

Hearing aid software predictive gain values: How accurate are they?

By David B. Hawkins and Jodi A. Cook

There are several ways to assess the electroacoustic characteristics of hearing aids. The most commonly used techniques have been the 2-cc coupler, functional gain, and real-ear probe-microphone measurements. In each of these methods, the actual hearing aid that the person will use is assessed either on that individual, in the cases of functional gain and probe-microphone measurements, or in a standard coupler, the HA-1 or HA-2 2-cc coupler.

Now, with the advent of digitally programmable and digital signal processing hearing aids, the clinician is offered a variety of choices for how to view hearing aid performance in the software provided by hearing aid manufacturers. On the programming screen, one can choose to display how the hearing aid is programmed in a number of ways, depending on the manufacturer.

Options found in the NOAH programming modules include: (1) 2-cc gain, (2) 2-cc output, (3) 2-cc SPL, (4) 2-cc SPLoGram, (5) insertion gain, (6) simulated insertion gain, (7) KEMAR gain, (8) amplified long-term speech spectrum, (9) ear simulator gain, (10) real-ear SPLoGram, (11) simulated real-ear SPL, and (12) real-ear aided gain. None of these on-screen representations have been made with the actual hearing aid; rather, they represent simulations based on average and expected performance values.

SIMULATED AND MEASURED VALUES DIFFER

Since the audiologist sees these simulated values while programming and adjusting hearing aids, he or she may be tempted to believe that the computer screen values are for the specific hearing aid being programmed and for the specific patient being fitted with the device. Unfortunately, this is not the case. The 2-cc coupler gain values are what the manufacturer specifies as the standard for that model, not for the particular device being programmed. Given tolerances of components such as the microphone and receiver, the values in a given hearing aid could vary by as much as plus or minus 5 dB at some frequencies.

To come up with the simulated insertion gain figures shown on the programming screen, the manufacturer has taken the specified average 2-cc coupler values for that model and the current settings and transformed the cou-

pler values with what the company believes is an appropriate Coupler Output for Flat Insertion Gain (CORFIG). The 2-cc coupler gain modified by the CORFIG yields the predicted insertion gain.

For the most accurate prediction of insertion gain, the CORFIG should be specific to the hearing aid style (behind-the-ear, in-the-ear, in-the-canal, or completely-in-the-canal) because of the different microphone locations associated with each style. The CORFIG should also be specific to the earmold configuration (long or short canal, bore diameter if a BTE, and vent size) being used with the patient.

Even when these critical factors of microphone location and earmold venting are taken into account, one must still expect sizable errors on some patients due to the variations that can occur across individuals in residual ear

canal volume and middle ear impedance. Moreover, there are no universally accepted CORFIGs. Many have been reported and they can be substantially different from one another.¹⁻⁹

In view of all these sources of variability, clinicians should be cognizant of the fact that the on-screen values are simply

simulated values and may not precisely represent how the hearing aid is performing in either a 2-cc coupler or on the patient in front of them. The purpose of the study reported in this article was to demonstrate the existence of these differences and to remind practitioners who fit hearing aids that if they wish to know how the actual hearing aid is amplifying for the patient at hand, they must make individual measurements.

METHOD

For this study, we used data collected as part of routine clinical practice for patients being fitted with new hearing aids. The hearing aids and software used for this study represent a variety of manufacturers and hearing aids. All patients were adults with sensorineural hearing loss typical of that found in an older population. To obtain 2-cc coupler and real-ear insertion gain measurements we used an Audioscan Verifit hearing aid measurement system.

Simulated 2-cc vs. actual 2-cc gain

As a routine part of clinical practice, we obtained 2-cc cou-

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pler gain curves on hearing aids after they had been programmed. We were careful to turn off any “noise reduction” circuitry, because to our knowledge manufacturers assume that noise reduction is not activated in their on-screen simulations. In addition, for the coupler measurements, we used the same input signal (pure-tone or speech-weighted noise) and signal level as the manufacturer used in its software simulations.

