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Reproducibility of temporal resolution tests in adults

Reprodutibilidade de testes de resolução temporal em adultos

Reproducibilidad de pruebas de resolución temporal en adultos

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Abstract

The behavioral test is frequent clinical practice in audiology due to its contribution to the diagnosis and speech therapy intervention processes. **Objective**: To verify the reproducibility of temporal resolution assessment protocols in adults. **Method**: A total of 34 subjects, 22 females and 12 males, with an average age of 26.21 years (20 to 52 years old; dp = 8.92) were included, following the criteria: absence of otological and/or audiological history and school complaints; normality in the audiological pattern and in the dichotic test of digits. The Random Gap Detection and Gap in Noise tests, at 50 dB, were used. Both were applied in two moments; the second application with a one-week interval of the first. The Wilcoxon test was used to analyze the performance of the sample in the GIN test in the ear and Friedman test in order to analyze the RGDT as a function of the frequency tested in the two moments. The level of significance of 5% was adopted. The intraclass correlation coefficient was used in the analysis of the agreement between the test (T1) and retest (T2) applications by the same evaluator (reproducibility).

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Authors'contributions:
EKS Study conception; Methodology; Data collection; Data interpretation; Outline of article; Critical review; LBA Data collection; Outline of article; Critical review; CKSE Data collection; Critical review; ADSN Data collection; Critical review; KRAL Data collection; Critical review; DLBS Data interpretation, Critical review, Orientation; SAB Study conception; Methodology; Data interpretation; Critical review; Orientation.

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Results: There was no difference between the frequencies tested in the RGDT (mean) in T1 and T2. There was a difference in GIN performance between the ears in T2. The test-retest reproducibility in the RGDT (mean) and GIN was substantial according to the intraclass correlation coefficient. **Conclusion**: There is reproducibility in the RGDT test when compared to the mean frequencies and in the GIN test bilaterally.

Keywords: Hearing; Reproducibility of Results; Auditory Perception; Adult.

Resumo

O uso de testes comportamentais é uma prática clínica frequente na audiologia devido à sua grande contribuição ao diagnóstico e aos processos de intervenção fonoaudiológica. **Objetivo:** Verificar a reprodutibilidade dos protocolos de avaliação da resolução temporal em adultos. **Método:** Participaram da amostra 34 sujeitos, 22 do sexo feminino e 12 do masculino, com média de idade de 26,21 anos (20 a 52 anos; dp= 8,92) seguindo os critérios: ausência de histórico otológico e/ou audiológico e queixas escolares; normalidade no padrão audiológico e no teste dicótico de dígitos. Foram utilizados na pesquisa os testes *Random Gap Detection Test* e *Gap in Noise*, a 50 dB. Ambos foram aplicados em dois momentos, sendo a segunda aplicação com intervalo de uma semana da primeira. O teste Wilcoxon foi utilizado para análise do desempenho da amostra no teste GIN em função da orelha e Teste de Friedman para análise do RGDT em função da frequência testada nos dois momentos. Foi adotado o nível de significância de 5%. O coeficiente de correlação intraclasse foi utilizado na análise da concordância entre as aplicações teste(T1) e reteste (T2) pelo mesmo avaliador (reprodutibilidade). **Resultados:** Não houve diferença entre as frequências testadas no RGDT (média) no T1 e T2. Houve diferença no desempenho do GIN entre orelha direita e esquerda no T2. A reprodutibilidade de teste-reteste no RGDT (média) e GIN foi substancial conforme o coeficiente de correlação intraclasse. **Conclusão:** Há reprodutibilidade no teste RGDT quando comparada a média das frequências e no teste GIN bilateralmente.

Palavras-chave: Audição; Reprodutibilidade dos testes; Percepção Auditiva; Adultos.

