Aided Masked Thresholds: Case of Deception

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Abstract
A case of contaminated functional gain measures from internal hearing aid noise is presented and clinical implications addressed. The contaminated functional gain measures underestimated real ear insertion gain. Recognition of this source of functional gain measurement error is essential for accurate hearing aid fitting.

Key Words: Functional gain, internal hearing aid noise, masked aided thresholds, real-ear insertion gain (REIG)

Invalid functional gain (FG) measurements may result from a variety of factors (e.g., Macrae and Frazer, 1980; Macrae, 1982; Rines et al, 1984; Mason and Popelka, 1986; Dillon and Murray, 1987; Haskell, 1987; McKenzie and Rice, 1987; Stelmachowicz and Lewis, 1988). Amplification of ambient noise and/or internal hearing aid noise can effectively produce a masking phenomenon resulting in aided thresholds that do not reflect true real-ear gain. Masking of aided thresholds typically occurs at frequencies below 1000 Hz where the client has hearing thresholds better than 30 dB HL (Macrae, 1982). However, it may occur in any frequency region of normal or near normal peripheral auditory sensitivity, such as occurs in sloping, rising, or trough-shaped audiograms (Rines et al, 1984).

To circumvent measurement error of real-ear gain, Rines et al (1984) advocated the use of aided and unaided sound-field acoustic reflex thresholds. They reported that real-ear gain predicted by the behavioral and acoustic reflex methods differed by a maximum of 20 dB for frequency regions of normal hearing. This procedure is limited to cases where acoustic reflexes are present. In addition, the reflex method may underestimate gain with high input levels with nonlinear or high-gain hearing aids. In 1984, Rines et al indicated that probe-microphone measurements would have clinical utility for the provision of accurate estimates of real-ear gain, as the measurements are made with moderate level inputs (typically 50 to 70 dB SPL) and the hearing aid output being measured is well above the noise floor.

The purpose of this report is to demonstrate a case in which FG measurements produced an invalid representation of real-ear gain due to internal hearing aid noise, while probe-microphone measurements of real ear insertion gain (REIG) were not susceptible to this contaminating problem.

BACKGROUND AND MEASUREMENTS

Audiologic data for a 9-year-old female with a bilaterally symmetrical high-frequency sensorineural hearing loss are presented in Table 1. Hearing sensitivity was within normal limits through 1000 Hz, followed by a steeply sloping to severe-to-profound hearing loss in the higher frequencies. Tympanometry was compatible with normal bilateral middle ear function. The subject had used binaural linear behind-the-ear hearing aids with nonoccluding earmolds for 1 year and occluding earmolds for 2 years. The switch in earmold type was necessitated by feedback problems. Annual audiologic re-evaluations, which included assessment of behavioral frequency-specific aided sound-field thresholds and aided word recognition assessment at 50 dB HL were performed. Subjectively, she reported the hearing aids to be of "some" benefit. Probe-microphone measurements had not been obtained during these routine evaluations.
Table 1  Audiologic Data for the Subject

<table>
<thead>
<tr>
<th>Frequency (Hz)</th>
<th>500</th>
<th>1000</th>
<th>1500</th>
<th>2000</th>
<th>3000</th>
<th>4000</th>
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<tbody>
<tr>
<td><strong>Unaided Earphone Thresholds (in dB SPL)</strong></td>
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<tr>
<td>Right Ear</td>
<td>19</td>
<td>18</td>
<td>58</td>
<td>76</td>
<td>95</td>
<td>106</td>
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<td><strong>Unaided SF Thresholds (in dB SPL)</strong></td>
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<tr>
<td>Right Ear</td>
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<td>13</td>
<td>58</td>
<td>81</td>
<td>100</td>
<td>101</td>
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<tr>
<td><strong>Hearing Aid Measurements</strong></td>
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<tr>
<td>Gain (in dB)</td>
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<tr>
<td>REIG</td>
<td>25</td>
<td>38</td>
<td>38</td>
<td>29</td>
<td>30</td>
<td>34</td>
</tr>
<tr>
<td>FG</td>
<td>-5</td>
<td>0</td>
<td>30</td>
<td>35</td>
<td>30</td>
<td>30</td>
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<tr>
<td>Internal Noise (in dB SPL)</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>CNA*</td>
<td>38</td>
<td>44</td>
<td>40</td>
<td>46</td>
<td>40</td>
<td></td>
</tr>
</tbody>
</table>

*Could not assess, given the noise floor level of the hearing aid test box at 500 Hz.

