Accuracy of Predicted 2cm³ Coupler Gain Values Across Manufacturers

Contributors

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Introduction

The purpose of this study was to evaluate the accuracy of manufacturers' predicted gain values as shown in their software. It has been shown that predicted gain targets (either 2cm³ coupler or real-ear aided response) can overpredict the actual gain of the devices by more than 10 dB. For example, Hawkins and Cook (2003) compared predicted 2cm³ gain values to actual 2cm³ gain measurements obtained from a variety of models of hearing aids from several different manufacturers. The authors point out that although some variability is expected due to variations in microphones, receivers, and placement in the test box, these differences should be equally distributed around the average, resulting in an average error close to zero. However, they found a clear trend for the manufacturers' predicted values from their software to overestimate the actual gain of the devices by as much 5 to 10 dB, with the largest errors at low and high frequencies. The high-frequency errors were even more pronounced when comparing measured real-ear insertion gain to predicted insertion gain; for some individuals, the actual high-frequency gain was as much as 15-20 dB less than that shown in the software. There were no instances of the measured gain exceeding that shown in the software.

Similarly, Aarts and Caffee (2005) compared the predicted and the actual real-ear aided response (REAR) values from one manufacturer, but for many individuals, and using two input levels and two different hearing loss configurations. They found that approximately 33% of the measurements were within 3 dB of the predicted values. However, about 40% were 4 dB or less than the predicted values, and about 27% were greater than the predicted values by 4 dB or more. The largest discrepancies were in the 3.0 to 4.0 kHz range, where the predicted values exceeded the measurements by up to 10-15 dB. It is not unexpected that the predicted and actual values do not coincided for all ears, as manufacturers rely on average RECD values to obtain their REAR values. However, one would expect that the average REAR from a large number of ears should be reasonably close to the predicted REAR values in the software.

At the time of these reports, it was very clear that clinicians should use real-ear measurements to verify hearing aid fittings rather than relying on the predicted values available in the manufacturers' software. Moreover, these reports should have been a "wake-up call" to the manufacturers to improve the accuracy of their software.

Methods

Devices: Two each of the "top-tier" behind-the-ear (BTE) hearing aids were selected from seven different manufacturers, including Velocity 24 BTEs from Sonic Innovations. Devices were programmed for a flat 55-dB HL sensorineural hearing loss using the most recent NOAH version of each manufacturer's software. The default fitting algorithm for an adult, experienced user was selected. All devices were set to an omnidirectional program with noise reduction and feedback management features turned off.

Coupler Measurements: Coupler measurements were completed using a Frye Fonix 7000 Hearing Aid Test System and an HA-1 2cm³ coupler. Pure-tone sweeps at two or

Hearing Aid	Soft	Moderate	Loud
A	50	70	
B	50		80
C	50	70	90
D	45	65	80
E	40	60	80
F	40	65	90
Velocity 24	50		90

Table 1: Stimulus levels used for 2cm³ coupler measurements. Levels are based on the target levels in each manufacturer's software for Soft, Moderate, and Loud inputs. *Specific levels for Hearing Aid 'A' were not available in the software and were obtained from their customer service representative.

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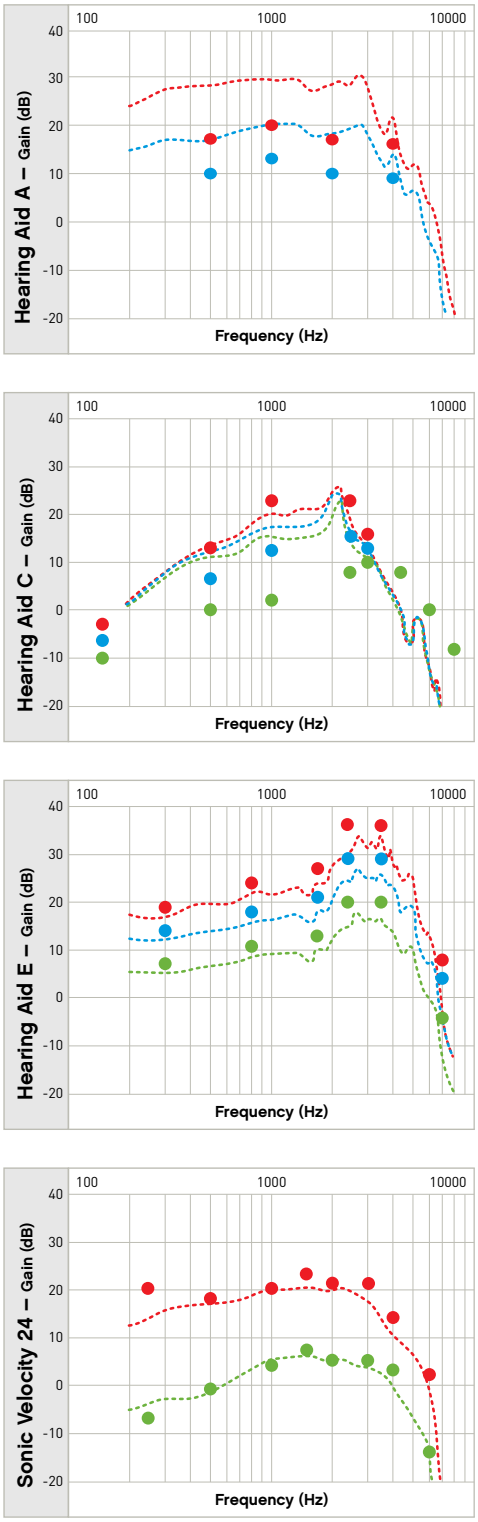
three different stimulus levels were used to measure the output of the hearing aid. The levels were selected based on the target levels shown in each manufacturer's software. The specific levels tested for soft, moderate, and loud inputs for each hearing aid are shown in Table 1 (previous page).

