Auditory temporal processing in elderly

Processamento temporal auditivo em idosos

Procesamiento Temporal Auditivo en Adultos Mayores

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Abstract

Objective: *to evaluate auditory temporal processing in elderly and to establish a comparison with the results obtained in the reference values set for adults.* ***Methods****: Tests, PPS, DPT and GIN were administered to 30 elderly individuals, 23 women and 7 men aged between 60 to 84 year.* ***Results:*** *Statistical analysis did not show any significant difference between the three tests and variables ear and gender. It Older age resulted in a statistically significant lower number of correct answers to DPS tests and a lower percentage of correct answers in GIN test, as well as increase in GIN threshold. The average results obtained in the elderly population were PPS -47.21%; DPT-56.45%; GIN-threshold 8.07ms; GIN-percentage of correct answers -44.44%.* ***Conclusion:*** *compared to the results expected for young adults, the scores obtained by the elderly were lower than the reference values in all the tests.*

Keywords: *Elderly; Aging; Hearing; Auditory Perception.*

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Resumo

Objetivo: *avaliar o processamento temporal auditivo em indivíduos idosos e estabelecer comparação com os resultados obtidos frente ao padrão de normalidade estabelecido para adultos jovens.* ***Método****: foram aplicados os testes TPF, TPD e GIN em 30 indivíduos idosos com idade entre 60 e 84 anos, sendo 23 do sexo feminino e 7 do sexo masculino.* ***Resultados:*** *não foram observadas diferenças significantes nos três testes segundo as variáveis sexo e orelha. Já quanto à variável idade observou-se que o aumento da idade levou a uma diminuição estatisticamente significativa no número de acertos dos testes TPD e percentual de acertos do teste GIN, além do aumento do limiar. As médias dos resultados dos testes obtidos na população idosa foram: TPF-47,21%; TPD-56,45%; Limiar GIN-8,07ms; Porcentagem de acertos GIN-44,44%.* ***Conclusão:*** *se comparados com os resultados esperados para indivíduos adultos jovens, o desempenho dos idosos nos testes foi inferior aos padrões estabelecidos.*

Palavras-chave: *Idoso; Envelhecimento; Audição; Percepção Auditiva.*

Resumen

Objetivo: *evaluar el procesamiento temporal auditivo en adultos mayores y establecer una comparación con los resultados obtenidos frente al patrón de normalidad establecido para adultos jóvenes.* ***Métodos:*** *las pruebas de TPF, TDP y GIN se aplicaron en 30 adultos mayores, 23 mujeres y 7 hombres, con edad entre 60 y 84 años.* ***Resultados:*** *el análisis estadístico no ha mostrado diferencia significativa entre las tres pruebas según las variables sexo e oído. Sin embargo, en la variable edad se observó que, con su aumento, hubo una reducción estadísticamente significativa en el número de aciertos para las pruebas de TPD y porcentaje de aciertos en la prueba GIN, además del aumento del umbral. Los promedios de los resultados de las pruebas obtenidos en la población de adultos mayores fueron: TPF-47.21%; TPD-56.45%; Umbral GIN-8,07ms; Porcentaje de aciertos GIN-44,44%.* ***Conclusión:*** *si comparados con los resultados esperados para adultos jóvenes, el rendimiento de los adultos mayores fue inferior a los patrones establecidos.*

Palabras claves: *Anciano; Envejecimiento; Audición; Percepción Auditiva.*

Introduction

Aging is part of a natural and universal process that can be defined as a series of changes that occur with time and result in the overall deterioration in the performance of an individual. It is a progressive and degenerative process characterized by decreased functional efficiency, with weakening of the body's human system that protects from environmental changes and loss of functional reserves. This process is intrinsic and is influenced by environmental stimuli and pathologies, which vary among the species[1].

