such tools have already been designed (e.g., Humes & Houghton, 1992; Kiessling, 1987; Seewald, Hudson, Gagne, & Zelisko, 1992), and others are emerging (Humes, 1992; IHAFF, 1994). These tools, together with the programmability of many devices, have made it possible to bypass the use of insertion gain as a necessary “middle man” in accomplishing the theoretical objectives of a particular prescriptive procedure. The theoretical objective of the POGO-II method, for instance, is to amplify conversational speech to the Most Comfortable Loudness (MCL) level (Schwartz et al., 1988). It is now possible to measure the sound pressure levels in the ear canal that correspond to a variety of loudness criteria, including MCL, at various frequencies and then to present a speech-shaped noise at a conversational level to see that it is, in fact, amplified to MCL. If not, the programmability of the many instruments makes it easy to fine-tune the device to accomplish this objective directly and quickly in the patient’s ear canal. This exciting set of developments in our field has been clouded somewhat by an almost dizzying array of choices confronting the clinician: too many different prescriptive methods for linear devices and, often, too many parameters to choose from on programmable devices. In the author’s opinion, however, we are on the verge of simplifying things enormously, at least regarding adjustments to the gain and SSPL90 of the patient’s hearing aid. We will soon be able to confirm the theoretical objectives of any prescriptive approach directly on the patient’s ear and to do so rapidly and reliably. In this context, a quotation from the scholarly audiologist who led us on this journey almost 50 years ago seems particularly appropriate here:

The field of hearing aids is in rapid flux. Substantial changes in instrument design and performance are occurring. Our understanding of patient requirements and of the important criteria for instrument selection are becoming more definite. We may expect the confusion which has clouded the field to dissipate steadily.

(Carhart, 1946)

Perhaps, by the turn of the century, Carhart’s prophecy will actually be realized.

References


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