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Original Article

Comparison of Performance with Hearing Aid programmed to First-Fit and Optimized Fit

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BACKGROUND: The study aimed to evaluate the impact of manufacturer first-fit (FF) vs. optimized-fit (OF) hearing aid conditions on the real-ear aided response (REAR), aided thresholds, speech identification scores (SIS) in quiet, and signal-to-noise ratio at 50% speech intelligibility (SNR-50) among adults with bilateral sensorineural hearing loss.

METHODS: Participants included 15 adults aged 29-49 years with no prior hearing aid experience. The study utilized a 16-channel non-linear digital behind-the-ear hearing aid, programmed to FF and optimized NAL-NL2 targets.

RESULTS: Significantly lower REAR and aided thresholds were observed in the FF condition across frequencies, particularly for soft and moderate input levels. The OF condition showed superior SIS in quiet and SNR-50, indicating improved speech recognition in quiet and noisy conditions.

CONCLUSION: Findings emphasize the need to use RE measures for hearing aid verification to achieve better auditory outcomes and enhance user satisfaction. This strengthens evidence-based practices in audiology for optimizing hearing aid performance and the quality of life of individuals with hearing loss.

KEYWORDS: First fit, optimized fit, real ear aided response, real ear measurement, speech identification score

INTRODUCTION

Real-ear measures (REM) are employed by hearing health specialists to assess and optimize the amplification delivered by hearing aids.[1] In this process, the hearing thresholds of the patient combined with a specific prescriptive approach generate a real ear prescriptive target. This target determines the required gain or output from the hearing aids, ensuring suitable audibility for the individual with hearing loss.

Audiology best practice guidelines recommend using probe microphone measurements to verify that hearing aid gain and output are accurately adjusted to meet the prescribed targets for each individual. Real-ear measures is considered "gold standard" for verifying amplification devices.[2] Measured real-ear insertion gain (REIG) should be between ±5 dB of the target up to 2000 Hz and between ±8 dB for frequencies between 3000 Hz and 8000 Hz, according to the British Society of Audiology.[3] Many hearing health professionals rely only on the first-fit (FF) provided by the manufacturer, and between 70% and 80% of hearing aids that are dispensed are not regularly evaluated and configured utilizing REM.[4,5]

In a study by Sanders et al,[6] the gain and output of a prescriptive formula using FF were compared with a customized programmed fit. Five premium mini Receiver in canal (RIC) hearing aids were fitted on 8 participants with sloping hearing loss. The programmed fit was verified utilizing real-ear aided response (REAR) for input levels of 55, 65, and 75 dB SPL based on the NAL-NL2 fitting formula. The results showed that at 55 dB SPL, the FF was below the target, especially in high frequencies, in 74% of cases. At 65 dB SPL, 55% of cases showed at least 1 frequency between 250 and 4000 Hz being 10 dB or more below the target, with levels 7-dB under the target above 2000 Hz. However, at 75 dB SPL, the FF matched or exceeded the target, especially for mid frequencies.[6] Similar results were found by Aarts and Caffee[7] and Swan and Gatehouse.[8]

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Narayanan and Manjula[9] compared the REAR, REIG, articulation index (AI), aided thresholds, and SIS in quiet, between 2 hearing aid programming methods, i.e., manufacturer NAL-NL1 FF and NAL-NL1 optimized-fit (OF) through REM. Eleven participants with bilateral moderate to moderately-severe sensorineural hearing loss, with a mean age of 41.09 years (standard deviation ± 9.95) were included in the study. The results revealed that NAL-NL1 OF provided significantly better outcomes in terms of REAR, REIG, AI, aided thresholds, and SIS in quiet compared to the FF.[9]

These studies highlight that FF often deviates from the prescriptive target, especially for soft signals. This suggests that patients may not achieve the necessary audibility for recognizing soft or possibly even average speech with an FF. To assess the implications of the reduced output and gain from the hearing aid, additional evidence is needed in the measurements of speech recognition, especially in challenging listening environments like noise. Hence, the present study aims to address the question of how the aided thresholds and speech identification in both quiet and noisy environments compare between individuals fitted with hearing aids using the FF and those fitted with the OF. Thus, REAR, aided thresholds, speech identification scores (SIS) in quiet, and signal-to-noise ratio at 50% speech intelligibility (SNR-50) were compared between the FF and the OF. Research to compare these measures across soft, moderate, and loud sounds is required for a complete understanding of hearing aid performance.

