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Speech recognition and speech intelligibility index in intra-aural hearing aids users: a comparative study

Reconhecimento de fala e índice de inteligibilidade de fala em usuários de próteses auditivas intra-aurais: um estudo comparativo

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ABSTRACT

Purpose: To compare the Speech Intelligibility Index (SII) and the Word Recognition Score (WRS) in quiet obtained pre and post adjustments according to prescribed values, to investigate correlations between the Speech Intelligibility Index before and after adjustments, and to investigate correlations between pre- and post-adjustment SII in intra-aural hearing aids users. **Methods:** 20 adults participated, aged 18 to 59 years, with moderate or severe bilateral sensorineural hearing loss. We compared the Speech Intelligibility Index and the WRS obtained with hearing aids in two moments: with the adjustments previously used (pre-adjustment moment) and after modification according to the values prescribed in verification using the NAL-NL1 method (post-adjustment moment). The data were analyzed through descriptive statistics and nonparametric tests, with a significance level of 0.05. **Results:** There was a negative correlation between the pre-adjustment WRS and its post-pre adjustment difference, as well as between the pre-adjustment Speech Intelligibility Index and its post-pre adjustment Delta. There was a positive correlation between post-adjustment PISR and the SII. **Conclusion:** The lower the pre-adjustment WRS and Speech Intelligibility Index, the greater their differences comparing the pre- and post-adjustment moments. The greater the access to speech sounds, promoted by the ideal regulation of the hearing aids, the higher the WRS.

Keywords: Hearing loss; Sensorineural hearing loss; Hearing disorders; Speech audiometry; Hearing aids

RESUMO

Objetivo: Comparar o Índice de Inteligibilidade de Fala e o Índice Percentual de Reconhecimento de Fala (IPRF) obtidos pré e pós-ajustes de acordo com valores prescritos, investigar correlações entre o Índice de Inteligibilidade de Fala pré e pós-ajustes e investigar correlações entre o IPRF pré e pós-ajustes em usuários de próteses auditivas intra-aurais. **Métodos:** Participaram 20 adultos de 18 a 59 anos, com perda auditiva neurossensorial bilateral de graus moderado e severo. Foram comparados o Índice de Inteligibilidade de Fala e o IPRF obtidos com próteses auditivas, em dois momentos: com os ajustes até então utilizados (momento pré) e após a regulagem de acordo com os valores prescritos em verificação, com emprego do método NAL-NL1 (momento pós). Os dados foram analisados por meio de estatística descritiva e de testes não paramétricos, com nível de significância de 0,05. **Resultados:** Verificou-se correlação negativa entre o IPRF pré-ajuste e seu Delta pós-pré-ajuste, assim como entre o Índice de Inteligibilidade de Fala pré-ajuste e seu Delta pós-pré-ajuste. Houve correlação positiva entre o IPRF e o Índice de Inteligibilidade de Fala pós-ajuste. **Conclusão:** Quanto menores o IPRF e o Índice de Inteligibilidade de Fala pré-ajuste, maiores suas diferenças, comparando os momentos pré e pós-regulagem. Quanto maior o acesso aos sons de fala, promovido pela regulagem ideal das próteses auditivas, maior o IPRF.

Palavras-chave: Perda auditiva; Perda auditiva neurossensorial; Transtornos da audição; Audiometria da fala; Auxiliares de audição

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INTRODUCTION

The success of selection and fitting of hearing aids depends primarily on the condition in which the speech signal is amplificated and delivered to the hearing-impaired.

Once the prescriptive method is selected and the hearing aids are adjusted, a verification is performed to measure the level of sound pressure resulting from the adjustment, and it is compared to the target gain and output values. This procedure provides parameters to improve audibility resulting from amplification, and may be used in the acoustic chamber (test box) or *in situ* (in the patient's ear). When, during verification, speech stimulus is employed, a Speech Mapping is obtained. From it, it is possible to obtain the Speech Intelligibility automatically provided by the measuring equipment *in situ* that allows to quantify the access to speech sounds in a certain regulation condition[1]. SII may vary from 0 to 100% — the higher the percentage, the greater the auditory access to phonemes — and its estimation is based on the Articulation Index[2] and the Count the Dots model[3,4].