We reviewed these data for our study and included 28 comparisons of the simulated and actual 2-cc gains for different models of hearing aids from several major manufacturers. If we found negative gain in the coupler measurement at any given frequency (typically in the lower frequencies for patients who had high-frequency hearing loss), we excluded these values from the data presentation.

Simulated insertion vs. actual insertion gain

We obtained insertion gain measures on 12 patients. The probe tube was carefully placed 25 mm past the tragus and that location was maintained throughout the real-ear unaided and aided response measurements. For these patients, we used the same signal and level to measure insertion gain as was specified in the software insertion gain simulation mode. Again, we deactivated any “noise reduction” circuitry. In multimemory hearing aids, these measurements were made only in the program with omnidirectional microphones and with any complex processing (e.g., “spectral enhancement”) removed.

For all patients, we recorded the simulated insertion gain at the time the actual insertion gain measures were made for later comparison. As with the coupler measurements, we did not include or compare negative gain values.

RESULTS

2-cc gain results

Figure 1 shows the difference (in dB) between measured 2-cc gain and the simulated gain from the hearing aid fitting software for 28 hearing aids of various styles from four major hearing aid manufacturers. Negative values indicate that the actual 2-cc gain was less than the simulated 2-cc gain and positive values indicate that the actual 2-cc gain was more than the simulated 2-cc gain.

In general, the manufacturer’s gain values shown in the hearing aid fitting software tend to overestimate the amount of actual gain in the hearing aid, especially in the lower and higher frequencies. We did not find that any one manufacturer’s simulated values were consistently closer to the actual values than any other manufacturer’s, nor were simulated and actual values closer for one style of hearing aid than for another.

One would expect some differences between actual measured values and simulated values due to multiple sources of variability. First, simulated values are just that, simulations, and thus reflect the average values for a given model. Variations in microphones, receivers, and amplifiers can easily cause differences of several decibels.

There are also variations in test box measurements due to slight positioning differences and minor calibration differences.

Since sources of variability could be combined and have a cumulative effect, one would expect that sizable differences between actual and simulated measurements would sometimes occur. However, one would also expect such differences to be normally distributed so that the average differences would be close to zero. This was not the case in our results. Instead, there was a clear trend for the simulated values to overestimate what was actually present in the hearing aids.

A possible explanation for the lower actual gain in the lower frequencies is that unintentional leaks were present in some of the in-the-ear hearing aid measurements. We took care to seal completely around the canal portion and the vent was closed with putty (FunTac). If, despite our efforts, leaks were present, they might account for the greater variability in the lower frequencies. However, if leakage were a problem, one might expect to see some increases in the region of 250-750 Hz due to the presence of vent-associated resonances in a hard-walled 2-cc coupler. Such increases are not evident in Figure 1.

It is not obvious why the simulations overestimated the high-frequency gain. What is clear is that clinicians could make a sizable error if they assume that the simulated 2-cc gain values are present in the individual hearing aids that they are programming.

Insertion gain results

Figure 2 shows the results of the difference between the measured and simulated insertion gain values across frequency for 12 patients. Hearing aids from several different major manufacturers are represented as well as all styles of hearing aids. Negative values indicate that actual insertion gains were less than simulated insertion gains and positive values indicate that actual insertion gains were greater than simulated insertion gains.

In the frequency region of 250 to 1000 Hz, the differences are distributed around the 0 line within plus/minus 5 dB. Given the variability of insertion gain measurements¹⁰ and the use of a simulation, the magnitude of the differences appears reasonable. In the higher frequencies, however, the actual insertion gain values