The aging process is dynamics and progressive involving morphological, functional, biochemical and psychological changes that cause progressive loss of na individual's ability to adapt to the environment, greater vulnerability and higher incidence of diseases that culminate in death[(2)]. Hearing loss in the elderly is one of the most incapacitating communication disorders, preventing these individuals to perform their tasks in society. Age-related hearing loss is known as presbycusis and is characterized by decrease in intelligibility of speech, with serious impact on the communication process[3].

There is a growing number of elderly individuals who complain of difficulties in understanding speech, which are not related to their level of hearing loss. Therefore, the relationship between aging and auditory temporal processing has been increasingly investigated in recent years[4,5].

Auditory temporal processing can be defined as the perception of temporal characteristics of a sound[6,7]. It can also be described as the processing of acoustic signal which depends on the time of reception and is correlated to perception of speech, sequence of events, sonority of phonemes, length of consonants and discrimination of similar words[(8)]. Temporal processing is an auditory behavior related to perception of speech, since processing of auditory information has several temporal oscillations[4]. Possible changes in temporal processing are

associated to deficits in phonological processing, auditory discrimination, receptive language and reading[8]. It involves hearing skills such as temporal ordering, temporal resolution, temporal integration and temporal masking[6,7,9].

The tests most commonly used to assess temporal processing skills are: (i) TPF or PPS - Pitch Pattern Sequence Test), which evaluates recognition of frequency patterns, temporal ordering and naming patterns of frequency; (ii) the TPD or DPT– Duration Pattern Sequence Test), which assesses duration patterns, temporal ordering and naming of duration and pitch pattern of sounds; and (iii) the (GIN – Gaps in Noise test), which evaluates the hearing skill of temporal resolution. These tests are sensitive to damage / dysfunction of hemispheric and inter-hemispheric areas[10].

It is believed that aging increases deficit in speech perception related to disorders in the temporal processing of sounds. Thus, the present study aimed to assess temporal processing regarding temporal ordering and resolution skills in elderly individuals and establish a comparison between the results obtained and the normal standards established for young adults.

Methods

The present study was approved by the Research Ethics Committee of CEFAC Saúde e Educação under no 057/08, in compliance with the applicable ethical rules.

Cases

The subjects were 30 elderly individuals divided into three age groups: Group 1, compoed of individuals aged 60-70 years; Group 2, individuals aged 71-80 years and Group 3, individuals aged 81-90 years. Distribution by gender is shown in Table 1 and distribution by age is shown in Table 2.

Table 1. Gender and number of participants in each group.

	Male gender	Female gender	Total
Group 1 60-70 years	6	14	20
Group 2 71-80 years	0	7	7
Group 3 81-90 years	1	2	3
Total	7	23	30

Table 2. Age and number of participants in each group

	Mean age	Minimum age	Maximum age
Group 1 60-70 years	65.5	60	70
Group 2 71-80 years	75.29	71	80
Group 3 81-90 years	82.33	81	84
Total	68.5	60	84

Procedures

The subjects were informed on the voluntary nature of participation, procedures and selection and exclusion criteria through the free informed consent form (TCLE).

The individuals who accepted to participate in the study by signing the TCLE were subjected to pure tone audiometry, imitanciometry and Mini-mental State Examination (MMSE). All the subjects had normal hearing thresholds up to 25 dB NA or had mild or moderate hearing losses up to 50 dBNA, according to the tritonal mean of hearing threshold[(11)], with A curves, indicating absence of middle ear disorders, and normal scoring for cognitive screening, consistent with the educational level of the individual, according to the Brazilian version of Mini-mental State Examination[12].

Subsequently, tests of evaluation of temporal ordering for pitch and duration – PPS and DPS – and test of temporal resolutions for identification of noise gaps – GIN (Gaps in Noise) – developed

by Musiek[6,13,14] were administered. A Beta Medical Beta 6000 audiometer coupled to a Sony CD player in a soundproof booth were used in the procedures, always monoaurally presented at 50 dBNS (according to the average of hearing thresholds in frequencies of 500, 1000 and 2000 Hz of each ear) in both ears.

