CoDAS
ISSN 2317-1782 (Online version)

Original Article
Artigo Original

Factors related to the performance of elderly people in temporal ordering tests

Fatores associados ao desempenho de idosos nos testes de ordenação temporal

Maysa Bastos Rabelo[1]
Marcia da Silva Lopes[2]
Ana Paula Corona[2]
Jozélio Freire de Carvalho[1]
Roberto Paulo Correia de Araújo[3]

Keywords

Hearing
Ageing
Hearing Tests
Auditory Perception
Auditory Perception Disorder

ABSTRACT

Purpose: To describe the performance of elderly individuals in Pitch Pattern Sequence (PPS) and Duration Pattern Sequence (DPS) tests and research related factors. **Methods:** An observational, cross-sectional study conducted with elderly people aged 60 to 79 years. The participants underwent cognitive screening tests, interviews containing socio-demographic data and general health, as well as audiologic evaluation and temporal auditory processing (PPS and DPS) evaluation tests. A descriptive analysis of the association between the performance in temporal processing and the variables gender, age, level of education and audiometric alterations was conducted through multiple linear regression. **Results:** 86 elderly people participated in the study, most of them female, with ages between 60 and 69. Male participants performed better in both tests as well as the participants with higher education, whereas no difference in performance was observed across the different age ranges. In the DPS, the participants with auditory alteration performed worse in relation to the ones with average frequencies of 0.5 to 4 kHz. **Conclusion:** The male gender and higher level of education were associated with better results in the temporal ordering tests, whereas auditory alteration was associated with worse performance only in the pitch pattern sequence test.

Descritores

Audição
Envelhecimento
Testes Auditivos
Percepção Auditiva
Transtornos da Percepção Auditiva

RESUMO

Objetivo: Investigar os fatores associados e descrever o desempenho no teste padrão de frequência e teste padrão de duração em idosos. **Método:** Estudo observacional, seccional, conduzido com idosos de 60 a 79 anos. Os participantes realizaram teste de rastreio cognitivo, entrevista contendo dados sociodemográficos e de saúde geral, avaliação audiológica e testes de avaliação do processamento auditivo temporal (padrão de frequência e padrão de duração). Foi conduzida análise descritiva da associação entre o desempenho nos testes de processamento temporal e as variáveis: sexo, idade, nível de escolaridade e alterações audiométricas, por meio da regressão linear múltipla. **Resultados:** Participaram do estudo 86 idosos, sendo a maioria do sexo feminino, com idade entre 60 e 69 anos. O desempenho para ambos os testes foi melhor nos homens e nos idosos com maior nível de escolaridade e similar nas diferentes faixas etárias. No teste padrão de frequência, idosos com alteração auditiva apresentaram pior desempenho do que aqueles com média nas frequências de 0.5 a 4 kHz normal. **Conclusão:** O sexo masculino e maior nível de escolaridade estão associados ao melhor desempenho nos testes de ordenação temporal, enquanto a alteração audiométrica apresenta associação com o pior desempenho apenas no teste padrão de frequência.

Correspondence address:
Maysa Bastos Rabelo
Departamento de Fonoaudiologia, Instituto de Ciências da Saúde, Universidade Federal da Bahia – UFBA
Endereço Av. Reitor Miguel Calmon s/n – Vale do Canela, Salvador (BA), Brasil, CEP: 40110-100.
E-mail: maysa_bastos@yahoo.com.br

Received: April 06, 2020
Accepted: August 13, 2020

Study conducted at Universidade Federal da Bahia – UFBA - Salvador (BA), Brasil.

[1] Programa de Pós-graduação Processos Interativos dos Órgãos e Sistemas, Instituto de Ciências da Saúde, Universidade Federal da Bahia – UFBA - Salvador (BA), Brasil.

[2] Departamento de Fonoaudiologia, Instituto de Ciências da Saúde, Universidade Federal da Bahia – UFBA - Salvador (BA), Brasil.

[3] Departamento de Bioquímica Oral, Instituto de Ciências da Saúde, Universidade Federal da Bahia – UFBA - Salvador (BA), Brasil.

Financial support: CAPES.

Conflict of interests: nothing to declare.

This is an Open Access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

INTRODUCTION

Hearing loss due to age-related degenerative changes is known as presbycusis, and is characterized by sensorineural impairment accompanied by reduced hearing sensitivity to pure tones, especially at high frequencies[1]. Cóser et al.[2] described the existence of significant hearing complaints in individuals without an audiological diagnosis compatible with the magnitude of the complaint. Thus, it is believed that there may be alterations at the Central Auditory Processing (CAP) level — not identified by the basic audiological assessment.

