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Cognitive and auditory aspects: the effect of aging on the decline of speech recognition

Aspectos cognitivos e auditivos: o efeito do envelhecimento no declínio do reconhecimento de fala

Aspectos cognitivos y auditivos: el efecto del envejecimiento sobre la disminución del reconocimiento de voz

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Abstract

Introduction: Difficulties in communicative performance and speech recognition in noise are associated with aging. The decline in speech recognition with competitive noise is due to a combination

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of auditory and non-auditory factors that worsens over time and with aging. **Objective**: To identify the cognitive and auditory aspects that contribute to the decline of speech recognition in noise in the elderly. **Method:** This is a prospective, analytical, observational and cross-sectional study. The sample consisted of two groups: one of adults and one of elderly, selected according to the following inclusion criteria: normal listeners; between 18 and 70 years old, of both sexes. The cognitive aspects were analyzed with the Montreal Cognitive Assessment and, in the auditory processes, pure-tone audiometry threshold tests, psychophysical speech recognition in difficult listening and temporal resolution were applied. Results: When compared by age group, psychoacoustic tests showed significant differences in conditions: 1) SSI / RE - SNR 0 (p = 0.001), 2) SSI / RE - SNR -15 (p = 0.000), 3) HINT / LE SNR -10 (p = 0.03), 5) HINT / LE SNR -15 (p = 0.02) when the Mann Whitney U test was applied. GIN and DDT tests did not show significant differences. When the psychoacoustic tests were compared regardless of the age group, the subjects with normal and changed MoCA did not present significant differences (p = 0.280). **Conclusion:** From the studied sample, cognitive aspects did not contribute to the performance of speech perception with competitive stimuli when comparing the adults and the elderly. On the other hand, the assessed auditory aspects showed that the elderly have greater difficulties in understanding speech in noise when compared to younger individuals.

Keywords: Auditory Perception; Speech Perception; Noise; Aging; Hearing.

Resumo

Introdução: Dificuldades de desempenho comunicativo e de reconhecimento de fala em ambientes ruidosos são associadas ao envelhecimento. O declínio do reconhecimento da fala com ruído competitivo é devido a uma combinação de fatores auditivos e não-auditivos que acentuam ao longo do tempo e com o avanço da idade. **Objetivo:** Identificar os aspectos cognitivos e auditivos que contribuem para o declínio do reconhecimento de fala no ruído em idosos. **Método:** Trata-se de um estudo prospectivo, analítico, observacional e transversal. A amostra foi composta por dois grupos: um de adultos e outro de idosos, selecionados conforme os seguintes critérios de inclusão: ouvintes normais; idade entre 18 e 70 anos, de ambos os sexos. Os aspectos cognitivos foram analisados pelo *Montreal Cognitive Assessment* e, nos processos auditivos, foram aplicados testes de audiometria tonal limiar, psicofísicos de reconhecimento de fala em escuta difícil e de resolução temporal. **Resultados:** Quando comparados por grupo etário, os testes psicoacústicos apresentaram diferenças significativas nas condições: 1) SSI / OD - S/R 0 (p=0,001), 2) SSI / OD - S/R -15 (p=0,000), 3) HINT / OE S/R -10 (p=0,03), 5) HINT / OE S/R -15 (p= 0,02) quando aplicado o teste *Mann Whitney U.* Quando comparados por grupo etário, os testes GIN e TDD não apresentaram diferenças significativas. Já quando os testes psicoacústicos foram comparados independentes do grupo etário, os sujeitos com MoCA normal e alterados não apresentaram diferenças significativas (p=0,280). **Conclusão:** A partir da amostra estudada, observou-se que os aspectos cognitivos não contribuíram no desempenho da percepção de fala com estímulos competitivos quando comparados os grupos de adultos e idosos. Por outro lado, os aspectos auditivos avaliados mostraram que os idosos apresentam maiores dificuldades de compreensão da fala no ruído quando comparados aos indivíduos mais jovens.