The test of temporal ordering of pitch (frequency) patterns PPT consisted in the presentation of low-frequency (880 Hz) and high-frequency (1122 Hz) tones, with duration of 200 ms and intervals of 50 ms between the tones. The tones were presented in groups of 3 tones with 6 possible frequencies (AAB, ABA, ABB, BAA, BAB and BBA). For each ear, 30 stimuli at a level of 50 dB NS were used. In this test, the patient was supposed to mimic the sequences of the three tones heard, by whispering them, verbalizing it as low and high-pitched sounds or indicate the sequence heard in a multiple choice form[14]. For this test, normality was assumed with 73.3%[15].

As for the test of temporal ordering for duration patterns - DPS – consisted in the presentation of long tones (500 ms) and short tones (250 ms), with intervals of 300 ms between the tones, with frequency kept constant in 1000 Hz, at 50 dBNS. In this test, 30 sequences of 3 tones with 6 possibilities (LLC, LCL, LCC, CLL, CLC and CCL) were presented. The patient was supposed to mimic the sequence heard (whispering), verbalize it as long or short tones or indicate the sequence heard in a multiple choice form[13]. For this test, nornality was assumed with 76.9% of correct answers[15]

The test of temporal resolution - GIN (Gaps in Noise) is composed of several segments of white noise with duration of 6 seconds, which include 0 to 3 intervals of silence (gaps) each. The noise segments are separated from each another by a 5-second silent interval (interval between the stimuli) and the gap duration is 2, 3, 4, 5, 6, 8, 10, 12, 15 and 20 ms. Both the duration and location of gaps in the segments of noise are pseudo-randomized regarding their occurrence. Ten items are used for practice before the beginning of the test. Each possibility of value of duration of gaps appears six times in each test range. For this study, two test--ranges were used: one for the right and the other for the left ear The patient was supposed to press the patient response button each time a gap was present. For each one of the test ranges, two measures were determined: the gap detection threshold corresponds to the lowest gap perceived by the patient in at least 66.67% of the presentations, which is equivalent to 4 detections of the 6 presentations of each possible value, and the percentage of correct responses per test range, i.e., the number of gaps detected[6]. For this test normality was assumed with a gap detection threshold of 4.19 ms and percentage of correct responses of 78.89%[16].

Statistical method

SPSS 2.0 was used in statistical data analysis. ANOVA was performed for testing the means for all independent variables investigated (gender, ear, age and education) regarding the performance of the participants in tests and Pearson's Correlation coefficient R between results and variable age. The values were considered significant when $p < 0.05$.

Results

Comparison between the right and left ears:

Table 3 shows that there was no statistically significant difference between the right and left ears in temporal ordering and resolution tests.

Comparison between genders:

As shown in Table 4, it can be concluded that there was no statistically significant difference between the male and female groups in any of the tests administered in this study.

Table 3. Percentage of performance in temporal and resolution ordering tests in the right and left ears

	PPS OD	PPS OE	DPS OD	DPS OE	GIN OD THRESHOLD	GIN OE THRESHOLD	GIN OD CORRECT RESPONSES	GIN OE CORRECT RESPONSES
Group 1	54.27%	55.45%	55.64%	54.86%	8.24 ms	7.35 ms	47.94%	50.88%
Group 2	34.41%	55.45%	66.60%	65.49%	8.11 ms	6.89 ms	44.07%	48.15%
Group 3	48.13%	42.48%	38.30%	41.63%	10.75 ms	10.25 ms	17.50%	21.67%
Total	47.50%	46.92%	56.62%	56.28%	8.53 ms	7.60 ms	42.72%	46.17%
	47.21%		56.45%		8.07 ms		44.44 ms	
SE	0.935		0.959		0.409		0.414	

SE- Statistical significance.