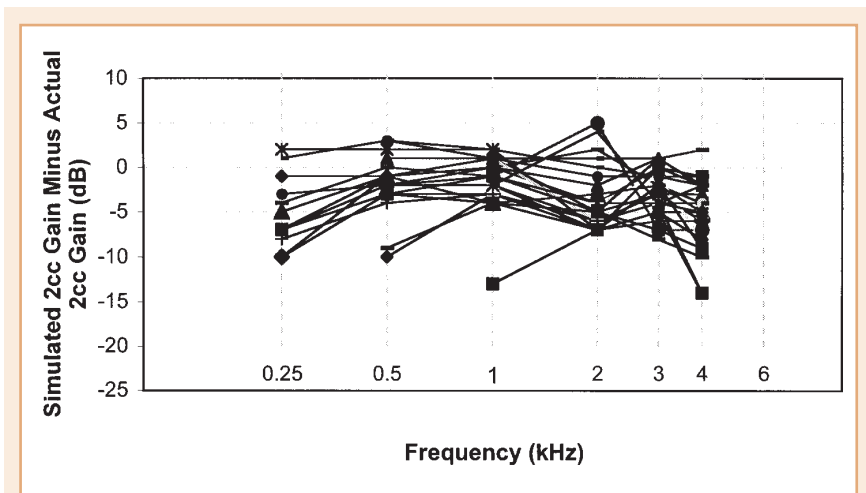


Figure 1. Differences in measured 2-cc coupler gain and software-simulated 2-cc coupler gain for 28 hearing aids. Negative values indicate that the software-simulated 2-cc coupler gain is less than the measured 2-cc coupler gain.

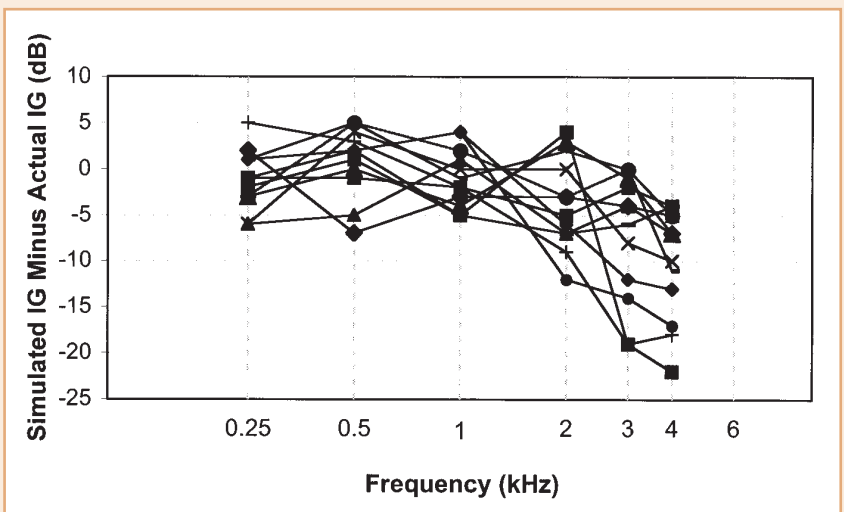


Figure 2. Differences in measured insertion gain and software-simulated insertion gain for 12 patients. Negative values indicate that the software-simulated insertion gain is less than the measured insertion gain.

decreased relative to the simulated values, and more patients showed substantially less insertion gain than was predicted.

For example, at 4000 Hz, 6 of the 12 patients showed insertion gains that were more than 10 dB less than the simulated values. At 3000 Hz and 4000 Hz, not one patient's actual insertion gain exceeded the simulated insertion gain. The simulation software always showed more high-frequency gain than was actually present in the hearing aid. It is clear from these data that audiologists should not expect the amount of high-frequency insertion gain that the simulations suggest.

DISCUSSION

The results of this study demonstrate what may well be an obvious and expected outcome to many hearing aid professionals: A simulation is just a simulation and one should not expect it to be accurate in every individual case.

However, many practitioners tend to view software simulations as showing values that are directly reflective of the particular instrument being programmed and the particular patient seated across the desk. For some patients, the simulations may do quite well, but for many others they may be off by a substantial amount, especially in the higher frequencies where important speech information is present.

