Original Article

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Speech perception evaluation in hearing aid users after fine tuning with speech mapping in Brazilian Portuguese

Avaliação da percepção de fala em usuários de próteses auditivas após ajuste fino via mapeamento de fala com estímulo em Português

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ABSTRACT

Purpose: To evaluate the speech perception of adult hearing aid users pre and post fine tuning based on Speech Mapping in Brazilian Portuguese (SMBP). **Methods:** Twenty adults aged 18 to 60 years old presenting moderate to severe bilateral symmetrical sensorineural hearing loss and wearing digital hearing aids programmed according to the prescriptive formula National Acoustics Labs, Non-Linear, version 1 (NAL- NL1) for at least six months participated in this study. The test Lists of Sentences in Portuguese (LSP) has been used to evaluate speech perception. The test was applied in two different moments: T1 - before hearing aid fine tuning based on the SMBP and T2 – after fine tuning based on SMBP. The LSP test allowed the Sentence Recognition in Silence (SRTS) and in Noise (SRTN) Threshold calculation and the minimal signal to noise ratio (SNR) required to understand the sentences. **Results:** There was significant improvement of SRTS and SRTN in moment T2, or after hearing aid fine-tuning, to reach the prescribed targets. In both tests decreased values could be observed; the average SRTS fell from 39.60 dB to 34.41 dB and the signal to noise ratio (SNR) fell from 5.82 dB to 3.34 dB. **Conclusion:** It was possible to establish a clear link between achieving the prescribed targets and the improvement in speech perception. Hearing aid users performed better on speech perception tests after adjustments of the electroacoustic characteristics of their hearing aids based on the Speech Mapping procedure.

Keywords: Hearing aids; Hearing loss; Protocols; Evaluation; Hearing

RESUMO

Objetivo: Avaliar a percepção de fala de adultos usuários de próteses auditivas, antes e depois do ajuste fino realizado com base nos resultados obtidos no Mapeamento de Fala com Estímulo em Português (MFP). **Métodos:** Participaram desta pesquisa 20 adultos, com idades entre 18 e 60 anos, com perda auditiva neurossensorial bilateral simétrica de grau moderado a severo, usuários de próteses auditivas digitais, com no mínimo, seis meses de experiência e programadas de acordo com a regra prescritiva *National Acoustics Labs, Non-Linear, version 1* (NAL-NL1). Para avaliação da percepção de fala, foi aplicado o Teste Listas de Sentenças em Português (LSP) em dois momentos distintos: T1, antes do ajuste fino realizado com base no MFPe T2, após ajuste fino realizado com base no MFP. O teste Lista de Sentenças em Português (LSP) possibilitou a pesquisa do Limiar de Reconhecimento de Sentenças no Silêncio (LRSS) e do Limiar de Reconhecimento de Sentenças no Ruído (LRSR), bem como a Relação Sinal/Ruído (S/R) necessária para compreensão das sentenças do teste. **Resultados:** Verificou-se melhora significativa dos LRSS e LRSR no momento T2, ou seja, após o ajuste fino para alcance dos alvos prescritos. Em ambas as medidas, houve redução dos valores: o LRSS médio caiu de 39,60 dB para 34,41 dB e a relação sinal/ruído, de 5,82 dB para 3,34 dB. **Conclusão:** Foi possível estabelecer uma relação nítida entre o alcance dos alvos prescritos e a melhora na percepção de fala. Usuários de próteses auditivas apresentaram melhor desempenho em testes verbais após o ajuste das características eletroacústicas de suas próteses auditivas, por meio do procedimento de mapeamento de fala.

Descritores: Auxiliares de audição; Perda auditiva; Protocolos; Avaliação; Audição

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INTRODUCTION

Hearing aids are the primary means of rehabilitation for the deaf when there is no medical or surgical treatment possible. The main purpose for hearing aid prescription is to correct or mitigate the hearing loss sensitivity, ensuring the audibility for soft signals and comfort for moderate to strong sounds as well as to reduce or eliminate the limitations caused by hearing loss and restore or expand personal social involvement(1).

Since the main goal of amplification is to guarantee that all the characteristics of speech are audible for average level conversation, verification procedures that provide this type of information should be prioritized(2).