Table 4. Percentage of performance in temporal and resolution ordering tests according to the gender

	PPS M	PPS F	DPS M	DPS F	GIN M THRESHOLD	GIN F THRESHOLD	GIN M CORRECT RESPONSES	GIN F CORRECT RESPONSES
Group 1	59.95%	52.74%	74.62%	47.18%	10.20 ms	6.79 ms	47.17%	50.35%
Group 2	38.31%	33.01%	93.24%	62.65%	8.0 ms	7.44 ms	55%	45.00%
Group 3	24.98%	52,08%	21.65%	46,07%	N/D	14 ms	N/D	26.11%
Total	51.86%	52.08%	69.71%	52.41%	8.43 ms	7.96 ms	41.55%	45.33%
	47.21%		56.45%		8.07 ms		44.44%	
SE	0.640		0.54		0.437		0.844	

SE- Statistical significance. M- Male gender and F- Female gender

Comparison of findings with age and between age groups:

Since no statistically significant difference was observed between the thresholds influenced by the independent variables ear and gender, for analysis of variable age, the data concerning the total number of ears (N=60 ears) were considered. At first, correlation between the performances in all tests with variable age was performed (Table 5) and a significant and negative correlation was observed, indicating worse performance in DPS test and in the percentage of gaps detected in GIN with aging. Correlation was significant and positive for analysis of detection threshold in GIN, indicating higher threshold values with aging. In PPS test, the negative correlation was not statistically significant. Since the distribution of participants in the age groups was very heterogeneous, as shown in Table 1, statistical analysis was not possible. In DPS and GIN tests, the effect of age on performance was significant, which was not observed in the PPS test, according to ANOVA described in Table 5.

Table 5. Percentage of performance in temporal ordering and resolution tests in age groups

	PPS	DPS	GIN THRESHOLD	GIN CORRECT RESPONSES
Group 1	54.86%	55.25%	7.79 ms	49.41%
Group 2	33.60%	66.05%	7.50 ms	46.11%
Group 3	45.31%	39.96%	10.50 ms	19.58%
Variable age	47.21%	56.45%	8.07 ms	44.44%
Pearson's R	-212	-538	486	-604
SE	0.11	>0.001*	>0.001*	>0.001*
ANOVA** SE	0.005*	> 0.001*	> 0.001*	> 0.001*

SE- **Statistical** significance. * significant for p<0.05 **ANOVA between the means of the results and factor age.

Comparison of the results of this study with the normal standards established for adults with normal hearing:

Temporal Ordering and Resolution tests:

Table 6 includes the results of temporal ordering tests – PPS and DPS, and the normal standards established for adults from 16 years on and Table 7 shows the results of temporal resolution – GIN. It should be stressed that regarding general performance (Figures 1 and 2), none of the subjects was able to perceive the interval of 2 ms, and in the intervals of 3 and 4 ms, the percentage of correct responses was always lower than 5%. For 8 ms, the percentage of correct responses increased considerably reaching approximately 65%. For longer intervals, i.e., 15 and 20 ms, the percentage of correct responses reached 81% or over, though not reaching 100%.

Table 6. Comparison between the average results in temporal ordering tests of the present study with the normal standards established for children and young individuals*