The evaluation of the results obtained from the fitting of hearing aids may be also performed with the use of behavioral examinations, among them the Word Recognition Score (WRS) in quiet, obtained by repeating 25 monosyllables recorded in silence[5], and determined by the ability to recognize the phonemes that compose the stimuli shown. It is, therefore, a task linked to the bottom-up mechanism that depends on the audibility of phonemes. When larger and more contextualized stimuli are shown in communicative tasks, the top-down mechanism is also used, which is linked to attention, memory and cognitive functions.

Some studies have already aimed to compare speech intelligibility predictions through the SII with behavioral speech recognition scores[6-9]. One of the investigations indicated that the old Articulation Index (AI) could point out the performance in the recognition test of meaningless syllables of adult individuals using hearing aids with moderate precision[6]. Another study, which sought to establish relations between the hearing ability and performance in tasks of speech perception in hearing-impaired children, revealed that there was no regularity in this correspondence, although the results suggested that the performance in recognition tasks of meaningless words has greater relation with the intelligibility index than words with meaning, possibly by limiting the strategies of semantic closure[7]. Another investigation detailed the relation between audibility and speech recognition prediction in 116 children and 19 adults. The bandwidth of the stimulus and the background noise level varied systematically, in order to assess speech recognition, as predicted by SII, and to derive functions of frequency importance. Unlike previous studies, children did not experience greater degradation in speech recognition than adults when the high-frequency bandwidth was limited. Both adults and children had a worse performance in speech recognition when linguistic clues were limited. This fact reaffirms the need to maximize the audibility of high frequencies, especially in situations in which context is limited and, particularly, for children that are developing linguistic knowledge and improving the efficiency of related cognitive processes. Results suggested that SII provides an estimate of audibility, but children require greater indexes to reach the same level of speech comprehension than adults[8].

This investigation was proposed precisely from the observation of the absence of consensus in literature regarding correspondence between the results reached with the intervention (in this case, the use of amplification) when comparing objective and behavioral methods of evaluation.

From these considerations, the objectives of this study, performed with users of intra-aural hearing aids and with moderate to severe sensorineural loss, were:

1) To compare the Speech Intelligibility Index with the Word Recognition Score (WRS) in quiet obtained before and after adjustments according to the values prescribed in verification;
2) To investigate correlations between the SII obtained pre- and post-adjustment, according to values prescribed in verification;
3) To investigate correlations between the Word Recognition Score (WRS) in quiet obtained pre-adjustment and the Word Recognition Score (WRS) in quiet obtained post-adjustment, according to the values prescribed in verification;
4) To investigate correlations between audibility for speech sounds measured by the Speech Intelligibility Index (SII) and by the Word Recognition Score (WRS) in quiet.

METHODS

The research was registered on the Plataforma Brasil, submitted and approved by the Ethics Committee of the Universidade Federal de São Paulo, number 2.177.850. Only patients who authorized the use of the collected data participated in the study, by signing the Informed Consent Form.

This is a cross-sectional, descriptive and observational study with non-probabilistic sample by convenience.

The study has a sample selected from consulting the files of Núcleo Integrado de Assistência, Pesquisa e Ensino em Audição - NIAPEA, belonging to Hospital Universitário, Escola Paulista de Medicina – Universidade Federal de São Paulo – EPM/UNIFESP.

The inclusion criteria were: being 18 to 59 years; diagnosis of moderate and severe bilateral sensorineural hearing impairment (mean tonal of hearing thresholds in frequencies 500, 1000, 2000 and 4000 Hz between 41-80 dB HL)[9]; use of intra-aural hearing aids for more than six months, in order to individualize the results by ear, all regulated using the NAL-NL1 prescriptive method; without other impairments associated to hearing loss that could compromise the evaluation that composed the research.

From these criteria, 20 patients were subjected to anamnesis and otoscopy.

