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ARTICLES

Temporal resolution in children: analysis of different tests

Resolução temporal em crianças: análise de diferentes testes

Resolución temporal en niños: análisis de diferentes test

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Abstract

Introduction: Understanding how acoustic stimuli are processed along the auditory pathway is fundamental to understand the processes that underline human communication. The time variable influences the speech comprehension, for it is related to the auditory ability of temporal resolution. The minimum time observed in sound change is known as the temporal resolution threshold, and there are two tests available for clinical use: Random Gap Detection Test (RGDT) and Gaps-in-Noise (GIN). **Objective**: To verify the performance of normal hearing children, without auditory processing complaint in the RGDT and GIN tests and to suggest one of them to evaluate this population. **Method**: A total of 33 children without complaints of auditory processing disorder, 17 of the female sex and 16 of the male sex, with age between seven and ten years and 11 months, and auditory thresholds within normality bilaterally participated in the study. All were submitted to the basic audiological evaluation to verify the peripheral hearing, RGDT and GIN. **Results:** For the GIN test, the mean value of gaps detection in children was 4.8 ms, whereas for RGDT it was 11.67 ms. **Conclusion**: The GIN demonstrated to be easier to apply to schoolchildren, while RGDT greater difficulty in the understanding of tasks by students, but it can detect more possible changes in temporal resolution ability in the evaluated population. Therefore, we

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suggested that the RGDT test be used in students in the age group of this study, when they are able to understand the task requested by the test.

Keywords: Child; Auditory Perception; Auditory Tests; Hearing; Understanding.

Resumo

Introdução: Entender como os estímulos acústicos são processados ao longo da via auditiva é fundamental para compreender os processos que subjazem à comunicação humana. A variável tempo influencia na compreensão da fala, pois está relacionada à habilidade auditiva de resolução temporal. O tempo mínimo percebido na mudança do som é conhecido como limiar de resolução temporal, e existem dois testes disponíveis para uso clínico: Randon Gap Detection Test (RGDT) e Gaps-In-Noise (GIN). **Objetivo:** Verificar o desempenho de crianças normo-ouvintes, sem queixa de processamento auditivo, nos testes RGDT e GIN e sugerir um deles para avaliar essa população. **Método:** Participaram do estudo 33 crianças sem queixa de alteração do processamento auditivo, 17 do sexo feminino e 16 do sexo masculino, com idade entre sete e dez anos e 11 meses e limiares auditivos dentro da normalidade, bilateralmente. Todos foram submetidos à avaliação audiológica básica para verificar a audição periférica, RGDT e GIN. **Resultados:** Para o teste GIN, o valor médio de detecção de gaps das crianças foi de 4,8 ms, enquanto que para o RGDT foi de 11,67 ms. **Conclusão**: O GIN mostrou-se de mais fácil aplicação nos escolares enquanto que o RGDT mostrou-se com maior dificuldade de entendimento da tarefa pelos mesmos, porém detecta mais as possíveis alterações na habilidade de resolução temporal na população avaliada. Assim, sugere-se que seja utilizado o teste RGDT em escolares na faixa etária deste estudo, quando os mesmos forem capazes de compreender a tarefa solicitada pelo teste.

Palavras-chave: Criança; Percepção Auditiva; Testes Auditivos; Audição; Compreensão.

Resumen

Introducción: Entender como los estímulos acústicos son procesados a lo largo de la vía auditiva es fundamental para comprender los procesos de comunicación humana subyacente. La variable tiempo influencia en la comprensión del habla, pues está relacionada a la habilidad auditiva de resolución temporal. El tiempo mínimo en la percepción del cambio de sonido es conocido como umbral de resolución temporal, y existen dos pruebas disponibles: Randon Gap Detection Test (RGDT) y Gaps-In-Noise (GIN). **Objetivo:** comprobar el desempeño de niños con audición normal, sin queja de procesamiento auditivo en las pruebas tests RGDT y GIN y sugerir uno de ellos para evaluarlo. **Método:** Participaron 33 niños sin queja de alteración del procesamiento auditivo, 17 del sexo femenino y 16 de sexo mascuino, entre siete y diez años y 11 meses y umbrales normales bilateralmente. Todos fueron sometidos a audiometría para verificar la audición periférica, RGDT y GIN. **Resultados:** Para el test GIN el valor medio detectar gaps en ellos fue de 4,8 ms, mientras que para el RGDT fue de 11,67 ms. **Conclusión:** El GIN se mostró de más fácil aplicación en los escolares, mientras que el RGDT se mostró con mayor dificultad de entendimiento de la tarea, sin embargo mostró detectar más las posibles alteraciones en la habilidad de resolución temporal en niños testados. Por lo tanto, se sugiere que se utilice el RGDT en los niños en ese grupo de edad, cuando son capaces de comprender la tarea solicitada por la prueba.

