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Speech Intelligibility Index (SII) and sentence recognition in noise. A study in elderly with and without cognitive disorders users of hearing aids*

Índice de inteligibilidade de fala – *Speech Intelligibility Index* (SII) e reconhecimento de sentenças no ruído. Estudo em idosos com e sem alteração cognitiva usuários de próteses auditivas

Erica Antero da Silva[1], Loretta Fabianne Nigri[2], Maria Cecília Martinelli Iorio[1]

ABSTRACT

Purpose: Investigate the effects of cognitive processes and Speech Intelligibility Index (SII) in sentence recognition in noise among elderly users of hearing aids with and without cognitive disorders. **Methods:** Study participants were 34 older adults, aged 64-87 years, with bilateral moderate sensorineural hearing loss, users of hearing aids for over a year. The individuals were divided into two groups: GA - without cognitive impairment (n=21) and GB - with cognitive impairment (n=13). In order to verify the adequate amplification of the hearing aids, participants of both groups underwent Visible Speech Mapping and had their Speech Intelligibility Indexes obtained. Subsequently, they were submitted to cognitive screening (10-CS) and the Brazilian Portuguese Sentence List Test. Evaluation consisted of a search for speech perception thresholds in noise (S/N ratio). This search was performed in free-field conditions first without and then with the hearing aids. Data were statistically analyzed at a significance level of 5% using the Chi-squared and Mann-Whitney tests. **Results:** No statistically significant differences were observed between the SII results obtained in both groups either with or without hearing aids. These results demonstrate that the older individuals in the GA and GB present the same access to speech sounds with and without hearing aids. Individuals in the GA presented lower S/N ratio under both conditions. **Conclusion:** Older individuals with better cognition present greater speech recognition in the presence of competitive noise.

Keywords: Elderly; Hearing aids; Cognition; Speech intelligibility; Speech perception

RESUMO

Objetivo: Investigar os efeitos dos processos cognitivos e do Índice de Inteligibilidade de Fala no reconhecimento de fala no ruído em idosos, com e sem alteração cognitiva, usuários de próteses auditivas. **Método:** 34 idosos, de 64 a 87 anos, com perda auditiva neurossensorial simétrica de grau moderado, usuários de próteses auditivas, foram distribuídos em grupos de idosos sem (GA; n=21) e com (GB; n=13) evidências de alteração cognitiva. A fim de garantir que o ajuste das próteses auditivas estivesse adequado, realizou-se o mapeamento visível de fala amplificada e foram obtidos os indices de ínteligibilidade de fala. Os idosos foram submetidos a uma triagem cognitiva (10-CS) e ao teste Lista de Sentenças em Português. A avaliação constou da pesquisa do limiar de reconhecimento de sentenças no ruído. Esta pesquisa foi realizada em campo livre, na condição sem e com próteses auditivas. Para análise estatística, foram utilizados os testes de Qui-Quadrado e Mann-Whitney. O nível de significância adotado foi de 0,05. **Resultados:** Não houve diferença significativa entre os índices de inteligibilidade de fala obtidos em ambos os grupos, tanto na condição com próteses auditivas, como na condição sem as próteses. Verificou-se que os idosos com e sem alteração cognitiva apresentaram o mesmo acesso aos sons da fala (SII), nas duas condições. Observou-se que os idosos sem alteração cognitiva apresentaram menor relação sinal/ruído média, para o reconhecimento de 50% das sentenças na presença de ruído tanto na condição sem próteses auditivas como na condição com próteses, do que aqueles com alteração cognitiva. **Conclusão:** Idosos com melhor cognição apresentaram melhor reconhecimento de fala em condições de escuta difícil.

