Using Loudness Data for Hearing Aid Selection: The IHAFF Approach

BY ROBYN M. COX

Remember when The Fonz made his splash on the small screen, Ford pardoned Nixon, ozone depletion was discovered, and Jimmy Connors and Chris Evert were love birds? It was about that time that Denis Byrne introduced his first target-gain fitting approach, and we were ordering linear peak-clipping custom hearing aids by mailing the manufacture a few pure-tone thresholds. Twenty years go by quickly, don't they? Events change, and so do hearing aids and hearing aid fitting procedures. Last year we witnessed the introduction of a new fitting procedure from the Independent Hearing Aid Fitting Forum, referred to as the IHAFF Protocol. This fitting method is based on the premise that dispensers would like to pre-select patient-specific hearing aid processing characteristics, and on the intuitive, though as yet unproven, notion that when hearing aid processing is matched to the patient's loudness growth function across frequencies, greater user benefits will result.

The IHAFF Protocol is still subject to modification, but its conceptual foundation is in place. This foundation was based in large part on the work of Robyn M. Cox, PhD, our Page Ten contributor for February. Dr. Cox, at the University of Memphis, is internationally recognized for her research in hearing aid evaluation and fitting.

While you may not think of the IHAFF Protocol as a "hands-on" topic today, it's well worth your time to read about it, digest some of the fitting philosophies underlying the protocol, and to consider trying it in your own practice.

Gus Mueller
Editor, Page Ten

Those who fit and dispense hearing aids long have been wondering how to impose some degree of structure on the confusing world of nonlinear instruments. There are so many available combinations of parameters, such as compression thresholds, compression ratios, and crossover frequencies, that practitioners often have difficulty determining for whom they are best suited and how to fit them.

Part of the problem is lack of a widely accepted philosophy about the appropriate applications of nonlinear processing. Many of us are uncertain when to use wide-range compression in preference to compression limiting or a compressor that begins to function at an intermediate level. Even when this decision is made, there is no widely accepted method of choosing appropriate settings for variables such as compression ratio and release time.

Apart from the absence of an overall philosophy, we face practical obstacles that inhibit routine application of nonlinear devices. One problem is that the most popular existing methods for selecting and fitting hearing aids were developed from research with linear instruments. Therefore, they do not help us apply the ability of nonlinear devices to adjust gain on the basis of input level. Furthermore, the behavior of nonlinear instruments at frequencies other than 2000 Hz (the only frequency at which the compression parameters are specified for many hearing aids) is often difficult to determine, and this contributes to their aura of inscrutability. The combination of these factors has given rise to a situation in which dispensers have a wide array of nonlinear devices to choose from, but no widely used, systematic approach to follow in selecting an optimal device for a particular hearing aid candidate.

The Independent Hearing Aid Fitting Forum (IHAFF) is a group of individuals who began to meet in 1993 in an attempt to address these and related issues. The group's short-term goals were: (1) to develop an approach to selecting and fitting amplification that can encompass both linear and nonlinear devices, and (2) to promote the use of consistent testing and fitting methods to implement the approach. The long-term plan is to collect data to evaluate these methods and to modify them as needed to improve the efficiency of the procedures and the efficacy of the fittings. We have made significant progress toward the short-term goals.

In this Hands On article, I will describe the fitting philosophy that IHAFF has developed. Also, I will review some of the methods that have been recommended to implement the approach in your practice. To feel fully familiar with the procedure, you will probably need more detail than I can provide here. Look for future articles and presentations by IHAFF members, in various venues, to supply additional information about the procedure.

THE FITTING PHILOSOPHY

Development of the IHAFF hearing aid selection procedure began with the adoption of the following overall goal: Amplification should normalize the relationship between environmental sounds and loudness perception. This means that a sound that appears soft to a normal-hearing listener should be audible but soft, after amplification, to the hearing-impaired person. Similarly, sounds that are comfortable or loud for the normal-hearing listener should be comfortable or loud, respectively, after amplification, for the hearing aid wearer. Finally, a sound that is not uncomfortably loud for a typical normal-hearing listener should not be uncomfortably loud, after amplification, for the hearing-impaired listener.