Palavras-chave: Percepção Auditiva; Percepção da Fala; Ruído; Envelhecimento; Audição.

Resume

Introducción: Las dificultades en el desempeño comunicativo y el reconocimiento del habla en entornos ruidosos están asociadas con el envejecimiento. La disminución del reconocimiento de voz con ruido competitivo se debe a una combinación de factores auditivos y no auditivos que se acentúan con el tiempo y con la edad**. Objetivo:** Identificar los aspectos cognitivos y auditivos que contribuyen al declive del reconocimiento del habla en ruido en las personas mayores. **Método:** Se trata de un estudio prospectivo, analítico, observacional y transversal. La muestra estuvo conformada por dos grupos: uno para adultos y otro para ancianos, seleccionados según los siguientes criterios de inclusión: oyentes normales; entre 18 y 70 años, de ambos los sexos. Los aspectos cognitivos fueron analizados por la Evaluación

Cognitiva de Montreal y, en los procesos auditivos, se aplicaron pruebas de audiometría tonal umbral, reconocimiento psicofísico del habla en audiencias difíciles y resolución temporal. Resultados: Cuando se compararon por grupo de edad, las pruebas psicoacústicas mostraron diferencias significativas en las condiciones: 1) SSI / OD - S / R 0 (p = 0,001), 2) SSI / OD - S / R -15 (p = 0,000), 3) HINT/ OE S / R -10 (p = 0.03), 5) HINT / OE S / R -15 (p = 0.02) cuando se aplicó la prueba Mann Whitney U. Las pruebas GIN y TDD no mostraron diferencias significativas. Cuando se compararon las pruebas psicoacústicas independientemente del grupo de edad, los sujetos con MoCA normal y alterado no presentaron diferencias significativas (p = 0,280). **Conclusión**: De la muestra estudiada, se observó que los aspectos cognitivos no contribuyeron al desempeño de la percepción del habla con estímulos competitivos al comparar los grupos de adultos y ancianos. Por otro lado, los aspectos auditivos evaluados mostraron que los ancianos tienen mayores dificultades para comprender el habla en ruido en comparación con los **más** jóvenes.

Palabras clave: Percepción auditiva; Percepción del habla; Ruido; Envejecimiento; Escuchando.

Introduction

In many social interactions permeated by oral communication, the interlocutor's speech is just one among other sounds within the environment. Many sounds, such as noise, in the same frequencies as speech, can affect the individual's perception while listening. Thus, elderly people may tend to social isolation due to an inability to adapt to the impaired speech intelligibility, leading to difficulties to maintain social relationships [1,2]. For proper speech recognition in the presence of competitive noise, the interlocutor needs to integrate, at a cortical level, the speech segments or the acoustic cues perceived by the numerous time windows and/or frequency characteristics, and only then assign meaning to this acoustic material. Such an integrative process guarantees the success of the communicative performance in situations of listening to speech concomitantly with noise [2,3].

Difficulties in communicative performance and speech recognition in noise have been associated with aging. Sensory hearing loss resulting from deficits in the peripheral auditory system, frequent in the elderly population, is indicated as one of the causes of the elderly's difficulty in recognizing speech sounds [4,5].

However, deficits of the peripheral system itself do not explain, completely, the difficulties of speech recognition in noise in the elderly. Elderly people with normal hearing thresholds, when compared to young listeners, have greater difficulty in recognizing speech in noise [6-9]. As an aggravating factor, compensatory cognitive strategies, frequently used in these situations, also seem to have less effect on older people, challenging communicative performance [3].

The decline in communicative performance related to the difficulty in speech recognition in the elderly is, in general, masked through compensatory mechanisms and strategies used in difficult listening situations[3,10].