The real-ear measurement is the most effective method to verify if the targets provided by prescriptive formulas have been achieved. It is recommended that the test is conducted in at least three different input levels, corresponding to soft, average and loud sounds, so that all speech sounds may be audible and comfortable to the patient(3).

As the main focus of amplification is to amplify speech, a speech signal, or an acoustic signal that has a spectrum similar to speech is recommended for the electroacoustic evaluation of hearing aids(4,5). There are several signals commonly used in verification systems that can provide precise speech amplification analysis. The most used ones are the ICRA signal, developed by the International Collegium of Rehabilitative Audiology (ICRA - ICRA Noises)(6), the International Speech Test Signal (ISTS) and signals in English(7).

Recently, a speech test signal has been developed in Brazilian Portuguese, allowing electroacoustic evaluation to be made with a speech signal in that language(2). This measurement is called Speech Mapping in Brazilian Portuguese (SMBP) and measures whether the hearing aid is providing ample speech amplification across frequencies(8).

Speech mapping can also be used as a counseling tool to the hearing aid user, as it allows better understanding of the amplification benefits, precise adjustments and greater patient involvement in the process of hearing aid fitting, as well as knowledge about the possible limitations of the prescribed amplification(9). It is also a verification method of easy and fast application(10).

The use of objective procedures for hearing aid verification is of extreme importance to ensure that all speech sounds are audible and comfortable across the frequencies of the patient's reduced dynamic range.

However, this is only the first step, once this analysis does not provide references on how that person is perceiving or interpreting the acoustic information, or how he/she will listen and respond to the sounds. Hence, the importance of using speech perception tests to validate the benefits of amplification that will help to characterize the speech perception obtained by the hearing aid user(2).

In Brazil, the Lists of Sentences in Portuguese (LSP) developed by Costa (1998) has been used in different populations to access the ability of individuals to recognize speech in quiet an noisy environments(11,12,13). Sentence in noise tests are considered essential tools in audiological evaluation and are used to access the hearing capabilities in conditions that are close to everyday listening(14). They provide a direct measuring of an individual to participate in a conversation, showing the hearing amplification benefits(15).

The hypothesis that justified this study was that the hearing aid electroacoustic verification with a speech signal - Speech Mapping – would bring important contribution to the audibility of all speech sounds and consequently an improvement in communication. The goal of this study was to verify the performance of adult hearing aid users in speech perception tests with and without competitive noise pre and post fine tuning based on Speech Mapping in Portuguese.

METHODS

This project was approved by the *Universidade Federal de São Paulo* Ethics Committee - file number 706.839. Previously to this study, all participants read and signed the consent form.

Participants

The test protocol was administered to 20 participants, 12 female (60%) and eight male (40%) between the age of 18 and 60 years (mean age 50.4 years). All participants had bilateral moderate to severe sensorineural hearing loss (averaged from 500 Hz, 1000 Hz, 2000 Hz and 4000 Hz) with symmetry between ears. All participants were experienced users of bilateral hearing aids; regular use for at least six months of binaural fitting with digital BTE or custom Phonak® or Oticon® basic level of technology (type A) or intermediate level of technology (type B) hearing aids available for dispensing by the Brazilian governmental hearing health program(16,17). The hearing aids were programmed according to the National Acoustics Labs, Non-Linear, version 1 NAL-NL1 prescriptive formula. The procedures used to prescribe the hearing aids' electroacoustic characteristics followed the Brazilian governmental hearing health program protocol(16,17).

Sample characterization

From the study sample 85 % (17) presented bilateral moderate sensorineural hearing loss; 10% (2) had bilateral severe sensorineural hearing loss and only 5 % (1) presented bilateral moderately-severe sensorineural hearing loss. The sloping configuration was the most prevalent, presented in 65% (13) of the cases followed by flat configuration presented in 35 % (7) of the patients.

Procedures

The study protocol consisted of the application of the test List of Sentences in Portuguese (LSP)[11] in all participants pre and post fine tuning of their hearing aids based on electroacoustic verification - Speech Mapping with the Brazilian Portuguese[2] signal. The LSP test was developed by Costa (1997) to evaluate the ability to recognize speech in silence and in background noise.