Studies have shown a relation between aging and decline in auditory capacity; however, the involvement of Central Auditory Nervous System (CANS) structures depends on extrinsic and intrinsic variables to which the individual is exposed throughout life. Extrinsic variables include the use of medication and exposure to noise, while intrinsic ones include genetic predisposition[3].

Temporal auditory processing reflects the individual's ability to process acoustic stimuli within a given time interval and seems to be the capacity most affected by aging[4]. Among temporal skills, ordering refers to discrimination of the order of occurrence of acoustic stimuli within a time interval and is directly related to speech comprehension[5].

Clinically, the tests used to assess temporal ordering skills are the Pitch Pattern Sequence (PPS) and the Duration Pattern Sequence (DPS), which assess, respectively, the ordering of sequences of sounds that differ by stimulus frequency (pitch) or duration[5]. These tests were developed by Musiek in 1994 in the United States of America (USA), and are sensitive to changes in temporal hemispheric areas and interhemispheric connections[6]. Studies in Brazil have been investigated the performance of these tests in adult individuals. For young adults aged between 17 and 30 years, Corazza[7] observed correct answers above 76% for the PPS and 83% for the DPS. Parra et al.[8], by evaluating elderly subjects aged over 60 years and with normal hearing, found that the percentage of correct answers was 49% for the PPS and 67% for the DPS, which could show an inverse correlation between age and test performance.

However, further studies have shown that central auditory skills can be influenced by gender, peripheral hearing loss and education level[9-11]. Despite the contributions of Corazza[7] and Parra et al.[8], these factors were not considered in their analyses; thus, using the standards established in these studies to interpret results in the elderly may not be the most suitable path, as it disregards the idiosyncrasies of this population[3,4].

In view of the above, the present study aimed at describing the performance of the elderly in the PPS and DPS tests as well as investigating associated factors.

METHODS

Study participants

The present study, observational and analytical, was conducted from June 2018 to January 2019, with a baseline population of individuals aged between 60 and 79 years of age who attended social and health centers of reference for the elderly located in Northeast Brazil. The study included individuals without a history of Traumatic Brain Injury (TBI) or stroke (or cerebrovascular accident (CVA)), who had neither a diagnosis of severe psychiatric disorders nor neurodegenerative diseases. Those diagnosed with conductive, mixed, or sensorineural hearing loss[12] with at least a moderately severe degree[13] in one ear were excluded. Moreover, those who presented an altered cognitive status were excluded, as well as those who were identified using the Portuguese version of the cognitive screening instrument, the Montreal Cognitive Assessment (MoCA)[14], and those who did not perform all assessment procedures proposed for the study.

Collection procedures

Evaluation procedures were carried out at the Audiology Department of a public teaching institution in Northeastern Brazil. Initially, a meatoscopy was performed and, in the presence of obstruction in the external acoustic meatus, the individual was referred to an otorhinolaryngologist, returning for the evaluation procedures. After this step, cognitive aspects were evaluated using the MoCA. The maximum score obtained in this instrument is 30 points, and values below 26 suggest cognitive impairment. In individuals with less than or 12 years of formal education, one point was added to the final test score[14].

The individuals, then, answered the interview created for the study, containing socio-demographic data (age, gender and education level) and clinical information on general health (diabetes and hypertension).

Audiometric evaluation was carried out in an acoustic booth, with equipment properly calibrated according to ISO 8253[15]. All procedures were carried out by the same researcher, duly qualified and using a single piece of equipment. To start with, the Speech Reception Threshold (SRT) was used, and then the PPS and DPS tests were carried out. The order in which the procedures were carried out was adopted with a view to ensure greater attention and reliability in the responses, minimizing the possible effects of fatigue and lowered concentration of the individual during the tests. In addition, the initial temporal processing test (PPS or DPS) was alternated according to the individuals entry into the study, in order to minimize interference of these factors in the second test to be performed, as well as the possible effect of learning on the results.

To perform the PPS and DPS tests, a Samsung tablet coupled to an Interacoustics audiometer model AC40 was used as well as the TDH 39 supra-aural headphones. Both tests were carried out binaurally, at the intensity of 50 decibels sensation level (dB SL), from the SRT obtained, presenting three initial training sequences and 30 evaluation sequences. Individuals who, after three trials, were unable to correctly discriminate the sequences established for training were invited to return for a new evaluation at a later date. Those who failed to complete the training were excluded from the study.

In the PPS, pure tones were presented at frequencies of 1122 Hz (high) and 880 Hz (low)[6]. For the DPS, sequences of three 1000 Hz tones were presented, differing in duration — short (250 ms) or long (500 ms)[6]. The individuals were asked to name the sounds in the perceived order of presentation in the PPS as being of "high" or "low" frequency, and in the DPS, as "long" or "short". Afterwards, the percentage of correct answers in each test was recorded.

