

ACCURACY OF IN-SITU AUDIOMETRY VERSUS TRADITIONAL AUDIOMETRY FOR
FIRST FIT HEARING AID FITTINGS

by

Abigail Grace Brazda

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Benjamin Russell Au.D., Ph.D., CCC-A, Thesis Chair

Gail Donaldson, Au.D., Ph.D., Thesis Co-Chair

Stephan Frisch, SLP, Ph.D., Departmental Honors Program Director

INTRODUCTION: LITERATURE REVIEW

The gold standard for adjusting and verifying the accuracy of hearing aid fittings is to perform real-ear measurements, which takes place after traditional audiometry (Valente, 2002). Audiometric thresholds are used to generate prescribed amounts of gain in the hearing aid, which reflect how much the levels of environmental sounds are increased to treat a patient's hearing loss. Real-ear measurements are then used to verify that a patient's hearing aid is delivering the correct amount of prescribed gain. This process is often referred to as *verification* because the goal is to verify that the hearing aid is delivering the correct amount of gain to the patient's auditory system.

In order to obtain real-ear measurements, a probe-tube microphone is inserted into the patient's ear canal near the tympanic membrane, and the hearing aid is then placed on the patient. The measurement from the probe microphone placed in the ear canal is compared to a measurement taken from a microphone that hangs just inferior to the patient's pinna, outside the ear. By comparing the sound outside the ear to the sound within the ear canal, the real-ear system is able to calculate how much the hearing aid is increasing the sounds in the environment, which is known as real-ear aided response (REAR) (Valente, 2002). Obtaining REAR is an essential part of the verification process because it ensures that the patient's hearing aid is providing enough gain to allow access to conversational speech (Valente, 2002).

There are many different formulas that may be used to generate prescribed targets from a patient's hearing test results. For example, each hearing aid company has their own proprietary target calculation method. However, the most widely accepted method for calculating prescribed targets for adults is the NAL-NL2 formula (Valente, 2002).

As technology improves, so does the process of verifying hearing aid amplification, resulting in a rise in the availability of fitting software linked to self-fitting hearing aids (Gade & Love, 2021). Current real-ear technology is capable of automatically adjusting gain values, and automatically sending information back to hearing aid programming software, resulting in an accurate fitting with the push of a single button (Gade & Love, 2021). Unfortunately, many audiologists do not perform real-ear measurements. In a survey, Kirkwood (2006) found that only 57% of hearing aid dispensers owned hearing aid verification equipment, and only 34% of respondents consistently performed real-ear measurements. A more recent study found a similar trend, with approximately 40% of hearing aid dispensers performing real-ear measurements, and approximately half of those who own the equipment use it regularly (Mueller & Picou, 2010). Common reasons provided by dispensers for not performing real-ear measurements include time constraints, cost of real-ear equipment, and lack of physical space for real-ear equipment (Mueller & Picou, 2010).

Those not performing real-ear measurements for hearing aid programming must rely entirely on the hearing aid manufacturer's "first fit" settings for hearing aid programming. Instead of making adjustments using objective data, those using a "first fit" approach rely entirely upon subjective information from the patient to guide adjustments to the hearing aid gain settings. There are many reasons that hearing aid gain settings may not be accurate without the use of real-ear measurements. Such reasons include individual variability in ear canal volume or shape, which can change the resonant characteristics of an individual's ear canal (Durisala, 2015). Another cause of inaccurate settings is low-frequency acoustic leakage, which occurs when an earmold or dome does not fully occlude the patient's ear canal as intended; as a result,

low-frequency sounds leak out of the ear canal resulting in gain values that are below the prescribed target.

An alternative to traditional audiometry for programming hearing aids is in-situ audiometry. In-situ audiometry uses the patient's hearing aid to deliver test stimuli to the patient's auditory system (Kiessling et al., 2015). All other procedures are performed in the same manner as the traditional audiogram, using a down-10, up-5 bracketing (Hughston-Westlake) method. The fitting software uses the measured in-situ thresholds to calculate target gain values for an individual's hearing aid (Kuk, 2012), similar to traditional audiometry.