The clear implication is that if you want to know what the actual hearing aid is doing on the patient who is going to be wearing it, you need to make a validation

measurement *in situ*. Such a measurement could be functional gain, but there are clear limitations in its use.¹¹⁻¹³ Probe-microphone measurements provide an excellent option for verifying real-ear performance on a specific patient, but care must be taken in the measurement and the choice of signal type if any sophisticated processing is present in the hearing aid. The use of actual speech signals, such as those available in the Audioscan Veri-fit, provides an excellent way to assess the real-ear performance of hearing aids with complex processing.

Assessing simulated values

If the audiologist chooses to use simulated

insertion gain values instead of actual measurements on the patient, then how the manufacturer arrives at the simulated values should be of interest.

First, one would expect more accurate simulations from the programming software packages that make inquiries about earmold configurations, vent size, etc., as it is known that these factors contribute to the actual gain obtained. These values are being used specifically for the real-ear simulations, as the CORFIGs are modified to reflect the earmold acoustic effects. Some manufacturers' inquiries are quite complete and the answers are clearly used in the simulations. There are also companies whose software does not ask about earmolds or venting and yet they show simulated insertion gain values. One would expect errors to be greater in the latter group, with larger errors as the earmold configuration deviates more from the standard one that is assumed.

The accuracy of real-ear simulations might also depend on what CORFIG the manufacturer chooses for its software. To take a cursory look at this issue, we calculated the behind-the-ear CORFIG used by four major hearing aid companies in their programming software. We did this by entering a flat 50-dB-HL hearing loss in NOAH and selecting a BTE with a standard earmold configuration (medium length, fully occluding with no vent). The default fitting algorithm generated the recommended gain curve, and we examined the recommended values for both 2-cc and insertion gain for the same input

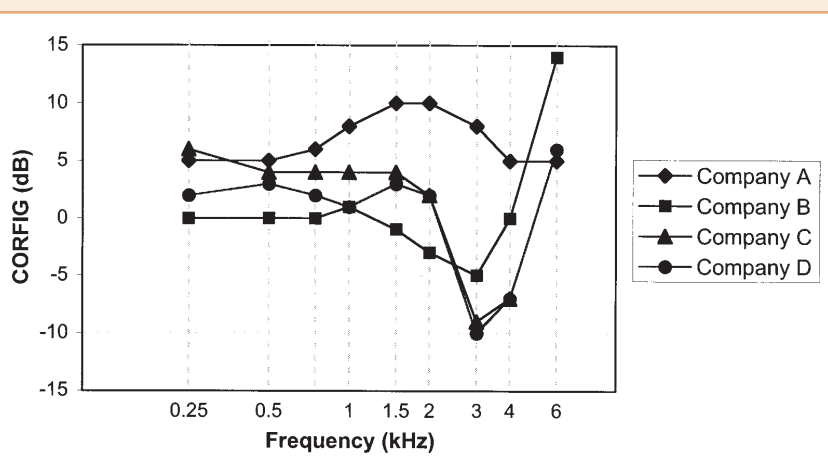



Figure 3. Derived CORFIGs for behind-the-ear hearing aids from four major hearing aid manufacturers. The CORFIGs were obtained by determining the differences between target 2-cc coupler and insertion gain values in the manufacturer's software.

signal and input level. The differences between these values represent the CORFIG used by the manufacturer.

The CORFIGs obtained from the four manufacturers are shown in Figure 3. There are clearly some substantial differences among the curves, with Manufacturer A showing a curve that is quite different in magnitude and shape from the other three manufacturers. Given the large differences among the CORFIGs used by different companies, it would not be surprising to find that some companies estimate simulated insertion gain better than others. However, in this study, there were too few subjects to address this issue.

In conclusion, the data reported in this study suggest that simulated gain values from hearing aid fitting software should be used only as a starting point. If clinicians want to know what the hearing aid is actually doing on the patient being fitted—and it can be argued that they should—then they need to make individual validation measurements. 

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