Temporal resolution in sensorineural hearing loss

Resolução temporal em perdas auditivas sensorioneurais

Giselle Goulart de Oliveira Matos[1], *Silvana Frota*[2]

ABSTRACT

Purpose: To evaluate temporal resolution in adults with mild and moderate sensorineural hearing loss using the *Gaps in Noise* (GIN) test to determine whether these losses affect the test performance. **Methods:** Fifty-seven patients between 20 and 59 years of age (30 men and 27 women) were evaluated; these patients had a complete medical history taken and underwent ENT examination, basic audiological evaluation, and auditory screening via the dichotic digits test. The subjects were divided into three groups: G1 (normal hearing), G2 (mild hearing loss), and G3 (moderate hearing loss). The appropriate statistical analysis was performed, and the adopted level of significance was 5%. **Results:** A significant proportion of men was observed in the group with hearing loss. There were no significant differences in test performance between the groups. However, the control group's performance was worse than the normality criteria set for young Brazilian adults. The mean gap detection threshold for the total sample was 8.2 ms in both ears, and the mean percentage of correct responses was 49.7% for the right ear (RE) and 50.6% for the left ear (LE). **Conclusion:** The temporal resolution evaluated by the GIN test was not influenced by mild-to-moderate sensorineural hearing loss either in the gap detection thresholds or in the percentage of correct responses for both ears.

Keywords: Hearing; Hearing loss; Auditory perception; Auditory perceptual disorders; Acoustic stimulation; Hearing tests; Adult

RESUMO

Objetivo: Avaliar a resolução temporal em adultos com perdas auditivas sensorioneurais de graus leve e moderado, por meio do teste *Gaps in Noise* (GIN), a fim de verificar se essas perdas influenciam no desempenho do teste. **Métodos:** Foram avaliados 57 pacientes, com idades entre 20 e 59 anos (30 homens e 27 mulheres), que realizaram anamnese, avaliação otorrinolaringológica, avaliação audiológica básica e triagem do processamento auditivo, com o teste Dicótico de Dígitos. Os sujeitos foram alocados nos grupos G1 (audição normal), G2 (perda auditiva leve) e G3 (perda moderada). Foi realizada análise estatística apropriada e o nível de significância adotado foi de 5%. **Resultados:** Observou-se presença significativa de homens no grupo com perda auditiva. Não foram encontradas diferenças significativas no desempenho do referido teste entre os grupos. Porém, no grupo controle, foram observados piores desempenhos, quando comparados com o critério de normalidade previsto para adultos jovens brasileiros. A média do limiar de detecção de *gaps*, da amostra geral, foi de 8,2 ms, em ambas as orelhas, e a média das porcentagens de acertos foi de 49,7% para a orelha direita (OD) e de 50,6% para a orelha esquerda (OE). **Conclusão:** A habilidade de resolução temporal avaliada pelo teste GIN não sofre influência da perda auditiva sensorioneural de graus leve e moderado, tanto nos limiares de detecção de *gaps* quanto na porcentagem de acertos, em ambas as orelhas.

Descritores: Audição; Perda auditiva; Percepção auditiva; Transtornos da percepção auditiva; Estimulação acústica; Testes auditivos; Adulto

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INTRODUCTION

Hearing integrity is necessary to ensure adequate perception of speech sounds so that stimuli can reach the central nervous system. It is believed that hearing disorders involve two aspects: 1) hearing loss, characterized by the impaired detection of sound energy; and 2) auditory processing disorders, which are hearing disorders characterized by the impaired analysis and/or interpretation of sound patterns[1]. An auditory processing disorder is a deficiency in one or more of the mechanisms and processes of the auditory system that are responsible for behavioral phenomena, such as sound localization and lateralization; auditory discrimination; auditory pattern recognition; temporal aspects of audition, including temporal resolution, temporal masking, temporal integration and temporal ordering; and auditory performance with competing and degraded acoustic signals[2].