Results

Results are shown in Figures 1A-1G. Predicted 2cm^3 coupler values, as reported in each manufacturer's software, are shown by the red, blue, and green circles for soft, moderate, and loud inputs, respectively. Coupler measurements, averaged across two devices, are shown by the dashed lines. Data are plotted in gain, rather than output to facilitate comparison across devices. Across manufacturers, there is substantial variability in the degree of accuracy between the predicted gain values and the coupler measurements from the actual devices. The coupler measurements for Hearing Aids A, B, C and D show significant deviations from their predicted gain values, whereas Hearing Aids E and F, and the Velocity 24 BTEs from Sonic Innovations are generally accurate; most values are within 5 dB or so of the coupler measurements. Although some of the discrepancies are simply due to the predicted gain values being too low or too high, others appear to mischaracterize the frequency response or signal processing strategy of the device. For example, Hearing Aid A is difficult to accurately characterize due to the input levels not being specified in the software. However, when using the stimulus levels provided by a representative in customer service, the predicted gain values are considerably lower than the actual gain measurements. The predicted gain values for Hearing Aid B show a fairly flat frequency response, whereas the actual measurements reveal a peaked response. The resonance peaks approximate the predicted gain values at those frequencies, but otherwise the measurements fall short of the predicted values. For Hearing Aid C, the coupler measurement for the soft input level is fairly accurate,



Figures 1A–1G: Predicted gain values (filled symbols) and 2cm^3-coupler measurements (dashed lines) for hearing aids from seven manufacturers. Results are shown for soft (red), moderate (blue), and loud (green) inputs. Graphs are plotted in terms of gain using the stimulus levels from Table 1.

Error for Soft Input Levels

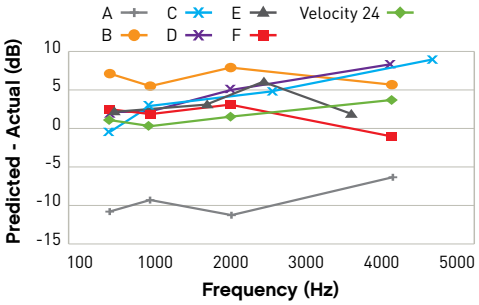


Figure 2: Differences between predicted and actual 2cm^3-coupler gain values for soft inputs for seven manufacturers. Values greater than 0 dB indicate predicted values are higher than the actual measurements.

Error for Loud Input Levels

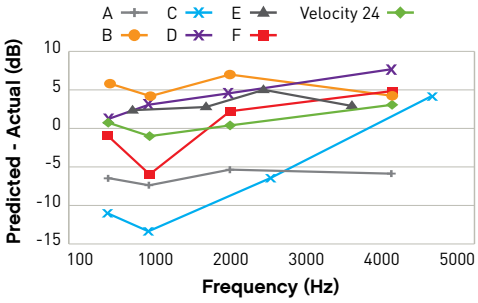


Figure 3: Differences between predicted and actual 2cm^3-coupler gain values for loud inputs for seven manufacturers. Values greater than 0 dB indicate predicted values are higher than the actual measurements.

whereas the measurements for moderate and loud inputs exceed the predicted values. As a result, the measurements at different input levels show similar amounts of gain, indicating almost linear processing, whereas the predicted gain values obtained from the software imply that wide dynamic range compression is being applied. The frequency response measured from Hearing Aid D is the same general shape as the predicted values, although displaced downward by as much as 7-8 dB in the high frequencies. That is, the hearing aid is providing less gain than suggested by the software.