Resumen

El uso de pruebas comportamentales es una práctica clínica frecuente debido a su contribución al diagnóstico y intervención del lenguaje y del habla. **Objetivo:** Verificar la reproducibilidad de los protocolos de evaluación de La resolución temporal en adultos. **Método:** Participaron de la amuestra 34 sujetos, 22 del sexo femenino y 12 del masculino, con un promedio de 26,21 años (20 a 52 años; dp= 8,92) siguiendo los criterios: ausencia de histórico otológico, audiológico y quejas escolares; normalidad del patrón audiológico y en la prueba dicótica de dígitos. Se utilizaron las pruebas *Random Gap Detection Test* y *Gap in Noise*, a 50dB. Ambos fueron aplicados en dos momentos, siendo la segunda aplicación con intervalo de una semana de la primera. La prueba *Wilcoxon* fue utilizada para analizar el rendimiento de la muestra en la prueba GIN en función de la oreja y la prueba de *Friedman* para el análisis del RGDT en función de la frecuencia probada en los dos momentos. Se adoptó el nivel de significancia del 5%. El coeficiente de correlación intraclase fue utilizado en el análisis de la concordancia entre las aplicaciones test(T1) y reprueba(T2) por el mismo evaluador. **Resultados:** No hubo diferencia entre las frecuencias probadas en el RGDT en el T1 y T2. Hubo diferencias en rendimiento del GIN entre las orejas en el T2. La reproducibilidad de prueba-reprueba en el RGDT y GIN fue sustancial conforme el coeficiente de correlación intraclase. **Conclusión**: Hay reproducibilidad en la prueba RGDT cuando se compara el promedio de las frecuencias y la prueba GIN bilateralmente.

Palabras claves: Audición; Reproducibilidad de los Resultados; Percepción Auditiva; Adulto.

Introduction

The use of behavioral tests is a very frequent clinical practice in audiology due to its great contribution to the audiological diagnosis and the speech-language intervention processes, particularly, in the detection of alterations in temporal resolution, which can significantly impact language[1] and is fundamental for understanding of human speech as well as reading[2].

Time resolution is one of the skills of auditory processing, and it refers to the ability to detect small changes in stimuli over time[3]. Another study[4] stated that temporal resolution is sensitive to the influence of several factors such as: environmental conditions, socioeconomic conditions, language alterations (phonology, writing, stuttering), neurological changes (Dyslexia, Attention Deficit Hyperactivity Disorder) and music education. Individuals who have normal auditory thresholds for sound detection may still have difficulty understanding speech sounds, as central auditory processing skills (CAP) are required to perform well, i.e. some subjects may not have problems detecting but have difficulty understanding the language in loud or quiet environments due to the auditory processing disorder[5].

The audiogram is a primary tool for determining the type, degree, and configuration of hearing loss and provides professionals with information on auditory sensitivity only and no information on central auditory processing or auditory processing of speech or music[6]. For this reason there are tests capable of evaluating the temporal resolution ability, they are: The Random Gap Detection Test - RGDT and the Gap-in-Noise - GIN.

The Random Gap Detection Test (RGDT)[7] aims to determine the range detection threshold. Its presentation consists of a sequence of binaural stimuli presented at frequencies of 500, 1000, 2000 and 4000 Hz, with a random time interval of 0 to 40 milliseconds (ms), in which individuals are instructed to respond verbally if they are listening to one or two sounds. The threshold is considered from the shortest interval that the individual happens to identify the occurrence of two stimuli.

The Gap-in-Noise (GIN)[8] test also evaluates the temporal resolution ability, however through a monaural presentation of white noise and randomly inserted intervals ranging from 2 to 20 ms. Studies with adults have been conducted showing the good sensitivity, specificity and reproducibility of the GIN[8] test and normative standards for similar adult individuals[3,9] as found in the original study with American individuals[8] and in another study with Polish individuals[10]. In this test, the subject is instructed to push a button whenever he or she hears the pauses present in the noise band. In another study[3], no differences were observed in noise gap detection thresholds between the ages of 18 and 31 years in normal young adults, indicating a similarity in performance between the ages of young people with normal hearing conditions.

The ability of temporal resolution worsens with aging, since the normal values of the GIN and RGDT tests are growing according to the age group of 20 to 60 years[11].