Temporal processing refers to the perception of sound characteristics and their changes within a time interval[3]. Temporal resolution refers to the minimum time required to segregate or resolve acoustic events[4]. Because temporal resolution is closely related to speech intelligibility[5,6], which is a complex acoustic signal that is rich in both spectral and temporal characteristics[7,8], and because hearing-impaired individuals may complain of not being able to understand speech[9], we may hypothesize that temporal resolution is impaired in auditory deficiency. In a recent investigation[10], this ability was demonstrated to be influenced by sensorineural hearing loss. However, a question arose in that study as to whether the influence was due to hearing loss or to aging, as there was a significant difference in the age of each group, which indicated the necessity of conducting similar research on cochlear hearing loss in a younger group.

Therefore, the objective of the present study was to evaluate the temporal resolution in adults with mild and moderate sensorineural hearing loss, using the *Gaps in Noise* (GIN) test to determine whether these losses affect the test performance.

METHODS

This study was approved by the Research Ethics Committee of the Municipal Health and Civil Defense Authority of Rio de Janeiro (Secretaria Municipal de Saúde e Defesa Civil do Rio de Janeiro - RJ-SMSDC CEP), protocol nº 204/09. Each participant was informed about the purpose of the study and began the trial after agreeing to participate and signing the informed consent form.

Data collection was performed at Centro Municipal de Saúde Waldyr Franco (CMSWF), which is a moderate-complexity unit of the Program for Hearing Health Care of the City of Rio de Janeiro, between the months of February and August 2010.

The following materials were used: a Danplex® DA 65 audiometer, an Interacoustics® AT 235h Immittanciometer; a Potenza® CD player connected to the audiometer; and CDs for the dichotic digits test[11] and GIN test[3].

The present investigation was a prospective, cross-sectional cohort study that (at the end of the selection process) included 57 individuals of both genders: 30 (52.6%) men and 27 (47.4%) women. The 57 subjects were distributed into the following three groups: G1, consisting of 22 individuals (38.6%) with normal hearing; G2, consisting of 17 individuals (29.8%) with mild hearing loss; and G3, consisting of 18 individuals (31.6%) with moderate hearing loss. The subjects' ages ranged from 20 to 59 years, with a mean age of 45.4 (±9.6) years. The group with normal hearing was matched with individuals in both hearing loss groups. The selection of groups of individuals with hearing loss was made according to convenience, due to the difficulty of gathering the sample.

All of the subjects underwent a selection process that consisted of a medical history, ENT examination, basic audiological evaluation, and auditory screening using the dichotic digits test.

To arrive at the final sample, the following subjects were excluded based on the medical history: individuals outside the defined age range, illiterate individuals who regularly practiced music, individuals with associated neurological diseases or disorders, individuals having used psychotropic drugs within the 12 months preceding the survey, and individuals with a history of ear disease or surgery. Based on the ENT evaluation, subjects with external and middle ear and/or mastoid involvement were excluded. Based on the basic audiological evaluation, the following patients were excluded: individuals with conductive and mixed hearing losses, individuals with differences between the RE and LE thresholds at each frequency greater than 20 dB HL, individuals with tritonal averages above 55 dB HL, individuals with a percentage index of speech recognition (PISR) below 92% (for normal hearing) and less than 80% (for mild and moderate hearing losses)[12], individuals with a type B or C tympanometric curve, and individuals with no contralateral acoustic reflex in at least two of the four tested frequencies. Based on the central auditory processing evaluation, in which we chose to screen using the dichotic digits test, subjects who had a percentage score of less than 95% in each ear were also excluded[13].

Tritonal means (TM) of 500/1000/2000 Hz were used with air thresholds of 3000/4000/6000 Hz[14] to define the degree of normality or the degree of hearing loss. If there were different TMs in the same ear, then the degree of loss was defined as the greater mean. To define the individual's degree of hearing loss as the difference between the degree of RE hearing loss and the degree of LE hearing loss, criteria were adopted similar to those described above, i.e., the degree was defined based on the worse ear.

