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ARTICLES

Study of correlation between Speech Intelligibility Index (SII) and speech recognition percentage index

Estudo da correlação entre índice de inteligibilidade de fala *Speech Intelligibility Index* (SII) e índice percentual de reconhecimento de fala

Estudio de Correlação entre el Índice de inteligibilidad del habla (SII) y el índice de porcentaje de reconocimiento de voz

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Abstract

Introduction: Hearing is one of the noblest senses, since its main function is linked to the acquisition and development of oral language, essential in interpersonal relations and with the environment. The impact of hearing sensory deprivation interferes with the ability to interpret speech sounds. **Purpose:** Check if there is a correlation between the values of Speech Inteligibility Index (SII) and Word Recognition (WR). **Method:** The data obtained in the records of 55 elderly of both sexes, with bilateral sensorineural hearing loss of moderate to severe, users of hearing aids accompanied in the auditory health service of Hospital São Paulo, were evaluated. The SII values obtained in the verification of the hearing aid gain in the Verifit ® Audioscan equipment and the IPRF values for monosyllabic stimuli were analysed. After data collection, the results were submitted to statistical analysis. **Results:** The hearing losses were classified as to the degree (moderate and severe). The values of SII and IPRF were characterized by ear (right and left). The mean of WR was 72,56% in the right ear and 73,85 % in the left ear. The mean of SII was 58,44 % in the right ear and 59,73 % in the left ear.There were certain equations for the

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classification of hearing loss according to groups and equations for determining the values of SII and IPRF, according to each ear. **Conclusion:** There was a weak correlation between the values of SII and of WR obtained with monosyllabic stimuli in the elderly with hearing loss of moderate to severe degree.

Keywords: Speech Intelligibility; Hearing Aids; Hearing Loss; Elderly

Resumo

Introdução: A audição é um dos sentidos mais nobres, uma vez que sua principal função está ligada à aquisição e ao desenvolvimento da linguagem oral, essencial para a comunicação nas relações interpessoais e para o contato com o meio ambiente. O impacto de uma privação sensorial auditiva interfere na habilidade de interpretar sons de fala. **Objetivo:** Verificar se há correlação entre os valores do Speech Intelligibility Index (SII) e do Índice Percentual de Reconhecimento de fala (IPRF). **Método:** Foram avaliados os dados obtidos nos prontuários de 55 idosos de ambos os sexos com perda auditiva neurossensorial adquirida bilateral de grau moderado a severo, usuários de próteses auditivas acompanhados no serviço de saúde auditiva do Hospital São Paulo. Foram analisados os valores de SII obtidos na verificação dos AASI por meio do equipamento Verifit®Audioscan e os valores de IPRF para estímulos monossilábicos. Após a coleta dos dados os resultados foram submetidos à análise estatística. **Resultados**: As perdas auditivas foram classificadas quanto ao grau. Os idosos foram caracterizados segundo a idade e gênero e os valores de SII e IPRF foram analisados por orelha (direita e esquerda). O IPRF médio foi de 72,56% na OD e de 73,85% na OE e o SII de 58,44% na OD e 59,73% na OE. Foram determinadas equações para classificação da perda auditiva conforme grupos e equações para determinação de valores de SII e IPRF, conforme cada orelha. **Conclusão**: Houve correlação fraca entre os valores de SII e o IPRF obtido com estímulos monossilábicos nos idosos com perda auditiva de grau moderado a severo.

Palavras-chave: Inteligibilidade de Fala; Auxiliares de Audição; Perda Auditiva; Idoso

