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Evaluation of temporal auditory abilities in Parkinson's disease

Avaliação das habilidades auditivas temporais na doença de Parkinson

Evaluación de las habilidades auditivas temporal en la enfermedad de Parkinson

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Abstract

Introduction: Temporal processing is one of the most important aspects to be analyzed due to its strong connection with language and cognition, thus, language comprehension difficulties may be present in parkinsonians. **Objective:** To assess the auditory temporal abilities of individuals with Parkinson's disease (PD). **Methods:** An observational, cross-sectional study in which 14 individuals (mean age 64 years) were evaluated, seven in the study group with PD diagnosis, and seven in the control group with healthy individuals. The individuals underwent the Mini-Mental State Examination and basic audiological evaluation to exclude evidence of dementia and the presence of high hearing loss. To assess auditory abilities, the following special tests of central auditory processing (CAP) were selected: Dichotic Digit Test, Frequency Pattern Test and Gaps in Noise Detection Test (GIN). Statistical analysis was performed using the Mann-Whitney and Chi-square tests. **Results**: The individuals in the study group had worse performance than the control group in all evaluated CAP tests. There was a statistically significant difference between the groups for the standard frequency test (p-value: 0.041) and for the GIN test in

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Authors' contributions:
LVS: Study conception and design, data collection, analysis of results and article writing.
HFB: Study conception, data collection and article review.
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the left ear (p-value: 0.015). **Conclusion:** It was possible to conclude that individuals with PD present a greater impairment of the auditory abilities of ordering and temporal resolution in relation to the group of healthy elderly people. It is suggested that individuals with PD perform an assessment of their auditory abilities, since rehabilitation involving the temporal aspects of hearing can improve communication and socialization of these individuals.

Keywords: Parkinson Disease; Hearing Tests; Auditory Perception; Hearing; Cognition.

Resumo

Introdução: O processamento temporal é um dos mais importantes aspectos a ser analisado por sua forte ligação com a linguagem e cognição; sendo assim, dificuldades de compreensão da linguagem podem estar presentes nos parkinsonianos. **Objetivo:** Avaliar as habilidades auditivas temporais de indivíduos com doença de Parkinson. **Métodos:** Estudo do tipo observacional, transversal, no qual foram avaliados 14 indivíduos (média de idade de 64 anos), sendo sete do grupo estudo com diagnóstico de DP, e o grupo controle composto por sete indivíduos sem a doença. Os indivíduos realizaram o Mini-Exame do Estado Mental e avaliação audiológica básica para excluir indício de demência e presença de perda auditiva com grau elevado. Para avaliar as habilidades auditivas foram selecionados os seguintes testes especiais do processamento auditivo central: Teste Dicótico de Dígitos, Teste de Padrão de Frequência e teste de detecção de *Gaps in Noise.* A análise estatística foi realizada por meio dos testes Mann-Whitney. **Resultados:** Os indivíduos do grupo estudo tiveram pior desempenho que o grupo controle em todos os testes do PAC avaliados. Houve diferença estatisticamente significante entre os grupos para o teste padrão de frequência (p-valor: 0,041) e para o teste GIN na orelha esquerda (p-valor: 0,015). **Conclusão:** Foi possível concluir que os indivíduos com DP apresentam maior comprometimento das habilidades auditivas de ordenação e resolução temporal em relação ao grupo de idosos saudáveis. Sugere-se que indivíduos com DP realizem avaliação das habilidades auditivas, pois a reabilitação envolvendo os aspectos temporais da audição pode melhorar a comunicação e sociabilização desses indivíduos.

Palavras-chave: Doença de Parkinson; Testes Auditivos; Percepção Auditiva; Audição; Cognição.