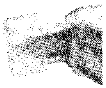
To implement this goal, at least two things were needed: (1) a standard test for loudness perception, and, (2) a fitting rule to relate loudness data to needed amplification.

continued on page 39

xp Peritympanic

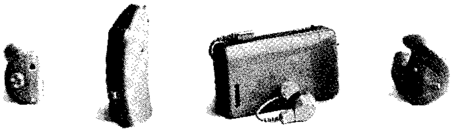
The desirable cosmetic benefits of deep-canal fittings are now widely recognized and imitated. But there still remains only one *true* peritympanic deep-canal hearing instrument that can also deliver optimum acoustical benefits:

the award winning XP Peritympanic from Philips.



The latest innovation from Philips is the Bony Seal Tip (or BST®) now supplied with the XP. For the first time, BST permits a hearing instrument tip to penetrate and make an active seal in the bony ear canal. This seal is maintained with the lightest pressure on the canal wall, but remains active and comfortable even when talking or chewing. The unique design of the BST requires only a standard CIC impression to provide peritympanic deep-canal benefits.

To assure successful first time fittings and long term satisfaction, the BST features an integral wax guard and easy removal for cleaning or replacement.



Philips has something for every hearing loss.

Body-worn, Behind-the-ear, in-the-ear, in-the-canal, completely-in-the-canal, and peritympanic deep-canal, with designs customized to meet individual needs comfortably and effectively. *What they all have in common are Philips quality in sound, user friendliness, wearing comfort and discretion.*

For more information please call: **USA: 800/544-1677** **Canada: 800/387-5271**

Circle 125 on Reader Service Card

Philips Hearing Instruments

U.S. address: *81 McKee Drive, Mahwah, New Jersey 07430*

Canadian address: *601 Milner Avenue, Scarborough, Ontario M1B 1M8*

PHILIPS

PHILIPS

Standard Test Of Loudness Perception

Persons with the same hearing loss often give widely differing judgments of the loudness of a given sound.[1] Therefore, meeting the procedure goals with a particular hearing aid candidate will require determining the levels of sounds that that candidate perceives as soft, comfortable, loud, and uncomfortably loud. A standard procedure is needed to measure loudness perceptions so that results will be repeatable across test sites, across professionals, and across test sessions. For a useful procedure, the following elements were considered desirable:

- *Measurement of a loudness growth function.* Many loudness tests assess a single point on the loudness dimension, such as MCL. However, more information is required to determine amplification needs for different input levels.
- *Standard instructions.* This is a critical factor in determining the results that will be obtained and their repeatability.
- *Ascending level.* Both dispensers and patients seem to prefer a procedure that progresses from softer to louder over one that uses random or descending levels.
- *Frequency-specific stimuli.* These are necessary in order to prescribe appropriate gain for different frequency regions.
- *Ability to perform either manual or computer-driven testing.* Computer-assisted testing and scoring are a boon for the busy practitioner, but they are not possible in all settings, so manual testing should be readily available.
- *Acceptable test-retest reliability within a reasonable time frame.* It is important to be reasonably confident that a patient's loudness perception as measured by the test will remain fairly constant over time (as long as nothing else changes). Most practices do not have the time for lengthy rest routines, so an acceptable compromise must be found between data reliability and testing time.
- *Generation of data in 2-cc coupler levels for direct comparison to hearing aid performance specifications or test-box results.* This facilitates application of the loudness data in a hearing aid selection and fitting procedure.

Table 1. Seven categories of loudness used in the Contour Test.

Categories of Loudness
7. Uncomfortably loud
6. Loud, but okay
5. Comfortable, but slightly loud
4. Comfortable
3. Comfortable, but slightly soft
2. Soft
1. Very soft

The Contour Test

A loudness test that meets the above specifications is the Contour Test developed at the Hearing Aid Research Laboratory of the University of Memphis and adopted by IHAFF for use in the fitting procedure. This test determines the levels of pulsed warble tones that correspond to each of seven loudness categories. The specific loudness categories were adapted from those suggested by Hawkins et al.[2] They are shown in Table 1. My colleagues and I reported some of the procedural details of the Contour Test at the 1994 American Academy of Audiology Convention.[3]

Software has been written to administer and score the test. To use the software, you must have an audiometer with a computer interface, which is connected to the serial port of an IBM-compatible computer. DOS drivers are available for Madsen, Beltone, Starkey, Fonix, Frye, and Grason Stadler audiometers. (Other drivers are under development.) If you can't use a PC in your setting, you can give the test manually with the easy-to-use score sheets that have been developed. For a packet of information, including the score sheets and details about administering the test, write to me.