The three groups defined for the research procedure according to their degrees of hearing are reported in Chart 1.

Chart 1. Groups selected for the study procedure and their respective degrees of hearing

Groups	n	Degree of hearing	
G1	22	Normal	Both TM ≤ 25 dB HL
G2	17	Mild loss	At least one TM between 26 – 40 dB HL
G3	18	Moderate loss	At least one TM between 41 – 55 dB HL
G2 + G3	35	Group with loss	******************

Note: G1 = Group 1; G2 = Group 2; G3 = Group 3; TM = tritonal mean

The GIN test[15] was applied under conditions of monaural presentation, at 50 dB SL above the TM of 500/1000/2000 Hz. To eliminate the ear variable at the beginning of the test, 29 subjects (50.8% of the sample) began testing with the RE, and 28 individuals (49.12%) began testing with the LE. A practice run was conducted, and each subject was given guidance or clarification if there were uncertainties concerning the achievement of the proposed task. The perceived gaps were counted and recorded according to their durations. The gap detection threshold was considered to be the shorter gap perceived in at least 67% of the presentations, i.e., four times, as each gap appeared six times per test. The percentage of total correct responses above the threshold was defined for each test, based on the 60 existing gaps. A mean threshold of 5.43 ms and a mean percentage of correct responses of 67.25% have been proposed as normality criteria for young Brazilian adults with normal hearing[16].

The presence of two false positives (false intervals of silence that are designated by the subject) was counted as an error, thereby deducting a correct response from the percentage of total correct responses without affecting determination of the threshold[3].

Mann-Whitney, Kruskal-Wallis ANOVA, Student's t-test, One-way ANOVA, and Chi-squared tests were used for the statistical analysis. Nonparametric tests were applied because the variables did not exhibit a normal distribution (Gaussian) due to scattering, lack of distribution symmetry, the rejection of the normality hypothesis according to the Kolmogorov-Smirnov test, and/or the small sample size in some of the groups. A significance level of 5% was adopted.

RESULTS

There were no significant differences between the mean ages of the groups with normal hearing and hearing loss (43.5 years, with a standard deviation [SD] of ± 7.7 years, and 46.6 years, with SD ± 10.5 years, respectively, p=0.23), verified by Student t-test for independent samples. Similarly, there were no significant differences between the groups with normal hearing, mild hearing loss, and moderate hearing loss (43.5 years, with SD ± 7.7 years; 45.9 years, with SD ± 11.3 years; and 47.3 years, with SD ± 10.0 years, respectively, p=0.45), analyzed by one-way ANOVA. The χ^2 test revealed that the groups with hearing losses (G2+G3) had a significantly higher proportion of men (p=0.051) than did the group with normal hearing, and there was no significant difference (p=0.078) in the proportion of males in G1 (36.4%), G2 (52.9%), and G3 (72.2%).

No significant difference existed in the gap detection thresholds between individuals who began testing with the RE and individuals who began with the LE. The χ^2 test revealed no significant difference (p=0.35) in the proportion of men among the subgroups that began with the RE (58.6%) *versus* the LE (46.4%).

The results are presented as the means of gap detection thresholds and the mean percentage of correct responses, as these were the independent variables.

Table 1 presents the measures of central tendency of the GIN test for the 57 evaluated patients. Table 2 presents the measures of central tendency according to the group: G1 *versus* G2+G3, G1 *versus* G2 *versus* G3, and the corresponding descriptive levels (p values) of the statistical tests.

There was no significant difference in the GIN test measures between the groups with normal hearing (G1) and hearing loss (G2 + G3), as illustrated in Figures 1 and 2, or between groups G1, G2, and G3, as illustrated in Figures 3 and 4.

Figure 5 depicts the gap recognition performance of each group and of the total sample.