Palavras-chave: Idosos; Auxiliares de audição; Cognição; Inteligibilidade de fala; Percepção de fala

Study carried out at Curso de Fonoaudiologia, Universidade Federal de São Paulo – UNIFESP – São Paulo (SP), Brasil.
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[1]Escola Paulista de Medicina – UNIFESP – São Paulo (SP), Brasil.
[2]Universidade de São Paulo – USP – São Paulo (SP), Brasil.
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Corresponding author: Maria Cecília Martinelli Iório. E-mail: cmartinelli@uol.com.br
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INTRODUCTION

Aging occurs globally, and sensorineural hearing loss is one of the consequences of this process, which significantly impairs the quality of life (QoL) of older individuals[1]. This disorder is known as Age-Related Hearing Loss (ARHL) or presbycusis. Older individuals with this type of loss present decreased audibility and, consequently, reduced speech intelligibility[2]. In these cases, fitting of hearing aids is one of the first steps towards the rehabilitation of individuals with ARHL[3].

Amplification aims at providing audibility of speech sounds at safe and comfortable levels. To this end, the parameters of gain and output of the hearing aids are calculated using prescriptive methods. After selecting the prescriptive method and fitting the hearing aid, it is important to verify the adjustments made, so that the access provided to acoustic information by sound amplification can be evaluated [4].

One of the procedures of the verification stage includes the amplified speech intelligibility index (SII), which determines how much of the speech signal is accessible. The Speech Intelligibility Index (SII) calculates the percentage of speech sounds to which patients have access (0-100%) with and without amplification[5]. This measure is used in Audiology clinical practice as a tool to verify the fit of hearing aids insofar as it is sought to achieve the predetermined targets of acoustic gain and, from this adjustment, quantify how much of the speech signal is accessible. It is known that not all speech sounds will be audible, even with amplification, depending on the degree and configuration of the hearing loss [6]. The purpose of amplification is to provide audibility of most speech sounds. However, it is also known that speech recognition (communication) involves both audibility and the cognitive processes of attention and memory, among others that are determinant for the effective use of this information. Thus, the adjustment of a sound amplification system is intended to provide audibility, but the communicative performance of an individual will depend on several aspects, such as cognitive processes, schooling, cultural level, etc.

According to some studies[7,8], the most frequent complaint of older listeners refers to their difficulty in understanding speech in situations of unfavorable communication, such as in the presence of noise, in reverberant environments, and with increased speech rate of interlocutors.

Speech recognition in noise depends not only on making speech audible, but also on non-audiometric factors such as temporal auditory and cognitive processing[9].

In noise, the effort to listen also increases, that is, the cognitive demand to process sound information is greater[10]. Only recently has there been concern to study the cognitive aspects associated with speech processing and comprehension, which are fundamentally important for the establishment of diagnoses and intervention strategies, selection of appropriate treatments, and improvement of the auditory QoL of the geriatric population[11].

Tests that use sentences as stimuli are considered the most appropriate to assess the communication of individuals in daily life [12], because they can demonstrate their performance in habitual speech situations. Considering that the ability to understand speech is extremely important for good communication, it is also necessary to investigate the Signal-to-noise Ratio in which the elderly users of hearing aids can recognize at least 50% of the information (sentences) because, in this way, it will be possible to understand how the presence of competitive noise and the presence or not of other impairments can interfere with the communication process of these individuals.

In this context, the hypothesis that guided the present survey was that older individuals with the same audibility of speech signals and with better cognition present greater speech recognition in the presence of competitive noise. This study aimed to investigate the effects of cognitive processes and SII in sentence recognition in noise among elderly users of hearing aids with and without cognitive disorders.

METHODS

This study was approved by the Human Research Ethics Committee of UNIFESP under protocol no. 0834/2016). All participants were informed about the procedures and signed an Informed Consent Form (ICF) prior to study commencement.

Inclusion criteria to compose the study sample were as follows:

- Aged ≥60 years;
- With bilateral moderate sensorineural hearing loss[13];
- User of hearing aids for over a year;
- With absence of other obvious impairments that could jeopardize the assessment;
- Having undergone the Alzheimer's disease Assessment Scale - cognitive subscale (ADAS-cog).