METHODS

Participants

Participants included adults in the range from 29 to 49 years, with bilateral sensorineural hearing loss ranging from mild to severe from 500 to 4000 Hz. The unaided SIS was more than 60% in the test ear. Participants had no previous experience with hearing aids. Those with a history of middle ear infections (such as otitis media), hyperacusis, loudness discomfort levels below 85 dB HL, previous ear surgeries were excluded. In symmetrical hearing loss, testing was conducted in the right ear, whereas in asymmetrical hearing loss, the better ear was used to test. A total number of 15 ears from 15 participants was tested. This sample size was found to be adequate in the G*Power analysis using *t*-family of tests set to 0.80 power at an error rate of 5% for detecting the mean difference in aided threshold, SIS, and SNR-50 between hearing aid fittings. Participants provided informed consent before being included in the study. Experimental procedures followed the ethical guidelines of bio-behavioral research prescribed by the institute where the research was carried out.[10] Informed consent was obtained from the patients before starting the procedure. This study was approved by the Ethics Committee of All India Institute of Speech and Hearing on 21 December 2020 with approval number EF-173/2018-19.

MAIN POINTS

- **Significant Improvement with Optimized Fit:** The optimized-fit consistently gave higher REAR across all frequencies compared to the first-fit, especially at lower frequencies and for soft and moderate input levels.
- **First-Fit Shows Compromised Gain:** The first-fit produced significantly lower gain at key frequencies (250, 500, 2000, and 4000 Hz) for input levels of 50 and 65 dBSPL, highlighting the need for optimization in hearing aid fitting.
- **Aided Thresholds and Speech Scores Improve with Optimized Fit:** Participants demonstrated significantly lower aided thresholds and better Speech Identification Scores (SIS) in quiet conditions and improved SNR-50 with the optimized-fit compared to the first-fit.
- **Limited Difference at Higher Frequencies:** The difference in gain between first-fit and optimized-fit at 8 kHz was not significant, likely due to the hearing aid's frequency response limitations.
- **Critical Impact of Fit on Hearing Aid Performance:** The study emphasizes the importance of optimized hearing aid fitting to achieve better hearing outcomes, particularly for speech perception and gain at critical frequencies.

Procedure

Otoscopy was performed on 15 young adults to rule out any contraindications for hearing aid testing. A 16-channel non-linear digital BTE hearing aid, with a fitting range from mild to severe hearing loss, was utilized during the testing. The test ear was fitted with the hearing aid using an appropriate eartip. A laptop equipped with the NOAH database and software specific to the model of the hearing aid facilitated the programming of the hearing aid, with HiPro 2 serving as an interface between the hearing aid and computer. Participants' information and audiological data were input into the NOAH database. The hearing aid was initially programmed for a FF based on the NAL-NL2 formula, with its settings adjusted to align with the NAL-NL2 FF prescription. The acclimatization option was disabled. The ear tips were used here, with #13 tubing and no venting. To prevent the influence of factors like noise reduction and directional microphone, these features were disabled through software during data collection. Subsequently, probe-microphone measures, such as REAR for this FF setting, were conducted.

During all real-ear testing, the participants were instructed to sit comfortably, positioned 1 meter away from the sound field speaker. The REM was conducted using the calibrated Aurical Freefit probe microphone measurement system. The probe tube positioning was achieved through a visually assisted method, with a mark placed 30 mm from the tube tip. When inserted into the external auditory meatus, the mark was aligned with the intertragal notch, ensuring that the tube tip remained 5-6 mm from the tympanic membrane. Further, after insertion of the probe tube, the frequency response curve was observed for any peaks in the high-frequency region. The absence of such peaks indicated optimal probe tube placement.

