Hearing Aid Programming Practices in Oregon: Fitting Errors and Real Ear Measurements

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Under-fitting to well-established real-ear targets results in decreased hearing aid utility

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> *This study shows that 97.7% of subjects showed deviations from the NAL-NL2 in excess of 5 dB in both ears—well in excess of the nearly two-thirds of hearing aid fitting errors reported by the now-famous Consumer Reports article of 2009. Research continues to show that hearing aids that provide more real-ear verified aided speech audibility result in better outcomes than hearing aids that do not provide as much aided speech audibility.*

In June 2009, *Consumer Reports* found that nearly two-thirds of the 48 hearing aids purchased in the New York City area by their 12 subjects were improperly programmed as determined by their panel of experts.[1] While the study gave no specific details as to how the hearing aids were improperly programmed, it was noted that nearly two-thirds of these hearing aids provided "too little or too much amplification."

Not unexpectedly, this report was criticized for lack of scientific rigor. However, it began a formal awareness on the part of the consumer that simply purchasing a hearing aid based on manufacturer-advertised features did not guarantee an optimum outcome.

Unfortunately, the discussion of factors that *do* impact optimum hearing aid outcome has not since been discussed in an extensively disseminated "consumer-based" publication. While there are references to these factors in audiology publications, this information has not reached the end user. Review of audiological literature suggests a recurrent factor in favorable hearing aid outcome is use of real-ear aided measures.

Sadly, such measures are the exception not the rule. For example, one year after the *Consumer Reports* findings were published Mueller and Picou[2] found that 40% of their 110 survey respondents, which included both hearing instruments specialists and audiologists, were self-reporting routine use real ear measures to validate hearing aid programming. In a subsequent discussion of these data, Mueller[3] noted that the actual number of survey respondents using real ear measures was more likely in the range of 30%. More recently, Leavitt, Clark, and Rector[4] found that only 30% of their 33 survey respondents, all of whom were Doctors of Audiology, reported using real ear verification consistently with every hearing aid fitting.

One might then ask when real-ear aided measures are not employed, what is the outcome? This question has been addressed in the literature.

Aazh, Moore, and Prasher[5] conducted probe-mic verification for 51 fittings for hearing aids programmed to the manufacturer's NAL-NL1 prescription. They found 29% were within ±10 dB of prescriptive target at all key frequencies. When reprogramming of these same hearing aids was undertaken they found that it was possible to fit 82% of the patients to the NAL-NL1 prescriptive target.

Mueller[3] showed that real-ear values for three different manufacturers hearing aids were significantly different than the NAL-NL2 target when the NAL-NL2 fitting algorithm is selected in the manufacturers' fitting software. Sanders et al[6] evaluated manufacturer's best fit algorithms and found that, for their 8 adult subjects, 74% of cases showed outputs that varied from the NAL-NL2 target by 10 dB or more for at least one frequency between 250 and 4000 Hz. Aarts and Caffee[7] found that real-ear aided responses (REAR) in 41 adults were significantly different from those predicted by manufacturer fitting software for most of the audiometric frequencies. Few REAR values (<12%) were judged to be clinically similar to software-predicted values.

While it cannot be shown that the hearing aid programming errors reported by *Consumer Reports* were due to lack of real-ear measures, the similarities among the data of *Consumer Reports* and the studies noted above are noteworthy. All of these studies suggest that, without real ear verification of hearing aid output, programming errors occur relative to well-established targets approximately 70% of the time.

The current study sought to quantify the incidence of hearing aid programming errors in a larger population over a larger geographic area than those provided by the *Consumer Reports* article of 2009 and other studies noted above.

Field Study

Subjects. A total of 97 subjects' hearing aid fitting data were analyzed from 24 clinics throughout Oregon. Nine (9) of these facilities were staffed exclusively by hearing instruments specialists, and the rest (15) were in medical centers, otolaryngology clinics, and private audiology practices staffed by Doctors of Audiology.

A total of 97 subjects (73 males, 24 females)with an average age of 75 years (range 23-93 years) were included in the study. These subjects wore 176 hearing aids (79 binaural users, 18 monaural users) from 16 manufacturers. The average hearing aid age was 3.16 years, with a range of 1.5 months to 10 years. All subjects were current hearing aid users, with an average of 3.5 years of hearing aid use experience, with a range of 1.5 months to 23 years.

The subjects were patients who had contacted the clinic for hearing evaluation, hearing aid evaluation, tinnitus evaluation therapy, auditory processing disorder complaints, or hearing aid repair/replacement issues. Several were physician referrals. No attempt was made to recruit subjects from any particular facility. All were included in this study as they had already obtained hearing aids from another facility.

Methods. Prior to real ear measurements all subjects' hearing aid receivers, microphones, and earmolds/tubing were analyzed for oxidation and debris using a MedRx video otoscope. If any problems were noted, the hearing aids were repaired or cleaned as needed prior to evaluation. All subjects' ear canals were inspected for debris with the video otoscope and, when appropriate, the debris was removed prior to audiological evaluation.

