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Speech recognition in noise in individuals with normal hearing and tinnitus

Reconhecimento de fala no ruído em sujeitos com audição normal e queixa de zumbido

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ABSTRACT

Introduction: Auditory performance for suprathreshold sounds may be compromised even when the audiogram is normal. Patients with tinnitus but without hearing loss often complain of speech recognition difficulties, especially in noisy environments. **Purpose:** To investigate the performance in noise tests in individuals with normal hearing thresholds with and without tinnitus. **Methods:** Twenty adult individuals were evaluated, aged between 18 and 45 years, with hearing within normal limits, presenting or not with tinnitus symptoms, divided into two groups, the tinnitus group and the control group. The SRTN (sentence recognition threshold in noise) were surveyed with the LSP test (list of sentences in Portuguese). **Results:** The tinnitus group had the worst performance for the two noises used, but with a statistically significant difference only when using "speech-noise". **Conclusion:** We found that the performance of individuals with normal hearing and tinnitus in speech recognition in the presence of background noise is poorer than in patients without the symptom mainly in step obtained with speech-shaped noise.

Keywords: Tinnitus; Auditory pathways; Hearing tests; Speech intelligibility; Signal-to-noise ratio

RESUMO

Introdução: O desempenho auditivo para sons supraliminares pode estar comprometido, mesmo quando o audiograma é normal. Pacientes com zumbido sem perda auditiva queixam-se frequentemente de dificuldades de compreensão de fala, principalmente em ambientes ruidosos. **Objetivo:** Investigar o desempenho em testes de fala com ruído, em indivíduos com limiares audiométricos normais, com e sem queixa de zumbido. **Métodos:** Foram avaliados 20 sujeitos adultos, com idade entre 18 e 45 anos, com audição dentro dos padrões de normalidade, que apresentavam, ou não, o sintoma de zumbido, divididos em grupo zumbido e grupo controle. Foram pesquisados os limiares de reconhecimento de sentenças no ruído, por meio do teste Listas de Sentenças em Português. **Resultados:** O grupo zumbido apresentou pior desempenho para os dois ruídos utilizados, porém, com diferença estatística somente na utilização do ruído *speech-noise*. **Conclusão:** O desempenho de sujeitos com audição normal e queixa de zumbido, no reconhecimento de fala na presença de ruído competitivo, foi pior que em indivíduos sem o sintoma, principalmente na etapa com o ruído *speech-noise*.

Palavras-chave: Zumbido; Vias auditivas; Testes auditivos; Inteligibilidade da fala; Razão sinal-ruído

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INTRODUCTION

Auditory sensitivity is usually assessed in the clinic by means of pure-tone audiometry, which measures the lowest detectable sound levels at different frequencies. Thus, this measurement may reflect the loss of sensitivity to weak sounds, making it impossible to distinguish between outer and inner hair cell dysfunction or changes in the auditory nerve, even though damage to these structures is known to occur without affecting audiometric thresholds[1,2,3].

Speech recognition is one of the most important aspects of human auditory function, since it enables individuals to communicate efficiently, which is fundamental for their social integration, and this understanding depends on the integrity of the auditory nervous system. It has already been described that listeners with normal audiometric thresholds may report difficulties in understanding speech in noisy environments[2]. In an epidemiological study, which investigated the prevalence of hearing difficulties, 26% of adults interviewed reported hearing difficulties in a noisy environment, whereas only 16% had audiometric threshold changes (worse than 25 dB HL)[4].

It has also been reported that patients with tinnitus, but without hearing loss, often complain of speech comprehension difficulties, especially in noisy environments; in addition to that, they perform worse in speech tests in noise when compared to individuals without tinnitus[5,6].

Tinnitus can be defined as an auditory illusion, or sound sensation unrelated to the external source of stimulation, i.e. a perception of sounds in the absence of a physical sound source. It is frequently related to hearing loss, but it is also known to be present in individuals without apparent hearing loss[7,8].

In a study investigating brainstem auditory evoked potential responses (BAERs) in individuals with normal hearing, with and without a complaint of tinnitus, a significant reduction in Wave I amplitude (generated by primary auditory fibers) was observed in the normal amplitudes of wave V[9]. According to the authors, these results provide physiological evidence for possible deafferentation (in this case, a synaptopathy), which manifests as a reduced cochleoneural response (wave I), with consequent normalization of the magnitude of the neuronal response within the brainstem (wave V). The clinical manifestations of this process could be perceived as poorer performance in psychoacoustic tasks, such as speech recognition in noise[4,5,6], tasks for discriminating temporal[7,10] and intensity[11] aspects.