After the CAP tests, threshold tonal audiometry was done with air conduction, at the frequencies from 250 to 8000 Hz, and bone conduction, at the frequency range of 500 to 4000 Hz, whenever any air threshold was equal to or higher than 25 dB HL.

Data analysis

For analysis purposes, age was stratified into two age groups: 60 to 69; and 70 to 79 years. Education was divided into three levels: Elementary School (illiterate, incomplete or complete — 0 to 8 years of formal schooling); High School (incomplete or complete — 9 to 11 years of formal schooling); and College (incomplete or complete graduation, incomplete or complete post-graduation — 12 or more years of formal schooling).

Audiometric alteration was so defined when mean thresholds obtained in the frequencies of 0.5, 1, 2 and 4 kHz were higher than 25 dB[16]. In order to investigate the frequency of this alteration, the results obtained in the best ear was used, as it represents the individual's social functioning, from the communicative point of view[17].

A descriptive analysis of the performance regarding the study population in the temporal ordering tests was carried out, according to the variables gender, age range, education level and clinical characteristics (audiometric alteration, diabetes and hypertension). Information about clinical variables (diabetes and hypertension) was obtained from the subjects answers and analyzed according to the presence ("yes") or absence ("no") of disease.

Results of the temporal ordering tests were compared with the normality standard established for adults by Corazza[7], where averages of correct answers above 76% and 83% for the PPS and DPS tests, respectively, were considered.

Statistical analysis

The analysis was performed using the R software, version 3.6.1. To check the normality of data distribution, the Shapiro-Wilk test was used for graphical analysis and analysis of the symmetry and flattening of the distribution. The *chi*-square or Fisher's exact test was used to identify associations between nominal variables, and the *t*-student test or Analysis of Variance (ANOVA) was used for associations between quantitative variables according to groups of interest followed by Bonferroni's *a posteriori* test. The significance level established for this study was 5%.

The selection of variables included in the multiple linear regression model followed the criterion of $p < 0.20$[18] in the univariate (analysis) association and was conducted using the stepwise (regression) method, which excludes from the model the variables whose parameters are not shown to be statistically significant at the 5% level. Considering its relevance in the CAP test performance according to previous studies, audiometric alteration was inserted into the regression model despite not meeting this criterion.

Ethical considerations

This study was approved by the Research Ethics Committee of the proposing entity, under opinion number 2.268.734. All participants signed the Free and Informed Consent Form (ICF) prepared for the study.

RESULTS

A total of 164 individuals were invited to participate in the study. Of these, 30 did not show up for the evaluation procedures and three were not eligible for the study due to a history of TBI or stroke. Of the 131 who did attend, 39 were excluded, where the most frequent reason for exclusion was an alteration in the result of the MoCA cognitive screening test (n=27), followed by a diagnosis of mixed or conductive hearing loss (n=7) and also for failing to perform the auditory processing tests (n=5) even after two evaluation attempts. Six female individuals over the age of 80 were not considered for analysis because no male individuals in the same age range had been included in the study.

Thus, the sample consisted of 86 individuals, of which 28 were men, with a mean age of 68.3 (± 5.9) years and a maximum age of 79. Of the 58 women included in the study, the mean age was 66.2 (± 4.19), with a maximum age of 76. Table 1 shows that younger seniors predominated in the sample (from 60-69 years). There was no statistically significant difference in levels of education between men and women, as well as presence of diabetes and hypertension. We noticed a difference in the distribution between genders in relation to age range and the presence of audiometric alteration.

Regarding individuals with hearing loss in the sample, we noticed that mean hearing threshold values show a descending audiometric configuration, with preservation of hearing thresholds up to 2 kHz and greater variability of these in high frequencies (Figure 1).

Considering the current standard of normality for adults[7], we found in the PPS test that 63.8% of women and 32.1% of men would be classified as altered. In the DPS test, 81% of women and 46.4% of men would be identified as showing altered performance.

The mean percentage of correct answers in the PPS was 85.3 (±12.5) for men and 73.7 (±14.6) for women, and in the DPS, 81.5 (±15.9) and 70.7 (±17.0) for men and women, respectively. Both tests showed a statistically significant difference between genders (p=0.001 for the PPS and p= 0.005 for the DPS).

Analysis of the percentage of correct answers in the temporal ordering tests according to gender (Figures 2 and 3) could reveal that half of male individuals or more got more than 90% of correct answers in the tests, while for females the frequency of correct answers in this same percentage range was under 25%. Additionally, it was found that the percentage of correct answers in the tests was similar between genders up to 40% and, from this value on, the number of females who reached a higher score was significantly lower than that of males.