Using a Grason-Stadler clinical audiometer, model GSI 61, and TDH 50 supra-aural headphones, a pure tone audiometry was performed in an acoustic booth, to establish the air-conduction and bone-conduction thresholds in dB HL for frequencies from 250 Hz to 8000 Hz and 250 Hz to 4000 Hz respectively.

Speech audiometry was carried out to obtain the Speech Recognition Threshold using the trisyllabic word list, and results up to 10dB higher than the mean audiometric thresholds of sound frequencies 500, 1000 and 2000 Hz were considered acceptable.

The WRS was carried out through presentation of a list of 25 recorded monosyllables D1 and D2[5], to evaluate the right and left ears, respectively. The lists were presented at the most comfortable level (MCL), since, to predict speech intelligibility with greater precision, it is necessary to decrease the chances of hearing discomfort and sound distortion generated by high sound pressure levels[10].

After checking the functioning of the hearing aids, through auscultation, to ensure the quality of amplification and absence of possible sound distortions, the WRS was carried out with the use of the same clinical audiometer and the same TDH 50 supra-aural headphones, with hearing aids in the usual usage programming, using the recorded monosyllables lists D3 and D4[5], to evaluate the right and left ears, respectively, also presented at the most comfortable level (MCL). All subjects evaluated used completely in the ear (CIC) hearing aids with a microphone cancellation system, in order to ensure the maintenance of sound quality during the test.

In the verification equipment, the following data were reported: type of hearing aid used, type of adaptation (binaural), age of the patient, transducer used for the research of tonal thresholds, prescriptive method used in the regulation of hearing aids (in this case, NAL-NL1) and auditory thresholds of the patient. From this, the verification equipment provided the values in dB SPL prescribed by frequency for speech output and maximum output for each of the amplification devices used by the patients.

Thus, we performed an *in situ* verification of the hearing aids in their usual settings: in an acoustic booth, patient seated and positioned at 0° Azimuth and 60 cm of the speaker of the *in situ* verification equipment, model Verifit VF-1, with the probe microphone positioned 5mm from the tympanic membrane, the reference microphone just below the ear pavilion, and the hearing aid placed in the ear canal, ensuring that the extremity of the probe microphone was not occluded by the hearing aid.

The stimulus used in the verification was the *International Speech Test Signal* (ISTS)[11], at 65 dB SPL. The stimulus used to measure the maximum output levels was the toneburst of 128ms, at 85 dB SPL. From the *insitu* verification, the equipment automatically provided the SII. Such data allows to quantify the percentage of access to speech sounds for 65 dB SPL input sounds in the settings used by patients until then.

After the first verification, the devices were regulated in the software of the manufactures, in order to reach the prescribed values not yet contemplated. The *in situ* verification procedures were repeated and, in order to be considered adequate, the output values for amplified speech should be within the target values ± 5 dB for each frequency of the spectrum[12], and the maximum output values should be below the estimated mean discomfort levels for the population (values already provided by the verification equipment according to the evaluation data inserted for each patient and determined according to a previously developed study[13]).

After ensuring the appropriate adjustment, the WRS was carried out with hearing aids, using the same clinical audiometer and the same TDH 50 supra-aural headphones, with the recorded monosyllables lists D3 and D4[5], to evaluate the right and left ears, respectively. The lists were again presented at the most comfortable level.

We sought to evaluate to what extent the SII and WRS values changed by comparing each of the moments in which they were carried out and how this same information could be correlated.

For data analysis, the following non-parametric tests were used, since the data set had a low sampling:

- Confidence Interval for Mean: used to verify the variability and/or homogeneity of the study according to the mean age of the studied population;
- Equality of Two Proportions Test: used to characterize the distribution of the relative frequency of the qualitative variables sex, degree and configuration of hearing loss;
- Paired Student T-Test (Equality Test of Two Means): used to test the hypothesis of homoscedasticity of the auditory thresholds and the speech recognition threshold (SRT) between the ears in order to ensure the use of parametric techniques. It was also used to compare the pre-adjustment and post-adjustment moments and in the post-pre adjustment variation (Delta) of the mean WRS and SII, both with the use of hearing aids;
- Pearson's Correlation: used to measure the degree of correlation between the WRS and SII in the moments before and after adjustment, as well as for the post-pre adjustment variation (Delta);
- Correlation Test: used in the validation of correlations between the WRS and SII, before and after adjustment, as well as for the post-pre adjustment variation (Delta).