DISCUSSION

The present study was based on the analysis of 641

Table 1. General description of the gap detection threshold means and correct response percentages, by ear, using the GIN test

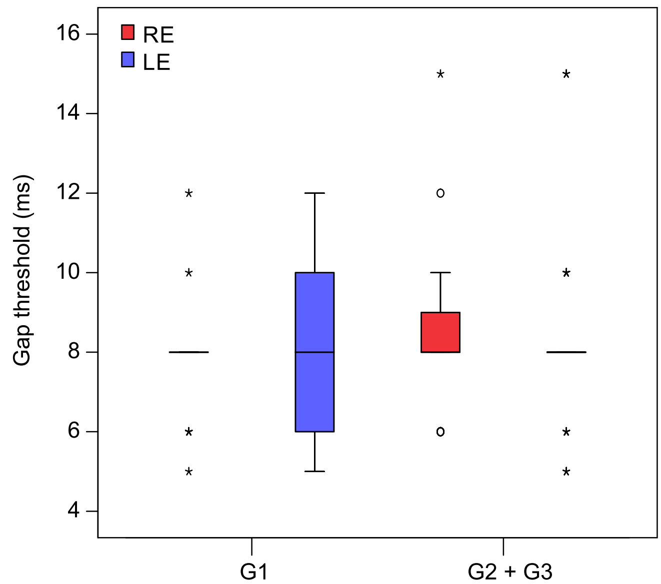
Variable		Ear	Mean	SD	Median	Minimum	Maximum
GIN	Threshold (ms)	Right	8.2	1.6	8	5	15
		Left	8.2	2.0	8	5	15
	% correct	Right	49.7	8.2	51.6	23.3	63.3
		Left	50.6	8.6	51.6	23.3	75

Note: SD = standard deviation

Table 2. Gap thresholds and percentage of correct responses, by group, for the GIN test

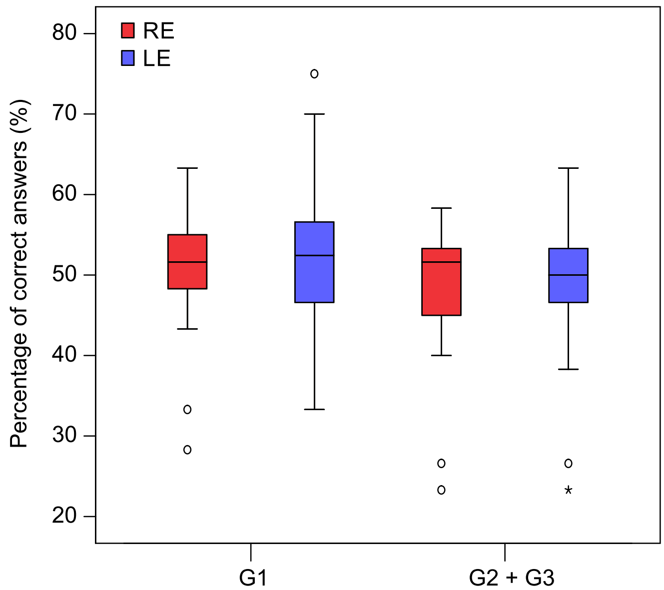
Variable		GIN			
		Threshold (ms)		Correct (%)	
		Right ear	Left ear	Right ear	Left ear
G1 (n=22)	Mean	7.8	8	51.3	52.7
	SD	1.4	1.8	8.7	9.3
	Med	8	8	51.6	52.5
	Min	5	5	28.3	33.3
	Max	12	12	63.3	75
G2+G3 (n=35)	Mean	8.5	8.3	48.7	49.2
	SD	1.7	2.1	7.9	8
	Med	8	8	51.6	50
	Min	6	5	23.3	23.3
	Max	15	15	58.3	63.3
p-value[a]		0.085	0.73	0.28	0.22
G1 (n=22)	Mean	7.8	8	51.3	52.7
	SD	1.4	1.8	8.7	9.3
	Med	8	8	51.6	52.5
	Min	5	5	28.3	33.3
	Max	12	12	63.3	75
G2 (n=17)	Mean	8.8	8.6	47.7	48.7
	SD	2	2.2	8	8.4
	Med	8	8	50	50
	Min	6	5	23.3	23.3
	Max	15	15	58.3	58.3
G3 (n=18)	Mean	8.2	8.1	49.7	49.7
	SD	1.4	2	7.8	7.7
	Med	8	8	52.5	50
	Min	6	5	26.6	26.6
	Max	12	15	58.3	63.3
p-value[b]		0.15	0.59	0.33	0.46