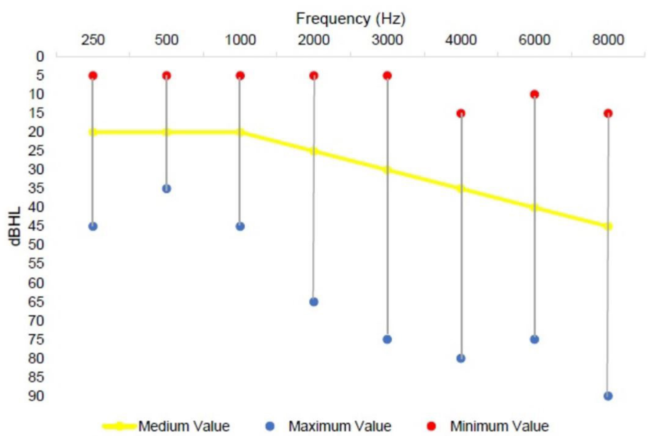
Investigating the performance in temporal ordering tests in relation to possible associated factors, we observed a statistically significant difference between mean test scores in relation to level of education for females (Table 2). It was observed that those with higher education (high school and college) had 10% or more correct answers than individuals with lower education (elementary school).

Figures 4 and 5 show the frequency of females corresponding to each percentage of correct answers in the PPS and DPS tests, respectively, with respect to the various levels of education. It

Table 1. Socio-demographic and clinical characterization according to the gender of the studied population

Variables	N = 86	Male (N=28)	Female (N=58)	*p*-value
	N (%)	N (%)	N (%)	
Age				
60-69	62 (72.1)	16 (57.1)	46 (79.3)	0.032*
70-79	24 (27.9)	12 (42.9)	12 (20.7)	
Education level				
Elementary School	30 (34.9)	8 (28.6)	22 (37.9)	0.665
High School	35 (40.7)	12 (42.9)	23 (39.7)	
Higher Education	21 (24.4)	8 (28.6)	13 (22.4)	
Audiometric alteration**				
	25 (29.1)	13 (46.4)	12 (20.7)	0.014*
Diabetes				
	14 (16.3)	4 (14.3)	10 (17.2)	1.000
Hypertension				
	46 (53.5)	16 (57.1)	30 (51.7)	0.637

*Value of $p \leq 0.05$; **Average values in the frequencies of 0.5, 1, 2 and 4 kHz > 25 dB. Source: Research data



Caption: Hz = Hertz; dB HL = Decibel Hearing Level

Figure 1. Audiometric thresholds of individuals with hearing loss

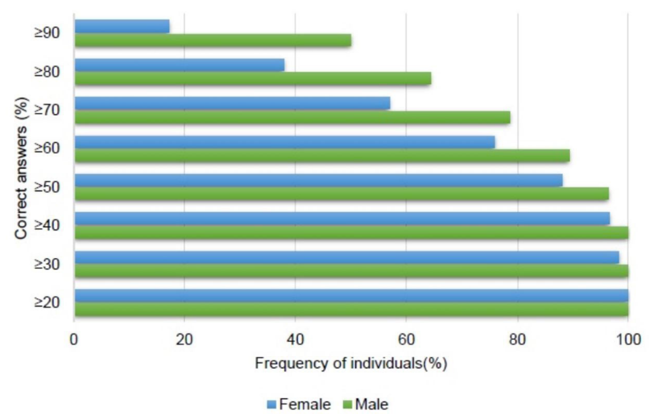


Figure 3. Frequency of individuals according to the percentage of correct answers in the Duration Pattern Sequence Test (DPS) according to gender

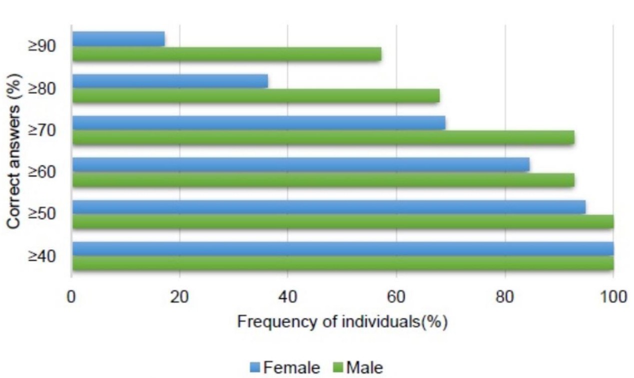


Figure 2. Frequency of individuals according to the percentage of correct answers in the Pitch Pattern Sequence Test (PPS) according to gender