Study sample

Sixty-one medical records were selected from the archive of the Integrated Center for Assistance, Research, and Teaching in Hearing (NIAPEA) of the aforementioned Institution. Approximately, half of these medical records described results suggestive of cognitive impairment and half of them reported normal results. Twenty-three patients were selected from the first group. The other patients in this group could not participate in the study for various reasons. In order to obtain a larger number of participants, a choice was made for a search in the medical records of the Center for individuals who had been submitted to hearing screening using the 10-point Cognitive Screener (10-CS)[14]. This screening integrates the assessment protocol of adult and elderly patients of the hearing aid fitting clinic since 2016.

After analysis of the medical records, the final sample of the study was composed of 34 older individuals with bilateral moderate sensorineural hearing loss aged 64-87 years[13], users of hearing aids for over a year.

Participants were divided into two groups according to cognitive status and the results obtained in the 10-CS, which was applied in the first assessment session at the time they were recruited for the study:

GA – 21 older individuals without cognitive disorders;

GB – 13 older individuals with cognitive disorders.

Procedures

Cognitive screening (10-point Cognitive Screener - 10-CS)

Cognitive screening was applied to all study participants aiming to classify their cognitive status. The 10-point Cognitive Screener (10-CS), whose score ranges from 0 to 10 points, evaluates temporal orientation, word recall, and category fluency. Individuals are more likely to present cognitive impairment when their score is <7 points. Considering that schooling can influence the test, a scale is used for education-effect adjustments. The test application time was approximately ten minutes.

Audiological assessment

Patients underwent routine monitoring, which included meatoscopy, pure-tone and vocal audiometry, and verification of hearing aid fitting. Patients who had not made effective use of amplification were reoriented and summoned to a new evaluation after effective use of the hearing aids. Eight hours daily were considered as effective use of the hearing aids. Time of use was verified by the data logging when available and, when not, through information provided by the patient. All hearing aids were class B, digital, with noise suppressor and feedback management, but not all of them provided data logging.

Electroacoustic verification - Speech Intelligibility Index (SII)

In order to assess whether the amplification provided was adequate, the older individuals were submitted to verification of hearing aid fitting by means of probe microphone measurements. The probe microphone measurement was performed to obtain the Speech Intelligibility Indexes (SII). This study was conducted *in situ* using an Audioscan, Verifit VF-1® analyzer. Patients were evaluated after effective use of the prescribed amplification based on the National Acoustics Laboratories/Non-linear 2 (NAL/NL2) prescription.

The test was performed with the patients seated at 0º azimuth and 80 cm away from the equipment loudspeaker, with the probe microphone positioned 5 mm distant from the tympanic membrane, the reference microphone immediately below the auricle, and the hearing aid placed in the external acoustic meatus (ensuring that the tip of the probe microphone was not occluded by the hearing aid).

The stimulus used for the measurement was the International Speech Test Signal (ISTS)[15], which was created from recordings in six different languages, completely unintelligible, but internationally accepted for testing hearing instruments at 65 dBNPS.

Based on the measurement (values should be within ±4 dB of the target values), the equipment calculated and made the SII available for the speech stimulus presented at 65 dBNPS and amplified by the hearing aid. These data enable percentage quantification of access to the speech sounds.

Hearing aid maximum output with tone burst stimulus at 85 dBNPS was also measured to ensure that it was below the average levels of discomfort estimated for the population[16].

Patients whose results were not within the prescribed targets had their hearing aids readjusted so that the targets could be achieved, and resumed their assessments after 15 days. Those who presented adequate results continued with the assessments on the same day.

Brazilian Portuguese Sentence List Test (SLT-BR)

Subsequently, the study participants were submitted to the Brazilian Portuguese Sentence List Test (SLT-BR)[17].