A possible explanation for the mnemonic impairment related to the aging effect is found in the changes in basic mechanisms underlying cognition, such as the reduction of information processing resources, including working memory, processing speed and inhibition mechanisms. Broader and more diffuse brain activations of frontal and temporal ventral, medial and superior areas are recorded in Functional Magnetic Resonance Imaging during speech comprehension activities in relation to young and adult populations that have activation more restricted to auditory cortical areas [3,10].

Sensory hearing loss degrades auditory input. To understand speech in noise, the elderly individual with this limitation needs a greater perceptual effort in comparison with the younger subject. Therefore, in these environments, the aged auditory system possibly activates compensatory processes to obtain better communicative performance (top-down). The discussion about this process lies on the need to use more cognitive resources, which are diverted to the perception (identification) of the word, with few resources remaining available for other tasks at a higher cognitive level, such as: understanding and memory of the words that were identified [11].

Thus, the Montreal Cognitive Assessment test (MoCA) is used as a brief screening tool, which assesses a wide range of cognitive functions (such as executive functions, visuospatial skills, nam-

ing, memory retrieval, digits, sentence, abstract reasoning and orientation) needed to contribute to the diagnosis of mild cognitive impairment [12].

Thus, as life expectancy increases every year, understanding the physiological processes of aging for the development of preventive and interventionist actions in this population is increasingly necessary. In this context, the objective was to identify the cognitive and auditory aspects that contribute to the decline in speech recognition in noise in the elderly.

Method

This is a prospective, analytical, observational and cross-sectional study, approved by the ethics committee of a Public University in Alagoas with CAAE nº. 60777416.4.0000.5011.

The sample consisted of two groups: one composed of adults (18 to 59 years) and the other of elderly people (60 to 70 years), selected according to the following inclusion criteria: normal listeners, with auditory sensitivity, that is, hearing thresholds equal to or below 20 dB HL (ANSI -1969), with frequency differences between the ears equal to or below 10 dB; aged between 18 and 70 years, of both sexes; without cerumen or foreign body in the external auditory meatus on visualization. As exclusion criteria, the following were established: life history for exposure to occupational or leisure noise; ear surgeries; over three ear infections in the current year; use of ototoxic medication; presence of tinnitus, vertigo, dizziness or other cochleovestibular changes; presence of systemic changes that may contribute to cochleovestibular diseases, such as diabetes, hypertension, etc.

Before the onset of the procedures, ethical aspects were addressed by reading the Informed Consent Form and after acceptance, the procedures were started.

The examinations were carried out in a laboratory of a Higher Education Institution of Alagoas. Initially, individuals were submitted to anamnesis to collect demographic data, including date of birth, gender, education level, occupation, hearing complaints, tinnitus and dizziness; inspection of the external auditory canal and pure-tone and vocal audiometry. Subsequently, the Montreal Cognitive Assessment test (MoCA) was performed to assess the subjects' cognitive abilities. The MoCA is a brief screening instrument, which assesses eight cognitive domains, including: visuospatial/executive function, naming, memory, attention, language, abstraction, delayed recall and spatiotemporal orientation[12]. The Brazilian version was used [13].

Following, psychoacoustic tests were performed using a two-channel audiometer model AC40, Interacoustics, calibrated according to the American National Standards Institute (ANSI), 1969, in an acoustic booth, to assess speech recognition in difficult listening conditions and temporal resolution assessment, as described below:

Sentence recognition in noise: The participants were instructed to repeat the simple sentences presented to them on the earphones, in a sound attenuated booth. The speech material used for this evaluation consisted of sentences from the Hearing in Noise Test (HINT) in the Brazilian Portuguese version[14], which is composed of everyday use sentences. As suggested by Bevilacqua[14] (2008), the noise is fixed at 65 dB and the intensity of the speech signal varies according to the repetitions, that is, with each correct answer the speech intensity decreases and with each error the intensity increases. The initial speech intensity is 65 dB, that is, signal/noise ratio (SNR = 0); during the presentation of the first four sentences, variations occur every 4 to 4 dB, which allows estimating the subject's threshold. From the fifth sentence on, the variation decreases to every 2 to 2 dB and the threshold of each test condition is determined after the presentation of the 20 sentences from the selected list. Competitive noise consisted of white noise, presented in a monaural way.