Palabras clave: Niño; Percepción Auditiva; Pruebas de Audición; Audición; Comprensión.

Introduction

"The auditory processing refers to the efficiency and effectiveness that the central nervous system has in grasping information by the peripheral auditory system"[1]. This processing is composed by different auditory skills, which are responsible for analyzing and interpreting auditory events[2].

Understanding how acoustic stimuli are processed along the auditory pathway is fundamental to comprehend the processes that underline normal and altered human communication[3]. The change in some of the auditory skills constitutes Auditory Processing Disorder (APD)[4].

Patients with APD may have difficulties for understanding spoken language, following verbal instructions correctly, grasping fast or broken speech and/or indentifying the acoustic source, which are disabilities that become worse with noisy and in reverberating environments. It may also be observed some harm for learning a foreign language, following sequential instructions and difficulties related to musical perception[5].

One of the explanations for those facts is that much of sound information is influenced by time[6].

The time variable affects speech comprehension, since it is related to the auditory skill of temporal resolution, which can be divided into four subcomponents or skills: temporal planning or sequence, temporal discrimination or resolution, temporal integration or summation and temporal masking. The minimum time interval recognized by the subject is called temporal resolution threshold, being the temporal auditory acuity[6].

The auditory skill called temporal resolution is the minimum time necessary to solve auditory events, being fundamental to speech comprehension, and can be evaluated by gaps detection tests, such as *Gaps In Noise* (GIN)[7] and *Random Gap Detection Test* (RGDT).

The RGDT test consists of pure tones pairs in the frequencies of 500, 1000, 2000 and 4000 Hz, with pauses between the two tones, in order to verify gap detection[8]. On the other hand, the GIN test aims to determine the gap detection threshold (silent interval) when inserted in white noise, which is used in clinical practice[9].

The temporal resolution enables the subject to identify small acoustic changes that occur in speech signal, allowing him/her to make different distinctions of segments, syllables and words in the continuous speech. Any change in temporal resolution may result in difficulties to identify small acoustic changes on speech, and, consequently, difficulties to produce speech sounds or to interpret the message heard[8] correctly, as well as difficulties on learning processes.

However, there is no indication in the certified literature about which one of the two tests is more appropriate to be applied in school population. Thus, in the light of these facts is focused this study justification. It aims to verify normal hearing children performance, with no auditory processing complaint in the RGDT and GIN tests and to suggest one of them to evaluate this population.

Method

This study was carried out prospectively, quantitatively and transversally. The evaluations and exams were performed in an audiology outpatient of a reference University Hospital.

The students and their guardians who agreed to participate in the research were informed about the procedures, risks, benefits and the research confidentiality, and, when everything was settled, they signed the Free and Clarified Consent Term (FCCT) that follows guidelines and standards of the Resolution 466/12, which protects subjects submitted to researches with human beings. This study was approved by Ethics Committee in research under the number CAAE: 25933514.1.0000.5346.

The students from three public schools were invented to participate. The schools were chosen by convenience and 223 invitations were handed for the first, second, third and fourth grades. A total of 108 students agreed to participate in the research, but only 35 appeared on the day of evaluation and 33 meeting the criteria of the research eligibility. Two of them were excluded by hearing loss and cognitive deficit.

The inclusion criteria for the sample were students of both genders, with age from 7 to 10 years and 11 months; auditory threshold within normal range (less than or equal to 25 dBNA in the frequencies of 250 Hz to 8 kHz); having right hand preference (self-reported in the anamnesis); Brazilian Portuguese as native language; type A tympanometric curve; and who presented contralateral acoustic reflexes, absence of neurological, cognitive and psychic changes; and with no complaint about auditory processing changes. The students who presented hearing loss, history of middle ear alteration, or some proven and visible cognitive deficit did not participate in this research, as well as the ones who failed to perform any of the proposed tests.

To meet the casuistry, the students were submitted to auditory anamnesis and to auditory processing; visual inspection in the external auditory meatus; pure tone audiometry (PTA); logoaudiometry; acoustic immittance measurements; and evaluation of temporal resolution skills through the GIN and RGDT tests.

The equipment used to PTA performance and logoaudiometry was the two-channel clinical audiometer, from brand *Fonix Hearing Evaluator*, model FA 12 type 1 and TDH-39P earphones, from brand *Telephonics*. In order to complete the auditory processing tests, it was also used a laptop, model X102B from the brand *Asus,* attached to the audiometer. For imitanciometry, it was used the middle ear analyzer from the brand *Interacoustics* model AT 235 and 226 Hz tone-probe.