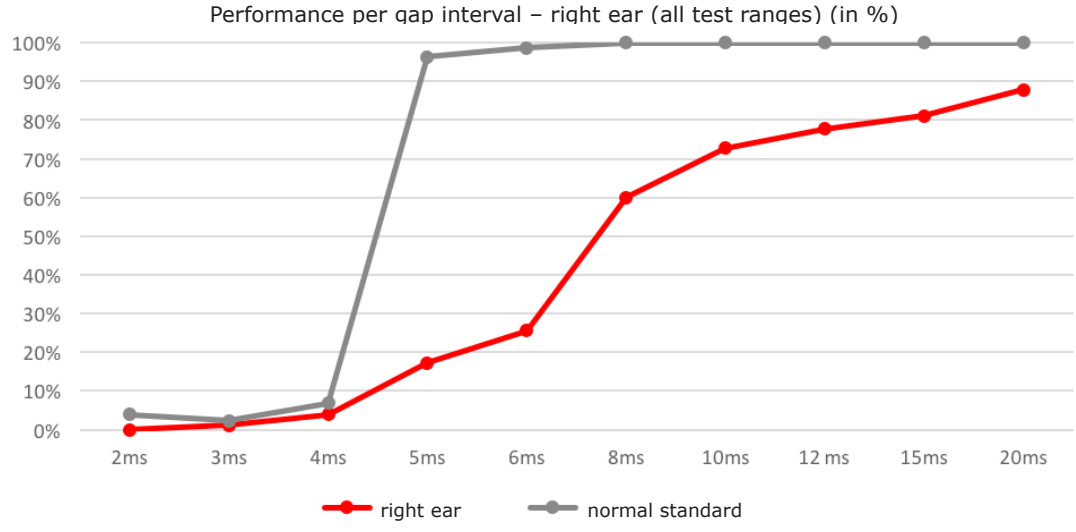
	PPS Right ear	PPS Standard	PPS Left ear	PPS Standard*	DPS Right ear	DPS Standard*	DPS Left ear	DPS Standard*
Group 1	54.27%		55.45%		55.64%		54.86%	
Group 2	34.41%	75.3%	32.78%	72.5%	66.60%	78.8%	65.49%	76.9%
Group 3	48.13%		42.48%		38.30%		41.63%	
Total	47.50%	75.3%	46.92%	72.5%	56.62%	78.8%	56.28%	76.9%

*Schochat, Rabelo, Sanfins, 2000[15]

Table 7. Comparison of the average results in the temporal resolution tests between the present study and the normal standards established for young adults*

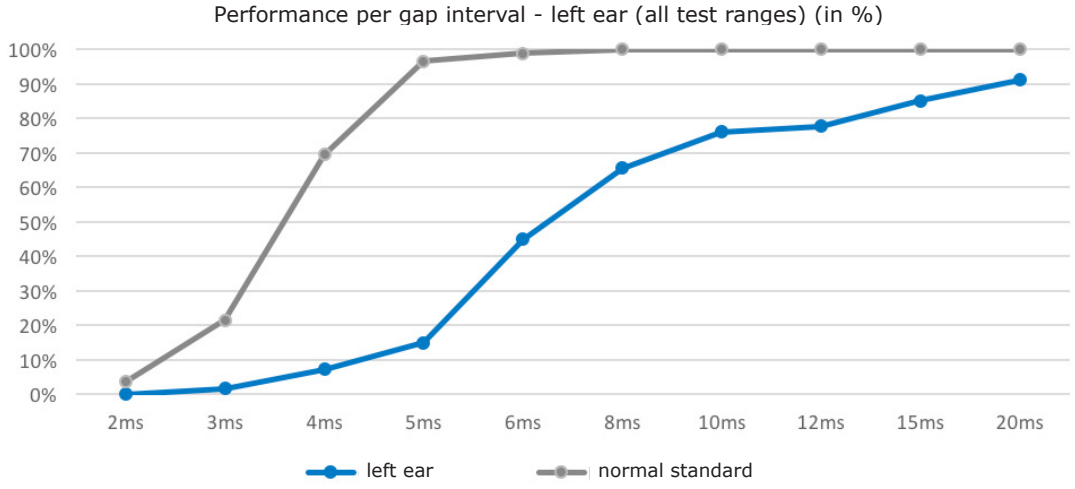
	Threshold	Normal standard Adults*	Correct responses	Standard Adults*
Group 1	7.79 ms		49.41%	
Group 2	7.50 ms	4.19 ms	46.11%	78.89%
Group 3	10.50 ms		19.58%	
Total	8.07 ms	4.19 ms	44.44%	78.89%

*Samelli & Schochat, 2008[16]



*Samelli, 2005[27]

Figure 1. Comparison of performance per gap interval between the present study and the normal standards established for young adults* - right ear (in %).



*Samelli, 2005[27]

Figure 2. Comparison of performance per gap interval between the present study and the normal standards established for young adults* - left ear (in %).