There is a difference between the detection thresholds obtained in the same sample with the RGDT and GIN tests in different populations[9,11,12,13]. It is hypothesized that acoustically, the signals exhibit opposition in their characteristics, which can contribute to the different responses and performances in both tests. This difference in thresholds is explained by the fact that RGDT is a more complex test involving auditory fusion (at the moment the two stimuli are perceived as a single sound) and temporal resolution (at the moment the gap is detected), which would justify their higher thresholds[14]. There is better performance for the GIN test than RGDT [9,12,13] noting that GIN is easier to understand and apply while RGDT presents a task of greater complexity for understanding.

The differences observed in these two protocols point to questions about the reproducibility of these tests for different clinical applications both regarding diagnosis and the rehabilitation process, since they are often tests applied before and after intervention[15] and may or may not indicate development of the temporal resolution ability depending on the intervention performed.

However, there are few reports in the literature about the reliability or reproducibility of these tests, since when evaluating the first competence we analyze the accuracy of an instrument and one of the ways to verify it is through test-retest, since this technique allows to verify if similar results are obtained when the instrument is applied under the same methodological conditions, but at different times (reproducibility)[16].

One study[6] showed no differences greater than 10 ms when the RGDT test was reapplied in adults one week apart from the first test. In other studies[1,8] the reproducibility of GIN was considered to be excellent for adults in the test and retest research, including good sensitivity and specificity when evaluated with individuals with confirmed neurological lesions[6].

Thus, the present study aimed to verify the reproducibility of temporal resolution tests in adults.

Methods

This study was approved by the Research Ethics Committee (CEP) of the University Hospital Onofre Lopes of the Federal University of Rio Grande do Norte (CAAE 67114017.2.0000.5292).

To compose the sample of this study, 57 adult subjects were recruited by convenience. The subjects were informed about the procedures, benefits and confidentiality of the research and signed the Informed Consent Term (TCLE).

After exclusion of a total of 23 individuals, due to the inclusion criteria, the sample consisted of 34 subjects (22 women and 12 men), with an average age of 26.21 years (20 to 52 years old, dp = 8.92).

Subjects with the following characteristics were included: auditory thresholds within the standards of normality[17] and without current audiological complaints; tympanometry type A[18]; absence of known neurological, hormonal, psychological/psychiatric disease or disorders; performance equal to or greater than 95% in the dichotic digit test[19] in a binaural integration task as an indicator of normality in central auditory processing, Portuguese as mother language and without musical education. Thus, 17 subjects were excluded because they did not attend the second test session, one subject for not having performed the dichotic digit test, three subjects for performing less than 95% performance in the dichotic digit test and two with neurological history.

All subjects underwent audiological anamnesis and auditory processing; inspection of external auditory meatus; threshold tonal audiometry, acoustic emittance measurements, dichotic digit test, and temporal resolution ability assessment through the GIN and RGDT tests.

In tonal threshold audiometry, audiometric screening was performed in the intensity of 20 dB by air way in the frequencies of 250 to 8000 Hz, in an acoustic booth, and the audiometer used was the Madsen Itera II. In immitanciometry we sought to eliminate any compromises of the middle ear, which could influence the findings of the research. Prior to the emittanciometry, all subjects underwent a visual inspection of the external acoustic meatus, confirming the absence of cerumen or other factors that could impede the effectiveness of the evaluation.

In the acoustic booth the dichotic digits test was applied in the binaural integration task, which is comprised in sequences of digits presented by recording on the CD reproduced from the computer to the audiometer, Madsen Itera II, to the TDH-39 headphones placed in the individuals. The performance of the individual was analyzed by the percentage of correct answers in each ear.

The Random Gap Detection Test (RGDT)[7] and the Gap-in-noise Test (GIN)[6] were used in the research. They were performed by the CD coupled to the *Madsen Itera II* audiometer in the hearing room and language of the Laboratory of Technological Innovation in Health of the Federal University of Rio Grande do Norte.