The REM system was leveled/calibrated before placing the probe tube, for controlled input across frequencies to the hearing aid. Subsequently, the REAR was measured at 50 (soft), 65 (moderate), and 80 dB SPL (loud) using the International speech test signal (ISTS) as the stimulus. The ear tip of the hearing aid was carefully inserted into the external auditory meatus, ensuring that the position of the probe tube remained undisturbed. Real ear measurements were performed using the NAL-NL2 FF program, which was saved as "Program 1" in the hearing aid.

A second program, "Program 2," identical to "Program 1," was established within the same hearing aid. During verification, "Program 2" underwent additional adjustments to align with NAL-NL2 targets.

Frequency-gain modifications were executed until REAR closely approximated the NAL-NL2 target at 50, 65, and 80 dB SPL input levels.

The REAR values were recorded in octave bands from 250 to 8000 Hz for "Program 2," representing the OF to NAL-NL2 targets. Programs 1 & 2, denoted as aided 1 and aided 2 conditions, respectively, were utilized for data collection on aided thresholds, SIS in quiet, and SNR-50. The order of testing in aided 1 and aided 2 was counterbalanced among participants to mitigate order effects. The REAR, in 2 aided conditions at octave frequencies for each participant, was tabulated.

A calibrated diagnostic audiometer was employed to evaluate aided performance in a sound-field environment, with a loudspeaker situated one1 meter from the participant at a 0-degree azimuth. The aided thresholds were recorded for both the FF (aided 1) and OF (aided 2) across octave frequencies ranging from 250 Hz to 8000 Hz, using frequency-modulated tones for each individual. This measure was used to evaluate the hearing performance of the individuals with hearing aids fitted using FF and OF methods, ensuring adequate amplification across various frequencies. The SIS in quiet for 2 aided conditions were assessed using a phonemically balanced (PB) Kannada word identification test for adults.[11] The word lists were presented at 45 dB HL, ensuring random presentation across participants and test conditions. This presentation level was chosen since it is the average conversation level. Scoring involved assigning 1 point for each correct word identified and 0 for incorrect responses, with a maximum SIS of 25 (as each PB word list consisted of 25 words). This was done for each participant. The goal of this testing was to assess the speech identification performance of the individual, at a normal conversational level, in quiet. This focus reflects the greater importance of real-world listening situations in daily life.

Another real-world listening scenario is listening to and understanding speech in noisy environments. Thus, the SNR-50 was measured to provide insights into individual performances in such situations in the 2 aided conditions. All stimuli were presented through loudspeakers using a calibrated audiometer. The presentation level of the words was maintained at 45 dB HL. The initial presentation level of the speech-shaped noise was 10 dB lower than the speech level. The test material contained a recorded PB word list[12] and the level of speech noise was varied in 2 dB steps from +10 to −10 dB SNR while maintaining a constant speech level. Each correct response was awarded a score of "1", and the total number of correctly identified words was tabulated for each participant. Before the main experiment, the participant underwent practice trials with varying SNRs, ranging from easy to difficult. These practice words were distinct from those used in the main experiment. The SNR-50 calculation employed the Spearman–Karber equation as described by Finney.[13]

$$\text{SNR-50} = i + 1/2(d) - (d)(\#correct)/(W)$$

where "i" represents initial presentation level (+10), "d" is the decrement in step size (2), "W" is keywords per decrement (4), and "#correct" is the total number of correct words repeated. This was tabulated for each participant.

RESULTS

The data from FF and OF were statistically analyzed using SPSS (version 20). Descriptive statistics were performed to determine the mean and standard deviation. The Shapiro–Wilk test for normality showed that the data were distributed normally; therefore, a paired sample *t*-test was utilized to compare the REAR between the FF and the OF.