Resumen

Introducción: La audición es uno de los sentidos más nobles, ya que su función principal está ligada a la adquisición y desarrollo del lenguaje oral, esencial en las relaciones interpersonales y en el medio ambiente. El impacto de la pérdida sensorial auditiva interfiere con la capacidad de interpretar los sonidos del habla. **Objetivo:** Verificar que existe correlación entre los valores de Indice de inteligibilidad de habla (SII) y Indice de reconocimiento de habla. **Método:** Los datos obtenidos en los registros de 55 ancianos de ambos sexos fueron evaluados con pérdida auditiva sensorineural bilateral de moderado a severo, usuarios de audífonos acompañados en el servicio de salud auditiva del hospital de São Paulo. Se analizaron los valores de SII obtenidos en la verificación de los ajustes de audifono en el equipo Audioscan Verifit ® y los valores IPRF para los estímulos monosilábicoy. Después de la recolección de datos los resultados se presentaron al análisis estadístico. **Resultados:** Las pérdidas auditivas se clasificaron en cuanto al grado (moderado y severo). Los valores de SII y IPRF se caracterizaron por el oído (derecha e izquierda). El Indice de reconocimiento de habla medio fue de 72,56% en la OD y de 73,85% en la OI y el SII de 58,44% en la OD y 59,73% en la OI. Había ciertas ecuaciones para la clasificación de la pérdida de oído según grupos y las ecuaciones para determinar los valores de SII y de IPRF, según cada oído. **Conclusión:** Había una correlación débil entre los valores de SII y el IPRF obtenido con los estímulos monosilábicoy en los ancianos con la pérdida de oído de moderate al grado severo.

Palabras claves: Inteligibilidad del Habla; Audífonos; Pérdida Auditiva; Anciano

Introduction

Hearing is one of the noblest senses, since its main function is linked to the acquisition and development of oral language, essential in interpersonal relations and with the environment. Hearing impairment is considered to be a highly disabling condition, given its effects on human communication as well as the impact on cognitive and psychosocial development, and on oral and written language[1].

In the adult population, the most common acquired hearing loss is the Age-Related Hearing Loss (ARHL) or presbycusis that is due to the aging process. This condition is characterized by a sensorineural, bilateral, gradual, and progressive hearing loss[2]. Hearing loss compromises the functionality of the elderly[3].

In order to mitigate the harmful effects of hearing loss, the Ministry of Health established the Ordinance No. 2.073 / 04 on September 28, 2004, which established the National Policy on Hearing Health Care. Initiatives are needed to promote hearing health, prevention and early identification of hearing problems for the fulfillment of actions in primary care, in addition to the development of educational and informative actions, guidelines and referrals Medium Complexity Health Care, when required.

Speech sounds include consonants and vowels of different levels of sound pressure and frequency. In addition, speech sounds can be also shown in an audiogram region that has been called as “speech banana”[4]. It is a simple way to check if and how speech sounds remain audible in the presence of a hearing loss[4].

The greater the degree of hearing loss, the less access to speech sounds. The access to weak and moderate speech sounds is already compromised in moderate hearing loss. In addition to less access to speech sounds associated with hearing loss, there is a commitment of temporal processing, which aggravates the difficulty of speech recognition in the presence of background noise[5,6].

The performance of individuals with different types and degrees of hearing loss has been investigated since the 1960s. Speech audiometry is among the tests used and it allows the professional to analyze how the patient perceives and recognizes speech sounds[7]. The Speech Recognition Test (SRT) and the Speech Recognition Index (SRI) are the tests with speech stimuli commonly used in the audiological evaluation.

One of the possible classifications of SRI results was proposed in 1968[8]. This classification predicts the difficulty in understanding speech from the percentage of correct answers in the SRI test. Scores from:

- 100-92% no difficulty in understanding speech
- 88-80% mild difficulty in understanding speech
- 76-60% moderate difficulty in understanding speech
- 56%-52% severe difficulty in understanding speech
- <50% likely to be unable to follow a conversation

The adaptation with a hearing aid is one of the first steps for the rehabilitation of the hearing impaired subject. The personal sound amplification product (PSAP) is a system that amplifies sounds for individuals with hearing loss. Therefore, the greater the hearing loss, the greater the required amplification[9].

The purpose of this amplification is to provide audibility for speech sounds. To this end, the parameters of gain added and output of the hearing aid are calculated through prescriptive methods, whether used for the selection and adaptation of linear or non-linear devices[9]. After the selection of the prescriptive method and the regulation of the hearing aid, it is important to check the adjustments made in order to assess the access to acoustic information[10].