Sentence recognition in monotic listening - SYNTHETIC SENTENCE IDENTIFICATION TEST WITH IPSILATERAL COMPETITIVE MESSAGE (SSI/ICM): A competitive message was presented in the ipsilateral condition (ICM) to the tested ear, and ten sentences were presented for each signal/noise ratio of 0 dB and -15 dB in both ears. During the test, the volunteer was instructed to indicate the sentences written in black on a white board in legible letters[15]. The synthetic sentences were presented at a sound level fixed at 40dB SL above the mean of the air-conduction auditory pure tone thresholds at frequencies of 500, 1000 and 2000 Hz.

Recognition of familiar words in dichotic listening - DICHOTIC DIGIT TEST (DDT): The digits were presented in dichotic listening, two submitted to the right ear and two to the left ear, each pair overlapped on each different ear, simultaneously. The sound level was 50 dB SL above the mean of the air- conduction pure-tone auditory thresholds at 500, 1000 and 2000 Hz. The patient was instructed to orally repeat the four heard words regardless of the presented order and the ear that received the stimulus.

Gaps identification test in noise segments - GAPS-IN-NOISE TEST (GIN): The temporal resolution assessment test was presented monaurally at 50 dB SL above the speech recognition threshold score (SRT). The requested task was the identification of the silence intervals, in milliseconds, distributed in white noise presentations [16].

Statistical analysis

Data were tabulated and processed with the Predictive Analytics Software - PASW® Statistic version 23.0 for computer application. For data description, the tabular and graphical presentation of means and standard deviations were used. Sample normality was observed using the Kolmogorov-Smirnov test.

To detect differences between the numerical variables of the control and experimental groups, the Mann-Whitney test for independent variables was applied. For the association among the MoCA test and the psychoacoustic test results, the bivariate correlation test with degree of linear relationship was used through Spearman's coefficient. Alpha values were considered significant when below 0.05.

Results

The sample consisted of 30 participants, 10 elderly and 20 adults, ages ranging from 20 to 58 years (mean age of 35.15 years and standard deviation of 13.78 years) for the group of adults, and 60 to 70 years (mean age of 64.6 and standard deviation of 3.45) for the elderly group.

Regarding gender, in both groups they were: 76.66% female and 23.33% male. In the adult group, 25% of participants were male and 75% female. In the elderly group, 20% were male and 80% female.

Regarding information on education level, the adult group was composed of individuals with higher education, while in the elderly group they all had completed high school. Regarding the data investigated in the anamnesis (hearing complaints, tinnitus and dizziness), individuals had no auditory and/or vestibular signs or symptoms.