Comparison of Real-Ear Aided Response Between First-Fit and Optimized-Fit

Descriptive statistics showed that the mean REAR with FF was consistently lower across frequencies compared to OF, which aligned with NAL-NL2 targets for all 3 input levels.

The paired *t*-test results indicated a significant ($P < .05$) reduction in REAR for the FF compared to the OF for soft and moderate input levels across frequencies, except at 8000 Hz and 2000 Hz for the moderate input level, and at 8000 Hz for the soft input level. Although the FF showed a lower gain at 8000 Hz compared to the OF, this difference was not significant. This is because of the frequency response of the hearing aid, which is from 125 to 8000 Hz. At loud input levels, significantly less gain for FF was seen only at 250 Hz and 4000 Hz. The gain was less for FF than OF at other frequencies, though not significantly different, as seen in Figure 1.

Comparison of Aided Threshold, Speech Identification Scores, and Signal-to-Noise Ratio at 50% Speech Intelligibility Between First-Fit and Optimized-Fit

Figure 2 shows the mean and standard deviation values of aided thresholds using OF and FF across frequencies. The paired *t*-test revealed a significant ($P < .05$) difference in aided thresholds between FF and OF, with FF exhibiting higher mean aided thresholds across frequencies from 250 to 4000 Hz. Figures 3 and 4 compare FF and OF conditions in SIS in quiet, and SNR-50, respectively. Significantly better scores were obtained for SIS ($P = .012$) and SNR-50 ($P = .007$) in the OF condition compared to the FF condition.

DISCUSSION

The objective of the current study was to compare the REAR, aided threshold, SIS in quiet, and SNR-50 between 2 aided conditions: the FF of NAL-NL2 and the OF. Notably, significant differences were observed in REAR, aided thresholds, SIS, and SNR-50 emphasizing the impact of real ear verification on hearing aid performance. The discrepancies were particularly noticeable in high-frequency ranges, highlighting the importance of optimizing the hearing aid fitting process for improved outcomes.

Previous research has consistently demonstrated that the output from the initial fitting falls significantly below standard prescriptive targets, whether measured through a 2 cc coupler or a probe-microphone.[14] It is to be noted that these earlier studies compared electroacoustic or real ear measures to the target; however, audiological measures were not considered. The variation in individual ear canal acoustic characteristics is a key factor contributing to the decreased gain with the FF. In addition, while programming a hearing aid, the programming is done as if it is in an ear simulator or coupler (whichever is chosen). This notable reduction in gain, particularly in the high-frequency range, has a disadvantage in terms of audibility, speech recognition in quiet and noise, and patient satisfaction.[6,8,9,7,15]