Descriptive statistics was composed, for categorical variables, of absolute (N) and relative (%) frequency, and for quantitative variables, mean, median, standard deviation, coefficient of variation, minimum and maximum values, and first and third quartiles. For all the tests in this study, a significance level of 0.05 (5%) and confidence intervals of 95% were adopted.

RESULTS

The difference in the distribution of the participants according to the variable "sex" was not statistically significant: 11 female patients (55%) and nine male patients (45%) were assessed (Equality of Two Proportions Test; p = 0.527). Age variability was low. The Coefficient of Variation (CV) was less than 50%, which demonstrates the homogeneity of the data. Mean age of the study participants was 35.6 ± 5.8 years.

There was a prevalence of patients with moderate bilateral sensorineural hearing loss (16 cases, 80%) in relation to the severe bilateral (two cases, 10%) and severe on the right ear and moderate on the left ear (two cases, 10%) (Equality of Two Proportions test; p<0.001*).

The right and left ears were compared regarding air conduction auditory thresholds and speech recognition thresholds (SRT), in dB HL. There was symmetry between the thresholds of the right and left ear for most of the frequencies evaluated, with statistically significant difference only for the values of 2k and 8kHz, with higher thresholds found on the right, which may be observed in Table 1. Once the similarity between the ears was observed, we chose to consider as N, in the other statistical analyses, the total of ears evaluated (N=40).

The comparison of the SII values obtained with the settings with which the patients arrived at the service (pre-adjustment) with the SII collected after adaptation according to the target values offered in the verification procedure (post-adjustment) are shown in Table 2.

The comparison of the WRS values performed with hearing aids in the usual usage settings (pre-adjustment) with the WRS

Table 1. Comparison between the right and left ears regarding the results obtained in the survey of the tonal thresholds by air and in the survey of the Speech Recognition Threshold

Hearing thresholds/SRT (dBHL)		Mean	Median	Standard deviation	Q1	Q3	N	CI	p-value
250 Hz	RE	43.3	45	10.5	39	50	20	4.6	0.366
	LE	45.3	48	10.8	39	50	20	4.7	
500 Hz	RE	52.8	50	8.2	45	60	20	3.6	0.522
	LE	51.5	55	8.4	50	55	20	3.7	
1 kHz	RE	56.0	58	9.3	50	60	20	4.1	0.881
	LE	55.8	58	5.9	54	60	20	2.6	
2 kHz	RE	62.0	60	7.5	55	66	20	3.3	0.015*
	LE	58.8	60	6.5	55	61	20	2.8	
3 kHz	RE	56.8	55	6.7	54	61	20	3.0	0.330
	LE	57.8	60	8.0	54	65	20	3.5	
4 kHz	RE	63.3	63	10.7	59	70	20	4.7	0.288
	LE	61.3	60	8.1	55	65	20	3.5	
6 kHz	RE	69.0	65	14.1	60	78	20	6.2	0.893
	LE	69.3	65	12.5	64	75	20	5.5	
8 kHz	RE	66.8	60	16.4	55	81	20	7.2	0.023*
	LE	61.8	63	17.9	50	75	20	7.9	
SRT	RE	61.0	60	6.4	55	65	20	2.8	0.863
	LE	60.8	60	5.9	55	65	20	2.6	

Paired Student t-test; significance level of 0.05 (5%); statistically significant values marked with *

Subtitle: SRT = speech recognition threshold; dB = decibels; HL = hearing Level; Q1 = first quartile; Q3 = third quartile; N = number; CI = confidence interval; KHz = kilohertz; Hz = Hertz; RE = right ear; LE = left ear.