Resumen

Introduccion: El procesamiento temporal es uno de los aspectos más importantes a analizar debido a su fuerte conexión com el lenguaje y la cognición, por lo que las dificultades em La comprensión Del lenguaje pueden estar presentes em los parkinsonianos. **Objetivo:** Evaluar la habilidade auditiva temporal de las personas com Enfermedad de Parkinson (EP). **Metodos:** Estudio observacional, transversal e nel que se evaluaron 14 individuos (edad media 64 años), siete del grupo de estudio con diagnóstico de EP, y grupo control de siete indivíduos sanos. Los individuos se sometieron a un Mini Examen del Estado Mental y una evaluación audiológica básica para excluir evidencia de demencia y la presencia de hipoacusia alta. Para evaluar las habilidades auditivas, se seleccionaron las siguientes pruebas especiales de procesamiento auditivo central (PAC): Prueba dicótica de dígitos, prueba de padrón de frecuencia y prueba de detección de *Gaps in Noise* (GIN). El análisis estadístico se realizó mediante las pruebas de Mann -Whitney y Chi-cuadrado. **Resultados:** Los indivíduos del grupo de estudio se desempeñaron peor que el grupo de control en todas las pruebas PAC evaluadas. Hubo una diferencia estadísticamente significativa entre los grupos para la prueba de frecuencia estándar (valor p: 0.041) y para la prueba GIN em el oído izquierdo (valor p: 0.015). **Conclusión:** Se pudo concluir que los indivíduos con EP presentan um mayor deterioro de las habilidades auditivas de ordenamiento y resolución temporal em relación al grupo de ancianos. Se sugiere que las personas con EP realicen una evaluación de las habilidades auditivas porque la rehabilitación que involucra aspectos temporales de la audición puede mejorar la comunicación y socialización de estas personas.

Palabras clave: Enfermedad de Parkinson; Pruebas auditivas; Percepción Auditiva; Audicion; Cognición.

Introduction

Parkinson's disease (PD) is a degenerative disease of idiopathic origin caused by the lack of production of a neurotransmitter synthesized in the *substantia nigra* known as dopamine. It is characterized by a motor disorder including at least two signs or symptoms of the classic tetrad: rest tremor, bradykinesia and muscle stiffness and postural instability[1].

The effects of degenerative changes caused by neuronal loss in the frontal region and fronto-striatal dysfunction lead to loss of movement control, visuospatial deficits and cognitive dysfunction. Since working memory and executive functions are affected, Parkinsonians may have deficits in language comprehension[2]. These issues are related to the neurodegenerative process of PD and the common neurobiological processes of aging[3,4].

All structures of the auditory system must be intact and transmit information detected by the peripheral system to the auditory cortex and association areas in order to decode sounds[5].

Central auditory processing (CAP) refers to the efficiency and efficacy of the central nervous system (CNS) in interpreting auditory information, consisting of skills such as: location and lateralization of the sound; auditory discrimination; hearing pattern recognition; auditory performance with competitive and degraded acoustic signals; temporal aspects of hearing, including temporal integration, temporal discrimination, temporal ordering, and temporal masking[6].

Due to its strong connection with language and cognition, the auditory temporal processing is one of the most important aspects among the auditory abilities analyzed in the CAP. In addition to providing information on the perception of speech intonation, the temporal ordering of phonemes is used in words, prosody and aspects of reading and writing[7]. Temporal abilities are clinically assessed through tests of temporal ordering, ability to sequence sounds at a given time, and temporal resolution ability to perceive the silence between two sounds produced[8].

Although some studies have found changes in the auditory abilities of temporal ordering and figure-ground in subjects with PD when compared with subjects without this comorbidity[3,4,8], in addition to difficulties in understanding sentences due to interruption in neural networks[9], there are few studies in the literature on this topic.

Thus, the auditory perception assessment is very important for the enrichment of scientific literature and measurement of the relationship between neuronal degeneration and auditory skills. Based on the above, this study aimed to assess temporal auditory skills in individuals with Parkinson's disease.

Material and Methods

This was an observational and cross-sectional study approved by the Research Ethics Committee of the Universidade Federal de Santa Catarina (UFSC) under the opinion no. 118.889. All subjects were informed about their free and spontaneous participation and signed a Free and Informed Consent Form.

The study participants were divided between the Control Group (CG), which included healthy individuals, and the Study Group (SG), which consisted of subjects with PD who were treated at a Reference Rehabilitation Center.