Discussion

Comparison between the right and left ears in temporal ordering tests:

Based on the results obtained, there were no statistically significant diferences between the ears tested (right and left) for frequency pattern and duration pattern tests, as shown in other studies[13,15,17,18]. The fact that these tests were not influenced by the side of the ear to which the stimulus is presented can be related to the joint action of the right and left hemispheres in this process[19], emphasizing the prevalence of central and not peripheral processing of auditory information in this task.

Comparison between the right and left ears in the temporal resolution test:

No ear side dominance was observed regarding the percentage of correct responses in GIN test, as well as regarding the threshold of this test in any of the analyzes carried out, which is consistent with literature findings.[16,20–22]. Probably, the peripheral skills of the auditory system have less influence on the requested task than central skills. The auditory pathways of sound, including interaural time differences are processed with the crossing of ipsi and contralateral information in the superior olivary complex. In the brainstem, the relationship between this information with the peripheral portion of the system can be minimized[23].

Comparison of performance between genders in temporal ordering tests:

Although the pertinent literature[17,24], as well as the present study, did not detect statistically significant differences between genders regarding performance in temporal ordering tests, the fact that the number of men and women in the sample was not equal did not allow analysis with sufficient statistical power for generalization.

Comparison between genders in the temporal resolution test:

There was no statistically significant difference between genders in the GIN test. This finding is consistent with the literature[6,16] regarding the performance of men and women in the GIN test (both in threshold and percentage of correct responses). One study[20], reported significantly better results in male individuals, but the authors said that these findings were caused by a selection bias. The male individuals were students of music therapy, which may favor a better performance in the test due to the hypothesis that musicians have better temporal resolution skills, and in the present study, the number of male subjects was not equal to the number

of female subjects, which may have reduced the possible effect of this variable.

Comparison of the findings with age and between age groups in temporal ordering and resolution tests:

The results obtained in the PPS test did not correlate with age. It is possible that the temporal processes involved in this test, or even the level of temporal skill required, are not so dependent on processing speed. On the other hand, DPS results confirmed that aging significantly worsens performance. The literature also points to a trend that the older the patient, the worse the performance in temporal ordering tests[22]. Although both tests consist of temporal ordering tasks, the different results obtained in the PPS and DPS tests may indicate different hearing skills and processes, or even that the age effect is apparently earlier or stronger in DPS. However, since the number of participants in each age group was not equal, the present study detected differences in the results of the tests, though with insufficient statistical power for generalization. Statistical evidence was significant when age variable was used without stratification. This evidence of the influence of the age factor and the trend observed in results associated to the age group could be analyzed in greater detail in future studies, with equal number of participants in each age group and larger samples.

Regarding the average number of correct responses found in temporal ordering tests, there was a decrease in the percentage of correct responses compared to data from a study with children and youngsters[(15)] with normal hearing sensitivity, and this difference was statistically significant in DPS test, probably due to the aging process. Studies with elderly individuals focused on the comparison between performance in temporal processing in elderly with and without hearing loss, showed average values in DPS test of 84.6% in the groups without hearing loss, which included 5 individuals, and 83.5% in a group of 15 elderly with normal hearing[25]. Although these data are not applicable for the elderly population, the values shown in the present study are lower, in average 56.28% of correct responses.

In the temporal resolution test, a direct correlation between gap detection thresholds and age and an inverse correlation between percentage of correct responses and the age of the subjects were found. This trend was observed both for the variable age in absolute numbers and for the age groups, despite the difference in the number of subjects in the age groups. The performance of the elderly participants evaluated in this study fell below the normal standards established for young adults[17,26]. In the GIN test, regarding performance per GAP interval (Figures 1 and 2), in contrast with the findings of another study[16,27], only for GAP intervals of 20 ms the percentage of correct responses reached 91%, compared to normal individuals who reach the same percentage in 5 ms. Comparison of results of studies with elderly in groups without hearing loss, showed an average detection threshold of 4.6 ms in the elderly of the group without hearing loss and 6,53 ms in elderly with hearing loss[25]. Although it did not intend to establish normal standards for the elderly population, another study[28] reported that the average threshold was obtained in 7.3 ms for the right ear and in 7.7 ms for the left ear in groups of 26 participants; also, for 4 ms, the percentage of correct responses was 10% and 90% of correct responses was reached for gaps higher than 10 ms. The authors also suggest that a threshold between 8 and 10 is considered for this population. The average threshold of 8.07 ms, of the present study, is within the suggested range.