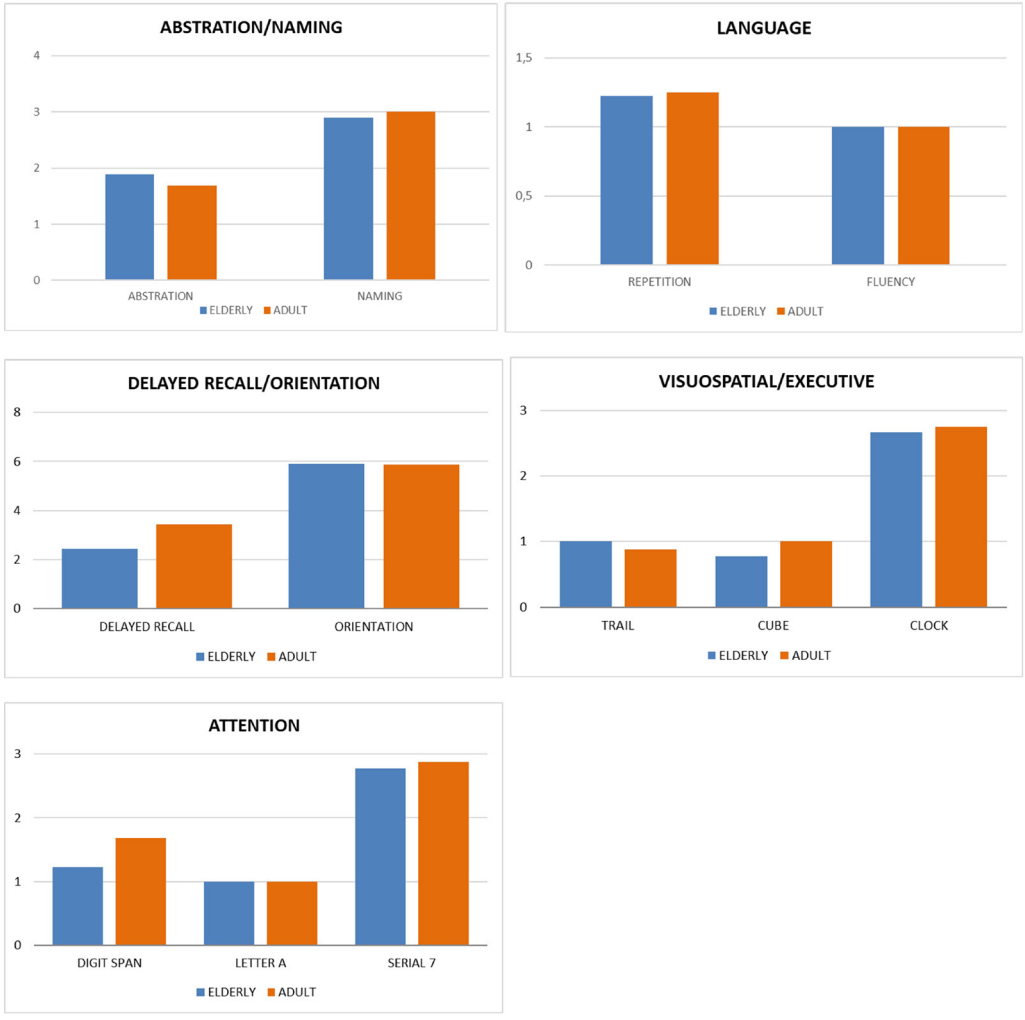
In the MoCA description, regardless of the age group, normal scores had an average of 26.83 points, while those with changed scores had an average of 22.66 points. MoCA scores by age group are described in Table 1.

Table 1. Descriptive and analytical statistics of MoCA scores (in points).

		Mean	Standard Deviation	CI Upper	CI Lower	p Value
MoCA	Adult	25.55	2.81	26.86	24.23	0.280*
	Elderly	24.40	2.41	26.12	22.67	

Caption: MoCA (Montreal Cognitive Assessment) *Independent T-test.

Regarding the assessed cognitive domains (visuospatial/executive function, naming, memory, attention, language, abstraction, delayed recall and spatiotemporal orientation), the elderly, regardless of normal or changed MoCA scores, presented similar results to adults, as observed in Figure 1.



Abstraction/naming (elderly, adult) – language (repetition, fluency)
Delayed recall / orientation – visuospatial/executive (clock, trail, cube)
Attention (Digit span, Letter A, Serial 7)

Figure 1. Descriptive statistics of cognitive domain scores assessed by MoCA, by age group.

Regarding the SSI and HINT psychoacoustic tests, descriptive and analytical statistics data can be observed in Tables 2 and 3, evaluated by age group.

Figures 2 and 3 present the GIN and DDT descriptive analysis.

Table 2. Descriptive statistics of SSI scores (by percentage of correct answers) per ear and SNR.