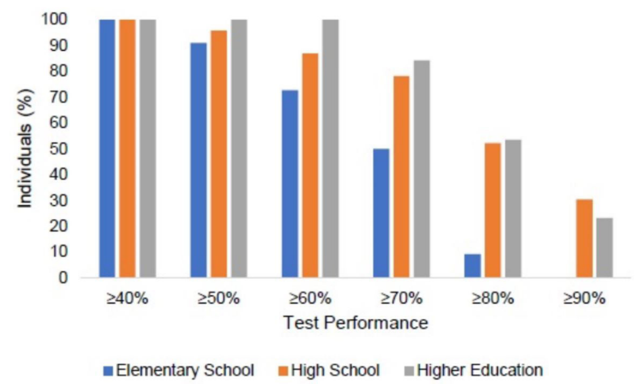


Figure 4. Performance in the Pitch Pattern Sequence Test (PPS) according to education level (female)

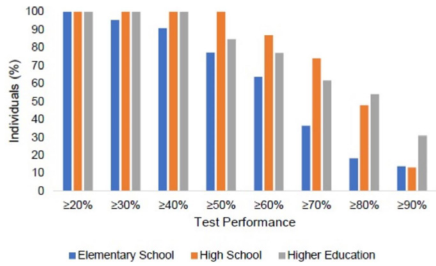


Figure 5. Performance in the Duration Pattern Sequence Test (DPS) according to education level (female)

was found that, as the percentage of correct answers increases, the frequency of individuals in level 1 decreases, and that the number of females in levels 2 and 3 is similar for all percentages of correct answers in the tests.

The multiple linear regression analysis of factors that influence performance in temporal ordering tests revealed that the variables gender, audiometric alteration and education level were associated with the PPS (Table 3) and, in the DPS, there was an association with gender and education level (Table 4).

Table 2. Analysis of factors associated with performance in the Pitch Pattern Sequence (PPS) and Duration Pattern Sequence (DPS) tests according to gender

Variables/gender	Male				Female			
	PPS		DPS		PPS		DPS	
	Average (DP)	*p*-value	Average (DP)	*p*-value	Average (DP)	*p*-value	Average (DP)	*p*-value
Age range								
60-69 years	85.4 (14.2)	0.993	77.9 (18.7)	0.141	74.4 (15.7)	0.469	71.1 (17.8)	0.592
70-79 years	85.3 (10.7)		86.2 (10.0)		71.0 (9.0)		68.1 (14.0)	
Education level								
Elementary School	85.4 (13.7)	0.586	81.4 (18.4)	0.403	65.8 (11.9) **A***	0.003**	62.7 (18.2) **A***	0.022**
High School	82.9 (12.1)		77.5 (15.7)		77.8 (15.4) **B***		75.5 (12.3) **B***	
Higher Education	89.0 (12.8)		87.5 (13.8)		80.0 (11.7) **B***		74.8 (18.7)	
Audiometric alteration* **								
≤ 25 dB	87.0 (14.8)	0.467	80.9 (19.5)	0.830	75.6 (14.6)	0.053	70.8 (17.9)	0.756
> 25 dB	83.5 (9.4)		82.1 (11.1)		66.5 (12.5)		69.1 (13.8)	
Diabetes								
Yes	88.7 (10.9)	0.569	75.5	0.429	73.8 (15.8)	0.992	74.0 (14.1)	0.476
No	84.8 (12.9)		82.4		73.8 (14.5)		69.7 (17.6)	
Hypertension								
Yes	86.5 (12.3)	0.587	81.9 (16.9)	0.878	73.6 (15.2)	0.926	68.8 (18.2)	0.446
No	83.8 (13.2)		80.9 (15.2)		73.9 (14.2)		72.2 (15.8)	

*Distinct letters within the same variable indicate statistically significant differences; **Value of $p \leq 0.05$; ***Average values in the frequencies of 0.5, 1, 2 and 4 kHz > 25 dB
Caption: PPS = Pitch Pattern Sequence Test; DPS = Duration Pattern Sequence Test; SD = Standard Deviation. Source: Research data

Table 3. Multiple linear regression analysis for performance in the Pitch Pattern Sequence Test (PPS) according to gender, age, hearing impairment and education

Variables	Coefficient	*p*-value	(95% CI)
Age	removed	0.889*	-
Female gender	-12.60	0.000	[-18.80 – (- 6.40)]
Audiometric Alteration	-7.66	0.021	[-14.12 – (- 1.19)]
Elementary School	7.25	0.028	(0.79 – 13.72)
High School	12.19	0.002	(4.75 – 19.63)

* ≥ 0.05
Caption: CI = Confidence Interval; adjusted $R^2 = 0.2399$. Source: Research data

Table 4. Multiple linear regression analysis for performance in the Duration Pattern Sequence Test (DPS) according to gender, age, hearing impairment and education

Variables	Coefficient	*p*-value	CI
Age	Removed	0.896*	-
Female Gender	-10.08	0.009	[-17.58 – (-2.58)]
Audiometric Alteration	Removed	0.788*	-
Elementary School	7.73	0.061	(- 0.35 – 15.82)
High School	10.79	0.023	(1.53 – 20.06)

* ≥ 0.05
Caption: CI = Confidence Interval; adjusted $R^2 = 0.1220$. Source: Research data

DISCUSSION

The literature states that central auditory skills are influenced by socio-demographic and clinical variables[9-11]. However, most studies in the elderly population do not consider these factors for interpretation of the results regarding temporal ordering tests. Thus, investigating the associated factors and describing the performance of elderly people in the PPS and DPS tests will contribute for accurate diagnosis and rehabilitation of auditory processing difficulties in this population.