The facilities of the Clínica Escola de Fonoaudiologia at the UFSC were used to assess the participants. The study included individuals who met the following inclusion criteria: 50 years of age or older, who had Portuguese as their first language, literate, non-alcoholics or illicit drugs users, hearing thresholds within normal limits, up to mild symmetrical bilateral sensorineural hearing loss[10], no conductive hearing impairment and no evidence of dementia.

The Mini-Mental State Examination (MMSE) cognitive screening test[11] was used to rule out dementia in patients, with maximum scores of 30 points divided into tasks of temporal and spatial orientation, immediate memory, attention and calculation, evocation and language. Scores from 21 were considered with no evidence of cognitive changes for subjects with complete elementary education. In turn, scores from 23 and 24 were considered for individuals with incomplete high school and complete higher education, respectively[12].

The patients included in the SG were classified as mild PD (1; 1.5; 2 and 2.5) and moderate PD (3 and 4), by the neurologist at a reference rehabilitation center, according to the Hoehn and Yahr scale[13].

All individuals already had a basic audiological evaluation consisting of pure-tone threshold audiometry, logoaudiometry and tympanometry. Tympanometry analyzed the tympanometric curve and stapedial acoustic reflexes. The acoustic reflexes were classified as adequate when the difference between the audiological threshold and the contralateral reflexes were between 70 and 100 dBNS. If they were reduced, increased or absent, they were classified as altered[14].

The CAP assessment was conducted in one day and included the following tests: Dichotic Digit Test (DDT), Frequency Pattern Test (FPT) and Gaps-In-Noise (GIN) test.

The DDT[15] is a dichotic listening test (two different stimuli produced at the same time in both ears), in which four digits are pronounced in pairs to the individual. This study assessed the binaural integration process, in which the individual is asked to repeat the four numbers listened to regardless of the order presented. This test was chosen for the purpose of screening in order to detect CAP disorders[16] according to the values considered for analysis as normal by Pereira and Schochat[15].

The Frequency Pattern Test (FPT)[17] consists of three tones of 150 milliseconds (ms), with frequencies of 880 Hz (low tone - "G") and 1122 Hz (high tone - "A") . The individual should name the three tones in the order heard and was classified according to the standards of normality proposed by Corazza[18].

The Gaps-In-Noise (GIN) test[19] was used in this study in order to determine the detection of silence intervals (gaps), thus evaluating the auditory ability of temporal resolution. This test consists of a monotic listening (two sounds produced at the same time in one ear) in which the individual hears a six-second white noise band, which included gaps in different positions and with different durations (0, 2, 3, 4, 5, 6, 8, 10, 12, 15 or 20 ms). Subjects were expected to discriminate gaps in this test. Normal standards were followed for elderly people with normal hearing[20] and for elderly people with hearing loss according to the national literature[21]. Many individuals, mainly from the SG, had great difficulty in understanding and performing this test, requiring the repetition of instructions and training tracks countless times. Thus, gaps produced manually by the evaluator on the audiometer were adopted for these individuals as training, using white noise to better understand the test. If the test was still not possible, the patient would be withdrawn from the study.

Mann-Whitney U test was used in order to compare the results between the groups. A 5% descriptive level ($p \leq 0.05$) was assumed for statistical significance. A superscript asterisk was added in the results to indicate statistical significance.

Results

Regarding the sociodemographic data of the 14 individuals who participated in the study, seven were male and seven female, with a predominance of females (71.42%) in the CG and males (71.42%) in the SG. The SG included five (71.42%) individuals with mild PD and two (28.58%) with moderate PD.

As shown in Table 1, there was no statistically significant difference between the groups regarding age, education and the subjects' cognitive aspects.

Table 1. Descriptive data from CG and SG, referring to age, education and MMSE

Groups		Age	Educational level	MMSE
CG	Mean (+/-SD)	64.43 (+/- 11.29)	9.57 (+/- 6.24)	26.14 (+/-1.95)
	Median	69	11	26
SG	Mean (+/-SD)	64.57 (+/-11.94)	4.14 (+/-3.08)	23.57(+/-3.04)
	Median	70	3	22
	p-value	0.94	0.05	0.12

Legend: CG=Control Group; SG=Study Group; SD=Standard Deviation; MMSE=Mini-Mental State Examination; Age and Educational Level=Presented in years; Mann-Whitney U test.