Once you are experienced in administering the test, it takes only about 5 minutes per frequency to collect the data. We recommend obtaining loudness data for two frequencies for each fitted ear. That adds an additional test time of 20 minutes for a binaural fitting. Hopefully, this investment in up-front time will have a long-term pay-off in fewer problems after the fitting.

Developing A Fitting Rule

How can we use loudness data to help select appropriate amplification? To understand the approach suggested in this article, recall the goal of the procedure, namely, to restore loudness relationships among environmental sounds to the way they are experienced by normal-hearing listeners. Since the most important environmental sound is almost always speech, we concentrated on it in developing the method. Specifically, we want to restore normal loudness relationships among soft speech, average speech, and loud speech. To apply the procedure, we need to know the relationship between typical speech levels and the loudness of warble tones for normal hearers, as measured by the Contour Test.

Table 2. 1/3-octave band levels in the free field, 1 meter in front of the talker, for three speech-level categories.

	Speech Level		
Third Octave	Soft	Average	Loud
250	40	58	66
500	42	60	74
1000	38	53	76
2000	30	48	72
3000	27	45	68
4000	25	43	66

In daily life, listeners are exposed to speech inputs at a variety of levels. Consider, for example, the level of speech produced in a library and that produced at a cocktail party; the party level is much higher. To implement the hearing aid selection procedure, it was necessary to choose several "typical" levels. However, the research base on this topic is fairly meagre. Thus, it is not obvious what levels should be used to characterize typical speech inputs. A few published studies indicate the levels of speech found in representative communication settings.[4,5] Others have shown the distribution of sound input levels experienced by hearing aid wearers during a typical day.[6,7] In addition, Pearsons, Bennett and Fidell[4] and Pavlovic[8] have studied how the long-term average speech spectrum changes as vocal effort increases. These data have been combined in the new ANSI standard for the calculation of the Speech Intelligibility Index, which is currently under review. Based on these research efforts, we have adopted the following levels to represent typical speech inputs:

- *Soft* speech is taken as 5 dB lower than the levels produced by talkers speaking with "casual" vocal effort in an anechoic room.

- *Average* speech is derived as the mean levels of talkers speaking with "normal" and "raised" vocal effort.
- *Loud* speech is set to an overall level about 5 dB higher than the mean of talkers speaking with "loud" and "shouted" vocal effort.

Free-field long-term rms 1/3 octave band levels for these three speech categories are given in Table 2. Based on these levels, long-term overall sound-pressure levels for soft, average, and loud speech would be about 50 dB SPL, 65 dB SPL, and 85 dB SPL, respectively.

Next, we compared these speech-input levels with results on the Contour Test obtained from 45 normal-hearing listeners. To develop the hearing aid selection method, we combined the seven loudness categories provided by the test (shown in Table 1) into three broad regions of loudness perception for warble tones.

Soft levels were defined as extending from category 1 (very soft), through category 2 (soft), and up to category 3 (comfortable, but slightly soft). Comfortable levels extend from category 3, through category 4 (comfortable), and up to category 5 (comfortable, but slightly loud). Loud levels extend from category 5, through category 6 (loud, but okay), and up to category 7 (uncomfortably loud).

Figure 1 illustrates the relationships between the typical speech input levels and loudness perceptions of warble tones for normal hearers. For comparison to the loudness data, the speech levels have been transformed into HA-1 2-cc coupler levels using the conversion provided by Bentler and Pavlovic.[9] Keep in mind that the speech levels are labeled in terms of the vocal effort used to produce them, whereas the warble-tone data are based on actual loudness judgments.

The relationships in Figure 1 might seem a bit surprising. On the surface, it seems reasonable to assume that speech spoken with average *vocal effort* would map into the comfortable region for warble tones. Similarly, we might anticipate that loud and soft vocal efforts would correspond to loud and soft warble tones, respectively.

Clearly, the data do not support these expectations. Instead, the spectrum of speech produced with loud vocal effort falls into the comfortable region for warble tones. Also, both average and soft speech spectra are found in the soft region for warble tones. Notice that none of the typical speech spectra correspond to the loud region for warble tones. We must conclude that, compared to the levels in typical speech, warble tones are judged to be less loud than we might expect.