There are a number of advantages to performing in-situ audiometry in place of traditional audiometry. In-situ audiometry provides ear-specific data that is not seen in functional gain measurements, and does not require the individual to be tested in an audiometric booth (DiGiovanni & Pratt, 2010). Any changes in gain from the hearing aid associated with acoustic leakage, venting, insertion depth, or an individual's ear canal anatomy will be accounted for in the test results, since the stimulus is being delivered directly from the hearing aid itself (Durisala, 2015). These advantages may result in more accurate hearing aid fittings for clinicians who are not performing real-ear measurements. As a result, using in-situ targets for hearing aid programming may result in improved patient satisfaction, fewer follow-up visits, and fewer returned hearing aids (Kochkin et al., 2010). These factors have been observed when clinicians utilize real-ear measurements to verify hearing aid performance, rather than the "first fit" method (Kochkin et al., 2010). If in-situ audiometry results are as accurate, or more accurate than traditional audiometry, they may contribute to the validity of remote hearing evaluations, or development of a self-fitting hearing aids, which may in turn improve access to care for those in rural communities or others who do not have access to a local audiologist (Wong, 2011).

To date, there is limited data concerning the validity of in-situ audiometry for hearing aid fittings. Durisala (2015) compared in-situ and conventional audiometric thresholds between 250 and 6k Hz. Mean thresholds were significantly different only at 2k and 6k Hz. Since the mean differences at these two frequencies were very small (less than 4 dB) and within clinically accepted standards (± 5 dB), the differences were considered to not be meaningful.

Convery et al. (2015) investigated the validity and reliability of in-situ audiometry under two conditions. In one condition, audiometry instructions and presentation of test stimuli were presented and controlled by an audiologist. In the other condition, participants were given written instructions on how to operate an automated audiometry program, allowing them to perform in-situ audiometry without an audiologist. This study found that when the procedure was administered by the audiologist, the results were reliable and valid thresholds were produced; however, when the participants followed directions, reliability and validity were negatively affected (Convery et al., 2015).

Finally, a level four, expert opinion research study by Wong (2011) reviewed existing literature on in-situ audiometry using evidence-based practice. Wong (2011) found through examining quality research, that in-situ audiometry measures are attainable and reliable. While previous studies have demonstrated that in-situ thresholds may be as accurate as traditional booth audiometry, no studies have been performed using contemporary hearing aids, and no studies have been conducted to evaluate the accuracy of hearing aid programming using in-situ thresholds compared to traditional thresholds.

The purpose of the current study was to investigate the accuracy of in-situ audiometry for hearing aid programming compared to conventional booth audiometry. Real-ear measurements were taken to determine how closely target gain settings approximated prescribed National

Acoustics Laboratories (NAL-NL2) targets when manufacturer first fit settings were generated from in-situ audiometric thresholds versus traditional booth thresholds. First fit was selected for the current study because most hearing aid dispensers are not using real-ear measurements in programming hearing aids; instead, they are using manufacturer first fit algorithms for hearing aid programming. As a result, the current study evaluates the most common scenario that may be encountered for hearing aid programming in the current market.

METHODS

Participants

This study was conducted at Appalachian State University (ASU) in the Audiology Clinic in the Leon Levine Hall of Health Sciences. Participants were recruited from an existing population of patients who indicated they were interested in participating in research studies. Patients were invited to participate during their normal appointment consultation.

At the start of their regular clinical appointment, participants were asked if they would like to participate. Those who indicated they would like to participate were informed that their participation would not impact their regular clinical care. Participants were given informed consent paperwork, explaining the purpose of the study, and potential risks. Participants were also informed that they may withdraw from the study at any point in time with no consequences. All methods were approved by the Institutional Review Board (IRB) at ASU.

Eighteen participants with thirty-four ears were selected for the study based on the order of responses received. Participants were assigned a subject identification (ID) number based on the order of their participation. For example, the fifth person who participated, received a subject ID of "5". Participants were not compensated for their participation in the study, but they were

made aware that knowledge obtained from the study may benefit them indirectly by improving hearing aid programming for those with hearing loss, more specifically, when real-ear equipment is not available.