The Speech Intelligibility Index (SII) is a measure that is highly correlated to speech intelligibility, since it quantifies the speech sounds that are accessible to the patient[11]. It was developed in the first half of the 20th century, when engineers of the Bell Telephone Laboratories developed the articulation model (Articulation Index) for predicting speech intelligibility transmitted through different telecommunication devices under varying electro-acoustic conditions. The profession of audiology adopted this model and its quantitative aspects, known as the Articulation Index and Speech Intelligibility Index, and applied these indexes to the prediction of unaided and aided speech intelligibility in hearing-impaired subjects[12]. Thus, the Articulation Index (AI) was developed to assist the engineers at Bell Telephone Laboratories in the construction of communication systems[13]. The audibility of speech sounds as received by the listener is related to this quantity called as "Articulation Index" or AI.

The Articulation Index, which was proposed in 1947,[13] did not have much applicability in clinical practice due to the complexity of its calculations. Therefore, this model proposed to quantify the audibility of the speech sounds went through some revisions of calculation. A new model called - "count-the-dots" - has become one of the simplest methods to calculate the percentage of access to speech sounds, since it has been simplified by 100 points translated into the speech spectrum set in the audiogram that traditionally includes the "speech banana"[14,15].

The method has been standardized as ANSI 3.5-1997 and it changed from AI to SII. The main differences are in the calculations for the prediction of audibility. Variables such as the speech signal spectrum, noise and audibility thresholds of individuals are considered in the calculation. In addition, it considers other corrections, as a way of presenting the stimulus and the importance of certain frequency bands.

Since frequency bands have different information, not all are equally important for speech intelligibility. The vowels, which provide energy, are at lower frequencies, while the consonants, which provide speech intelligibility, are at higher frequencies[12].

The result of the SII calculation ranges from 0% to 100%. An SII value of 0% indicates that no speech sound is accessible, while a value of 100% indicates that all speech sounds are accessible.

The SII is used in audiology as part of the tool to check the adjustment of hearing aids in the extent that the predetermined targets of acoustic gain should be reached and this adjustment allows to quantify the access of the patient to speech signals. It is known that, even with amplification, not all speech sounds will be audible, depending on the degree and configuration of the hearing loss[16].

The amplification aims to provide the audibility of most possible speech sounds, depending on the degree and configuration of the hearing loss.

It is also known that the research of the Speech Recognition Index (SRI) with monosyllabic stimuli reveals the ability to detect the sounds that make up the monosyllable[17,18,19].

There is no possibility of inferring the correct word with this type of stimulus, since there are no other facilitating clues, such as closure or knowledge, that are used when stimuli of greater extension are presented.

Given the relevance of conducting performance verification measures of the PSAP to ensure that the goals of the adjustment procedure have been met, the Speech Intelligibility Index (SII) is one of the potential measures. According to the intensity, the SII can be obtained for weak, medium and strong speech signals. It is known that the communication is conducted at medium levels – 65 dB NPS; therefore, the SII values obtained at 65 dB NPS are the ones that guide this process in a more relevant way[12].

Based on the above, this research aims to study the correlation between audibility of speech signals measured through SII and SRI.

Method

This study was conducted at Integrated Center for Assistance, Research, and Teaching in Hearing (NIAPEA) of the aforementioned Institution.

This study followed the precepts laid down in the Code of Research Ethics involving human subjects and it was approved by the Research Ethics Committee of the Integrated Center for Assistance, Research, and Teaching in Hearing (NIAPEA).

This is a cross-sectional study. The study analyzed the data collected in the medical records of the patients who attended at Integrated Center for Assistance, Research, and Teaching in Hearing (NIAPEA) in 2016 and 2017.

The eligibility criteria for sample composition were:

- Patients over 60 years of age
- Users of hearing aids for over a year
- Have moderate or severe acquired bilateral sensorineural hearing loss[20]

From the defined criteria, the study collected data from 55 elderly, of whom 30 were male and 25 were female, ranging from 61 to 96 years old.