There are probably several factors contributing to this outcome, including loudness summation across bandwidth, power summation within speech, crest-factor differences between speech and tones, and duration differences between speech samples and the tones used to test loudness perception.

That the loudness of warble tones does not match the levels of speech with corresponding vocal efforts need not deter us from using these data to construct a hearing aid selection and fitting method. It is important only that we know the relationship between warble tones and speech for normal-hearing listeners, so that we can then attempt to reconstruct this relationship for hearing-impaired listeners.

The fitting rule can be stated in the following general way: Each speech level should be amplified so that it falls at the same *relative* position on the loudness map of the hearing-impaired person as it does on the map of the typical normal hearer.

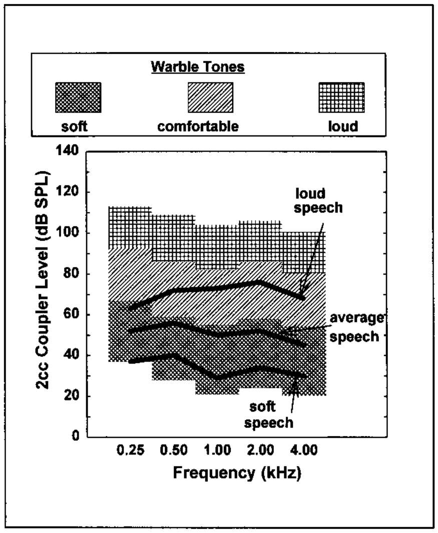


Figure 1. Relationships between typical speech-input levels and loudness perceptions of warble tones for normal hearers.

Referring to Figure 1, this means that speech produced with soft vocal effort should be amplified to fall near the bottom of the patient's soft region for warble tones (measured with the Contour Test). Also, after amplification, speech produced with average vocal effort should fall near the top of the patient's soft region for warble tones, and speech produced with loud vocal effort should fall slightly above the middle of the patient's comfortable region for warble tones. The precise locations of the 1/3-octave bands for each speech input level are given in Table 3.

APPLYING THE APPROACH

Figure 2 depicts a theoretical example of the application of this fitting rule to a hearing aid candidate. The person's loudness map was determined using the Contour Test, and the shaded areas correspond to those in Figure 1. Comparing the loudness maps in the two figures reveals that the soft, comfortable, and loud warble-tone regions in Figure 2 for the hearing-impaired patient become progressively higher in level and smaller in range of levels as frequency increases. This is the typical finding with a cochlear hearing loss. The heavy lines in Figure 2 give the prescribed amplified speech levels for soft, average, and loud speech inputs. The locations of the lines were determined using the loudness map for the patient and the relationships given in Table 3.

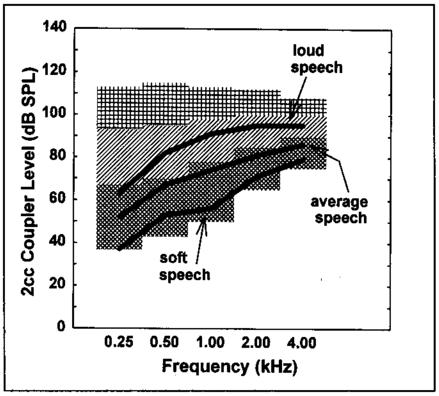


Figure 2. Application of the fitting rule to a hearing aid candidate. Shaded areas depict loudness perception for warble tones. Heavy lines show amplification goals for typical speech-input levels.

Table 3. Relationships for normal-hearing listeners between typical speech levels (soft, average, and loud) and loudness perceptions measured for pulsed warble-tone stimuli using the Contour Test. Each entry gives the 1/3-octave speech-band level in terms of proportion, from the bottom, of the soft (s) or comfortable (c) loudness range for warble tones. These relationships are used to define the target levels for amplification. For example, in a speech signal of average level, the 1000-Hz 1/3-octave band should be amplified to a point that is .85 of the range of the patient's "soft" judgments for warble tones (measured from the bottom of the range).

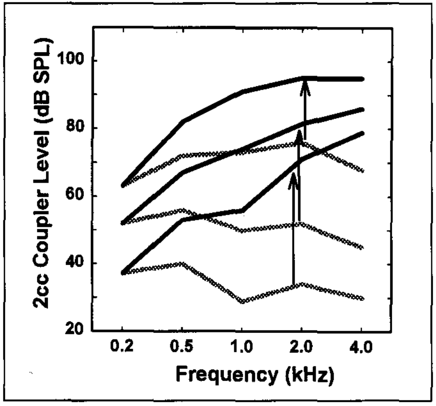


Figure 3. Unamplified speech spectra (gray lines) compared with targets for amplified spectra (black lines) for a hearing aid candidate.