The test was applied under free-field conditions, in acoustically treated environment, using a GSI audiometer coupled with a CD player to present the sentences and the noise, which were recorded in independent channels. Signal-to-noise (S/N) ratios were obtained, in which 50% of the sentences presented in noise at 65 dB(A) using loudspeakers were recognized, with the participants positioned at a distance of 1 m from the loudspeaker at 0° azimuth. The participating older individuals were assessed with and without hearing aids. A sequential strategy of the up-and-down type was used in the present study[18]. According to this strategy, competitive noise is maintained at 65 dB (A) and the first sentence is presented to the individual at an S/N ratio equivalent to zero. If a correct response is obtained, the S/N ratio is decreased in the next stimulus; if an incorrect response is obtained, the S/N ratio is increased in the following stimulus. Intervals of 4 dB were used and, from the first change of response, the sentences were presented with intervals of 2 dB (Chart 1).

Based on this strategy, it was possible to determine the S/N ratio of the presented stimuli and calculate its difference between the mean intensity of the sentences presented and the level of competitive noise. A positive difference shows that the individual needs the speech signal intensity to be higher than the noise level, whereas a negative difference demonstrates that the individual requires the speech signal intensity to be lower compared with the competitive noise.

List 1A was used for training the patients, whereas Lists 1B and 2B were presented to obtain S/N ratios with and without hearing aids, respectively.

Chart 1. Parameters used in the application of the Brazilian Portuguese Sentence List Test (SLT-BR)

Parameter	Standard setting
List of sentences used for training	1A
List of sentences (without hearing aids)	2B
List of sentences (with hearing aids)	1B
Initial level of speech stimulus	65 dB
Noise Level	65 dB
Increase of first sentences	4 dB
Increase of sentences from error	2 dB
Maximum equipment output	120 dB

Statistical analysis

Data were analyzed using the Mann-Whitney and Chi-squared tests. A significance level of 5% ($p \leq 0.05$) was adopted for all statistical analyses; this value is marked with an asterisk (*) throughout this manuscript.

RESULTS

Characterization of the study sample

Group GA (without evidence of cognitive disorders) was composed of 21 older individuals aged 64-87 years and group GB (with evidence suggestive of cognitive disorders) comprised 13 older individuals aged 71-84 years.

In order to characterize the study sample, descriptive statistics of the variables age, gender, and education level were calculated and a comparative analysis was conducted between the groups GA and GB according to these variables.

No statistically significant difference was observed between groups GA and GB regarding the variable age (Table 1).

No statistically significant differences were found between groups GA and GB with respect to the variables gender and education level (Tables 2 and 3, respectively).

Study of the Speech Intelligibility Index (SII) and Signal-to-noise Ratio (S/N ratio)

SII mean values were obtained in the verification of the hearing aids, under the conditions with and without amplification, in the older individuals with and without cognitive impairments, in order to quantify the percentage of access to speech sounds with and without amplification (Table 4).

No statistically significant difference was observed between the SII results obtained in both groups under the conditions with and without hearing aids.

The Brazilian Portuguese Sentence List Test (SLT-BR) was used to determine the Signal-to-noise ratio (S/N ratio), in which 50% of the sentences with competitive noise were recognized in groups GA and GB.

Older individuals without evidence of cognitive disorders presented lower mean S/N ratio in the conditions with and without hearing aids. Under the condition with hearing aids, this difference was statistically significant (Table 5).

Table 1. Mean age of the older individuals in groups GA and GB and comparative study between the groups

		GA	GB	*p* value	Result
Age	Mean	76.6	77.5		
	Median	78.0	77.0	0.780	A = B
	SD	6.9	3.8		
	N	21	13		

Subtitle: N = number of individuals; GA = group without cognitive impairment; GB = group with cognitive impairment; SD = standard deviation

Table 2. Distribution of the study sample by group and comparative study according to gender

		GA		GB				*p* value	Result
		N	%	N	%	N	%		
Gender	**F**	13	61.9	8	61.5	21	61.8		
	M	8	38.1	5	38.5	13	38.2	1.000	A = B
Total		21	100.0	13	100.0	34	100.0		

Subtitle: N = number of individuals; GA = group without cognitive impairment; GB = group with cognitive impairment; F = female; M = male

Table 3. Distribution of the study sample by group and comparative study according to schooling