This deafferentation (or cochlear synaptopathy, as it has been called)[12] has been described as "hidden hearing loss", since it is not possible to detect it with the standard measurements of hearing, namely audiometry[13,14].

In addition to this alteration, there is bound to be observed a probable malfunction in the medial olivocochlear system (MOCS), which plays a fundamental role in the recognition of target tones in the presence of noise[15].

Thus, the hypothesis is that individuals with normal audiometric thresholds and a complaint of tinnitus present with more difficulties in speech recognition in acoustically unfavorable environments as compared to those who do not present with the symptom. Accordingly, the purpose of the present study was to investigate the performance in the LSP test (list of sentences in Portuguese) of individuals with normal audiometric thresholds, with and without tinnitus.

METHODS

This prospective study was approved by the Research Ethics Committee at the *Faculdade de Ciências Médicas da Santa Casa de São Paulo* (number 1.003.002). The study population was composed of volunteers and participants from the researchers' social networks, who authorized their participation by signing the Voluntary Informed Consent Term.

Twenty individuals of both genders, who met the following inclusion criteria, were evaluated: aged between 18 and 45 years (the age limit was established so that the aging process did not interfere in the results); normal hearing (from 0 to 20 dB dB HL), at frequencies from 250 to 8000 Hz by air conduction; presence or absence of tinnitus symptoms; presence of distortion product otoacoustic emissions (DPOAE) (3 dB S/N above background noise, in all f2 surveyed). Individuals presenting with hearing loss, a complaint of neurological dysfunctions and problems in the middle and/or external ear were excluded from the study.

The patients were divided into a tinnitus group (TG), comprising seven individuals with tinnitus symptoms, bilaterally, and a control group (CG), comprising 13 individuals without a complaint of tinnitus. All participants in the tinnitus group presented with a complaint for at least the previous six months, always bilaterally. Importantly, all the patients in the tinnitus group were referred from medical care settings, through which an in-depth investigation of their complaint had been made and any possible confounding factors in this study had been ruled out.

Initially, individuals responded to an interview protocol with their personal, clinical and occupational data (anamnesis). Acoustic immitance measurements were then made, only in order to rule out middle ear alterations, followed by tonal audiometry and otoacoustic emissions. Once met the initial selection criteria, the individual subsequently underwent speech recognition testing, namely the LSP (Lists of Sentences in Portuguese) test[16]. The LSP test consists of a list of 25 sentences, plus another seven lists with ten sentences and a noise with speech spectrum. The sentences and the noise are recorded on a CD, in independent channels, allowing their presentation in both silence and noise.

In the tinnitus group, psychoacoustic measurements were taken of tinnitus (frequency and intensity) and the level of

annoyance from tinnitus was measured by means of the Tinnitus Handicap Inventory (THI)[17].

Sentence recognition thresholds in noise (SRTN) were obtained using the LSP test. The output of each channel was calibrated using the VU-meter on the audiometer, before testing started. The 1000 Hz tone, present in the same channel as that of the CD on which the sentences were recorded, as well as the masking noise present in the other channel, were set to zero-level. SRTN measurements were taken from each ear, separately, with the use of earphones, and the two stimuli (speech and noise) were presented ipsilaterally.

Testing was conducted with two types of noise: with the noise on the CD, as proposed by the author[16], and also with the speech shaped noise (SN), contained in and calibrated with the audiometer used. Calibration was performed in accordance with ISO-8253.

The application of the material was performed according to the criteria proposed by the author of the test[16], by employing the procedure referred to as "adaptive sequential or ascending-descending strategy", which allows to determine the speech recognition threshold, i.e. the level necessary for the individual to correctly identify around 50% of speech stimuli presented in a given signal/noise condition. This procedure was used for measuring sentence recognition in noise, both with the noise on CD and speech noise, both of whose intensities were maintained constant at 65 dB HL.

Initially, all individuals were tested with the sentences from list 1A (a list containing 25 sentences), used for training. The training was always presented only in one ear along with the noise recorded on the CD. The initial level for presenting the sentences was 75 dB HL, i.e. +10 signal/noise ratio.

Testing started after the training. Firstly, with the presentation of the subsequent lists, along with the noise recorded on the CD and then with the use of speech-noise noise present in the audiometer, and with the remaining lists. Different lists were always used for different noises and different ears.