The GIN test presents stimuli distributed between four test-tracks and one practice-track with ten items for practicing, ensuring that the subject understands the test. There are six seconds of segments of white noise randomly interspersed with gaps (2, 3, 4, 5, 6, 8, 10, 12, 15 and 20 ms). Each one of the gaps is represented six times in the total items of each test-track, amounting 60 gaps per test-track[10]. In this study, only the test-tracks 1 to 40 dBNS were applied in a binaural mode and every time that the student notices the gap, he/she should press the button to indentify the response. The gap detection threshold was determined by the smaller gap perceived 50% of the times.

The RGDT test was also performed with 40 dBNS in binaural presentation. It is composed by sequences of pure tones paired, in the frequencies of 500, 1000, 2000 and 4000 Hz. The intervals between the tones randomly range from zero to 40 ms, with increments varying from 2 to 10 ms. There was no need to apply the expanded stage of the test. The student was guided to answer verbally if he/she heard one or two stimuli. The interval detection threshold is the shortest interval in which the subject has consistently identified the occurrence of two stimuli. The interval detection threshold for tone sounds is calculated by the mean of all frequencies[11].

The test presentations in a binaural mode and the GIN's test-track 1 presentation are supported by studies that revealed no difference between one ear and the other[7,12,13] and that the four test-track are equivalent[9], thus it was not necessary to delay the evaluation session.

The comparisons between the results of the GIN and RGDT tests, classified as normal or altered, followed the normality criteria of 5 ms for the GIN[13] and 9.25 ms for the RGDT[14]. It is important to point out that the aforementioned study, used as base to define normality on the GIN test, was carried out in a monaural mode, since the binaural application was not found in literature with this age range. However, several studies that performed this test in children did not confirm difference between the ears[7,10,12,13].

For the statistical analysis, the significance level of 5% ($P<0.005$) was adopted. The Wilcoxon test was used to compare the results in the RGDT and GIN tests.

Results

The descriptive data of sex and age variables are shown in Table 1.

Table 1. Descriptive data of the sample regarding sex and age (n= 33 students)

Sex	Frequency	Percentage %
F	16	48.48
M	17	51.52
Age	**Frequency**	**Percentage %**
7	7	21.21
8	14	42.42
9	7	21.21
10	5	15.15

In the test descriptions for normal and altered, there was a greater number for normal in the GIN test (84.38%) than in the RGDT test (65.52%). It has to be observed that four children were not able to perform the RGDT test and one did not perform the GIN test, not being computed for statistical analysis, and so causing difference in the sample number for each test (Table 2).

Table 2. Descriptive values for Gaps In Noise and Random Gap Detection Test regarding normality (according to the existent reference criterion). (Gaps In Noise: n= 32; Random Gap Detection Test: n= 29)

	Frequency (n)	Percentage %
GIN Normal	27	84.38
GIN Altered	5	15.63
RGDT Normal	19	65.52
RGDT Altered	10	34.84

In the comparison between temporal resolution threshold of the GIN and RGDT tests in ms, for students who perform both tests, there was a statistically significant difference between the tests, as long as the greatest values, in ms, were for the RGDT test (Table 3)

Table 3. Comparison between threshold, in milliseconds, found for Gaps In Noise and Random Gap Detection Test in the evaluated population (n= 28 students)

Variable	N	Average	SD	Min.	Q1	Mdn	Q3	Max	P Value
GIN	28	4.18	1.12	2.00	3.50	4.00	5.00	6.00	P<0.001
RGDT	28	11.67	10.75	2.00	4.00	6.75	16.88	40.00	
DifRGDT_GIN	28	7.49	11.00	11.00	-3.25	0.00	13.38	36.00	

Subtitles: N= total sample number; SD= Standard deviation; Min= minimum; Mdn= median; Max= maximum. Wilcoxon test. P<0.05

Discussion

In the analysis of the sample of this study (Table 1), it was possible to observe that there was sex equivalence, 48.48% female and 51.52% male, but there was a predominance of age, since 42.42% of students were 8 years old. Such data agree with other studies on temporal resolution in children, in which there is no predominance of sex and most children are in the 8-year age group[8,14,15]. The research of this ability in students has major importance, since alteration in the ability of temporal resolution can lead to a low scholastic performance related to alterations in reading, writing and learning processes[16].

In this research, the age from 7 years-old onwards was used and the analysis was not performed for sex or age, since there are studies in the certified literature highlighting that there is no difference between the female and male sex for gap detection threshold and indicating that temporal resolution maturation occurs until this age[7,16].