LSP Test

The LSP was applied in two different moments: T1: before probe-microphone speech mapping with the Brazilian Portuguese speech signal, with their personal hearing aids adjusted to their use-gain settings and T2: two months after probe-microphone speech mapping measures, that were used to verify and adjust the hearing aid's output based on the Audioscan Verifit derived NAL-NL1 earcanal SPL prescriptive targets using the Brazilian Portuguese input signal. Prescriptive targets were verified and recorded for three inputs: 55, 65 and 75 dB SPL.

The LSP test was conducted in a soundproof booth via an Interacoustics® AC33a two-channel digital audiometer and an amplification system for free field audiometry. The LSP test was presented via a compact disc (CD) connected to the audiometer.

The LSP test consists of eight lists (1A, 1B, 2B, 3B, 4B, 5B, 6B and 7B) of phonetically balanced sentences in Brazilian Portuguese and a speech spectrum noise. It was applied in free field, with participants making use of their hearing aids in order to obtain the Sentences Recognition Threshold in Silence (SRTS) and the sentences recognition threshold in noise (SRTN), expressed by the signal to noise ratio (SNR) in T1 and T2.

Patients were seated one meter from the speaker in 0º azimuth, and instructed to repeat the test sentences at first in silence (SRTS) and then in noise (SRTN). The level of noise used for the test was 65 dB SPL.

The strategy used to get the SRTS and SRTN was the sequential or adaptive[18], that allowed measuring the necessary level for individuals to correctly identify approximately 50% of the sentences presented at a given SNR. According to this strategy, when individuals were able to correctly recognize the sentences, the intensity presentation was decreased. On the contrary, when individuals were unable to correctly recognize the sentences, the intensity presentation was increased. To be considered correct the whole sentence should be repeated without any errors or omissions.

The lists used were 1B, 2B, 3B, 4B, 5B and 6B presented randomly to avoid biased results. Presentation levels of each sentence were noted during the evaluation.

The averaged presentation level was calculated based on the presentation level on which was noted the first response variation and the presentation level of the last list sentence. To calculate the SNR, obtained by SRTN, the SRTN level was subtracted from the presented noise level, 65 dB NPS. Therefore, it is characterized that the SNR is the difference in dB between the SRTN level and the competitive noise used for the test.

Note that the SRTS and SRTN were retrieved in two moments (T1 and T2) with all the participants wearing their hearing aids, once the aim of this study was to determine if there was any improvement in speech perception depending on the fitting of their hearing aids (pre and post speech mapping). For this reason, the values obtained here were not correlated with Word Recognition Score test (WRS), that is measured with supra-aural or insert phones without hearing aids and have no correlation with SRTS or SRTN.

Electroacoustic verification - Speech mapping in Brazilian Portuguese

Speech mapping was performed using the speech test signal in Brazilian Portuguese[2] via Audioscan - Verifit® verification system. Before the measurement, calibration was done by placing the probe tube to the end of the reference microphone positioned at a distance of 20 cm from the speaker. The test was performed in a quiet room with the participants seated 50 cm from the speaker at 0 ° azimuth They were instructed to sit as still as possible during the test.

To perform speech mapping, the record of the hearing thresholds of the patient is necessary (dB HL), which are automatically converted to sound pressure levels (dB SPL) by the electroacoustic verification equipment. Information about the prescriptive formula used for hearing aid fitting and the type of hearing aid (BTE or custom) were also inserted in the equipment for correct calculation of output levels and discomfort levels in SPL.

The hearing aid was then turned on and placed into the patient's ear canal together with the probe microphone to record the SPL in the ear canal after amplification of the speech signal. Prescriptive targets were verified and recorded for three inputs: 55 dB SPL - soft sounds, 65 dB SPL - average and 75 dB SPL - loud sounds. The measurement was done from 250 Hz to 6000 Hz.

The maximum output level (MPO) was also measured for a pure tone sweep at 85 dB SPL. When necessary the hearing aid output was adjusted not to exceed the limits of comfort calculated by the prescriptive formula.

The hearing aids were then fine-tuned to better reach the NAL - NL1 prescriptive formula targets with the manufacturer's software. Two months after this adjustment, corresponding to the T2 moment of this study, participants repeated the LSP test to provide their SRTS and SRTN.