Procedures

The data of the medical records were collected with the prior consent of the elderly. All elderly individuals were submitted to the electroacoustic assessment and verification protocol as performed by all patients attending the hearing health service at the Integrated Center for Assistance, Research, and Teaching in Hearing (NIAPEA).

The verification procedure was performed in situ (with probe microphone) through an Audioscan Verifit VF-1 as In Situ Measurement device. The equipment was calibrated in the test environment before the assessment, by positioning the reference microphone near the probe microphone 50 to 80 cm away from the loudspeaker.

The patient was sitting at 0° azimuth and 80 cm from the loudspeaker of the device, with the probe microphone positioned 5 mm from the tympanic membrane, the reference microphone is placed just below the auricle and the hearing aid is placed in the external acoustic meatus (ensuring that the tip of the probe microphone is not occluded by the hearing aid).

Initially, the type of hearing aid was selected at the device, as well as the type of adaptation (mono or binaural), the age of the patient, the transducer used for the screening of the hearing thresholds, the NAL N/L2 / DSL-V5 prescriptive method for determining targets and the audibility thresholds of the patient by air from 250 to 8000 Hz and by bone from 500 to 4000 Hz. The International Speech Test Signal (ISTS)[21] was the stimulus used for this measurement, which was designed from recordings in six different languages, completely unintelligible, but internationally accepted to verify hearing aid adjustments.

From this measurement (amplified speech values must be between the target values ± 4dB), the device calculates and provides the Speech Intelligibility Index (SII) for the speech stimulus presented, as in this study, at 65 dB NPS amplified by the hearing aid. These data allow quantifying the percentage of access to speech sounds.

The Speech Recognition Index (SRI) was performed at follow-up visits after the adaptation of hearing aids. This test was performed at the level of greater comfort for the patient, starting with the ear of better audibility and then the other ear. This research used lists composed of 25 monosyllables and they were presented in different orders to compose the test material with four lists, named as D1, D2, D3 and D4[22]. The patient is instructed to repeat the word heard in the way he/she has heard. Each correct answer corresponds to 4%, so that if the 25 words are correctly repeated, the patient will get a SRI of 100%. This test was performed in an acoustic booth, using an Interacoustics AC33 two-channel audiometer, with supra aural headphones. The monosyllables were presented orally.

Statistical Methods

The sample with 55 subjects was characterized in terms of age and gender. As this sample was obtained for convenience, the Test Power was calculated using the GPower 3.1.9.2 software based on an effect size of 32.1% and a significance level of 5%, obtaining a Power of 76.0%.

In order to verify the homogeneity related to the age, SRI and SII with PSAP, a Levenne test was performed and the normality assumption was evaluated through the Shapiro-Wilk test.

All descriptive analyzes were performed and data concerning age, SRI and SII with PSAP (dependent variables - numerical) were analyzed with univariate GLM (generalized linear models) considering gender as an independent (categorical) variable.

The Pearson Correlation test was used in order to verify the linear correlation between the SII (Right and Left ears) and the SRI (Right and Left ears).

A significance level of 0.05 was established for all statistical tests.

Results

This chapter presents the results obtained in the assessment of 55 elderly people with moderate (81.8%) to severe (18.2%) bilateral sensorineural hearing loss, of which 30 (54.5%) were male and 25 (4565%) were female, with a mean age of 70.29 (± 24.45) years.

Sample Characterization

Sample characterization is performed according to age and gender and related statistics. Table 1

The distributions of the variable age (years) by gender, with approximations, in the Error Bars. Figure 1

According to the univariate independent GLM test, there was no significant difference between the mean age in relation to genders (F=1.140, p=0,290, eta-square=0.021).