The results of the present study revealed that performance in the PPS and DPS tests in elderly individuals was associated with gender and education level. The presence of audiometric alterations was found to be associated only with the PPS test.

These results were evidenced by the higher performance of men in the temporal ordering tests, regardless of age range, as well as a better performance of individuals with a higher level of education and of those who obtained a lower than 25 dB mean in the frequencies of 0.5 to 4 kHz in the PPS.

When analyzing the age range of individuals, some authors could corroborate the current investigation[3,19]; however, other studies have identified a decline in temporal ordering skills with advancing age[8,20]. It is possible that after 60 years of age, which is the age range of the participants in this study, reduction in the performance of temporal ordering tasks is lower than in the transition between adulthood and senescence. Additionally, it is believed that the most significant changes in central auditory processing, which culminate in a decline in auditory skills in the elderly, take place after 80 years of age; however, this age range was not assessed in the current investigation.

In the literature, the mean value of correct answers in temporal ordering tests in adult individuals was described by Corazza[7], and compared to the present study, we noticed that the mean value of correct answers in women was lower for the PPS (73.7%) and the DPS (70.5%). As for men, the average percentage of correct answers in the PPS was higher (85.3%), and in the DPS was slightly lower (81.5%). Although the author[7] stated that the performance of men was higher than that of women, the percentage of correct answers according to gender was not identified, which makes it difficult to compare results.

In other investigations with elderly individuals described in the literature[4,8,19], the percentage of correct answers was lower than that identified in the current study, ranging from 47 to 68%. However, most of the participants in these studies were women and, since this variable was not considered in the presentation of results, we believe that the percentage found reflects with greater precision the profile of women's performance in these tests, which is lower than that of men, as mentioned above.

The literature describes the difference between genders in the performance of temporal ordering tests, corroborating the current investigation, and the authors emphasize the importance of setting normality standards accounting for this variable[3,20]. The difference between genders, with better performance for males in behavioral hearing tests, is also described in other auditory skills[21]. However, most studies investigating temporal ordering in the elderly population[4,8,19] did not consider gender for analysis, which makes it difficult to compare their findings with the present study.

Regarding the difference in performance in temporal ordering tests between genders, we suggest that there may be a relationship with other aspects that do not directly involve the central auditory system. It is known that cognition is essential for auditory processing, and authors have reported that cognitive decline happens more slowly in men[22]. Moreover, they performed better in tests involving processing strategies, which can favor discrimination, memorization and later evocation of the stimuli in the order presented[23].

Education level has been described in the literature as a factor that influences performance in tests assessing temporal resolution and ordering[11,24], which confirms the findings of this study. Although Lenehan et al.[25] suggested that current scientific evidence did not allow for a consistent association between schooling and decline in specific cognitive functions, the literature review conducted supports the theory that a higher schooling level predisposes to better cognitive reserve. Thus, it is possible to surmise that this reserve may favor performance of tasks mediated by cognitive functions, resulting in better performance in temporal ordering tests by older adults with more schooling. On the other hand, the lower performance in the ordering tests of the elderly with lower education levels in our study, even without scores indicating cognitive impairment in the MoCA, may reflect a greater vulnerability to the development of a cognitive decline[26] not detectable by the instrument.

Since the tasks involved in temporal ordering tests require cognitive-linguistic abilities, demand for information processing may reflect not only auditory abilities, but also a better understanding of the test execution[24]. The biological plausibility of this relationship can be explained by the greater volume of white and gray matter, especially in the temporoparietal and orbitofrontal lobes, described in elderly people with higher levels of education, which, according to the authors, would compensate for the signs of cognitive decline[27]. It is also important to consider that, throughout life, neuronal activation resulting from intellectual experiences allows for the dynamic construction of cognitive reserve, which depends mostly on genetic and socio-economic aspects, schooling and type of professional activity[28].

The relationship between temporal ordering tests and hearing loss is controversial[3,19,29]. Studies that have been shown a relation between peripheral hearing loss and temporal processing[29] could state that sensorineural alteration reduces the strength of temporal coding at a more peripheral level of auditory processing. Furthermore, synaptic losses and cochlear degeneration imply a reduction in redundancy of neural coding and possible changes in central auditory processing, justifying the difficulty in speech perception, especially in noisy environments[29]. We should also consider that in audiometry the frequencies of 500, 1000 and 2000 Hz are assessed; however, it is not known for sure if there is sound distortion in the frequencies assessed by the test (880 and 1122 Hz), which could justify the association found in the current study between DPS and audiometric alteration.