All participants were adults, ages 67 to 89, who previously purchased an Oticon brand Receiver in the Canal (RIC) hearing aid. Participants experienced both traditional booth audiometry and in-situ audiometry in the study. Participant demographic information is provided in Table 1.

Table 1: Participant Demographic Information

Subject # (age)	Diagnosis	Severity of Hearing Loss	Oticon Hearing Aid	Receiver	Dome Size/Type
Subject 1 (67)	Presbycusis	Mild sloping to severe	OPN S3	85 gain	8mm closed double vent
Subject 2 (90)	Presbycusis	Mild Sloping to moderately severe	Ruby 2	85 gain	6mm closed double vent
Subject 3 (75)	Presbycusis	Mild Sloping to moderately severe	More 3	100 gain	8mm closed double vent
Subject 4 (81)	Presbycusis	Moderate flat	More 3	85 gain	6mm closed double vent
Subject 5 (69)	Presbycusis & Noise Induced Hearing loss	Moderate Flat with notch at 4k Hz	OPN s3	85 gain	10mm closed double vent
Subject 6 (78)	Presbycusis	Mild sloping to moderately severe	More 3 (only left side)	85 gain	8mm power
Subject 7 (69)	Right: Vestibular Schwannoma	Moderate reverse cookie bite	More 1	85 gain	6mm closed double vent
Subject 7 (69)	Left: Presbycusis	Mild sloping o moderately severe	More 1	85 gain	6mm closed double vent
Subject 8 (89)	Presbycusis & Noise Induced Hearing loss	Mild sloping to moderately severe	OPN S3	85 gain	8mm closed double vent
Subject 8 (89)	Presbycusis & Noise Induced Hearing loss	Moderate sloping to profound	OPN S3	100 gain	10 mm closed double vent
Subject 9 (70)	Presbycusis	Mild sloping to moderate	OPN 3	85 gain	8mm closed double vent
Subject 10 (85)	Presbycusis	Mild sloping to moderate	OPN 2	85 gain	8mm closed double vent
Subject 11 (73)	presbycusis	Moderate flat hearing loss	OPN S1	85 gain	8mm closed double vent
Subject 12 (70)	Presbycusis & Noise Induced Hearing loss	Mild sloping to moderately severe with notch at 3k Hz.	OPN 3	85 gain	10mm closed double vent
Subject 13 (72)	Right: Presbycusis	Mild sloping to moderate	OPN3	85 gain	8mm closed double vent

Subject 13 (72)	Left: Sudden sensorineural hearing loss	Severe flat	OPN3	100 gain	8mm closed double vent
Subject 14 (70)	Presbycusis	Moderately Severe Flat	OPN S3	85 gain	8mm closed double vent
Subject 15 (81)	Presbycusis	Mild sloping to moderate	More 1	85 gain	6mm closed double vent
Subject 16 (70)	Presbycusis & Noise Induced Hearing loss	Mild sloping to severe with notch at 4k Hz	OPN S1	100 gain	10mm closed double vent
Subject 17 (74)	Presbycusis	Mild sloping to moderate	OPN3	85 gain	8mm closed double vent
Subject 18 (70)	Presbycusis	Mild sloping to moderately severe	OPN S3	85 gain	8mm closed double vent

Materials and Procedures

Traditional booth audiometry was conducted using a Medrx AVANT Stealth audiometer and ER-3A insert transducers. In-situ audiometry was conducted using the participant's personal RIC hearing aid. Both audiometry conditions always occurred prior to real-ear measurement, and test order was counterbalanced across subjects to control for potential training effects. After in-situ and traditional audiometry measurements were completed, booth audiometry results were digitally transferred to an Audioscan Verifit 2 real-ear machine. The participant was then placed in front of the machine and the probe tube was placed into the participant's ear canal. Proper insertion depth was verified by using the Audioscan "Probe Guide" software, which provides confirmation that the probe tube is within 5 mm of the tympanic membrane. The probe was not removed until real-ear measurement for both conditions was completed, ensuring that the probe tube was in the same position for both measurements. The hearing aids were then inserted into the ear canal. The hearing aids, which were wirelessly connected to the programming software, were then set to 100% of the NAL-NL2 prescribed thresholds based upon traditional booth testing. Real-ear measurements were then obtained for 65 decibel sound pressure level (dB SPL) speech stimuli. A stimulus level of 65 dB SPL was selected because it is thought to reflect the

level of conversational speech. Results were then transferred back to the programming computer, and a digital image of the test results was saved to a folder identified only by the participant’s ID number. The hearing aids were then programmed using in-situ thresholds. The same real-ear measurement was taken, and then saved into the subject’s folder. Real ear data was initially stored as an image of a table displaying the prescribed NAL-NL2 targets and the real ear measurements, before being manually entered into a spreadsheet for analysis. An example of saved data saved in an image format for this study is presented in Figure 1 below.