Do not be concerned because Figures 1 and 2 show loudness maps based on five frequencies. This was done to make the examples as clear as possible. In actually using this procedure, you would test loudness perception for only two frequencies per ear most of the time.

It is instructive to compare the prescribed amplified speech levels in Figure 2 with the unamplified speech levels in Figure 1, since this illustrates the complexity of choosing a hearing aid to match these amplification goals.

Figure 3 depicts the unamplified speech levels (gray lines) and the corresponding amplified speech levels from the example in Figure 2 (black lines). Figure 3 includes three arrows. The left arrow connects the soft unamplified and amplified spectra, the middle arrow connects the two average spectra, and the right arrow connects the two loud spectra. All three arrows are at approximately the same frequency. The length of each arrow is proportional to the amount of gain needed at that frequency for that speech input.

If we compare the lengths of the arrows, it is obvious that the amount of gain needed is different for each speech-input level. A careful examination of Figure 3 will reveal that this is true for most other frequencies as well. Thus, to meet the prescribed amplification goals for this patient, you must select a hearing aid for which the gain varies not only with frequency but also in a specific way with input level.

The task of selecting an appropriate instrument from the array of devices available is a formidable one. There is no widely used hearing aid selection procedure that simultaneously accounts for gain changes across both frequencies and input levels. Therefore, for the past year, we have been developing a new method to facilitate the process of selecting a hearing aid to match these goals. The method is called VIOLA—the Visual Input/Output Locator Algorithm. Using this method, you select a hearing aid based on a consideration of its gain, maximum output, and input/output (I/O) functioning at two or more frequencies.

A Digression On Input/Output Functions

Because the method relies on I/O functions, it is important to establish a set of terms to describe the elements of these functions. Figure 4 illustrates the parameters that need to be considered and depicts how output levels change in response to changes in input level.

The function can be divided into three regions on the input axis: below kneepoint 1 (kp1), between kp1 and kneepoint 2 (kp2), and above kp2. Each kneepoint is a level at which the slope of the line changes. Below kp1, the hearing aid functions linearly, that is, any change in input produces an equal change in

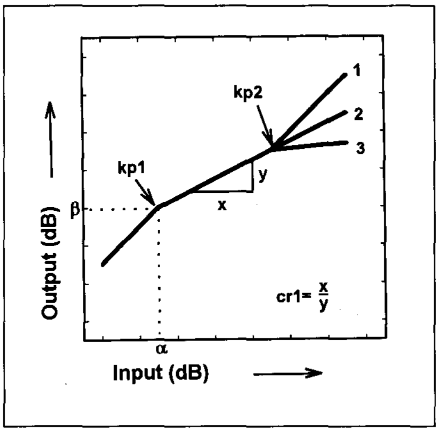


Figure 4. Elements of an input/output function as used in VIOLA.

output. Between kp1 and kp2, the hearing aid compresses the input, that is, an input change of x produces a smaller output change of y. Above kp2, the hearing aid may revert to linear functioning (line 1), remain unchanged (line 2), or use more compression (line 3).

The level at which kp1 occurs is called the compression threshold (ct1). For an input compression hearing aid, ct1 can be estimated from the I/O function by dropping a line from kp1 perpendicular to the x-axis. The point where the line intersects the x-axis is the compression threshold. To estimate ct1 for an output-compression device, the line must be drawn from kp1 perpendicular to the y-axis. The point of intersection with the y-axis is the compression threshold. Thus, referring to Figure 4, for an input-compression hearing aid, ct1 would be ∂ dB. If the hearing aid is an output compressor, ct1 would be ß dB.

The amount of compression between kp1 and kp2 is defined by the compression ratio (cr1), which can be estimated from the I/O function as illustrated in the figure (cr1 = x/y). Of course, if the hearing aid is a linear processor, there are no kneepoints and the "compression ratio" is 1. When using VIOLA with a linear device, set ct1 = ct2 = any value below the SSPL90 (I use 40), and cr1 = cr2 = 1.