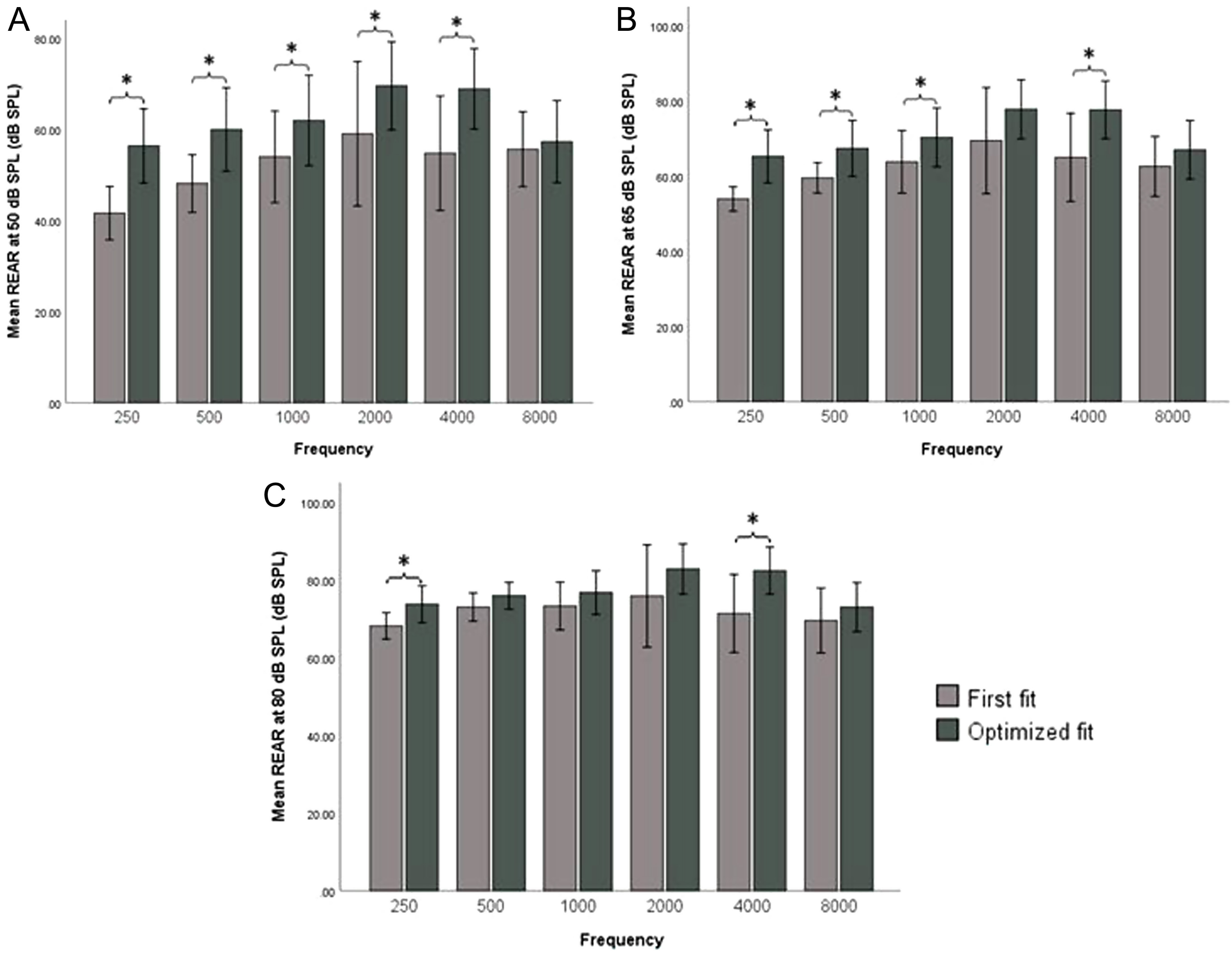

Figure 1. (A) Input level of 50 dB SPL, (B) input level of 65 dB SPL, and (C) input level of 80 dB SPL. Mean and standard deviation (n = 15) of the REAR (in dB SPL) using first-fit and optimized-fit at different frequencies (in Hz) at different input levels: * indicates a significant difference at $P < .05$.

The results in the present study showed that the FF setting exhibited reduced gain across all frequencies, except 8000 Hz, at a soft input level of 50 dB SPL. Consequently, individuals with hearing impairment, fitted using FF, would report difficulty in hearing soft sounds. This can be attributed to poorer aided thresholds in the FF compared to the OF. However, aided thresholds are not an appropriate measure for non-linear fitting,[16,17] especially at higher input levels. Nonetheless, this test measure was included in the study because it provides information about the perception of soft sounds, which is also important.