Table 1. Descriptive statistics for **Age (years)**, by gender

Group	n	Mean	Standard Deviation	Minimum	Median	Maximum
Male	30	73.50	21.62	61	80	95
80	95	66,44	27,41	61	78	96
Female	25	66.44	27.41	61	78	96
Total	55	70.29	24.45	61	79	96

Legend:
n – number of subjects by gender

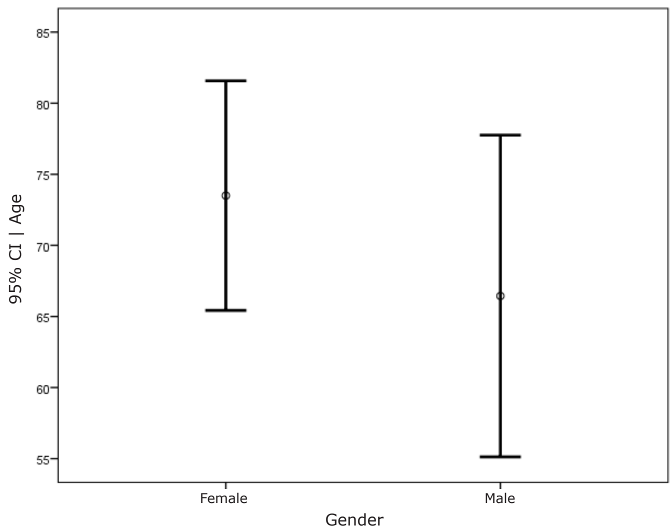


Figure 1. Error Bars for **Age (years)**, by gender

Descriptive statistics for SRI (Right and Left Ears) by gender. Table 2

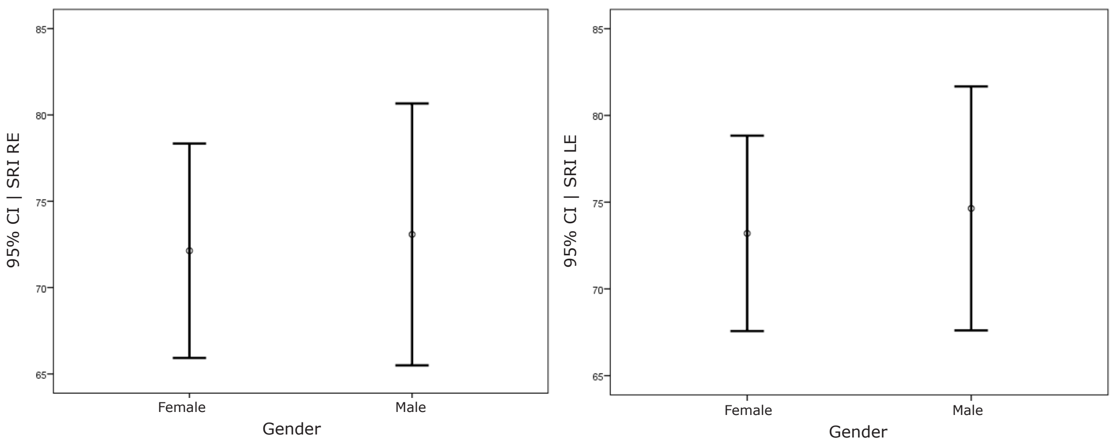
The distributions of the variable SRI - Right and Left Ears by gender, with approximations, in the Error Bars. Figure 2

According to the univariate independent GLM test, there was no significant difference between the SRI - Right (p=0.842) and Left (p=0.741) Ears mean values in relation to gender.

Table 2. Descriptive statistics of the variable **SRI (Right and Left Ears)**, by gender

	n	Mean	Standard Deviation	Minimum	Median	Maximum
Male	25	73.08	18.37	28	76	96
Female	30	72.13	16.62	24	76	96
RE	55	72.56	17.82	24	76	96
Male	25	74.64	17.04	28	76	92
Female	30	73.20	15.08	28	76	96
LE	55	73.85	15.86	28	76	96

Legend:
n – number of subjects by gender
RE – Right Ear
LE – Left Ear



Legend:
RE – Right Ear
LE – Left Ear

Figure 2. Error Bars for **SRI (RE and LE)**, by gender

Descriptive statistics for SII with PSAP, Right and Left Ears, by gender. Table 3