Present testing was conducted in a double-walled audiometric test booth with the subject seated 1 m from the loudspeaker at a 45 degree azimuth. Aided and unaided sound-field thresholds were measured by conventional audiometric techniques in response to warble-tone stimuli produced by a clinical audiometer (Grason-Stadler, Model 10). Unaided word recognition scores in quiet were obtained under earphones at 80 dB HL with taped Phonetically-Balanced Kindergarten word lists. Aided word recognition scores in quiet were obtained in the sound field at 50 dB HL.

REIG measures were obtained using a clinical probe-microphone system (Fonix, Model 6500) located in a self-contained, quiet room with carpeting and acoustic tile. The probe tube was inserted 5 mm beyond the earmold tip for aided and unaided measures. A 70 dB SPL speech weighted composite signal was used.

The spectrum of the internal hearing aid noise was measured in the 2-cm³ coupler within the Frye 6500 hearing aid test box (noise reduction: off; composite: source off) with the volume control wheel taped at use setting. Spectral analysis was computed at 100 Hz intervals but only data pertinent to the functional gain measures are reported. Six measurements were made and the results averaged.

RESULTS

FG and REIG values are shown in Table 1. Large differences are observed between these two measures of real-ear gain at and below 1000 Hz, the region of normal hearing for this client. REIG measurements revealed 25 dB of gain at 500 Hz and 38 dB at 1000 Hz. In contrast, FG measurements indicated negative gain was present at 500 Hz (the aided threshold was 5 dB poorer than the unaided threshold) and no gain was present at 1000 Hz. At higher frequencies where substantial hearing loss was present, there was reasonable agreement between REIG and FG. Unaided word recognition at 80 dB HL was 88 percent, and aided word recognition at 50 dB HL was 60 percent.

The results of the internal hearing aid noise measurements are also shown in Table 1. The spectrum analysis of the internal hearing aid noise indicated values from 38 to 46 dB SPL (level per cycle) across the range from 1000 to 4000 Hz, with more energy being located in the higher frequencies.

DISCUSSION

This report demonstrates a clear case of the inadequacy of FG to assess hearing aid gain when there is a region of normal hearing. The audiologist, in an attempt to eliminate feedback, changed from a nonoccluding to an occluding earmold. The attempt to determine whether the gain in the low frequencies was now excessive was contaminated by the FG measurement. Without the nonoccluding earmold to attenuate the low-frequency gain, excessive low-frequency amplification was present, but could not be measured due to the circuit noise acting as an effective masker. By using more typical input levels, such as 50 to 70 dB SPL, and assessing the amplified output levels, probe-microphone measurements are not susceptible to this masking phenomenon and more accurately demonstrate the manner in which a hearing aid actually operates. In reality, a hearing aid amplifies input levels above constant, elevated thresholds, and does not improve thresholds.

In order to confirm that the circuit noise in the hearing aid did in fact act as a masker, the spectrum level at 1000 Hz was converted to effective masking level through a method described by Killion (1976), and the gain of the
hearing aid was subtracted to yield the predicted best possible aided sound-field thresholds (Hawkins et al, 1987). These calculations produce a best possible aided threshold of 18 dB SPL at 1000 Hz. This value is quite close to the subject’s unaided threshold of 13 dB SPL at 1000 Hz. Using this approach, one would predict a FG value of +5 dB at 1000 Hz which is within 5 dB of that obtained by the subject. It is clear that the circuit noise accounted for the lack of measurable FG.

While it is tempting to speculate that the drop in word recognition score from the unaided to aided condition (88% to 60%) is due to excessive low-frequency amplification, we would not make that conclusion without further testing using different frequency response configurations.

In summary, the use of FG with persons having regions of normal or near-normal hearing can produce erroneous conclusions regarding the actual amplification that the hearing aid is providing. The FG paradigm, while providing useful and sometimes unique information in many cases (Stelmachowicz and Lewis, 1988), does not reflect how hearing aids operate and can provide erroneous information under circumstances such as described in this case.

REFERENCES