The second kneepoint (kp2) may or may not occur in any given hearing aid. If there is no kp2, the I/O function appears like line 2 on Figure 4. Many nonlinear hearing aids are of this type. When using VIOLA with one of these instruments, set ct2=ct1 and cr2=cr1.

On the other hand, several types of contemporary hearing aids have I/O functions that are quite closely simulated using a second kneepoint. In such cases, the compression threshold and compression ratio associated with kp2 are ct2 and cr2, respectively. They can be estimated from the I/O function in the same manner as described for ct1 and cr1. For example, if the hearing aid is a K-AMP™ device, the I/O function appears like line 1: ct2 is at a relatively high-input level and cr2 = 1.0. In contrast, if the hearing aid has a curvilinear-compression function in which the compression ratio increases with input level, this produces an I/O function similar to line 3. For this type of device, VIOLA requires you to approximate the I/O function by selecting values of ct2 and cr2 that produce an I/O function that is as similar as possible to the hearing aid's actual performance.

By adopting appropriate values for ct1, cr1, ct2, and cr2, we can describe the input/output performance of a very wide variety of linear and nonlinear hearing aids. Keep in mind that any I/O function depicts the performance of the instrument for the test frequency only. Performance at another frequency will often be different.

Using VIOLA

Now let's return to the hearing aid selection process. VIOLA is a DOS-based software program that lets you try out different hearing aids to see if they would meet the goals of the procedure. It also enables you to compare instruments. It is important to realize that linear as well as nonlinear hearing aids can be compared. The goal of the comparison is to determine which hearing aid will come closest to amplifying the three typical speech inputs to the levels prescribed based on the results of the Contour Test. Note that VIOLA will not recommend a hearing aid: Deciding which instrument is best entails consideration of many variables and must remain the responsibility and prerogative of the practitioner.

The Selection Process

To use VIOLA, you must have Contour Test results, and we recommend at least two frequencies. For most fittings, 500 Hz and 3000 Hz are probably the best choices; however, at times, you may wish to select other frequencies, depending on the patient's hearing loss. You will also need the 2-cc coupler specifications of the hearing aids you want to try.

- First, the program needs to know the patient's loudness data. If you have used a PC to administer the Contour Test, the data are automatically entered into VIOLA. If you administered the Contour test manually, it takes only a few moments to enter the data by hand.
- Second, VIOLA draws a pair of I/O graph templates on the screen, one for each test frequency. Each template shows the loudness data, typical speech-input levels, and the amplification goals (see Figure 5).
- Third, for each test frequency, the dispenser enters six pieces of information from the specifications of a hearing aid, and the program uses this information to draw an I/O function on each template.
- Fourth, the dispenser inspects the match between the I/O function and the amplification goals.
- Fifth, additional data may be entered to try other hearing aids to see if a better match can be obtained.

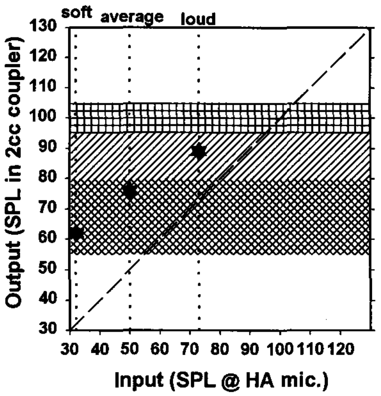


Figure 5. Example of the input/output function template provided by VIOLA.

Figure 5 gives an example showing the basic I/O template provided by VIOLA for a frequency of 3000 Hz. The figure assumes that the dispenser is planning to fit an ITE hearing aid.

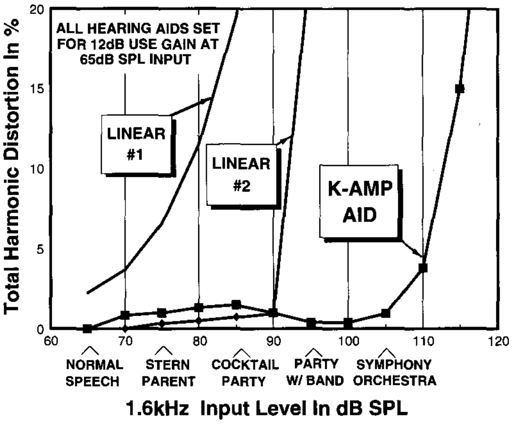
The horizontal shaded areas portray the soft, comfortable, and loud regions for the patient, determined by the Contour Test. The vertical dotted lines show the 1/3-octave band values for soft, average, and loud speech-input levels at the hearing aid's microphone. The diagonal dashed line indicates the zero-gain locus. The three stars indicate the amplification goals according to the fitting procedure.