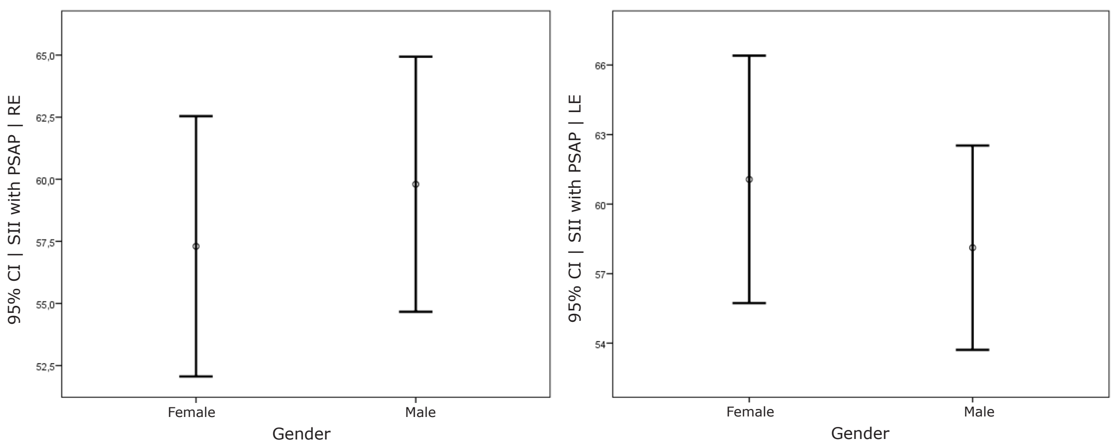
The distributions of the variable SII with PSAP - Right and Left Ears by gender, with approximations, in the Error Bars. Figure 3

According to the univariate independent GLM test, there was no significant difference between the SII with PSAP - Right (p=0.492) and Left (p=0.399) Ears mean values in relation to gender. .

Table 3. Descriptive statistics of the variable **SII with PSAP (Right and Left Ears)**, by gender

	n	Mean	Standard Deviation	Minimum	Median	Maximum
Male	25	59.80	12.44	31	60	82
Female	30	57.30	14.03	28	57	79
RE	55	58.44	13.27	28	58	82
Male	25	58.12	10.68	26	58	80
Female	30	61.07	14.29	32	61	88
LE	55	59.73	12.75	26	60	88

Legend:
n – number of subjects by gender
PSAP – Personal Sound Amplification Product
RE – Right Ear
LE – Left Ear



Legend:
RE – Right Ear
LE – Left Ear
PSAP – Personal Sound Amplification Product

Figure 3. Error Bars for **SII with PSAP (RE and LE)**, by gender.

The study of the best values obtained according to the side (right and left ear) showed that the best values were corresponding in 11 (20%) of the 55 elderly. Table 4 shows the descriptive statistics of SRI and SII of the best ear for those 80% with coincident results.

Table 4. Descriptive statistics of the best values of **SRI** and **SII** (%) obtained (N=44) in the elderly assessed

	Best SRI	Best SII
Mean	76.36	63.72
Max value	96	88
Min value	28	42

Study of correlation between Speech Intelligibility Index (SII) and SRI (Speech Recognition Percentage Index)

The results of the Pearson Correlation test between SII (Speech Intelligibility Index) and SRI (Speech Recognition Index) for right (RE) and left (LE) ears showed a weak linear correlation between the SRI and the SII with PSAP both for the right ear ($p<0.0001$; $r=0.471$) and for the left ($p<0.0001$; $r=0.482$). Table 5

Table 5. Correlation between **SRI** and **SII with PSAP**

		SII with PSAP (RE)	SII with PSAP (LE)
SRI	Correlation coefficient	0.471	0.482
	p-value	0.000	0.000
	n	55	55

Legend:
n – number of participants
LE – Left Ear
RE – Right Ear
SII - Speech Intelligibility Index
PSAP – Personal Sound Amplification Product

Discussion

All acoustic information related to speech is very important for the development of auditory and language skills. The Speech Intelligibility Index (SII) is a measure used in speech-language pathology due to its ability to reflect the probable potential of hearing use, although there are inherent limitations in any complex phenomenon, such as intelligibility, it can guide the clinician on the impact of hearing loss in speech and language development[23].