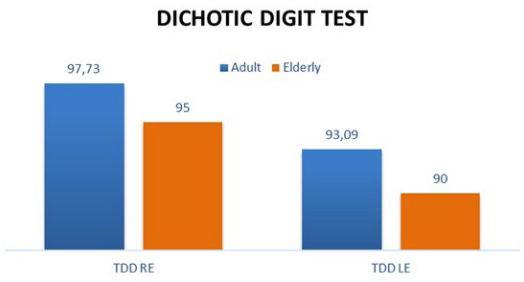
		Mean (% of correct)	Standard Deviation	Upper bound	Lower bound	p Value
SSI / RE SNR 0	Adult	90.00	11.88	95.90	84.09	0.001*
	Elderly	61.00	17.28	73.36	48.63	
SSI / LE SNR 0	Adult	82.77	19.64	92.54	73.00	0.14
	Elderly	59.00	20.78	73.87	44.12	
SSI / RE SNR -15	Adult	83.88	25.8	95.59	72.17	
	Elderly	-	-	-	-	
SSI / LE SNR -15	Adult	82.22	15.16	89.76	74.67	
	Elderly	-	-	-	-	

Caption: SSI (Synthetic Sentences Identification Test with Ipsilateral Competitive Message). SNR (Signal-to-Noise Ratio). RE (right ear) / LE (left ear).
*Mann-Whitney statistical test

Table 3. Descriptive statistics of HINT scores (by percentage of correct answers) per ear and SNR.

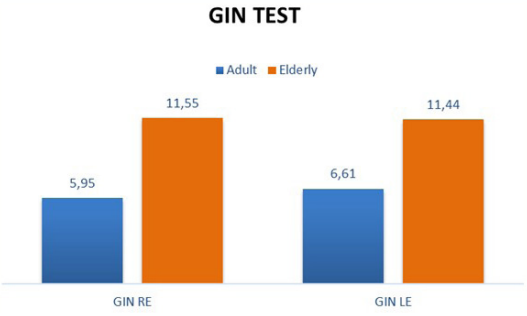
		Mean (% of correct)	Standard Deviation	Upper bound	Lower bound	p Value
HINT / RE SNR 0	Adult	19.95	0.22	20.05	19.83	0.35
	Elderly	19.66	0.57	21.10	18.23	
HINT / LE SNR 0	Adult	19.9	0.45	20.11	19.67	0.65
	Elderly	20	0	-	-	
HINT / RE SNR -10	Adult	19.84	0.37	20.02	19.66	0.40
	Elderly	18.66	1.52	22.46	14.64	
HINT / LE SNR -10	Adult	19.89	0.31	20.04	19.89	0.03*
	Elderly	19.66	0.57	21.10	18.23	
HINT / RE SNR -15	Adult	19.31	0.82	19.71	18.92	0.11
	Elderly	19.33	0.57	20.76	17.89	
HINT / LE SNR -15	Adult	18.89	2.82	20.25	17.53	0.02*
	Elderly	18.66	1.57	22.46	14.87	

Caption: HINT (Hearing in Noise Test). SNR (Signal-to-Noise Ratio). RE (right ear) / LE (left ear). *Mann-Whitney statistical test.



Dichotic Digit Test
Adult - Elderly
DDT RE – DDT LE
Caption: DDT (dichotic digits test). RE (right ear) / LE (left ear).

Figure 2. Descriptive statistics of DDT scores (by percentage of correct answers) per ear..



GIN Test
Adult - Elderly
GIN RE – GIN LE
Caption: GIN (Gaps-In-Noise)

Figure 3. Descriptive statistics of GIN scores (gap in milliseconds) per ear.

Descriptive analysis of the samples was observed using the Kolmogorov-Smirnov test, and after its completion, a non-normal sample was observed, thus non-parametric tests were performed.