[a]Mann-Whitney test (p>0.05)
[b]Kruskal-Wallis ANOVA (p>0.05)
Note: SD = standard deviation; Med = median; Min = minimum; Max = maximum; G1 = normal hearing group; G2 = mild loss group; G3 = moderate loss group; G2 + G3 = loss group



Note: RE = right ear; LE = left ear

Figure 1. Gap detection thresholds for the right and left ear in the normal-hearing (G1) and hearing-loss (G2+G3) groups



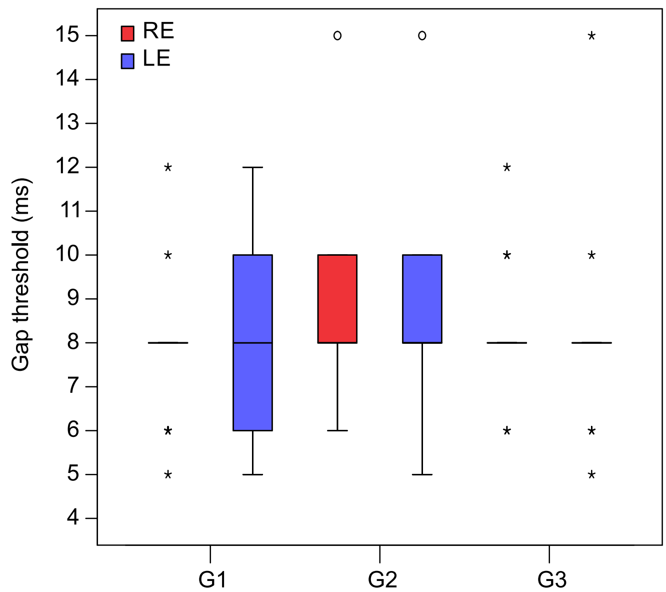
Note: RE = right ear; LE = left ear

Figure 2. Percentage of gaps perceived in the right and left ears of the normal-hearing group (G1) and the groups with hearing losses (G2+G3)

evaluation forms for patients enrolled in the Program for Hearing Health Care at CMSWF. It was extremely difficult to collect the sample. The small number of patients in the mild and moderate hearing-loss groups was due to the rigorous nature of the inclusion criteria, such as age, absence of asymmetries between the ears, presence of an acoustic reflex in at least two of the four frequencies tested and as a result of auditory processing screening using the dichotic digits test[(13)].

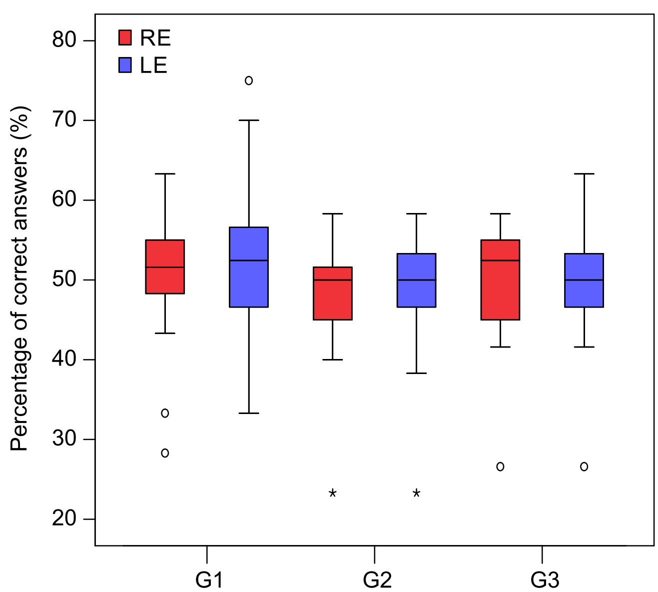
After obtaining the patient's medical history and conducting an ENT examination and an audiological evaluation, 66 patients were selected. However, of these, nine subjects were excluded as a result of the dichotic digits test. Despite the fact that the dichotic digits test does not evaluate the entire central auditory nervous system but only evaluates dichotic listening with binaural integration[(11)], this test was nonetheless chosen for auditory screening because the evaluation is widely used and described for this purpose[(16,17)]. Changes in central auditory processing in dichotic listening interfere with the performance of temporal resolution[(18,19)].