This study aimed to evaluate the access to the speech sounds of elderly subjects with moderate and severe bilateral sensorineural hearing loss through the Speech Recognition Index (SRI) and using the monosyllabic stimulus lists by comparing the results to the values of the Speech Intelligibility Index (SII) obtained in the verification of the performance of sound amplification devices according to the DSL v5 prescriptive rule. The SII value is an indicator for the audibility of speech sounds and it may guide auditory behavior assessments.

The audiological evaluation in the elderly population shows an Age-Related Hearing Loss (ARHL) characterized by a progressive bilateral sensorineural hearing loss with greater loss in the high frequencies for both ears, which corresponds to the data obtained in this study and is also consistent with studies from other researchers[24].

There was a prevalence of moderate (81.18%) hearing loss when compared to severe (18.2%) hearing loss in the studied population, using the proposed WHO 2012 classification. SRI and SII were evaluated in 55 elderly hearing aid users, of which 30 were male and 25 were female with a mean age of 70.29 years.

SRI is obtained with monosyllabic stimuli that are best suited to investigate the real difficulties of accessing speech sounds. When greater stimuli are presented, other skills may help the patient to infer which word or sentence is presented. Polysyllabic words are more easily identified than monosyllabic words and meaningless words, as each phoneme must be correctly identified in order for the latter to be recognized[25].

The SII value is determined by in situ evaluation and it objectively quantifies the accesses of the speech signal to the hearing aid user.

In this study, the SRI scores ranged from 28-96% and SII values ranged from 24-88% with mean values of 73.20% and approximately 60%, respectively.

In order to evaluate the functioning of the elderly in daily life activities, the SRI and SII values obtained in the best ear were analyzed in 80% of the elderly in whom these values were coincident (that is, better SRI and better SII values in the same ear). This study showed SRI and SII mean values of 76.36% and 63.72%, respectively. Since the mean values were better, a better functional performance is expected in these cases.

According to a study conducted in 2017, a SII greater than or equal to 50 provides enough audibility to show significant benefit in several measures of outcome assessment[26].

Regarding the SRI and the classification proposed in 1968,[8] scores below 50% significantly compromise communication. In this way, an access to speech sounds of 50% is recommended as a minimum condition for effective communication. However, it should be noted that factors such as cognition and schooling, among others, improve the understanding of speech even in difficult listening conditions[27,28] .

Researchers conducted a study using the Nonsense Syllable Test (NST) aiming to evaluate the standard error of consonants in individuals with normal hearing and Sensorineural Hearing Loss in consonant recognition tasks. Data analysis allowed noticing that the test was sensitive in the identification of differences in the recognition of consonants both in individuals with normal hearing as in those with sensorineural hearing loss. The study also showed that individuals with sensorineural hearing loss in the high frequencies had great difficulties in speech intelligibility, since the loss of acoustic information increases the likelihood of the individual not understanding the speech. This is due to the fact that the consonants have the most of their acoustic energy concentrated in the high frequencies and are emitted in lower levels of sound pressure when compared to the vowels. Therefore, the context in which the phoneme is inserted influences its recognition[29].

The results of the analyzes conducted in this study show that the access to speech sounds, as measured by the SII and SRI tests, is obviously due to the degree and configuration of the hearing loss. Thus, the importance of adjusting the hearing aids as appropriately is highlighted, especially given that currently there are devices with effective amplification in the higher frequencies and better sound quality. The requirements for most appropriate adjustment are imperative based on this technological development. The tests for electroacoustic verification of the performance of hearing aids in the user's ear were designed due to these considerations. It is known that this procedure is not new. It dates back to the 1980s, but is currently mandatory, since it allows more precise adjustments of the equipment that efficiently amplifies speech sounds.

Final considerations

It can be concluded in this study that there was a weak correlation between SII and SRI values for the elderly population with moderate and severe bilateral sensorineural hearing loss.

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