To quantify the discrepancies observed between the predicted 2cm^3-coupler gain values and the actual measurements, the differences (in dB) at four frequencies (500, 1000, 2000, and 4000 Hz, or the closest frequencies available in the software) for two stimulus levels were calculated. The results are shown in Figures 2 and 3 for the soft and loud input levels, respectively. (Note that predicted gain values for soft and moderate inputs were used for Hearing Aid A as values were not available for loud inputs.) Values greater than 0 dB indicate that the hearing aid is providing less gain than the predicted gain values shown in the software.

Using only these eight measurement points for reference, it appears that the hearing aids frequently provide less gain than that predicted by the software, regardless of input level or frequency. However, the largest errors (>10 dB) are seen in the opposite direction, where the actual gain of the device is greater than the predicted values. This was observed for two different hearing aids (A and C) and was primarily observed for the low frequencies and the louder inputs.

To further examine the accuracy of the predicted gain values, the percentage of the eight measurements (4 frequencies x 2 levels) that are within 3 dB of the values obtained from the software are plotted for each hearing aid in Figure 4 (following page). Sonic Innovations' Velocity 24 is the most accurate, followed by Hearing Aids E and F, where the majority of the measurements are within 3 dB of the predicted gain values. Less than half of the measurements for Hearing Aids C and D are accurate within 3 dB, and none of the measurements from Hearing Aids A and B are within 3 dB.

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Accuracy of 2cm³ Gain Values

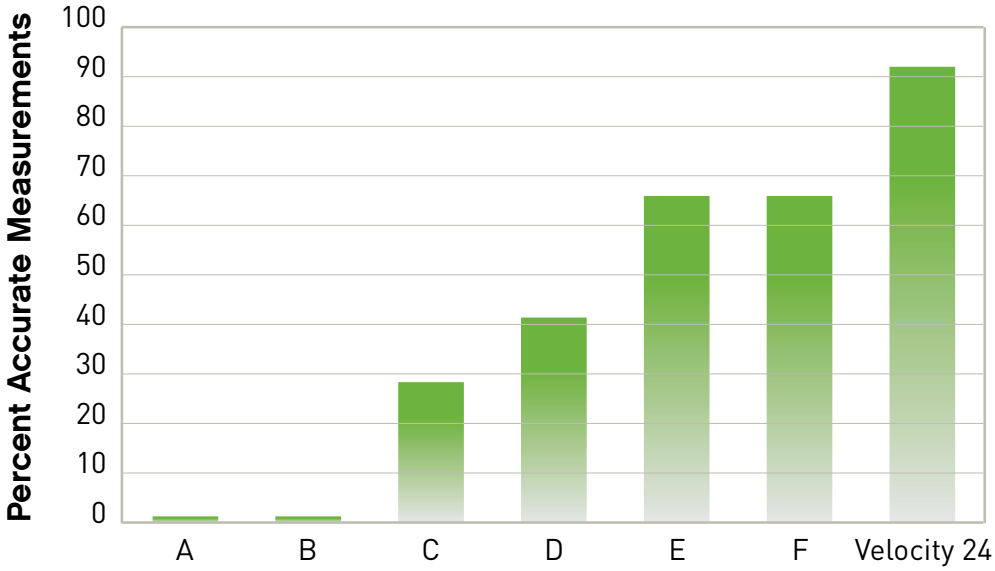

Figure 4: Percentage of coupler measurements that are within +3 dB of the predicted gain values obtained from each manufacturer's software.

Summary

There is significant variability in the degree of accuracy when reporting predicted 2cm³ coupler gain values for high-end BTEs. In general, most predicted gain values tended to exceed the actual gain measurements, although there were measurements from two hearing aids where the output of the devices exceeded the predicted values by more than 10 dB. The predicted gain values reported for Sonic Innovation's Velocity 24 BTE were the most accurate, followed by two other hearing aids that had the majority of their predicated 2cm³ coupler gain values within 3 dB of the actual measurements. The remainder of the hearing aids had less than half of the predicted gain values within 3 dB of the actual values, and two devices had no predicted gain values within 3 dB of their actual values.

These results emphasize the need for clinicians to verify that the gain and output from the hearing aids they are fitting reflect the specifications provided by the manufacturer. Although clinicians should expect variability in predicted real-ear gain values relative to actual measurements, as there is significant variability in ear canal size and shape, the discrepancies that exist between what some manufacturers indicate as predicted 2cm³ gain values in their software and what their high-end devices actually deliver is not easily understood. Much greater accuracy should be expected given the standardized measurement system.

References

1. Hawkins, D.B. and Cook, J.A. (2003). Hearing aid software predictive gain values: How accurate are they? Hearing Journal, 56(7), 26-34.
2. Aarts, N.L. and Caffee, C.S. (2005). Manufacturer predicted and measured REAR values in adult hearing aid fitting: Accuracy and clinical usefulness, International Journal of Audiology, 44, 293-301.

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