It is likely that the higher frequency of younger individuals, aged up to 69 years, has contributed for age not being identified as a variable that affects performance on the test. Although this relationship was not verified, we noticed a high frequency of alterations in temporal ordering ability, when considering the normality standard established for adults. This fact pointed out to a difference in performance of adults and elderly in the tests, which leads to the conclusion that this standard should not be used to evaluate the elderly.

The findings of this study should be interpreted with caution due to potential methodological limitations. Since this was a convenience sample, the implications of selection bias cannot be ruled out. In addition, we did not investigate elderly individuals over 80 years of age. Despite these limitations, the results of the present study contributed to a better understanding of aspects that need to be considered when interpreting the results of temporal ordering tests in the elderly. Some of these aspects were observed with greater frequency in this population because they were associated with the aging process, such as hearing loss(30) and cognitive decline(25), or with issues that imply greater difficulties during senescence, such as low schooling, which may result in lower cognitive reserve. Thus, in addition to being considered in the interpretation of results, these aspects should guide development of strategies that promote care and assistance to this population, contributing to more effective communication and socialization processes.

CONCLUSION

Based on the results obtained in the present study, it was possible to conclude that elderly men aged between 60 and 79 years presented better performance in temporal ordering tests when compared with females of the same age range. Education level, likewise, is a factor influencing performance in temporal ordering tests and, therefore, must be considered when analyzing results. Moreover, the audiometric alteration analyzed in this study was associated with the performance of the elderly in the PPS test.