It was observed (Table 2) that the student's number with normal results in the RGDT test was 62.65% and in the GIN test was 84.38%, according to the normality criteria of 5 ms for GIN[17] and 9.25 ms for RGDT[13]. This study results corroborate with the studies of authors[13,18] who verified greater values for the RGDT test with children.

A hypothesis for those results can be explained by the difference between the presentation attractiveness of the psychoacoustic characteristic on the tests. The presentation of white noise in the GIN test induces the students to pay more attention on the test, since it is in white noise that they insert the silence intervals they must detect, working as a challenge – in other words, for each beginning of the noise presentation, there will be a challenge on identifying the silence. In the RGDT test, the stimulus in pure tone and in fast presentation result in more difficulty, due to the complexity for attending the whole time of the test without having a stimulus that gives the notion of beginning and ending of the maximum attention, as it occurs in the GIN.

Those findings corroborate with other studies[13,18] that raised different hypothesis for such discrepancy. Some authors[18] hypothesized that the GIN and RGDT tests were not evaluating the same auditory skill, or requiring non-auditory processes in the requested tasks, being the RGDT, in fact, an auditory fusion test. Thus, another research[13] complements saying it would be a test more complex that concerns auditory fusion (at the right moment in which both stimuli are noticed as only one sound) and temporal resolution (at the moment in which the gap is detected), justifying its higher threshold.

There are a higher number of students who did not perform the RGDT test (4) than the GIN test (1). This is not in line with the study[18] which presented a smaller number of children who did not perform the GIN test. However, the circumstances are different, since here the non-performance of the RGDT test was due to the lack of comprehension and, in the aforementioned study, it was due to the evaluation evasion. But it corroborates with another research[13] in which the authors related some children excluded because the necessity of being applied the expanded version of the RGDT test. This fact was justified by the difficulty on comprehending the requested task, which proves the greater complexity of the test, according to the difficulty declared by children after their performances.

The analysis of gaps mean value was carried out only with the children that could perform both tests; consequently only 28 children were analyzed. It can be observed that the detection of gaps mean value for the GIN test was 4.8 ms, while for the RGDT test, it was 11.67 ms (Table 3).

The results for the GIN test corroborate with other authors[7] that researched students' performance with ages from 8 to 10 in GIN test, regardless of ear, sex and age range variables. They determined that the average of gaps detection threshold was of 4.7 ms. Another study[17] evaluated 37 children performances for GIN test, but with ages between 7 and 12 years, in which the mean gap detection threshold was 5 ms for right ear and 5.19 ms for left ear.

It is understood by this study that the GIN test is easier to students, but the RGDT test may capture more changes than GIN, because of the variation between the minimum and maximum values in RGDT for this kind of population (the GIN test ranged from 0 to 6 ms and the RGDT test ranged from 2 to 40 ms) and because of the hypotheses already mentioned. However, it is necessary to be sure that the child has understood the required task.

In another study[18], also comparing GIN and RGDT tests, in a sample of 73 children in a broader age range, from 6 to 14 years-old, it was observed for RGDT test a silence intervals average for the frequencies of 500 Hz, 1000 Hz, 2000 Hz, 4000 Hz of 10.13 ms, 8.69 ms, 11.94 ms, and 10.56 ms, respectively, not occurring any statistically significant differences in relation to the frequency tested. For the GIN test, the threshold average was 5.7 ms for right ear and 5.4 ms for left ear, with no difference in the evaluated ear. Such study defends that the investigation nature of RGDT and GIN test was different, considering the difference between the detection thresholds obtained on the same sample in both tests protocols.

It was also observed in the aforementioned research that the gap detection thresholds and silent intervals are not similar, and the thresholds for RGDT test were bigger than the ones for GIN test[18], which corroborates with this study. Therefore, it demonstrates that the values in ms for the RGDT test are higher and may better detect possible changes, in the same way that there is more variability in the results for the RGDT test than for the GIN test. This variance in the minimum and maximum values may be associated with the description of children's compliment, which happens several times, but they could not describe it, or their guardians did not observe or associate their behavior issues with auditory skills or problems.

It is considered that this study, herewith with other researches already carried out with temporal processing, has collaborated to the scientific community, supporting a more proper decision for a test that evaluates the temporal resolution skill in the clinical practice, since it is very important for children population in their learning development.

Conclusion

The GIN test application in the students proved to be easier, while in the RGDT test it was more difficult for them to understand the tasks, but it detects more possible changes in the temporal resolution skill in children between 7 to 10 years and 11 months-old. Thereby, the RGDT test is recommended to students with the same age range of this study, when they are able to comprehend the task required by the test.

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