Table 2. Comparison of Speech Intelligibility Index (SII) obtained in the moments pre and post-adjustment with the use of hearing aids

SII with hearing aids (%)	Pre-adjustment	Post- adjustment
Mean	44.4	55.9
Median	45	58
Standard deviation	14.8	11.5
Q1	34	49
Q3	52	62
N	40	40
CI	4.6	3.6
p-value	<0.001*	

Paired Student t-test; significance level of 0.05 (5%); statistically significant values marked with *

Subtitle: SII = Speech Intelligibility Index; Q1 = first quartile; Q3 = third quartile; N = number; CI = confidence interval

Table 3. Comparison of the Word Recognition Score (WRS) obtained in the moments pre and post-adjustment with the use of hearing aids

WRS with hearing aids (%)	Pre-adjustment	Post- adjustment
Mean	74.8	78.9
Median	76	80
Standard deviation	13.9	11.1
Q1	64	71
Q3	88	88
N	40	40
CI	4.3	3.4
p-value	0.002*	

Paired Student t-test; significance level of 0.05 (5%); statistically significant values marked with *

Subtitle: WRS = Word Recognition Score; Q1 = first quartile; Q3 = third quartile; N = number; CI = confidence interval

results after adjustment according to the values prescribed in the verification (post-adjustment) are shown in Table 3.

Both for SII and WRS, there was a statistically significant difference in the results obtained before and after adjustment, with higher values of both variables after regulation. For the SII, the increase in relation to the mean was from 44.4% to 55.9% (p<0.001*), and for the WRS, it increased from 74.8% to 78.9% (p = 0.002*).

Then, the variation (Delta) of the SII and PISR was compared, and we observed that the first was statistically greater than the second (p=0.002*), with means of 11.5% and 4.1%, respectively (Table 4).

The correlations between WRS and SII were performed before and after adjustment, as well as their Deltas, and the more relevant findings were: negative correlation between the pre-adjustment and the pre-post Delta of the same variable (-60.2%); negative correlation between the pre-adjustment SII and the pre-post Delta of the same variable (-63.4%); and positive correlation between the post-adjustment PISR and the post-adjustment SII (39.6%) (Table 5).

DISCUSSION

This study included participants with minimum age of 18 years and maximum age of 59 years (mean age of study participants was 35.6 ± 5.8 years), in order to reduce the chances that participants showed hearing impairment due to the aging process, which could lead to a greater occurrence of impairments not only in the peripheral structures. Healthy aging is associated to neurophysiological changes in all stages of the human auditory system, including not only cochlea, but spinal ganglion neurons, cochlear nuclei and other structures along the brain stem[14]. Literature shows that, even for short stimuli with monosyllables, these changes have an impact: when evaluating the perception of speech with hearing aids of 392 amplification users, it was possible to observe the scores decrease with increasing age, especially after 80 years. Above 70 years of age, there is a clear trend of decreased performance: –3% between 70–80 years; –7% between 80–90 years and –18% > 90 years[15]. Perhaps for this same reason, a recent study

Table 4. Variations (Delta) of the Percentage Index of Speech Recognition (PISR) and the Speech Intelligibility Index (SII): post-adjustment in relation to pre-adjustment

Difference Pre – post-adjustment (Delta) (%)	Word Recognition Score (WRS)	Speech Intelligibility Index (SII)
Mean	4.1	11.5
Median	4	11
Standard deviation	7.9	10.6
Q1	-1	3
Q3	8	18
N	40	40
CI	2.4	3.3
p-value	0.002*	

Paired Student t-test; significance level of 0.05 (5%); statistically significant values marked with *

Subtitle: WRS = Word Recognition Score; SII = Speech Intelligibility Index; Q1 = first quartile; Q3 = third quartile; N = number; CI = confidence interval

Table 5. Correlation between the Word Recognition Score (WRS) and the Speech Intelligibility Index (SII), in the situations pre-adjustment, post-adjustment and in the post-pre-adjustment variation (Delta)