The lack of statistical significance between the mean ages of



Note: RE = right ear; LE = left ear

Figure 3. Gap detection thresholds in the right and left ears of the normal-hearing (G1), mild-loss (G2), and moderate-loss (G3) groups

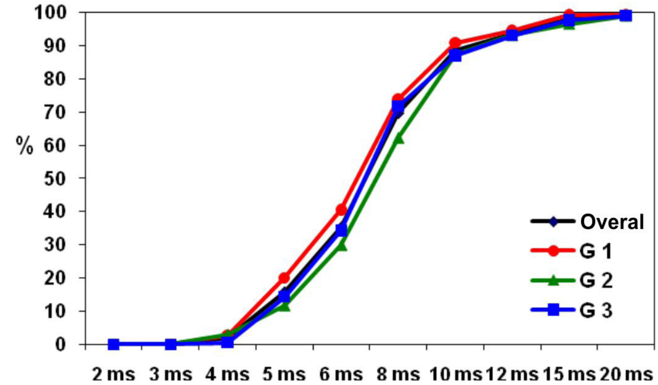


Note: RE = right ear; LE = left ear

Figure 4. Percentage of gaps perceived in the right and left ears of the normal-hearing (G1), mild-loss (G2), and moderate-loss (G3) groups

the groups eliminated age bias, which could have compromised the sample analysis[10].

The overall sample was homogeneous as to gender. The significantly higher proportion of men in the groupwith hearing loss may be attributed to two factors: first, this study was conducted with adults of working age, in whom there is a higher incidence of male subjects with hearing loss induced by high sound pressure level (HSPLIHL)[20]; second, there was



Note: G1 = normal hearing group; G2 = mild loss group; G3 = moderate loss group

Figure 5. Gap detection performance curve for whole sample and by group

participation by military personnel complaining of HSPLIHL, who reported not using proper protection during shooting activities[21].

The GIN test revealed a low incidence of false positives, which did not alter the final percentage of correct responses. This test was applied monaurally, although research has indicated that there are no differences between the performance of the RE and LE[10,17,22,23] due to the involvement of ipsilateral and contralateral pathways. Such differences were not found in our study (Table 1).

Based on the GIN test performance of the normal-hearing group, our control group, which showed mean gap detection thresholds of 7.8 ms in the RE and 8 ms in the LE and a percentage of correct responses of 51.3% in the RE and 52.7% in the LE, the mean gap detection threshold in both ears was longer, and the percentage of correct responses was lower than the normality criterion for young Brazilian adults with normal hearing[16]. Our findings also differed from the previously reported results[3,22]. In a study comparing the GIN test performance in individuals with normal hearing and with neurological impairment of the central auditory nervous system[3], gap detection thresholds of 4.8 ms for the RE and 4.9 ms for the LE were found in the control group for subjects aged 13 to 43 years, with a mean age of 24.6 years. In a study comparing the performance of GIN tests and *Random Gap Detection Tests* (RGDT) in a group of adults aged 18 to 29 years[22], thresholds of 5.38 ms were found for the RE and 4.88 ms for the LE. However, in the latter study, because the research was performed with men enrolled in a music therapy course, the results might have been influenced by the training on musical instruments, as musical perception cues are located within the temporal processing field[24], and this auditory experience might have modified the sensory coding[25,26]. In our study, musical training was one of the exclusion criteria in the medical history.