The RGDT with intervals between the two tones ranging from 0 to 40 ms and from 50 to 300 ms (RGDT-Expanded), consists of pairs of pure tones in the frequencies of 500, 1,000, 2,000 and 4,000 Hz at 50 dB level of sensation presented binaurally. All subjects were properly instructed to signal gesturally if they heard a tone or two. Thus, the test was started at the frequencies of 500, 1000, 2000 and 4000 Hz in variable intervals from 0 to 40 ms. At the initial moment, in the training range if the subject did not identify any of the intervals as two tones from 0 to 40 ms, the RGDT-Expanded was used, measuring the same frequencies, but with intervals of 50 to 300 ms. In the RGDT analysis, it was considered the shortest interval from which the individual started to identify the presence of two tones consistently. Initially we obtained the value of the shortest interval per frequency and then we obtained the average among the four frequencies evaluated.

The GIN[8] test consisted of 6-second white noise stimuli interspersed with gaps randomly presented between 2 and 20 ms duration and are presented six times throughout each test range. These quiet intervals lie amid the white noise with varying durations and positions to attenuate inconsistent deductions and responses from the patient. The GIN features a training list and four test lists presented at a 50 dB level of sensation presented monaural. Thus, subjects were instructed to hear a continuous noise and when it was interrupted by a silence interval, they should push a button indicating that they had identified the silence interval. We consider the gap detection threshold to be the one detected in four of the six presentations. The reference value for normality in adults in the GIN test is mean of 4.9 ms (dp -1ms) for both ears[8].

Both tests were applied in two moments, the second application (retest - T2) was with an interval of one week of the first one (test-T1)[8,20] under the same conditions of application. Thus, the same evaluator was kept, same day of the week, same equipment and similar schedules for conducting the tests. The order of the procedures was randomized between each subject.

Data were tabulated and analyzed in SPSS 22.0. Initially, the Shapiro-Wilk test was used, which showed that the data did not present a normal distribution. The Wilcoxon nonparametric test was used for dependent data in the analysis between the performance of the sample in the GIN test in the ear and the Friedman test in order to analyze the RGDT as a function of the frequency tested at each moment (test and retest). The significance level of 5% was adopted.

In the analysis of the agreement between the applications of the tests and retest by the same evaluator (reproducibility), 95% confidence intervals and the use of the interclass correlation coefficient (ICC) were estimated. The following criteria were considered for agreement interpretation: 0 (absence), 0-0.19 (poor), 0.20-0.39 (weak), 0.30-0.59 (moderate), 0.60- 0.79 (substantial), and 0.80-1.0 (almost complete)[21].

Results

From the analysis of the performance of individuals in GIN and RGDT at the two moments of application (test and retest), no difference was found between the frequencies tested in the RGDT in the test (T1) and retest (T2), as observed by the similarity among the medians, means and standard deviation, showing great variability due to the values of the first and third quartiles, besides the standard deviation (Table 1).

In the GIN test, the study sample showed no difference in performance between the right and left ears in the test (T1), but this difference was evidenced in the retest (T2), with the left ear being with a longer duration threshold than the right ear (Table 2).

Data from the sample show that the mean and standard deviation in the RGDT test are higher than in the GIN test, with less variability in both ears when compared to the RGDT test in all frequencies evaluated (Tables 1 and 2).

The test-retest reproducibility in the RGDT (mean) and GIN (RE and LE) tests was substantial according to the interclass correlation coefficient (Table 3).

When observing the CCI by frequency in the RGDT test it is verified that there was a difference in the performance, since in the frequencies of 1000 and 2000 Hz the correlation was poor, in the frequency of 500 Hz moderate, and in the frequency of 4000 Hz there was substantial correlation. Thus, there was variation in the reproducibility of the RGDT test by frequency (Table 3).

Table 1. Descriptive and inferential statistics of the miliseconds performance of the sample in the RGDT test by frequency in the two evaluation moments (T1 and T2).