Pure-tone air- and bone-conduction thresholds were obtained using the 1959 Carhart-Jerger adaptation[8] of the Hughson-Westlake procedure. Acoustic immitance was performed with both ipsilateral and contralateral reflexes measured at 500, 1000, 2000, and 4000 Hz bilaterally. Word recognition tests were conducted at the patient's preferred listening level in quiet using the recorded version of the Maryland CNC 50-word lists. Where possible, a 40 dB sensational level was used for word recognition testing.

Tone decay was performed on all subjects as described by Olsen and Noffsinger. [9] Pure-tone uncomfortable listening levels were measured at 250, 500, 1000, 2000, 3000, and 4000 Hz bilaterally using the instructions recommended by the British Audiology Society.[10] A Quick Speech in Noise (QuickSIN) test was administered in aided sound field at a 60 dB SPL presentation level,[11] and the mean audiogram with range markers is shown in Figure 1.

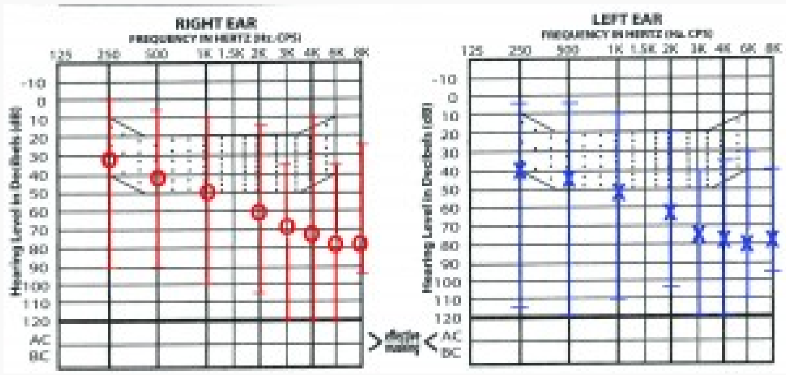

Figure 1. Mean audiogram of subjects in study with range markers for both ears.

All subjects' hearing aid outputs were analyzed with an Audioscan Axiom real ear system. The NAL NL-2 formula was used as the preferred target. Measurements were conducted at 50, 60, and 75 dB SPL using the carrot passage stimuli.

The deviation from NAL target at 60 dB SPL was computed with a Microsoft Excel spreadsheet. Root Mean Square (RMS) errors were computed for all subjects for each ear separately at 500, 1000, 2000, 3000, and 4000 Hz. A repeated linear, mixed-model measure analysis of variance was performed with frequency error and ear as within-subject factors. Provider (audiologist vs hearing aid dispenser), brand, and age of hearing aid were between-subject factors.

Results

Figure 2 shows the average fitting errors with range markers for all subjects at each of five frequencies for both ears. In this clinical population, RMS fitting errors of 10 dB or more were present in 72% of fittings. Using the ±5 dB RMS criteria suggested by McCreery, Bentler, and Roush,[12] hearing aid programming errors were present in 97.7% of fittings. Such findings are not surprising if one looks at the manufacturer's best-fit data as described by Hawkins and Cook,[13] Leavitt and Flexer,[14] and Sanders et al[6] as described below. Other key findings were:

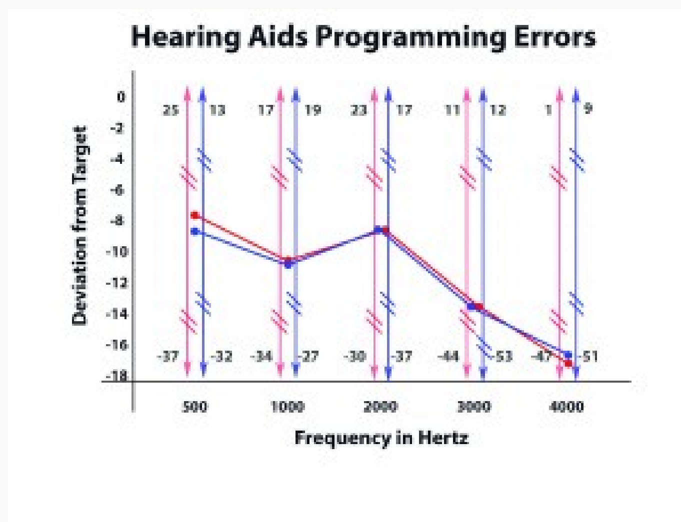

Figure 2. Average fitting errors with range markers at 5 frequencies for both ears. In this clinical population, RMS fitting errors of ≥10 dB were present in 72% of fittings.

- The analysis of variance showed RMS difference between NAL target and measured output at 60 dB SPL was significant at every frequency in both right and left ears. There was a significant frequency effect in that the fitting errors were least at 500 and 2000 Hz.
- There was a significant difference in fitting accuracy among brands. Specifically, five of the "Big 6" manufacturers' products were closer to the NAL target than the other 11 brands.
- There was no significant ear effect in that the RMS errors on the right ear were not significantly different from those on the left.
- There was no significant age of hearing aid effect in that the RMS errors were as great on new hearing aids as on old hearing aids, thereby refuting the hypothesis that the older hearing aids may have degraded in

performance, making them more underfit relative to the NAL-NL2 target.