Aging seems to have a negative impact on the temporal resolution skill[4,17,26,29,30]. The results of the GIN test were below the normal standards and worsened with aging. Regarding temporal resolution processing, processing speed appears to gradually decrease with aging.

The findings of the present study suggest that the performance of elderly individuals falls below the normal standards set for young adults without peripheral auditory impairment and that this performance tends to worsen with aging. For a real standardization of ordering tests such as the PPS and DPS, and of temporal resolution tests, such as the GIN test, further studies comparing young adults and elderly individuals are needed to verify the effect of aging on temporal processing skills. Moreover, studies aimed to establish a new standardization of these tests in the elderly population are suggested, as well as studies with equal numbers of men and women, in order to confirm that the variable gender has no influence on temporal processing.

Conclusion

The tests that evaluate temporal processing temporal ordering skills were not influenced by ear and gender variables. In DPS and GIN tests performance worsened significantly with aging.

Compared to the results expected for younger adults, the performance of the elderly in these tests was below the established standards.

The sample of the present study allowed establishing trends in temporal processing in elderly individuals, considering age and ear groups. However, the findings cannot be generalized for this population.

References

1. Ribeiro A. Aspectos Biológicos do Envelhecimento. In: Russo ICP, organizador. Intervenção Fonoaudiológica na Terceira Idade. Rio de Janeiro: Revinter; 1999. p. 1–11.

2. Serro Azul JG, Filho ETC, Filho MF, Al E. Biologia do Envelhecimento. In: Serro Azul JG, Filho ETC, organizadores. Décourt Clínica do Indivíduo Idoso. 1o ed Rio de Janeiro: Guanabara-Koogan; 1981. p. 2–11.

3. Russo ICP. Distúrbios da Audição: A Presbiacusia. In: Russo ICP, organizador. Intervenção Fonoaudiológica na Terceira Idade. Rio de Janeiro: Revinter; 1999. p. 51–82.

4. Vera T. das Neves MÂGF. Controvérsias ou complexidade na relação entre processamento temporal auditivo e envelhecimento? Controversies. Rev Bras Otorrinolaringol. 2003; 69(2): 242–9.

5. Cibian AP, Pereira LD. Utilização de questionário no monitoramento dos resultados do treinamento auditivo. Distúrbios da Comun. 2015; 27(3): 466–78.

6. Musiek FE, Shinn JB, Jirsa R, Bamiou D-E, Baran J a, Zaida E. GIN (Gaps-In-Noise) test performance in subjects with confirmed central auditory nervous system involvement. Ear Hear. 2005; 26(6): 608–18.

7. Shinn JB, Chermak GD, Musiek FE. GIN (Gaps-In-Noise) performance in the pediatric population. J Am Acad Audiol. 1 de abril de 2009; 20(4): 229–38.

8. Keith RW. Random gap detection test. Missouri (USA): Auditec of Saint Louis; 2000.

9. Moraes AA, Rocha-Muniz CN, Schochat E. Efficacy of auditory training in elderly subjects. Front Aging Neurosci. 2015; 7: 1-9.

10. Momensohn-Santos TM, Dias AMN, Assayag FM. Processamento Auditivo. In: Momensohn-Santos TM, Russo ICP, organizadores. Prática da Audiologia Clínica. 5o ed São Paulo: Cortez; 2005. p. 275–90.