		WRS pre-adjustment	WRS post-adjustment	SII pre-adjustment	SII post-adjustment	Post-pre-adjustment variation (Delta) WRS
WRS post-adjustment	Corr (r)	82.5%				
	p-value	<0.001*				
SII pre-adjustment	Corr (r)	20.2%	29.1%			
	p-value	0.210	0.069			
SII post-adjustment	Corr (r)	36.1%	39.6%	70.1%		
	p-value	0.022*	0.011*	<0.001*		
Post-pre-adjustment variation (Delta) WRS	Corr (r)	-60.2%	-4.6%	5.3%	-7.9%	
	p-value	<0.001*	0.780	0.744	0.628	
Post-pre-adjustment variation (Delta) SII	Corr (r)	11.0%	2.4%	-63.4%	10.7%	-16.0%
	p-value	0.501	0.884	<0.001*	0.512	0.324

Correlation Test and Pearson's Correlation. significance level of 0.05 (5%); statistically significant values marked with *

Subtitle: WRS = Word Recognition Score; SII = Speech Intelligibility Index; Corr(r) = correlation coefficient

with 55 elderly people of both sexes with moderate to severe acquired bilateral sensorineural hearing loss, hearing aids users, showed a weak correlation between SII and WRS values[16].

There was a prevalence of moderate hearing impairment (80% of the evaluated population). It is known that mild and moderate sensorineural hearing losses are usually associated to the restricted degeneration of external hair cells, which, due to the mechanical role they play as amplifiers, are responsible for the audibility of weak sounds and for the selectivity of frequencies in the cochlea[17]. Since the aim of this study was to precisely evaluate audibility, objectively and behaviorally, and to compare these two forms of measurement in two moments, it was fundamental to study participants who, in most cases, had only impaired auditory sensitivity. In these patients, the amplification offered by the hearing aid tries to fulfill the role of the external hair cells, and the expectation is that the benefit achieved in tasks dependent only on audibility will be easily observed. In contrast, severe or worse hearing impairment is also associated with loss of function of internal hair cells, which, in the role of sensory transducers, transmit information from the cochlea to the auditory nerve. The lesion of these structures results in an even greater loss of the encoded sound message transformed into electric impulse than in losses in lower degrees[17]. In these cases, the difficulties observed are hardly resolved satisfactorily only with the use of amplification: these patients will depend on the use of visual and contextual cues to communicate more successfully. In this way, the inclusion of patients with more important degrees of sensory deprivation would show different results from those obtained. This conclusion is consistent with a research previously performed with users of cochlear implants (CI). Due to hearing impairment and the large individual variability in the performance of these patients, the SII did not predict the speech performance of this group of CI users using traditional calculation. However, new SII models were developed, incorporating predictive factors, which improved the accuracy of predictions. Demographic variables (audibility with the device and duration of hearing loss) and perceptive-cognitive skills are necessary, according to the authors, to improve the use of SII for CI users[18].

Regarding the difference observed in the SII when compared to the moments before and after adjustment of the hearing aids, it was possible to note an increase in the mean value of the variable: from 44.4% (pre-adjustment) to 55.9% (post-adjustment). Since the SII is obtained by purely mathematical calculation[5], it was already expected that, by promoting greater access to speech sounds through the new adjustment of the hearing aid, the SII would also increase.

The comparison of the pre- and post-adjustment WRS showed significant increase of the variable, from 74.8% (pre-adjustment) to 78.9% (post-adjustment), which signals a better audibility. Similarly, a study that compared the performance of patients in conditions before and after adjustments, observed, in a speech test with the use of sentences, a significant improvement of the Sentence Recognition Threshold in Silence(SRTS), in which the mean value decreased from 39.60 dB to 34.41 dB HL[19]. Thus, both in our research with monosyllables and in a previous study with sentences, there was improvement in behavioral tests after verification and regulation of hearing aids. The lexical properties of the stimuli must be considered, but audibility is paramount in any scenario. A study developed in Germany electronically simulated three distinct cases of audibility in 160 patients (80 participants with normal thresholds, 40 with mild hearing impairment simulation, and 40 participants with moderate hearing impairment simulation). The researchers estimated the audibility for each case through the SII, in different intensities of speech stimulus presentation, and compared this index to the speech recognition obtained through the *Freiburg Monosyllabic Speech Test*. The most important predictor for word recognition was audibility, a factor that notably interacted with lexical properties: if the audibility is low, word recognition may be considered a task with an "all or nothing" result, in which the impact of lexical resources is small: the individual who receives little auditory information hears the stimulus and does the task correctly, or does not hear it and makes a mistake, without the possibility of intermediary answers. Only when speech is audible to a certain extent can one make use of lexical information such as the frequency of a word in the language or the density of lexical neighborhood (words with orthographic, phonological or semantic similarities in relation to the target stimulus that interfere in lexical access) and which, if evaluated, also influence speech recognition[20].