Statistical methods

Nonparametric Wilcoxon test was used to data analysis with significance level of 0,05 (5%).

RESULTS

Speech mapping

For target matching comparison, the frequency response difference pre and post speech mapping were calculated. Negative values indicate that the hearing aid was set below the prescribed targets and equal or positive values indicate that the hearing aid is at or above the prescribed target for each frequency.

It was observed that for soft input levels (55 dBSPL), the mean difference from the prescribed targets and the response after probe-microphone speech mapping adjustment was very little, except for the frequency of 250 Hz (p=0.899), where the difference was not significant (Figure 1) .

For 65 dBSPL input level, the mean difference between the prescribed targets and the response after speech mapping adjustment was smaller with a significant difference (p<0.001) from 500 Hz to 6000 Hz and a trend towards significance (p=0.083) at 250 Hz (Figure 2).

For 75 dBSPL input level the mean difference between the prescribed targets and the response after speech mapping adjustment was also lower with significant difference (p<0.001). In other words, the output levels of the tested hearing aids better approached the prescribed targets in T2 (Figure 3).

It has been demonstrated that for all input levels there was a significant difference in target matching (p<0.001) between T1 and T2.

Speech perception

There was a significant improvement in SRTS and SRTN at T2 moment after probe-microphone speech mapping adjustment. For both tests there was a reduction in the presentation levels in T2. The average SRTS fell from 39.60 dB to 34.41 dB (p<0.001) and the SNR from 5.82 dB to 3.34 dB (p=0.010) (Figures 4 and 5).

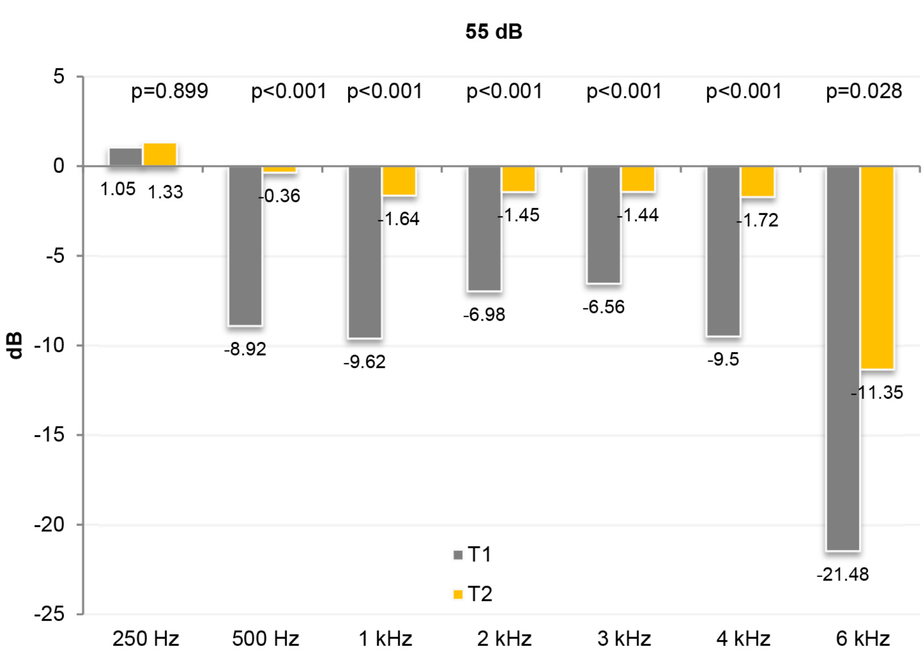
DISCUSSION

In clinical practice, currently validated prescriptive fitting approaches often are not used or verified when fitting hearing aids for adults. It has become popular to audiologists to deviate from validated methods and use manufacturers' proprietary algorithms[19]. In Brazil, a survey of 72 dispensing audiologists showed that only nine (12.5%) of these professionals use probe microphone verification in their practice[20].

One study evaluated 31 bimodal users (hearing aids and cochlear implants), in which hearing aids were programed according to NAL-NL1 prescriptive formula through their hearing aid's programing software without REM verification. After probe-tube speech mapping verification 25 (81%) of these subjects had their hearing aids outside targets. After adjustment and reassessment, 19 participants (61%) achieved the NAL-NL1 targets[21].