Speechmap/NAL-NL2										
	Max TM SPL									
R	250	500	750	1k	1k5	2k	3k	4k	6k	8k
Entered UCL										
Target1	67	69	69	70	78	86	87	87	79	75
Test 1	56	56	56	55	69	78	81	73	73	50

Figure 1. An example of raw data image captured from the real-ear machine. Target 1 represents the prescribed NAL-NL2 target. Test 1 represents the observed measurement from the participant’s ear canal.

Data was transferred for 8 different frequencies (250, 500, 1k, 2k, 3k, 4k, 6k, and 8k Hz) at 65 dB SLP. This level was selected because it is considered to be representative of conversational speech. These frequencies have been chosen because they are the frequencies tested in conventional audiometry, and they span the full spectrum of speech information.

The total duration of real-ear data collection was approximately 15 minutes for both ears. Both audiometry conditions and real-ear measurements were completed by an Audiologist (Au.D./Ph.D.) with more than 10 years of clinical experience.

RESULTS

This study included a within subjects’ comparison between real-ear measurements obtained under two different conditions. More specifically, we compared how close real-ear

measurements were to first fit targets based upon traditional booth audiometry, and in-situ audiometry.

A box plot graph was created to represent the real-ear measures mean deviation from the NAL-NL2 targets for hearing aids programmed using in-situ audiometry versus traditional audiometry. The results are demonstrated in figure 2 below. This graph depicts how similar real-ear measures for in-situ audiometry are in comparison to traditional audiometry.