		GA		GB				*p* value	Result
		N	%	N	%	N	%		
Education level	Elementary School - Complete	2	9.5	0	.0	2	5.9		
	Elementary School - Incomplete	15	71.4	8	61.5	23	67.6		There is no
	High School - Complete	2	9.5	2	15.4	4	11.8	Not applicable	evidence of
	High School - Incomplete	1	4.8	1	7.7	2	5.9		differences
	Illiterate	1	4.8	2	15.4	3	8.8		
Total		21	100.0	13	100.0	34	100.0		

Subtitle:: N = number of individuals; GA = group without cognitive impairment; GB = group with cognitive impairment

Table 4. Descriptive statistics and comparative study of Speech Intelligibility Index between older individuals with and without hearing aids in groups GA and GB

		SII (without)	SII (with)	*p* value	Result
GA	Mean	14.3	50.3	0.834	
	Median	8.00	48.5		GA = GB
	SD	14	13.4		
	N	21	21		
GB	Mean	12.8	49.6	0.889	
	Median	8.0	51.5		GA = GB
	SD	9.7	10.7		
	N	13	13		

Subtitle: SII = Speech Intelligibility Index; N = number of individuals; GA = group without cognitive impairment; GB = group with cognitive impairment; SD = standard deviation

Table 5. Means and medians of Signal-to-noise Ratio with and without hearing aids according to presence of cognitive impairment

		GA	GB	*p* value	Result
List 1B S/N (with PSAP)	Mean	7.01	9.17		
	Median	7.40	9.80	0.050*	A < B
	SD	3.22	2.78		
	N	21	13		
List 2B S/N (without PSAP)	Mean	4.91	5.52		
	Median	4.40	5.60	0.276	A = B
	SD	3.48	1.90		
	N	21	13		

*Significance level ($p \leq 0.05$) – Mann-Whitney test

Subtitle: S/N = Signal-to-noise ratio; PSAP = Personal Sound Amplification Product; N = number of individuals; GA = group without cognitive impairment; GB = group with cognitive impairment; SD = standard deviation

DISCUSSION

In this section, the results obtained in the present study will be discussed and confronted, when possible, with those reported in the specific scientific literature.

About characterization of the study sample

Group GA (without evidence of cognitive disorders) was composed of 21 older individuals (13 women (61.9%) and eight men (38.1%)) aged 64-87 years and group GB (with evidence suggestive of cognitive disorders) comprised 13 older individuals (eight women (61.5%) and five men (38.5%)) aged 71-84 years. No statistically significant difference was found between the groups regarding the variables gender and age (Tables 1 and 2, respectively).

Although no statistically significant difference was observed between the groups with respect to the variable gender, the number of women was larger than that of men in both groups. In general, women live six to eight years longer than men on average, thus they tend to present lower death rates at all ages[19].

The health of older women varies significantly from culture to culture and from country to country[19], but work environment, lower prevalence of smoking and alcohol use, differences in attitude before diseases, and disabilities[20] are factors that promote longevity in women.

In this study, Elementary School - Incomplete was the predominant education level in both groups (Table 3). A study conducted by Pilger et al.[20] verified a high percentage of older individuals with little or no schooling. The authors reflect that, due to this reality, it is possible to understand the reason why many public initiatives and non-governmental actions turn to literacy and continuing education of adult and elderly individuals, because they influence their social and economic life and their search for health services. As reported in the aforementioned study, the sociodemographic profile of Brazilian older individuals shows that a large part of the urban population is affected by illiteracy.

According to a national study[21], schooling should always be analyzed, because individuals with higher education level present better performance in communication situations. Most cognitive screening instruments can be adjusted according to education level, as it occurred with the instrument used in the present survey - 10-CS[14].

Discussion on Speech Intelligibility Index (SII) and speech perception in the presence of competitive noise

No statistically significant differences between the SII scores were observed in both groups and both conditions - with and without use of hearing aids These results demonstrate that the older individuals in the group without evidence of cognitive

disorders and those in the group with evidence suggestive of cognitive disorders presented the same percentage of access to speech sounds with and without hearing aids (Table 4).