It is important to mention that in the first study with earphones[18], a 7 dB difference between the recording volume of the two signals presented (speech and noise) was observed, and the sentences were recorded at an average intensity 7 dB below the intensity of the noise. For this reason, the author of the test indicated that, for the evaluations using earphones, it is necessary to subtract 7 dB from the speech values observed on the equipment's dial, a procedure thus adopted in this study.

Acoustic immittance measurements were performed with the AZ7 – R - Interacoustics® middle ear function analyzer. For recording otoacoustic emissions, the Echoport ILO292 USBII, ILO V6 Clinical software, was used. The audiometry and speech recognition tests were performed in an acoustic booth with an AC33 - Interacoustics® clinical audiometer and duly calibrated Telephonics® TDH-39 earphones. The sentences were presented using the original CD of the LSP test and a Compact Disc Digital Player, coupled to the audiometer.

The results were then submitted to statistical analysis for comparison between the control and the tinnitus groups. Because of the reduced size of the tinnitus group, and considering that the purpose of the study was to verify the influence of tinnitus on speech recognition in noise rather than to identify differences between the ears, it was opted to group the results from the right and left ears together for data analysis. It is worth mentioning that comparative tests were performed between the ears and no statistical relevance was found. The results from both ears were grouped together. The SRTN test data from both groups were compared by using Student's t-test. In all statistical analyzes, a significance level of 5% was adopted for rejecting the null-hypothesis.

RESULTS

Thirteen individuals from the control group and seven individuals from the tinnitus group were evaluated, totaling 26 ears from the control group and 14 from the tinnitus group. The distribution of the study population according to gender and age is shown in Table 1.

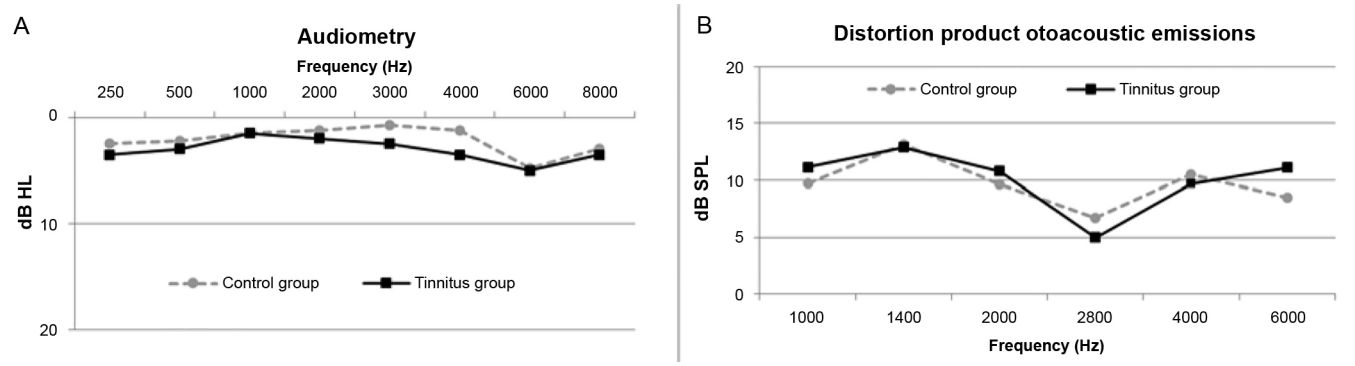
The mean tonal thresholds and the amplitude of distortion product otoacoustic emissions in both groups are shown in Figure 1.

With respect to the psychoacoustic testing of the tinnitus group, i.e. the mean frequency and intensity of the tinnitus and the THI questionnaire results, it was found that, on average, tinnitus could be qualified as negligible (0 to 16%) and, at most, could be considered as having a mild impact (18% to 36%), by one participant (Table 2).