When comparing the pre- and post- adjustment conditions of SII and WRS, it was observed that the increase shown by the SII was statistically greater. Although the WRS is also a substantially mathematical value (given by the percentage of correct answers), its result depends on biological capacity, given also by the integrity of the auditory pathway of the individual in the identification and recognition of the phonemes and words of the test. This may justify the fact that the SII improvement was greater than the WRS.

The results of the correlation tests between the two indexes, SII and WRS, showed that the lower the regulations at the arrival of the patient to the service were from the ideal values prescribed in verification, the greater the chances of promoting changes in both indexes, with adequacy of the gain and output parameters, and, consequently, obtaining improvement of the two forms of assessing speech access that were compared: objective (SII) and behavioral (WRS). The SII shows the speech access that the hearing aid begins to provide to the individual, and the WRS shows how well the individual takes advantage of this access. The two measures in the post-adjustment moment are positively correlated — when one increases, the other follows: the objective measure guides, but the behavioral measure of each individual allows to prove the improvement in speech recognition performance. Such results prove what is already common sense in all good practice guidelines, protocols and researches in the field of audiological rehabilitation: verification procedures are essential, and behavioral evaluations, added to them, make the process of selection, adaptation and follow-up of patients using hearing aids safer, more ethical and correct[21-23].

The study showed limitations that must be considered in future researches: the sample could be larger, which would allow the choice of more accurate statistical tests, and the comparison of these measures in other age groups and degrees of loss beyond those studied would give more certainty of the inferences made in the discussion.

CONCLUSION

The lower the pre-adjustment WRS and SII, the greater their differences when comparing the moments before and after adjustment.

The greater the access to speech sounds promoted after ideal regulation of hearing aids, the greater is the ability to recognize monosyllables in a quiet environment.

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REFERENCES

1. ANSI: American National Standards Institute. ANSI S3.5-1997: methods for the calculation of the speech intelligibity index. New York: Acoustical Society of America; 2012.
2. French NR, Steinberg JC. Factors governing the intelligibility of speech sounds. J Acoust Soc Am. 1947;19(1):90-119. http://dx.doi.org/10.1121/1.1916407.
3. Mueller HG, Killion MC. An easy method for calculating the articulation index. Hear J. 1990;43(9):14-7.
4. Killion MC, Mueller HG. Twenty years later: a NEW count-the-dots method. Hear J. 2010;63(1):10-2. http://dx.doi.org/10.1097/01.HJ.0000366911.63043.16.
5. Pen MG, Mangabeira-Albernaz PL. Lista de monossílabos para discriminação vocal. In: Mangabeira-Albernaz PL, Ganança MM, editors. Surdez neurossensorial. São Paulo: Moderna; 1976. p. 20.
6. Humes LE. Understanding the speech-understanding problems of the hearing impaired. J Am Acad Audiol. 1991;2(2):59-69. PMid:1768875.
7. Camargo N, Mendes BCA, Novaes BCAC. Relações entre medidas de capacidade auditiva e desempenho em tarefas de percepção da fala em crianças com deficiência auditiva. CoDAS. 2020;32(1):e20180139. http://dx.doi.org/10.1590/2317-1782/20192018139. PMid:32022219.
8. McCreery RW, Stelmachowicz PG. Audibility-based predictions of speech recognition for children and adults with normal hearing. J Acoust Soc Am. 2011;130(6):4070-81. http://dx.doi.org/10.1121/1.3658476. PMid:22225061.
9. WHO: World Health Organization. Grades of hearing impairment [Internet]. Switzerland: WHO; 2019 [citado em 2020 Mai 12]. Disponível em: http://www.who.int/pbd/deafness/hearing_impairment_grades/en/
10. Studebaker GA. The effect of equating loudness on audibility-based hearing aid selection procedures. J Am Acad Audiol. 1992;3(2):113-8. PMid:1600213.
11. Holube I, Fredelake S, Vlaming M, Kollmeier B. Development and analysis of an international speech test signal (ISTS). Int J Audiol. 2010;49(12):891-903. http://dx.doi.org/10.3109/14992027.2010.506889. PMid:21070124.
12. Baker S, Jenstad L. Matching real-ear targets for adult hearing aid fittings: NAL-NL1 and DSL v5.0 prescriptive formulae. Can. J Speech Lang Pathol Audiol. 2017;41(2):227-35.