- While the magnitude of audiologist RMS fittings errors were smaller than the dispenser fitting errors, the difference did not achieve significance.
- In virtually all instances, these hearing aids were programmed well *below* established mathematical targets in a manner indicative of manufacturer's best-fit protocol.

Discussion

If there were no data suggesting these fitting errors resulted in unfavorable outcomes for people with hearing loss, this recurring 72-97.7% error rate would be inconsequential. However, research shows that hearing aids providing more real-ear verified aided speech audibility result in better outcomes than hearing aids that do not provide as much aided speech audibility.

For example, Kochkin et al[15] showed lack of hearing aid verification by real ear measures was the number one factor resulting in decreased hearing aid user satisfaction. In a second publication, Kochkin[16] showed ability to perceive soft sounds with the hearing aid was the greatest need expressed by hearing aid nonusers which has been repeatedly shown to be related to real-ear verification of aided speech audibility.

Leavitt and Flexer[14] showed reliance upon manufacturer's best-fit software and associated under-fitting of the subjects' hearing aids resulted in decreased speech recognition in noise as measured by the QuickSIN. Stiles et al[17] reported children with mild to moderately severe hearing loss with real-ear verified aided SII less than 0.65 demonstrated greater delays in vocabulary development than children with better aided audibility.

McCreery, Bentler, and Roush[12] showed that 55% of their 199 subjects showed deviations of 5 dB or more from real-ear verified targets resulting in significant academic difficulties. Moreover, 26% of the children in the study had aided audibility less than 0.65 on the Speech Intelligibility Index (SII). These researchers noted that aided audibility was significantly predicted by the proximity to prescriptive targets and pure-tone average.

In 2016, Boothroyd and Mackersie[18] showed that 19 of their 20 subjects achieved an NAL NL2 target match within ±5 dB when instructed to self-program their amplification for maximum recognition of sentences in quiet. Notably their subjects came closer to an NAL NL2 target match than the majority of audiologists and dispensers in the present study.

In a comparison of hearing aid users versus cochlear implant users, Lovett and colleagues[19] reported children whose hearing losses exceed 80 dB at 250-4000 Hz are *4 times* more likely to show better word recognition in quiet and noise with cochlear implants than with hearing aids. While it is not readily apparent this favorable outcome with cochlear implants over hearing aids for such patients is related to greater speech audibility provided by the implant, examination of the DSL/IO or NAL aided targets for children with 80 dB hearing losses as compared to the recommended sound field thresholds for children with cochlear implants suggests dramatically improved speech audibility with cochlear implants over real-ear programmed hearing aids using either the DSL/IO or NAL targets.

Additional studies have confirmed improved outcomes with implant sound-field thresholds in the 20 dB range across the speech spectrum.[20-23]

It is recognized the cochlear implant outcomes based on sound-field thresholds are not equivalent to real-ear validated aided speech audibility. It is, however, of interest to note that the preponderance of evidence for subjects with mild to profound hearing losses consistently shows better speech understanding when more speech audibility (higher SII scores) are obtained either with hearing aids or cochlear implants.

Based on functional magnetic image resonance (MRI) data, Sharma[24] showed abnormal brain reorganization resulting from untreated hearing loss can be appropriately reallocated when appropriately fit hearing aids are provided. She hypothesized this cortical reorganization likely requires full target programming.

Thus it has been shown that under-fitting hearing aids results in decreased hearing aid user satisfaction,[15,16] decreased word recognition in noise,[14] poorer academic performance,[12,17] and possibly compromised brain organization as shown by functional MRI.[24]

If one believes that today's deluxe hearing aid features obviate the need for real ear validated speech audibility, as suggested by some hearing aid manufacturers' representatives, the data of Cox et al[25] suggests otherwise. Specifically, Cox and her colleagues showed that, for their 45 subjects, there were no statistically significant differences between premium and basic level hearing aid offerings from two major hearing aid manufacturers either in terms of clinical measures, self-report measures, or open set diaries provided that all hearing aids were programmed equally as validated by real ear measures. From these data, the researchers suggested that we should stop focusing on hearing aid features and redirect our attention to aural rehabilitation and real ear verification.

The current research supports this position. In the present study, 97.7% of these subjects showed deviations from an NAL NL-2 in excess of 5 dB in both ears—well in excess of the nearly two-thirds of hearing aid fitting errors reported by *Consumer Reports* in 2009.

Previous surveys reporting routine use of real ear measures in the 30-40% range also seem overstated in this population. Specifically, whether one chooses an NAL or DSL I/O target, 97.7% of these fittings are significantly under-fit. Our data suggest that, at best, 2.3% of these hearing aid programs were subjected to real ear aided verification using an NAL-NL2 target.

To the extent that under-fitting of well-established real ear targets results in decreased user satisfaction, decreased word recognition in the presence of background noise, reduced academic performance in children wearing hearing aids, and possible unfavorable reallocation of the cortex, such errors cannot be tolerated.

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