By comparing the locations of the stars with the values for 3000 Hz in Table 3, you can confirm that the goal for soft speech is .27 of the range of soft warble tones, the target for average speech is .82 of the range of soft warble tones, and the loud-speech target is .59 of the range of comfortable warble tones. The vertical difference between each star and the diagonal line indicates the amount of gain needed for that speech-input level.

Notice that each star will always appear in the same proportionate position within the appropriate loudness range. However, the ranges themselves will move up and down on the template based on the individual patient's responses to the Contour Test, thus changing the distance between the stars and the diagonal line.

The six pieces of information needed by the program to draw each I/O function are: (1) Gain for a low-level input (either 40-dB or 50-dB tones), (2) SSPL90 for tones, (3) ct1, (4) cr1, (5) ct2, and, (6) cr2. In addition, you must indicate whether the compression thresholds are referred to input levels or output levels. The SSPL90 values are readily available from standard hearing aid performance specifications. Also, specifications for nonlinear hearing aids always include a gain curve for a 50-dB tone input, and some include curves for 40-dB inputs.

Information about compression parameters may be more difficult to obtain. For compression hearing aids, all manufacturers provide an input/output function tested at 2000 Hz. This can be used to estimate compression threshold(s) and compression ratio(s) for this frequency (see Figure 4). However, even for single-band nonlinear instruments, compression thresholds tend to vary with test frequency. Despite this, only a few manufacturers now supply data for frequencies other than 2000 Hz, possibly because there has been no clear application for such data in the past.



Additional data can be provided in the form of multiple I/O functions (at different test frequencies) or a figure that illustrates compression threshold as a function of frequency. If dispensers express a need for additional information about compression parameters, it seems likely that manufacturers will fill that need in the future. In the meantime, we have had success calling manufacturers for information not included in the published specifications.

VIOLA will show you two I/O templates, one for each test frequency. Your task is to enter the six data values described above, for each test frequency, to specify the performance of a hearing aid that you are interested in trying. The program will then draw an I/O function on each template. You must then decide whether the hearing aid's performance matches the amplification goals well enough or whether you should try other instruments before you make a selection. Future articles by IHAFF members will describe some examples of the use of VIOLA with specific hearing aid patients.

A final but important note: This fitting procedure must be considered a work in progress. Investigations are planned or in progress on several important issues, including the limits of the loudness-restoration approach, assumptions in the I/O-based fitting strategy, and overall satisfaction resulting from this type of fitting. Don't be surprised if the procedure changes as we accumulate more data on its application.

Acknowledgment: This work was supported by Department of Veterans Affairs Rehabilitation Research and Development funds.

REFERENCES

1. Skinner MW: *Hearing Aid Evaluation.* Englewood Cliffs, NJ: Prentice Hall;1988:154.
2. Hawkins DB, Walden BE, Montgomery AA, Prosek RA: Description and validation of an LDL procedure designed to select SSPL90. *Ear Hear* 1987; 8:162-169.
3. Cox RM, Goff CM, Martin SE, McLoud LL: The Contour Test: Normative data. Presented at the American Academy of Audiology Convention, Richmond VA., April 1994.
4. Pearsons KS, Bennett RL, Fidell S: Speech levels in various noise environments. EPA Report No 600/1-77-025, 1977.
5. Teder H. Noise and speech levels in noisy environments. *Hear Instr* 1990;41(4):32-33.
6. Macrae JH: Noise exposure of adult hearing aid users. *Aust J Audiol* 1993;5:5-8.
7. Macrae JH: Temporary threshold shift caused by hearing aid use. *JSHR* 1993;36:365-372.
8. Pavlovic CV: Statistical analysis of speech for various vocal efforts. Presented at the American Speech-Language-Hearing Association National Convention, Anaheim, CA, November 1993.
9. Bentler RA, Pavlovic CV: Transfer functions and correction factors used in hearing aid evaluation and research. *Ear Hear* 1989;10:58-63

Correction

In the 1995 Hearing Health Industry World Directory the 800 telephone number for Prairie Labs was printed incorrectly. The correct number is (800) 322-8238. We regret the error.