In regard to the results from the LSP (Lists of Sentences in Portuguese) test, performed with the noise recorded on CD and speech-noise noise, the values refer to the signal/noise ratio obtained, i.e. to the lowest ratio the individuals needed for recognizing 50% of sentences presented in the

Table 1. Population distribution according to gender and age

Group	Gender				Age (years)	
	Female		Male		Mean	Median
	n	%	n	%		
Control	8	61.54	5	38.46	26.1	26
Tinnitus	4	57.14	3	42.86	31.75	31



Subtitle: DPOAE = Distortion product otoacoustic emissions

Figure 1. A: Mean curve of the audiometric thresholds. B: Mean curve of the DPOAE amplitudes by f2 in both groups

Table 2. Analysis of the psychoacoustic responses of tinnitus, as to frequency and intensity, and performance in the THI[17] test in the tinnitus group

Group	Acuphenometry				THI			
	Frequency		Intensity		Mean	Median	Minimum	Maximum
	n	f	n	dB SL				
Zumbido	14	8,21	14	11	11,7%	9,5%	0%	29%

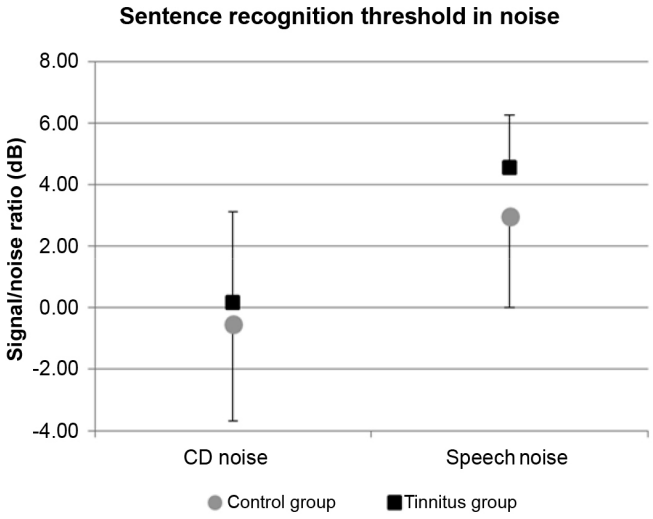
Subtitle: THI = Tinnitus Handicap Inventory

Table 3. Analysis of the signal\noise ratio responses in the Lists of Sentences in Portuguese test using the noise on the CD and speech noise, according to mean, median, minimum values and maximum values, and p value, separated by group

Noise	Group	Mean	Median	SD	Min	Max	n	p value
CD	Control	-7.54	-7.5	3.13	-13.3	-3.2	26	0.131
	Tinnitus	-6.85	-7.3	2.97	-12	-1.9	14	
SN	Control	-4.02	-3.8	2.98	-10.7	0.8	26	0.013*
	Tinnitus	-2.45	-2.75	1.72	-5	-0.1	14	

* Significant values (p<0.05)

Subtitle: CD = masking noise contained in the test; SN = speech noise contained in the audiometer; SD = standard deviation



Subtitle: SRTN = sentence recognition threshold in noise; LSP = Lists of Sentences in Portuguese; CD = masking noise contained in the test

Figure 2. Mean and standard deviation of the SRTN in the LSP test using the noise on the CD and speech noise, separately, by group

presence of noise (Table 3). In Figure 2, the mean results of both conditions are presented.

It can be observed in Table 3 and Figure 2 that, for both noises, i.e. both the noise on the CD and speech noise, the tinnitus group needed a higher signal/noise ratio in order to recognize 50% of presented sentences, with the difference being statistically significant between the groups when speech-noise noise was being investigated.

DISCUSSION

In this study, the LSP (Lists of Sentences in Portuguese) test was used, with the noise on the CD contained in the test itself and an added step with another masking noise contained in the audiometer, the speech noise. The two noises were used due to the fact that auditory perception is different for noises with different spectra[19,20,21]. The performance of the tinnitus group presented with worse performance for both noises; however, the difference was only significant when using speech-noise noise. In comparing the responses from both

groups to the two noises, it is possible to state that the study conditions with the speech-noise were more difficult than were the conditions with the noise on the CD. Both groups needed a more favorable signal/noise ratio for recognizing 50% of sentences with speech-noise noise as compared to the noise recorded on the CD. Similar results have also been presented elsewhere[22] and similar data have been reported in other studies[5,6,21].

With regard to the psychoacoustic measurements of tinnitus and the level of annoyance as measured by the THI, as in other studies, no correlation could be established[7,8,14,23].

In a study in which the Threshold Equalizing Noise (TEN) test(23) was used in order to investigate the performance in identifying target sounds in the presence of noise, the thresholds obtained in the presence of ipsilateral noise were statistically higher (worse) in the tinnitus group than in the control group. The authors[23] point out that it was possible to observe that the target tone in the tinnitus group did not benefit from unfavorable listening conditions, unlike what was observed in the control group, in which the thresholds remained practically unchanged with the introduction of noise.