13. Pascoe DL. Clinical measurements of the auditory dynamic range and their relation to formulas for hearing aid gain. In: J. Jensen (Ed.). Hearing Aid Fitting: Theoretical and Practical Views: Proceedings of the 13th Danavox Symposium; 1988; Copenhagen. Copenhagen: Danavox Jubilee Foundation; 1988. p. 129-52.

14. Peelle JE, Wingfield A. The neural consequences of age-related hearing loss. Trends Neurosci. 2016;39(7):486-97. http://dx.doi.org/10.1016/j.tins.2016.05.001. PMid:27262177.

15. Hoppe U, Hocke T, Müller A, Hast A. Speech perception and information-carrying capacity for hearing aid users of different ages. Audiol Neurootol. 2016;21(Supl. 1):16-20. http://dx.doi.org/10.1159/000448349. PMid:27806356.

16. Nigri LF, Iório MCM. Estudo da correlação entre índice de inteligibilidade de fala Speech Intelligibility Index (SII) e índice percentual de reconhecimento de fala. Distúrb Comun. 2019;31(1):33-43. http://dx.doi.org/10.23925/2176-2724.2019v31i1p33-43.

17. Ryan AF, Kujawa SG, Hammill T, Le Prell C, Kil J. Temporary and permanent noise-induced threshold shifts: a review of basic and clinical observations. Otol Neurotol. 2016;37(8):e271-5. http://dx.doi.org/10.1097/MAO.0000000000001071. PMid:27518135.

18. Lee S, Mendel LL, Bidelman GM. Predicting speech recognition using the speech intelligibility index and other variables for cochlear implant users. J Speech Lang Hear Res. 2019;62(5):1517-31. http://dx.doi.org/10.1044/2018_JSLHR-H-18-0303. PMid:31058575.

19. Tonelini CFM, Garolla LP, Iório MCM. Avaliação da percepção de fala em usuários de próteses auditivas após ajuste fino via mapeamento de fala com estímulo em Português. Audiol Commun Res. 2016;21(0):e1647. http://dx.doi.org/10.1590/2317-6431-2015-1647.

20. Winkler A, Carroll R, Holube I. Impact of lexical parameters and audibility on the recognition of the Freiburg monosyllabic speech test. Ear Hear. 2020;41(1):136-42. http://dx.doi.org/10.1097/AUD.0000000000000737. PMid:31033700.

21. Valente M, Abrams H, Benson D, Chisolm T, Citron D, Hampton D, et al. Guidelines for the audiologic management of adult hearing impairment. Audiology Today. 2006;18(5):32-7.

22. Jardim IS, Sizenando CS, Bento RF, Iwahashi JH. Hearing aid fitting protocols for adults and elderly individuals. Arq Int Otorrinolaringol. 2011;15(02):214-22. http://dx.doi.org/10.1590/S1809-48722011000200015.

23. Jorgensen LE. Verification and validation of hearing aids: opportunity not an obstacle. J Otol. 2016;11(2):57-62. http://dx.doi.org/10.1016/j.joto.2016.05.001. PMid:29937811.