The prescriptive gain displayed in the manufacturer's software may be quite different in real ear. Despite the increasing sophistication on hearing aid programming software, simulation data do not replace the probe microphone measurement[22].

Possible complaints about the hearing aid acceptance may be related to the fact that adjustments were made based only on simulated data and not on probe microphone measures. It is also important to note that the proprietary software algorithms



Subtitle: T1 = before hearing aid speech mapping fine tuning; T2 = after hearing aid speech mapping fine tuning

Figure 1. Mean differences between the prescribed gain and real ear measurement (dB) by frequency (Hz) at 55 dB SPL

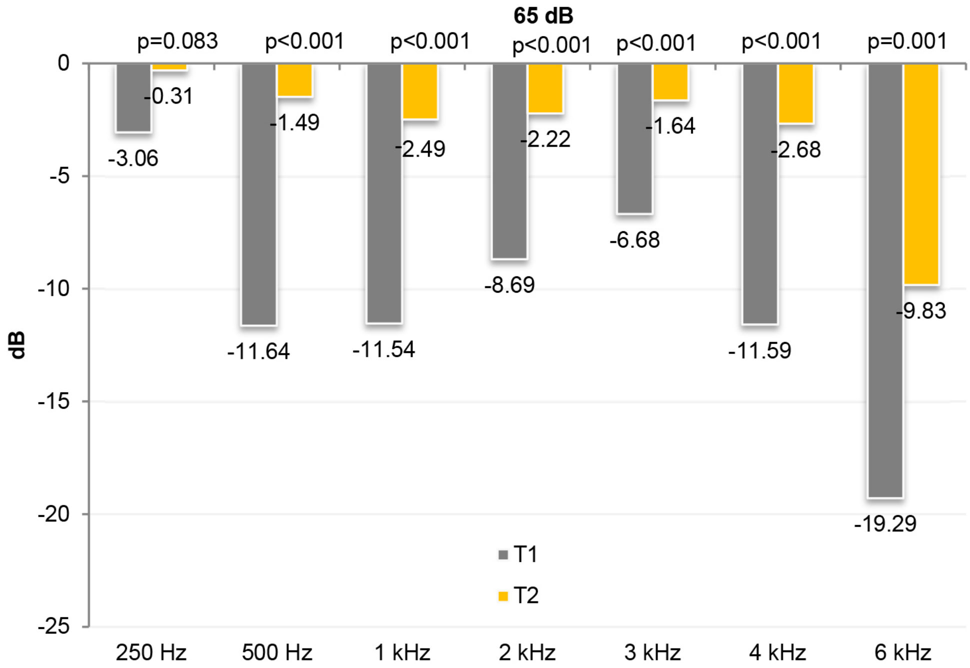


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Figure 2. Mean differences between the prescribed gain and real ear measurement (dB) by frequency (Hz) at 65 dB SPL