	RGDT	500 Hz	1000 Hz	2000 Hz	4000 Hz	Average freq.
T1 (ms)	Mean±dp	13,32±15,20	16,47±15,37	13,64±13,68	11,88±10,81	13,91±10,51
	Q1	2,00	5,00	5,00	5,00	5,50
	Medium	5,00	10,00	5,00	10,00	11,87
	Q3	16,25	32,50	20,00	16,25	18,81
				p= 0,563		
T2 (ms)	Mean±dp	10,00±11,64	12,94±19,20	11,06±12,97	12,38±13,05	11,59±10,08
	Q1	5,00	5,00	5,00	5,00	5,00
	Medium	5,00	5,00	5,00	10,00	8,37
	Q3	10,00	10,00	10,00	15,00	14,25
				p = 0,392		

Caption: RGDT - Random gap detection test; Average Freq. - Average of the frequencies of 500, 1000, 2000 and 4000 Hz; T1 (ms) - Test in milliseconds; T2 (ms) - Retry in milliseconds. dp - standard deviation; Q1 - first quartile; Q3 - third quartile. Frideman test with p value> 0.05 in the test and retest.

Table 2. Descriptive and inferential statistics of the performance in miliseconds of the sample in the gin test by ear in the two evaluation moments (T1 and T2).

	GIN	RE	LE
T1 (ms)	Mean±dp	7,47±2,16	7,50±1,91
	Q1	5,00	6,00
	Medium	8,00	8,00
	Q3	8,50	8,00
		p = 0,869	
T2 (ms)	Mean±dp	6,97±2,10	7,53±1,81
	Q1	5,00	6,00
	Medium	6,00	8,00
	Q3	8,00	8,00
		p = 0,030*	

Caption: GIN - Gap in noise; T1 (ms) - Test in milliseconds; T2 (ms) - Retry in milliseconds. RE - right ear; LE - left ear; dp - standard deviation; Q1 - first quartile; Q3 - third quartile. * Wilcoxon test with p value <0.05 on the retest between the ears.

Table 3. Test-retest (T1 x T2) reproducibility measures of the rgdt and gin tests considering the single measures.

	CCI	IC 95%
RGDT 500 Hz	0,438	0,125-0,672
RGDT 1000 Hz	0,099	-0,240-0,417
RGDT 2000 Hz	0,141	-0,199-0,452
RGDT 4000 Hz	0,780	0,605-0,883
RGDT – Average freq.	0,610	0,350-0,783
GIN RE	0,779	0,603-0,883
GIN LE	0,706	0,490-0,841

Caption: RGDT - Random Gap Detection Test; GIN - Gap in noise; RE - right ear; LE - left ear; ICC - Interclass correlation coefficient (single measures); 95% CI - 95% confidence interval.

Discussion

After analyzing the results obtained in the research it is noticed that the limitations of this study refer to the number of the sample as well as the age group of the individuals that is restricted only in young people and adults. Despite this, it is possible to discuss the findings by separately analyzing the performance of the sample in the GIN and RGDT test at both times of application.

Analysis of the GIN test

The absence of differences in performance between the ears in the GIN test to obtain criteria of normality in normal adults in Brazil in the female and male subjects did not have an advantage of one ear over the other, since the thresholds and percentages were better varied from one ear to the other, in agreement with the findings of more recent studies[3,9,11] that obtained absence of a statistically significant difference between the ears for the GIN test.

Our sample had no differences in the performance between the ears in the GIN (T1) test. Research that investigated the performance of adult Brazilian listeners in the test did not benefit from one ear over the other, the thresholds and percentages were better varied from one ear to the other in agreement with the findings of more recent studies[3,9,11] that obtained absence of a statistically significant difference between the ears for the GIN test.

However, a study[8] that gave rise to the GIN test when evaluating individuals with brain lesions showed differences between the ears, suggesting that the test should not be used in a binaural way.