In the current study, the OF provided significantly better performance at the conversation level in quiet listening situations. This is in consonance with results reported by Valente et al[18] and Narayanan and Manjula.[9] They reported significant improvements in monosyllabic word and phoneme recognition with the programmed fit compared to the FF, particularly at 50 dB SPL. However, no significant differences were reported in subjective outcome measures, i.e., Abbreviated Profile of Hearing Aid Benefit (APHAB) andThe Speech, Spatial and Qualities of Hearing Scale (SSQ).[2]

The results showed a significant difference in SNR-50 between the FF and the OF. This indicates that speech understanding in noise was better when individuals were fitted using OF, which was on par with the results from Leavitt and Flexer,[15] who reported a mean improvement of 6.6 dB SNR loss using the QuickSIN test for the OF. However, Valente et al[18] reported no significant differences in sentence recognition in noise, except for a slight advantage in speech perception in the presence of background noise with the programmed fit.

At all input levels, the FF showed reduced gain, particularly in the high-frequency range. The FF was programmed according to the NAL-NL2 fitting formula, which uses the average 2 cc coupler-based measurement. The absolute output SPL measured in the 2 cc coupler is comparatively less than the output SPL from the REM. This is attributed to the volume of the 2 cc coupler being more than the volume found in the typical ear canal.[19] In addition, the impedance of a 2 cc coupler does not accurately reflect that of the average human ear.

Given the established significance of high frequencies in speech recognition due to their role in conveying consonants, the OF offered

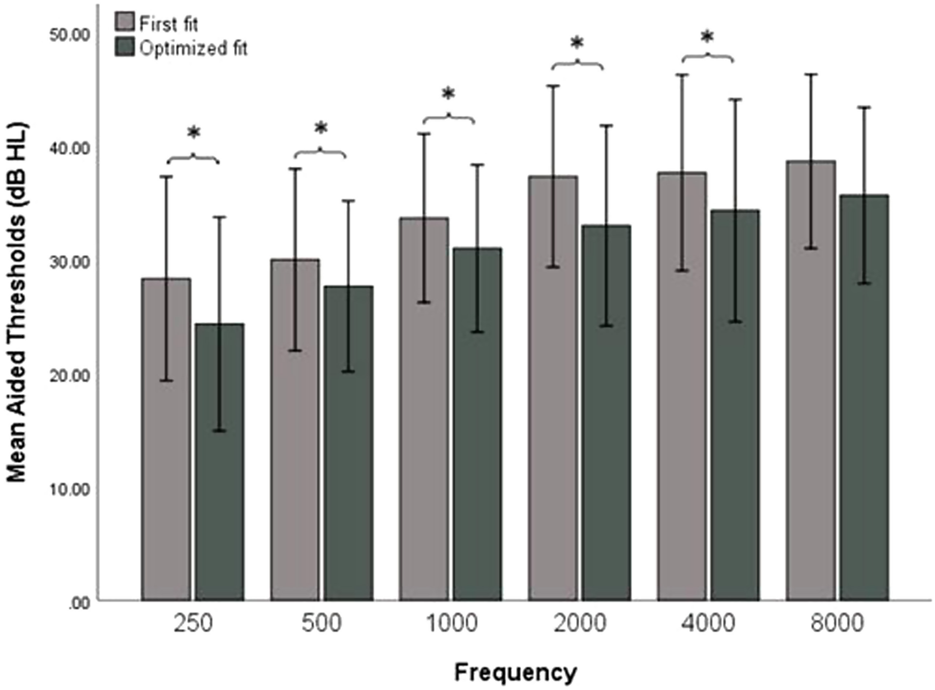

Figure 2. Mean and standard deviation (n = 15) of the aided thresholds (in dB HL) using optimized fit and the first fit at different frequencies (in Hz). * Represents a significant difference at $P < .05$.

enhanced audibility of consonants compared to the limitations associated with the FF. Inadequate amplification of soft sounds in hearing aids equipped with automatic volume control can lead to users receiving under-amplified speech, hindering proper auditory perception.[20] Thus, the study advocates for the routine use of REM to align hearing aid settings with prescribed targets, encouraging clinicians to go beyond the initial fit and utilize the OF method for better speech identification and overall hearing aid performance.