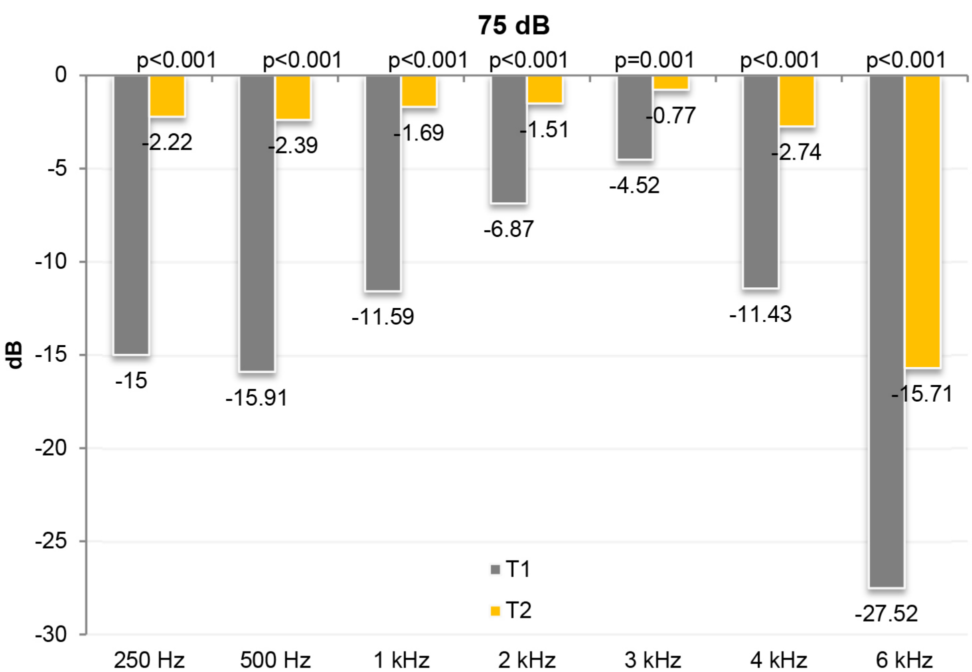

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Figure 3. Mean differences between the prescribed gain and real ear measurement (dB) by frequency (Hz) at 75 dB SPL

are based on coupler values and even if those values match the desired target gain, it is difficult to predict real ear gain from coupler gain on an individual ear canal[23]. In this study, data show that the targets were better approached at T2 moment.

For 55 dB SPL input signal, there was significant difference on target matching post probe tube measurement except for 250 Hz (Figure 1); for 65 dB SPL input signal the difference on target matching was also significant (Figure 2); for 75 dB SPL input level the difference pre and post REM was significant for all frequencies (Figure 3).

A study in 2011[24] used a modulated speech signal to measure the gain for 50 dB SPL, 65 dB SPL and 80 dB SPL in 15 hearing aid users. Data showed that the gain was closer to the prescribed

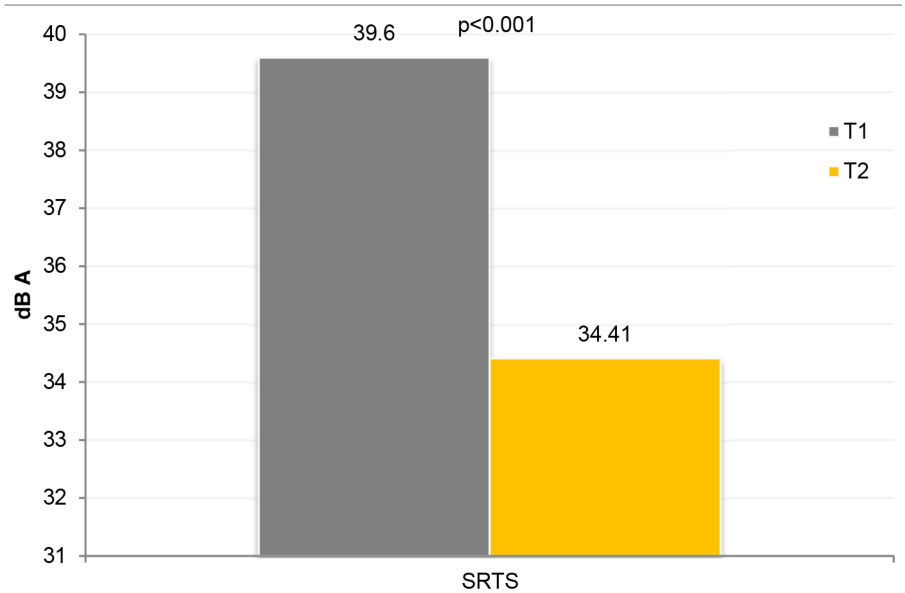

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Figure 4. Sentence Recognition in silence in the T1 and T2 moments