In the retest (T2) of the GIN test it was evidenced a difference in the performance between the right and left ear, the left ear being with a longer duration threshold than the right ear. However, this finding does not corroborate other studies[3,9] that affirm the similarity between the performance of the ears. There are no studies in the literature that compare the performance of the right and left ears in a retest situation (T2). On the other hand, inter-hemispheric differences have been studied; researchers[22] reported advantage of the right ear over the left pointing advantages of the left hemisphere in tasks of temporal resolution. Another research[23] found similar results – with the use of two types of noise (white and narrow band) with stimulus duration of 300 ms and gaps of 3, 4 or 5 ms. The authors observed hemispheric asymmetry with right ear advantage for white noise and hemispheric symmetry for narrow-band noise. The explanation for these findings was that the differences obtained (symmetry versus asymmetry) would be attributed to the different parameters of the stimuli used. Although there was no performance study with different stimuli, the results indicate that there may be differences between the ears, as found in the present study.

Because these tests were reapplied in a second moment (T2) after a seven-day interval, under the same conditions of application, the right ear may have presented better performance in the present sample due to the habituation of the test conditions. Such habituation may be justified by the fact that this ear has advantages for left hemisphere specialization for speech, which may be related to the identification of specific acoustic parameters for the discrimination of speech sounds and the ability to encode and analyze temporal aspects of acoustic information[8]. There is probably no relationship between performance and age, since a study with a similar age group, as the present study did not find a temporal resolution difference assessed by age-related GIN[24].

RGDT Analysis

When observing the performance by frequency in the RGDT, it is possible to notice great variation in its reproducibility in the two moments of application (T1 and T2). This finding has not been described in the literature in test and retest studies[20], since there were no differences greater than 10 ms in the RGDT when it was reapplied in adults with a seven-day interval. However, during clinical research, one can observe greater variability in the RGDT test, corroborating with a study[9] that claims the advantages of GIN over RGDT and also shows variability in RGDT performance by frequency.

The great variability and poor performance in the RGDT test-retest was also reported in a survey[25] that mentioned RGDT as a poor clinical tool due to poor test-retest reproducibility.

When observing the means of the 500 Hz, 1000 Hz, 2000 Hz and 4000 Hz frequencies in the RGDT test, it was observed that the values corroborate with the findings of another study[9] with adult individuals between 18 and 29 years of age found an average of 10.09 ms. However, in the other two studies they found, respectively, 6.5 and 6.0 ms in the mean of the duration threshold in the RGDT test in typical adult subjects[5,11]. It is also possible to analyze that the means of the frequencies at the time of retest (T2) were smaller than in T1, demonstrating that the individuals presented better performance at the second moment of application but without statistical significance.

GIN and RGDT Analyses

There were no differences in the performance of the GIN test at the two application times (T1 and T2) and the same occurred in the RGDT test, with no differences between the frequencies tested in the test and retest, although it showed greater variability than the GIN. These data corroborate a survey[25] that found mean RGDT thresholds greater than the mean thresholds obtained for GIN and observed a greater range of thresholds for RGDT when compared to GIN.

There are authors in the literature[4] who stated that despite the two tests evaluating temporal resolution, GIN provides a more faithful measure of gap detection and RGDT reflects, at least in part, auditory fusion. In addition, the authors emphasized that the two tests differ in other ways, such as presentation mode, type of stimulus, response mode, response task, total number of gap presentations, and approach to measure the shortest distance detected, which can generate differences in the performance of individuals in both tests.

However, this reproducibility in the GIN test (RE and LE) and RGDT (mean), corroborates with reproducibility studies[1,20] which showed that there were no changes between the test and retest period of the two tests in adults.

Conclusion

From the results described, it was concluded that there were no differences in the performance of the GIN test of the right and left ear in the test (T1), but in the retest (T2) the right ear presented advantages over the left.

No differences were observed between the frequencies tested in the RGDT in the test (T1) and retest (T2), but demonstrated greater variability in the frequencies evaluated than the GIN test.

The results of the GIN (RE and LE) and RGDT (mean) were reproduced in the test-retest. However, the performance by frequency in the RGDT test showed variation in its reproducibility in test and retest, in particular, with poor reproducibility in the frequencies of 1000 and 2000 Hz.

Therefore, the GIN test showed perceptive advantages in terms of its reproducibility when compared to the RGDT test, which showed higher reproducibility, which were confirmed in this study.

Further test and retest studies are still required with sample enlargement and age range to confirm the findings.

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