Regarding acoustic immittance measures, type A curves had a higher occurrence in both groups. In turn, only one Air curve was recorded in the RE and LE of each group, suggesting that there was no statistically significant difference (p-value=1.00).

As for the presence of the stapedial acoustic reflex, the frequency of 4000 Hz showed the greatest change in both groups. No significant differences were found for any frequency in both ears when comparing the CG and SG.

Table 2 shows the descriptive data from the CAP tests that assessed hearing skills.

Table 2. Descriptive data from auditory processing tests and result of statistical analysis

GROUPS		FPT%	GIN T RE ms	GIN T LE ms
CG	Mean (SD)	78 (+/-6.37)	7 (+/-2.39)	7.57 (+/-1.98)
	Median	93.3	6	8
SG	Mean (SD)	39.52 (+/-7.64)	9.33 (+/-2.06)	10.37 (+/-3.44)
	Median	50	10	9
Analysis between groups	p-value	0.04*	0.07	0.10

Legend: CG=Control Group; SG=Study Group; SD=Standard Deviation; FPT=Percentage of Correct Answers in the Frequency Pattern Test; GIN T=GIN Test Threshold; RE=Right Ear; LE=Left Ear; *=Statistical Significance; Mann-Whitney U test.

Table 2 also shows that there was a significant difference between the performance of the SG and CG in the FPT and GIN test when analyzing the percentages of correct answers in the LE.

Discussion

CNS aging is one of the most compromising physiological implications. The loss of neurotransmitters occurs between 50 and 80 years of age, with the onset of PD around this stage. The *substantia nigra* that contains dopamine is particularly sensitive to aging when compared to other brain structures, and the PD is caused by its low production[22].

With regard to sociodemographic data (shown in Table 1), this study had a homogeneous population in terms of age, gender and education. As the mean age of the SG is within the range of greatest onset of the disease, the findings of this study are in line with the current literature[23]. Regarding the gender variable, some studies[8,23] report a higher incidence of PD in male individuals (in a ratio of 3:2), which is also in line with the results found in this study. Many studies[8,24,25] have used the MMSE cognitive screening test to assess executive functions. In this study, the mean score of individuals with PD in the MMSE was very similar to the score of a study[24] that included individuals with mild PD. Since the score tends to be lower in individuals with moderate to severe PD, the lack of statistical association in this study is believed to be due to the exclusion of cognitively compromised individuals.

As the study population underwent cognitive screening through the MMSE, the participants did not have dementia at the time of the examination. However, it should be noted that the low educational level and the duration of drug treatment used to deal with the motor symptoms of the disease may affect the onset of dementia in PD. The results found in this study in relation to the educational level (Table 1) showed that most of the individuals in the SG did not complete elementary school. Thus, the low educational level of the group may be a susceptibility factor to the possible onset of dementia[26].

According to the normality pattern of auditory thresholds of up to 25 dB followed by this study, the auditory thresholds reported in both groups are within the normal range, since the average of the speech frequencies (500 to 2000 Hz) was 13.56 and 17.13 in the CG and SG, respectively.[10]. Only one subject in the CG had mild sensorineural hearing loss in the left ear, while an individual in the SG also had hearing loss of the same type and degree, on the right ear. These two subjects were the oldest participants in each group, aged 80 years.

The hearing loss found in individuals with PD is similar to the hearing loss found in the elderly, known as presbycusis, in which there is greater impairment of the high frequencies bilaterally. However, the degree of impairment is greater in

individuals with PD, suggesting the participation of factors intrinsic to PD that potentiate the natural effects of aging[8,27].

Regarding stapedial acoustic reflexes, although both groups did not record occurrences at various frequencies, there were no statistically significant differences between the groups.

The protection of the inner ear against loud sounds is one of the main functions of the acoustic reflex. The absence of these reflexes may lead to discomfort in noisy environments and affect the socialization of individuals. This absence can be caused by several factors, including aging and changes in the CAP, especially at higher frequencies[28], which may explain the absence of acoustic reflexes in individuals in this study.