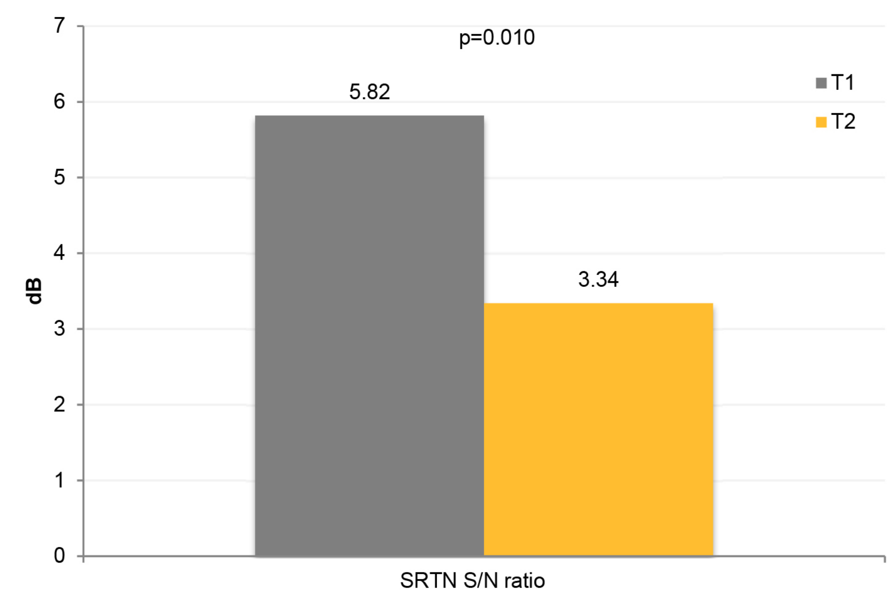

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Figure 5. Sentence Recognition in silence in noise (SNR) for T1 and T2 moment

formula only from 500 Hz to 2 kHz; on average half of the subjects had their hearing aids below targets at 3 kHZ e 4 kHz[24].

In this study it was observed that even after hearing aid adjustments the gain variation for 250 Hz was smaller compared to other frequencies (Figures 1, 2 and 3). The reason for that may be related to the audiogram configuration of our sample, sloping for most tested adults. In mild sloping sensorineural hearing loss the hearing gradually slops from 5 to 10 dB per octave toward the high frequencies; for greater sloping the range is 10 dB to 15 dB per octave[25].

Therefore, in this type of configuration, the frequency of 250 Hz is normally preserved, requiring less gain to match the prescribed target. On the other hand, despite a better approach of the prescribed target at T2 moment, the 6 kHz was the most difficult frequency to match (Figures 1, 2 and 3). For all input levels of 55 dB SPL, 65 dB SPL and 75 dB SPL, it was on average, 11.35 dB SPL, 9.83 dB SPL and 15.71 dB SPL respectively below prescribed targets.

However, it is known that even with current advanced hearing aid technology frequencies above 4000 Hz may not be effectively amplified[26], a factor that may explain the difficulty for matching targets in 6 kHz.

Speech perception

It was found that there was a significant improvement after probe-microphone speech mapping adjustment for Sentence Recognition Threshold in Silence (SRTS) test as well as for the signal to noise ratio (SNR). For both tests, there was a reduction on presentation levels for 50% sentence recognition (Figures 4 and 5). It is expected that after one month of constant hearing aid use there was a progressive improvement of language skills that could be reflected in the LSP test results[27,28] and that after two months a favorable SNR is not as necessary as it is at the initial fitting[27].

However, all participants of this study were already experienced users, showing that if the hearing aid fitting is not within the prescribed targets, they will not be able to use their ability to recognize speech in quiet or competitive noisy situations.

Speech recognition tests (validation) combined with probe microphone speech mapping (electroacoustic verification) provide better counseling, better adjustments in order to get the expected benefits and support hearing aid orientation, favoring the maximum hearing performance associated with the satisfaction and benefit of the individual[29]. This will result on significant decrease of patients' return for adjustments, and shows that such procedures should be considered standard for audiology services [30].

Final considerations

Our findings show that when probe tube verification is not performed the hearing aid electroacoustic characteristic adjustments may be compromised once the values displayed on the fitting software differ significantly from the prescriptive targets, which can make speech understanding in quiet and in background noise even more difficult to the hearing impaired.

The REM verification is crucial to the hearing aid fitting process as it shows exactly how much amplification is being provided to the patient's ear canal. It is important to emphasize the need to perform REM in clinical practice, especially speech mapping. Objective information along with the subjective information may help to determine the best approach during the hearing aid fitting process. Further studies with larger case sample are suggested in order to continue the investigation about the factors that will help to maximize the use of amplification in adults with sensorineural hearing loss.

CONCLUSION

Experienced hearing aid users showed significant better performance in speech perception tests in quiet and in noisy environments after probe-microphone speech mapping fine-tuning.

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