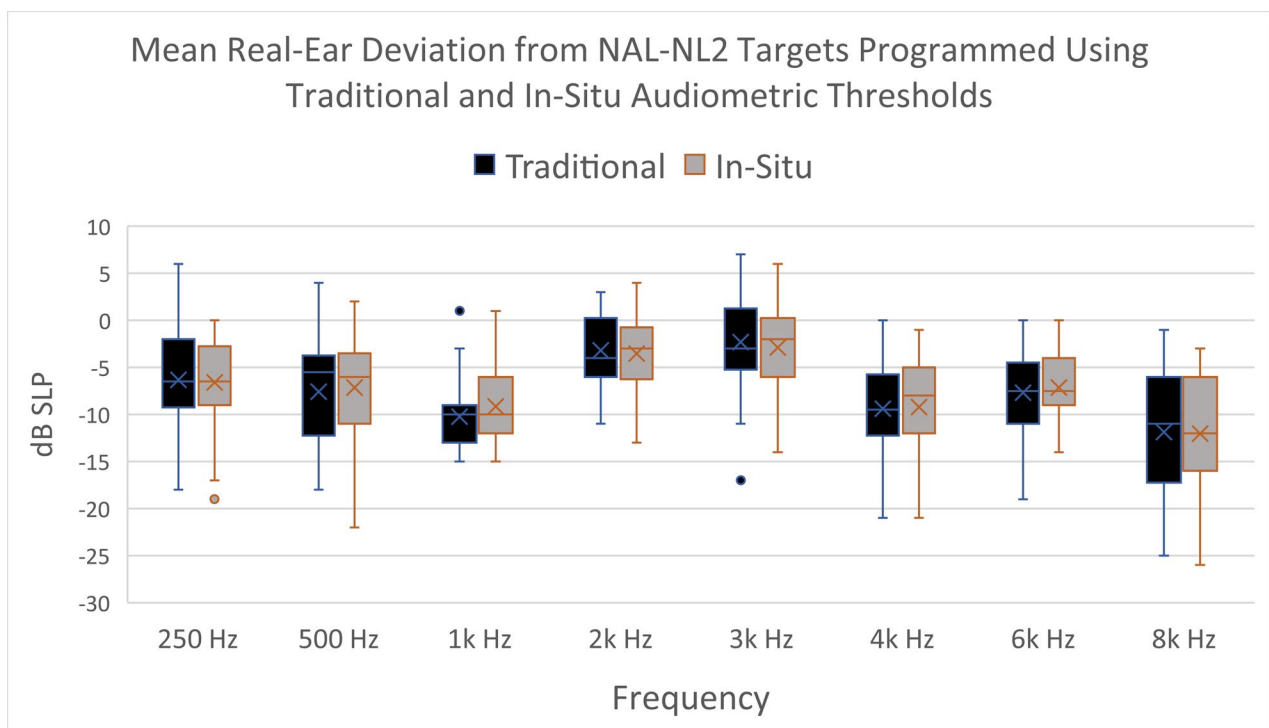


Figure 2. Mean deviation from NAL-NL2 targets observed on real-ear measurements, for settings generated from traditional audiometry (black), and those generated with in-situ audiometry (grey).

A paired sampled t-test was used to examine the mean difference of real-ear measurements for in-situ audiometry and traditional audiometry for each frequency. The results are presented in table 2 below. None of the frequencies demonstrated a significant difference, except for 1k Hz. While mean scores did show a statistically significant difference at 1k Hz, the difference between the two means was only 1.09 dB. This difference is within clinically accepted

standards (-/+ 5 dB); therefore, this finding is not considered to be a clinically meaningful difference. This interpretation is similar to Durisala (2015), who also considered their statistically significant differences that were below 5 decibels to not be clinically relevant differences.

Table 2. Mean deviation, mean difference and *p*-value evaluating the statistical difference between in-situ and traditional real-ear measurements.

Frequency Comparison	Traditional Mean Deviation	In-situ Mean Deviation	Mean Difference	P-value
250 Hz	-6.32 dB	-6.59 dB	0.26 dB	0.48
500 Hz	-7.59 dB	-7.15 dB	-0.44 dB	0.31
1,000 Hz	-10.24 dB	-9.15 dB	-1.09 dB	0.04
2,000 Hz	-3.21 dB	-3.53 dB	0.32 dB	0.55
3,000 Hz	-2.29 dB	-2.88 dB	0.59 dB	0.21
4,000 Hz	-9.38 dB	-9.21 dB	-0.18 dB	0.771
6,000 Hz	-7.68 dB	-7.15 dB	-0.53 dB	0.493
8,000 Hz	-12.12 dB	-12.03 dB	-0.09 dB	0.895

DISCUSSION

The primary goal of this study was to determine the validity of in-situ audiometry compared to traditional booth audiometry for first fit programming of Oticon hearing aids in adults with hearing loss. Real-ear measurements were used to determine the accuracy of hearing aid fitting with in-situ and traditional booth generated NAL-NL2 targets. Our results show that of 8 frequencies analyzed, real-ear measurements were only significantly different at 1k Hz, with

in-situ audiometry resulting in more accurate target gain values. However, the difference was so small (~1 dB), that it did not translate to a clinically meaningful difference.

One important observation across all measurements was that mean real-ear measurements were below the prescribed NAL-NL2 targets. This finding suggests that hearing aids programmed only using manufacturer software, with no real-ear verification, will typically have gain settings that are below NAL-NL2 recommended targets.

One limitation of this study is that only Oticon brand hearing aids were used. As a result, it is unknown if similar findings would be expected for other manufacturers.

CONCLUSION

Results from this study suggests that hearing aids programmed using in-situ audiometry will result in hearing aid gain settings that are comparable to those obtained in a sound booth using an audiometer. While the gold standard for hearing aid programming should still be considered to utilize real-ear measurements, most hearing aid dispensers are not utilizing real-ear measurements (Valente, 2002). Given these findings, a hearing evaluation performed remotely, through in-situ audiometry in a quiet environment, may be considered a valid form of telehealth in the future. Especially for those who are physically unable to attend hearing evaluations in person. Such populations may include those in remote regions of the world, or those who are in skilled care facilities.

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