Data of this research suggest that the older individuals in both groups presented access to 50% of the speech sounds on average, which is considered appropriate[22]. It is known that not all speech sounds will be audible, depending on the degree and configuration of the hearing loss. The purpose of amplification is to provide audibility, and the use of Visible Speech Mapping shows, in a more concrete and visual way, how much audibility is being provided. However, the simple provision of audibility is not sufficient for understanding speech. What each individual will do with auditory information depends on several aspects, such as selective attention (figure-background and closure), cognition, education level, etc.

Understanding speech is one of the most important elements in human communication, and this is the reason why the use of sentences is considered the most accurate instrument to assess the communication of individuals, because their performance before sentences will provide results of everyday speech situations[8,12,21]. Habitual speech situations are typically associated with presence of competitive noise, and this aspect is also one of the complaints most frequently mentioned by older individuals[23]. Therefore, in this study, a choice was made for the use sentence recognition tests with presence of competitive stimulus (noise), under free-field conditions, so that the individuals could be assessed in a situation more closely related to the daily lives.

Thus, it was necessary to calculate the Signal-to-noise Ratio (S/N ratio), which is the difference between speech signal levels and noise. The higher the S/N ratio, the greater the difficulty for speech comprehension in the presence of competitive noise. The results revealed that older individuals in the group GA (without cognitive impairment) presented lower mean S/N ratio under both conditions - with and without hearing aids.It was possible to verify that the older individuals with results compatible with absence of cognitive disorders required the signal to be at least 7.01 louder than the noise on average, whereas those with results suggestive of cognitive impairments needed the signal to be 9.17 louder than the noise on average, so that they could recognize 50% of the sentences in the condition with hearing aids, and this difference was statistically significant (Table 5). Such data are compatible with the hypothesis that older individuals with better cognition present greater speech recognition in the presence of competitive noise.

It was also possible to verify that the older individuals with results compatible with absence of cognitive disorders required the signal to be at least 4.91 louder than the noise on average, whereas those with results suggestive of cognitive impairments needed the signal to be 5.52 louder than the noise on average, so that they could recognize 50% of the sentences in the condition without hearing aids. Although the older individuals in group GA presented lower mean S/N ratio, this difference was not statistically significant (Table 5).

Speech recognition in noise presents a demand for cognitive skills that are declining in the elderly population[24]. Other studies have also verified a correlation between speech recognition in noise and cognition. These data are similar to the findings of a study[25] that reported that older individuals with results suggestive of cognitive disorders presented higher S/N ratio to recognize 50% of the sentences presented.

A study[26] conducted in the aforementioned Institution found correlation between the S/N ratio scores of the SLT-BR and the cognitive tests (Alzheimer's Disease Assessment Scale - cognitive subscale - ADAS-cog and Mini-Mental State Examination - MMSE). The lower the cognitive level, the worse the performance of older individuals in noise. Findings of the aforementioned survey show that education level, cognitive performance, and symptoms of depression influenced the speech recognition in noise of elderly users of hearing aids. The higher the cognitive level, the better the performance of the older individuals.

Studies[3,7,8] have demonstrated that a common complaint among the elderly population refers to the difficulty in understanding speech in presence of competitive noise. When difficulty in understanding speech is observed, especially in noise, it is suggested that temporal processing is in decline [7].

Results of the present study demonstrated that the access to the speech signal, reported by the SII, was similar in the two groups analyzed and, therefore, did not determine speech recognition performance in noise. Investigation of the complaint about difficulty in understanding speech in noise and, consequently, the S/N ratio required for greater speech recognition may be fundamentally dependent on cognitive functions, as they can interfere with the process of quality of life (QoL) rehabilitation in the elderly population.

CONCLUSION

Access to speech sounds - Speech Intelligibility Index (SII) - does not determine the performance of older individuals with hearing loss in the presence of competitive noise. Assuming similar audibility of the participants in both groups, older individuals without cognitive disorders required lower Signal-to-noise ratios, on average, to recognize 50% of the sentences under the conditions with and without hearing aids.

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