Communication difficulties, in the majority of patients with tinnitus, are typically attributed to poor performance in speech perception, caused by hearing loss[4,5]. The effect of tinnitus on speech perception, without hearing loss, is still unclear[5], indicating that, in noisy environments, individuals with tinnitus appear to have a lower speech recognition capacity than those without tinnitus, as observed in this study. These data add to the evidence that the effect of tinnitus on the perception of speech or pure-tone in the presence of noise is in fact negatively manifested, compromising the performance of individuals in these situations. The results obtained in the present study confirm this premise[23].

It has been previously shown that patients with tinnitus and normal audiometry presented with worse pure-tone detection thresholds in the presence of competitive noise[14,23]. While the data obtained in this study alone do not allow one to state what actually makes performances different, a recent hypothesis for this to occur would be the reduction in the number of afferent auditory fibers (deafferentations), culminating in a reduction in feedback from the medial olivocochlear system and contributing to the increase of tone detection thresholds in noise. Thus, normal hearing thresholds can also be accompanied by an impaired function of the efferent fibers, which protrude from the brainstem into the cochlea[23,24,25].

In individuals with tinnitus and normal hearing, it is possible that the deafferentation of the auditory nerve fibers is present[9], as evidenced by the intensity discrimination thresholds, which are significantly higher in the tinnitus group with[11]. Thus, obtaining higher thresholds in the presence of noise could be the psychoacoustic result of a possible auditory information processing deficit[9,11].

The hypothesis of deafferentation has been discussed by several authors[7,9,10,11,12,14,18,22], but it has only been proven in animal models[3,12]. Although it presents as a subclinical alteration, auditory deafferentation could cause a reduction in the probability and synchrony of nerve fiber firings and, consequently, impair speech coding, especially in unfavorable listening conditions[13,19]. The reduction of auditory information from the injured area would decrease the inhibition that the medial olivocochlear system normally exerts on the hair cells. One of the actions resulting from this mechanism would be the reduction of the masking effect, produced by noise or other sounds[24,25].

Considering the functions of the medial olivocochlear system, if deafferentation modifies auditory information input and, consequently, interferes with the firing and the functioning of this system, the amplification of the previously reduced noise, favoring the perception of the target signal in the latter's presence, will no longer take place. Accordingly, the recognition of stimuli in the presence of noise may be compromised or, at least, different from that in an intact system. Bearing this in mind, this behavior could be observed in the tinnitus group's worse performance in the LSP test, with both noises. In other words, the signal/noise ratio required for 50% target sentence recognition was statistically higher in the tinnitus group, indicating that this noise, which should be attenuated by the medial olivocochlear system, was making the conditions for the main sound to be heard less favorable.

The normal hearing sensitivity, as evidenced by audiometric thresholds within the normal range up to 8000 Hz, may thus be masking subclinical auditory changes[12,13]. The hypothesis is that, in the present study, these neural changes would be reflected by the thresholds for the LSP test with speech noise, which were statistically higher in the tinnitus group. In a way, it can be said that the results of this study converge towards other studies[7,11,14,23] in regard to psychoacoustic behavior.

An important limitation to this study is that the high frequency thresholds (> 8000 Hz) were not obtained. Along with the processes described above, it is possible that a significant loss at ultra-high frequencies is also present in the cases of tinnitus, which contributes to worsening the performance. In a recent study investigating deafferentations in young people exposed to noise, a statistical difference was observed in ultra-high frequency audiometric thresholds. The authors concluded that differences between groups (exposed and unexposed) were due to deafferentations. However, the striking differences in the ultra-high frequency thresholds may justify the divergent performance among the evaluations performed[26].

Regardless of the hypotheses raised, the results presented in this study highlight the importance of investigating subclinical auditory aspects, taking into consideration the complaints brought by the patient. Even with audiometric

thresholds within normal ranges, the symptom should be investigated by using instruments that can reproduce and/or reveal facts evidencing any difficulty or dysfunction of the system. This would be the first step towards an appropriate intervention.

CONCLUSION

The performance of individuals with normal hearing and a complaint of tinnitus in speech recognition in the presence of competitive noise was worse than in individuals without the symptom, especially in the step with speech-noise noise.

The analysis sums up that, in fact, the control and tinnitus groups are different in regard to the performance in speech tests in the presence of noise.

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