REFERENCES

1. Fonseca CBF, Iório MCM. Aplicação do teste de lateralização sonora em idosos. Pró-Fono R. 2006;18(2):197-206. http://dx.doi.org/10.1590/S0104-56872006000200009.
2. Cóser MJ, Cioquetta E, Pedroso FS, Cóser PL. Potenciais auditivos evocados corticais em idosos com queixa de dificuldade de compreensão da fala. Arq Int Otorrinolaringol. 2007;11(4):396-401.
3. Sanchez ML, Nunes FB, Barros F, Ganança MM, Caovilla HH. Avaliação do processamento auditivo em idosos que relatam ouvir bem. Rev Bras Otorrinolaringol. 2008;74(6):896-902. http://dx.doi.org/10.1590/S0034-72992008000600013.
4. Azzolini VC, Ferreira MIDC. Processamento auditivo temporal em idosos. Int Arch Otorhinolaryngol. 2010;14(1):95-102.
5. Gois M, Biaggio EPV, Bruckmann M, Pelissari I, Bruno RS, Garcia MV. Temporal ordering ability and level of specificity at different pure tone tests. Audiol Commun Res. 2015;20(4):293-9.
6. Musiek FE. Frequency (pitch) and duration patterns tests. J Am Acad Audiol. 1994;5(4):265-8. PMid:7949300.
7. Corazza MCA. Avaliação do processamento auditivo central em adultos: testes de padrões tonais auditivos de freqüência e teste de padrões tonais auditivos de duração [tese]. São Paulo: Universidade Federal de São Paulo; 1998.
8. Parra VM, Iório MCM, Mizahi MM, Baraldi GS. Testes de padrão de frequência e de duração em idosos com sensibilidade auditiva normal. Rev Bras Otorrinolaringol. 2004;70(4):517-23. http://dx.doi.org/10.1590/S0034-72992004000400013.
9. Nishihata R, Vieira MR, Pereira LD, Chiari BM. Processamento temporal, localização e fechamento auditivo em portadores de perda auditiva unilateral. Rev Soc Bras Fonoaudiol. 2012;17(3):266-73. http://dx.doi.org/10.1590/S1516-80342012000300006.
10. Tun PA, Williams VA, Small BJ, Hafter ER. The effects of aging on auditory processing and cognition. Am J Audiol. 2012;21(2):344-50. http://dx.doi.org/10.1044/1059-0889(2012/12-0030). PMid:23233520.
11. Pinheiro MMC, Dias KZ, Pereira LD. Efeito da estimulação acústica nas habilidades do processamento temporal em idosos antes e após a protetização auditiva. Rev Bras Otorrinolaringol. 2012;78(4):9-16.
12. Silman S, Silverman C A. Basic audiologic testing. In: Silman S, Silverman CA, editores. Auditory diagnosis: principles and applications. San Diego: Singular Publishing Group; 1997. p. 44-52.
13. Lloyd LL.; Kaplan H. Audiometric interpretation: a manual of basic audiometry. Baltimore: University Park Press; 1978.
14. Nasreddine ZS, Phillips NA, Bédirian V, Charbonneau S, Whitehead V, Collin I, et al. The Montreal Cognitive Assessment, MoCA: a brief screening tool for Mild Cognitive Impairment. J Am Geriatr Soc. 2005;53(4):695-9. http://dx.doi.org/10.1111/j.1532-5415.2005.53221.x. PMid:15817019.
15. ISO: International Organization for Standardization. ISO 8253-1:2010: acoustics: audiometric test methods. Part 1: pure-tone air and bone conduction audiometry. Geneva: ISO; 2010.
16. WHO: World Health Organization. Prevention of blindness and deafness [Internet]. Geneva; 2014 [citado em 2019 Out 18]. Disponível em: https://www.schwerhoerigen-netz.de/fileadmin/user_upload/dsb/Dokumente/Information/Politik_Recht/Hoergeraete/who-grades-hearing.pdf
17. Gondim LMA, Balen AS, Zimmermann KJ, Pagnossin DF, Fialho IM, Roggia SM. Estudo da prevalência e fatores determinantes da deficiência auditiva no município de Itajaí, SC. Rev Bras Otorrinolaringol. 2012;78(2):27-34.
18. Melo MMDC, Souza WV, Couto GBL. Comparação de métodos de regressão multivariada no estudo de determinantes da cárie dentária em crianças. Rev Bras Saúde Mater Infant. 2014;14(4):343-52. http://dx.doi.org/10.1590/S1519-38292014000400004.
19. Liporaci FD, Frota SMMC. Envelhecimento e ordenação temporal auditiva. Rev CEFAC. 2010;12(5):741-8. http://dx.doi.org/10.1590/S1516-18462010005000078.
20. Kołodziejczyk I, Szelsg E. Auditory perception of temporal order in centenarians in comparison with Young and elderly subjects. Acta Neurobiol Exp. 2008;68(3):373-81. PMid:18668160.
21. Fonseca CBF, Iório MCM. Aplicação do teste de lateralização sonora em idosos. Pró-Fono R. 2006;18(2):197-206. http://dx.doi.org/10.1590/S0104-56872006000200009.
22. Meinz EJ, Salthouse TA. Is age kinder to females than to males? Psychon Bull Rev. 1998;5(1):56-70. http://dx.doi.org/10.3758/BF03209457.
23. Ho SC, Woo J, Sham A, Chan SG, Yu AL. A 3-year follow-up study of social, lifestyle and health predictors of cognitive impairment in a Chinese older cohort. Int J Epidemiol. 2001;30(6):1389-96. http://dx.doi.org/10.1093/ije/30.6.1389. PMid:11821352.
24. Lima IMS, Miranda-Gonsalez EC. Efeitos da perda auditiva, escolaridade e idade no processamento temporal de idoso. Rev CEFAC. 2016;18(1):33-9. http://dx.doi.org/10.1590/1982-0216201618110415.
25. Lenehan ME, Summers MJ, Saunders NL, Summers JJ, Vickers JC. Relationship between education and age-related cognitive decline: a review

of recent research. Psychogeriatrics. 2015;15(2):154-62. http://dx.doi.org/10.1111/psyg.12083. PMid:25516261.

26. Livingston G, Sommerlad A, Orgeta V, Costafreda SG, Huntley J, Ames D, et al. Dementia prevention, intervention, and care. Lancet. 2017;390(10113):2673-734. http://dx.doi.org/10.1016/S0140-6736(17)31363-6. PMid:28735855.

27. Amieva H, Mokri H, Le Goff M, Meillon C, Jacqmin-Gadda H, Foubert-Samier A, et al. Compensatory mechanisms in higher-educated subjects with Alzheimer's disease: a study of 20 years of cognitive decline. Brain. 2014;137(Pt 4):1167-75. http://dx.doi.org/10.1093/brain/awu035. PMid:24578544.

28. Sobral M, Pestana MH, Paúl C. A importância da quantificação da reserva cognitiva. Rev Port Enferm Saude Mental. 2014;12:51-8.

29. Henry KS, Heinz MG. Diminished temporal coding with sensorineural hearing loss emerges in background noise. Nat Neurosci. 2012;15(10):1362-4. http://dx.doi.org/10.1038/nn.3216. PMid:22960931.

30. Baraldi GS, Almeida LC, Borges ACC. Evolução da perda auditiva no decorrer do envelhecimento. Rev Bras Otorrinolaringol. 2007;73(1):64-70. http://dx.doi.org/10.1590/S0034-72992007000100010.

Author contributions

MBR participated in the idealization of the study, collection, analysis and interpretation of the data and writing of the article; MSL and APC participated in the analysis, interpretation of the data and writing of the article; JFC and RPCA carried out the intellectual review of the article.