The results obtained regarding the CAP tests (Table 2) show that individuals with PD had changes in the auditory skills of ordering and temporal resolution. The results are in line with the current literature, which reports the impairment of the brain areas responsible for hearing processing, especially the auditory cortex, caused by this disease[8].

Among the tests applied, the DDT is a widely used test to assess binaural integration and is commonly recommended as a screening to detect CAP disorder in individuals with brain injuries[16]. However, this was the test that reported the least difference when comparing the CG and SG groups.

The DDT is sensitive to investigate the progressive degradation of the corpus callosum. This can be seen by the asymmetric percentage performance between the ears, while this asymmetry may explain a decline in the efficiency of inter-hemispheric transfer[29]. Although there was no significant difference between the groups, there was a greater asymmetry in the SG between the ears than in the CG. As PD intensifies the aging of the auditory pathways, this may have caused a more pronounced asymmetry in the SG.

The FPT showed a greater difference between the groups in this study, being considered the most difficult test by the participants (Table 4). The SG had an average of 39.52% correct answers, with a lower performance in individuals with PD (aged 50 to 80 years) who had an average of 70% using a FPT with musical tone stimulus[3]. The result of this study suggests that PD may affect the auditory ability of temporal ordering.

A patient in the CG who had mild sensorineural hearing loss had an average of correct answers in the FPT of 43.3%, which was below the normality criterion. In turn, another participant of the SG, who also had mild hearing loss, was unable to perform the test. Both participants were eighty years old, showing that aging combined with hearing loss causes changes in temporal ordering ability. However, in these cases, it caused disability when associated with PD.

A study including individuals with PD reported that the difficulties in distinguishing temporal patterns may be due to dysfunction of the auditory cortex that limits the ability to perceive the slight frequency changes presented in the test[4].

Responsible to assess the auditory ability of temporal resolution, the GIN test showed statistically significant results when the groups were compared only for the LE. However, no significant differences were found between the groups of individuals with PD and the control group in another study[8]. The authors believe that this result reflects the tasks used required greater cognitive expression.

It should be noted that the temporal resolution ability does not depend exclusively on the central nervous system, but also on peripheral hearing related to the spectral change and, as reported above, the aging of the auditory pathways is asymmetric and this may lead to a difference in the efficiency to detect gaps between ears[19].

When comparing the gap detection thresholds of this study with the results reported in the literature (7.3 ms in the RE and 7.7 ms in the LE), it is possible to notice greater efficiency of the elderly in detecting gaps when compared to individuals with PD[21].

The national literature reports that regardless of the degree of hearing loss, the ability of temporal resolution is impaired in the elderly population[22].

In general, the SG showed great difficulty in understanding this test, requiring several repetitions of instructions for most individuals and only the training range was not enough in some cases for them to understand the test. In these cases, gaps were produced manually by the evaluator on the audiometer, using white noise as a form of training, before effectively starting the GIN test.

The literature shows that PD makes the auditory system unable to follow fluctuations of rapid intensity, which led to the conclusion of the difficulty in detecting short temporal gaps, that is, in the temporal resolution ability. This can be

explained by the non-dopaminergic forms found in this pathology, which can affect the perception of gaps, due to the dysfunction of the auditory cortex[8].

Thus, the auditory tests that assess peripheral and central hearing should be included in the tests proposed for the assessment of PD patients to contribute to a more detailed diagnosis in relation to the patient's communication difficulties.

Initially, this study aimed to compare healthy individuals to individuals with mild and moderate PD. However, due to the need for adequate understanding for the performance of the CAP tests, it was not possible to compare the most advanced degrees of the disease as they had cognitive changes. Therefore, this limiting factor was a criterion for the exclusion of the subject from the sample.

The assessment and rehabilitation of hearing skills in individuals with PD are believed to potentially improve their communication and socialization process. It is essential that the communication of these patients is taken into account, as the rehabilitation of these abilities will assist in social inclusion and consequently improve their quality of life.

Conclusion

The results showed that individuals with PD have a greater impairment of auditory skills in ordering and temporal resolution in relation to the group of healthy elderly people. Therefore, as rehabilitation involving the temporal aspects of hearing can improve communication and socialization of individuals with PD, these individuals should perform an assessment of their auditory skills.

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