11. Russo ICP, Lopes LQ, Brunetto-Borginanni LM, Brasil L. Logoaudiometria. In: Momensohn-Santos TM, Russo ICP, organizadores. Prática da Audiologia Clínica. 5o ed São Paulo: Cortez; 2005. p. 135–54.

12. Folstein MF, Folstein SE, McHugh PR. "Mini-mental state". A practical method for grading the cognitive state of patients for the clinician. J Psychiatr Res. 1975; 12(3): 189–98.

13. Musiek FE. Frequency (pitch) and duration pattern tests. J Am Acad Audiol. 1994; 5(4): 265–8.

14. Musiek FE, Pinheiro ML. Frequency patterns in cochlear, brainstem, and cerebral lesions. Vol. 26, Audiology. 1987. p. 79–88.

15. Schochat E, Rabelo CM, Sanfins MD. Processamento Auditivo Central: Testes Tonais de Padrão de Frequência e de Duração em Indivíduos Normais de 7 a 16 anos de idade. Pró-Fono. 2000; 12(2): 1–7.

16. Samelli AG, Schochat E. The gaps-in-noise test: gap detection thresholds in normal-hearing young adults. Int J Audiol. 2008; 47(5): 238–45.

17. Parra VM, Iório MCM, Mizahi MM, Baraldi G dos S. Testes de padrão de freqüência e de duração em idosos com sensibilidade auditiva normal Frequency. Rev Bras Otorrinolaringol. 2004; 70(4): 517–23.

18. Ishii C, Arashiro PM, Desgualdo L. Ordenação e resolução temporal em cantores profissionais e amadores afinados e desafinados. Pró-Fono. 2006; 18(3): 285–92.

19. Chermak GD. (Central) Auditory Processing Disorders: New Perspectives. San Diego: Singular Publishing Group; 1997.

20. Zaidan E, Garcia AP, Tedesco MLF, Baran JA. Desempenho de adultos jovens normais em dois testes de resolução temporal. Pró-Fono. 2008; 20(1): 19–24.

21. Samelli AG, Schochat E. Estudo da vantagem da orelha direita em teste de detecção de gap. Rev Bras Otorrinolaringol. 2008; 74(2): 235–40.

22. Liporaci FD, Frota SMMC. Resolução temporal auditiva em idosos. Rev Soc Bras Fonoaudiol. 2010; 15(4): 533–9.

23. Campbell RAA, King AJ. Auditory neuroscience: A time for coincidence? Curr Biol. 2004;14(20):886–8.

24. Onoda RM, Pereira LD, Guilherme A. Reconhecimento de padrão temporal e escuta dicótica em descendentes de japoneses, falantes e não-falantes da língua japonesa Temporal. Rev Bras Otorrinolaringol. 2006; 72(6): 737–46.

25. Mesquita LG de, Pereira LD. Processamento temporal em idosos: o efeito da habilidade de resolução temporal em tarefas de ordenação de série de sons. Rev CEFAC. 2013; 15(5): 1163–9.

26. Sanchez ML, Nunes FB, Barros F, Ganança MM, Caovilla HH. Avaliação do processamento auditivo em idosos que relatam ouvir bem. Braz J Otorhinolaryngol. 2008; 74(6): 896–902.

27. Samelli AG. Alessandra Giannella Samelli O teste GIN (Gap in Noise): limiares de detecção de gap em adultos com audição normal. USP; 2005.

28. Lima IM da S, Miranda-Gonsalez EC de. Efeitos da perda auditiva, escolaridade e idade no processamento temporal de idosos. Rev CEFAC. 2016; 18(1): 33–9.

29. Pinheiro MMC, Pereira LD. Processamento auditivo em idosos: estudo da interação por meio de testes com estímulos verbais e não-verbais. Rev Bras Otorrinolaringol. 2004; 70(2): 209–14.

30. John AB, Hall JW, Kreisman BM. Effects of advancing age and hearing loss on Gaps-in-Noise test performance. Am J Audiol. 2012; 21(2): 242–50.