When compared by age group, the psychoacoustic tests showed significant differences in conditions: 1) SSI / RE - SNR 0 (p=0.001), 2) SSI / RE - SNR -15 (p=0.000), 3) HINT / LE SNR -10 (p=0.03), 5) HINT / LE SNR -15 (p=0.02) when applying the Mann Whitney U test.

When compared by age group, the GIN and the DDT tests did not show significant differences.

When the psychoacoustic tests (SSI, DDT, GIN and HINT) were compared regardless of the age group, subjects with normal and changed MoCA did not show significant differences (p=0.280).

In order to correlate the cognitive domains (visuospatial/executive function, naming, memory, attention, language, abstraction, delayed recall and spatiotemporal orientation) and the psychoacoustic tests (SSI, DDT, GIN and HINT), the Correlation Test using Spearman's coefficient was used. It was observed that there was no correlation between the assessed domains and the psychoacoustic tests. It was only possible to observe an inverse correlation from moderate to strong (-0.69) in the SSI test for age. In the HINT, there is a moderate inverse correlation (-0.40) also for age.

Discussion

Aging is often accompanied by cognitive decline. Therefore, it is important to assess auditory and cognitive aspects through specific tests that can measure the ability to recognize speech in noise. In the present study, the MoCA was used to assess the subjects' cognitive abilities. Nasreddine et al. [12] reported 87% of the test's specificity in terms of sensitivity to identify hearing-impaired elderly people, and 90% in normal people to detect mild cognitive impairment; in addition to the psychoacoustic tests of speech in difficult listening - dichotic and monotic listening - and of temporal resolution.

The literature reports that the elderly struggle in the various skills of central auditory processing and this difficulty intensifies with age [4,17]. Thus, complaints or difficulty in understanding speech, especially in noisy environments are often reported [3-7,18-20]. This difficulty can be observed both in individuals with hearing loss and in those with normal hearing [7]. This is in line with what was found in the present study, as both HINT and SSI had statistically significant differences. Thus, this discussion allows us to understand the difficulty in recognizing speech in noise with aging.

The ability to recognize speech in a competitive environment is a challenging task, which is part of everyday life. Therefore, the assessment of this task is important to analyze how the subject deals with usual listening situations [21]. The most appropriate test to determine how well the person is able to hear and understand in noise is the HINT, which assesses situations similar to everyday conversations [22,23]. In the present study, when comparing the two assessed age groups, the values showed statistically significant differences under the conditions: HINT / LE SNR -10 (p=0.03), HINT / LE SNR -15 (p= 0 .02). This confirms the results of the study, in

which elderly people require a higher signal/noise ratio to obtain a performance equivalent to that of younger adults in speech-in-noise tests, even if they have normal audiograms [22].

In view of the Spearman coefficient test results, an inverse correlation of moderate to strong (-0.691) was observed between the variables age and the SSI score in the right ear, which suggests that there is a reduction in the speech understanding on the test with aging. Such results corroborate the initial hypotheses of the study, and are in agreement with previous data in the literature [24].

In the present study, no significant difference was observed in the DDT test results. This is in line with the research carried out by Rosa et al., in which, the normal hearing group, even with preserved hearing, 70% of those analyzed had changed perception in the processing test. Probably, this result was found due to the sample size.

It is important to highlight that education level can directly interfere with the performance of cognitive tests, as reported by Bertolucci et al. According to Pichora-Fuller [25], for a better understanding of the influence of hearing on an individual's participation in daily activities, the age variable should be considered, as well as differences in performance.

Conclusion

From the studied sample, this study observed that cognitive aspects did not contribute to the performance of speech perception with competitive stimuli when adult and elderly groups were compared. On the other hand, the assessed auditory aspects showed that the elderly have greater difficulties in understanding speech in noise when compared with younger individuals. Thus, for the study participants, the auditory aspects were observed to contribute to a decline in the cognitive process due to speech recognition.

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