Despite awareness of the possible influence of age on performance in temporal processing tests[10,27-29], it was not possible to allocate younger individuals to the control group because the groups had to be matched for age and it was extremely difficult to find young people with hearing losses appropriate for the sensorineural loss groups (i.e., G2 and G3). In our control group of 22 participants, 16 subjects were older than 40 years (72.7%), and of these, eight subjects were older than 49 years (50%).

The mean age (45.4 years) in the present investigations was higher than the mean age in the studies that determined shorter gap detection thresholds and higher percentages of correct responses. This fact created problems in comparing the values found because no reference values existed for this age group. Despite the lower mean age, our results were similar to those of the control group from another study, in which the mean age was 67.3 years. In that investigation, mean gap detection thresholds of 7.3 ms for the RE and 7.7 ms for the LE were observed, and there were 57.6% correct responses for the RE and 55.8% for the LE[(10)].

Because of this intermediate mean of ages with no reference values, we recommend additional studies that would divide the groups by decades to better monitor performance in this regard. Our suggestion is based on research that has revealed an age-related decrease in response speed[(27)] and duration[(28)]. Did performance change in this group due to the age factor? If so, this fact may be a possible reason for our findings, in addition to possible changes in central auditory processing that were not evident because our screening was only conducted using the dichotic digits test, which evaluates only dichotic listening via binaural integration rather than evaluating the entire central auditory nervous system[(11)], as mentioned above.

Figure 5 reveals that, up to an interval of 4 ms, the gap recognition percentage was less than 10%. After 10 ms, the recognition percentage began to surpass 90%. However, it was only after 12 ms that all of the groups obtained a recognition percentage above 90%. The performance for each gap interval did not differ between the groups and the overall sample.

No significant differences were found between the group with normal hearing and the group with hearing loss or between the group with normal hearing and the groups with different degrees of hearing loss, regarding either the gap detection threshold or the percentage of correct responses (Table 2). There was no variation in the test performance, as evidenced by p values above the significance level for this study. The temporal resolution, as evaluated by the GIN test, was not affected by mild-to-moderate sensorineural hearing loss. These findings agree with studies that have demonstrated no influence of hearing loss on this ability[(28,29)]. However, the audiometric configurations found in the groups with hearing loss were mostly descending, with greater involvement of high frequencies. Thus, we hypothesize that audiometric configurations worse than those found in this study, with involvement of low frequencies, may negatively influence the level of temporal resolution. Ideally, additional investigations of temporal resolution in sensorineural hearing loss should be conducted with larger samples and various audiometric configurations to explain the hearing-impaired population's difficulties in understanding speech.

Temporal resolution appears to be more closely related to aging than to hearing loss[(28)], which may be associated with a decreased perception speed processed by the auditory cortex[(27)]. The study of elderly individuals[(10)] did not clarify whether the decrease in GIN test performance was influenced by hearing loss or by aging, as each group had a significantly increased mean age, compared with the previous group. Based on this discussion, we conclude that the decrease in GIN test performance is due to aging[(28)].

Certain complaints of difficulty hearing or of singing the same melody as the one heard are caused not by hearing loss but rather by decreased ability to temporally process the acoustic cues heard[(30)].

The results of the present investigation appear to contradict studies that designate temporal resolution as critical for speech intelligibility. However, we must analyze the suggestions described and conduct additional research to further clarify these findings.

CONCLUSION

In the present study, the temporal resolution, as evaluated by the GIN test, was not influenced by mild-to-moderate sensorineural hearing loss either in terms of gap detection thresholds or in the percentage of correct responses for both ears. However, one must consider that the control group individuals only received a dichotic digits test and, thus, might have had some type of auditory processing disorder.

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