CONCLUSION

The results reinforce the recommendations for audiologists by prioritizing evidence-based best practices. In particular, they advocate for the use of REM to verify hearing aid fittings instead of relying solely on predictions from manufacturer software. This, in turn, will definitely bring about better performance. The inaccurate predictions by the programming software may contribute to the reduced satisfaction rates reported by hearing aid users. As one of the best practices in clinical setups, utilizing REM for optimizing hearing aid fittings will improve the performance with hearing aids and, thus, satisfaction and quality of life.

1. The study emphasizes the importance of optimized hearing aid fitting to achieve better hearing outcomes, particularly for speech perception and gain at critical frequencies.
2. The FF provided significantly lower gain at all the frequencies amplified by the hearing aid for input levels of 50 and 65 dB SPL, highlighting the need for optimization in hearing aid fitting. However, the difference in gain between FF and OF at 8000 Hz was not significant, likely due to the hearing aid's frequency response limitations.

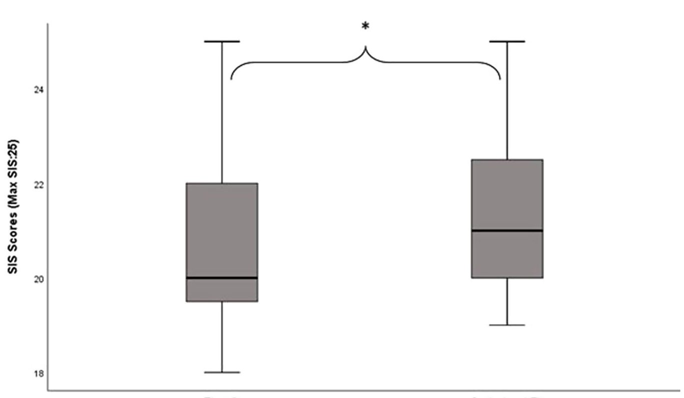

Figure 3. Box plot showing the SIS (mean and standard deviation) at optimized fit and first fit conditions (n = 15). *Represents a significant difference at $P < .05$. Greater SIS scores indicate better performance.

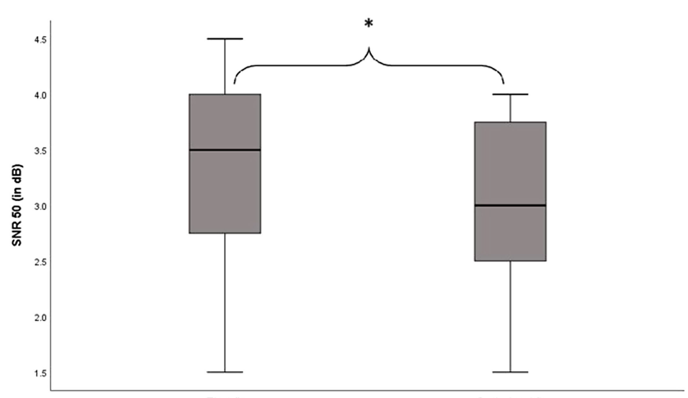

Figure 4. Box plot showing the SNR-50 (mean and standard deviation) at optimized fit and first fit conditions (n = 15). *Represents a significant difference at $P < .05$. Lesser SNR-50 values indicate better performance. Learner outcome: as a result of this activity, the readers will be able to appreciate the importance of optimized fit compared to first fit and its impact on audiological measures of performance.

3. Participants demonstrated significantly lower aided thresholds and better SIS in quiet conditions and improved SNR-50 with the OF compared to the FF.

Availability of Data and Materials: The data that support the findings of this study are available from the corresponding author upon reasonable request. Due to privacy and ethical considerations, certain restrictions may apply to the availability of data.

Ethics Committee Approval : This study was approved by the Ethics Committee of All India Institute of Speech and Hearing (approval no: WF-173/2018-19; date: December 21, 2020).

Informed Consent: Verbal informed consent was obtained from the patients who agreed to take part in the study.

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Declaration of Interests: The authors have no conflicts of interest to declare.

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