Performance of 7 to 12-year-old children on the Gaps-in-Noise test

Desempenho de escolares de 7 a 12 anos no teste Gaps-in-Noise

Helena Aparecida Bertolo Barreira[1], Marcela Silva[1], Fátima Cristina Alves Branco-Barreiro[1], Alessandra Giannella Samelli[2]

ABSTRACT

Purpose: To investigate the performance of children with no hearing complaints with ages between 7 and 12 years on the Gaps-in-Noise (GIN) test. **Methods:** All children were submitted to otoscopy, pure tone audiometry, speech audiometry, acoustic immittance measures, and dichotic digits test. Only children who passed the previous audiological assessment carried out the GIN test (37 children – 20 who were enrolled in private schools, and 17 from public schools). As there was no difference between the performance of children from public and private schools, both groups were combined for the analysis. **Results:** The following average values were found for performance on the GIN test: 7-year-olds (5.65 ms), 8-year-olds (5.12 ms), 9-year-olds (4.87 ms), 10-year-olds (5.1 ms), and children over 11 years old (4.75 ms). **Conclusion:** The mean gap detection threshold in the right ear was 5 ms and in the left ear, 5.19 ms. No age, gender, or ear effects were found for gap detection thresholds assessed by the GIN test.

Keywords: Acoustic stimulation; Auditory perception; Hearing tests; Hearing; Child; Questionnaires

INTRODUCTION

Temporal auditory processing is the ability of perception or differentiation of temporal characteristics of sound on a limited time frame. Evidence suggests that temporal processing skills are the basis of auditory processing, since many of the characteristics of auditory information are somehow influenced by time(1-5).

The encoding of temporal information, such as duration, interval and order of different stimulus patterns provides crucial information to the nervous system. All these are important clues for the perception of speech and music since the structure of these two events is presented as rapid changes of the acoustic signal(6-8). In addition, temporal processing is a pre requisite for language skills and reading(9-11).

Although there are many methods to evaluate other temporal processing abilities, there are only few commercially viable approaches to measure the temporal resolution. The classical procedures for assessing the gap detection are often time consuming and are not available to clinicians. For this reason, the test Gaps-in-Noise (GIN) test was developed to provide a clinical tool to evaluate the ability of auditory temporal resolution in a variety of populations, particularly in patients with (central) auditory processing disorders(4).

Given the importance of temporal resolution for auditory development and language processing associated with the diversity of literature findings concerning the maturation period of the temporal resolution ability and the lack of standardization of GIN in the Brazilian pediatric population, the purpose of this study was to investigate the performance of children aged from 7 to12 years with no hearing complaints on the GIN test.

METHODS

This study was approved by the Ethics Committee of Instituto de Estudos Avançados da Audição, under protocol number 018/09. Parents or guardians of the participants signed an informed consent form (ICF) authorizing the participation of their children in the study.

To minimize the influence of a possible difference in stimulation/socio-economic status of the participants, children from two schools in the State of São Paulo, one public and one private, were invited to participate. In total, 82 children were assessed being 53 from the public school and 29 from the private one. However, only 37 children of both genders and age range between 7 and 12 years met the following inclusion criteria: no hearing complaints, no middle ear impairment, and hearing thresholds within the normal range (less than or equal to 15 dBHL at frequencies from 250 Hz to 8 kHz). The result for the dichotic digits test should also be within normal range of the age group of the child.

Study conducted at the Instituto de Estudos Avançados da Audição – IEAA – São Paulo (SP), Brazil.

(1) Instituto de Estudos Avançados da Audição – IEAA – São Paulo (SP), Brazil.

(2) Undergraduate Program in Speech-Language Pathology and Audiology, School of Medicine, Universidade de São Paulo – USP – São Paulo (SP), Brazil.

Correspondence address: Helena Aparecida Bertolo Barreira. Av. Jardim Japão, 372/01, Jardim Brasil, São Paulo (SP), Brasil, CEP: 02221-000. E-mail: hbarreira@hotmail.com

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First, parents or guardians of participants responded to an interview and participants were submitted to inspection of the external ear canal, pure tone audiometry, speech audiometry and acoustic impedance measurements in order to select individuals with normal hearing.

Then the dichotic digits test (binaural integration stage) was conducted as a screening for possible (central) auditory processing disorder. The test consists of 20 pairs of disyllabic digits simultaneously presented in each ear. The evaluation was conducted in a sound-attenuating booth at an intensity of 50 dBSL (according to the mean thresholds for 500 Hz, 1 and 2 kHz in each ear). Once an alteration was detected, the child was referred to perform a complete evaluation of (central) auditory processing and was not included in the sample of the study.

Only children who presented results within normal limits in the tests applied in the first phase underwent the procedures of the second phase.

The second phase was composed by the GIN test. The test was recorded on a compact disc (CD) and applied through a PAC Auditec® device coupled to a CD player from Sony®. This procedure was carried out in a sound-attenuating booth at an intensity of 50 dBSL in both ears (according to the mean thresholds for 500 Hz, 1 and 2 kHz in each ear). The test was presented in the monaural condition.

The GIN test CD consists of a one track training and four tracks of test. Each track consists of several test stimuli of 6 seconds of white noise, with a five-second between stimuli interval. There are several gaps (silent intervals) in different positions and varying durations embedded in the white noise stimuli. The gaps (silent intervals) can be of 2, 3, 4, 5, 6, 8, 10, 12, 15 and 20 ms. In some stimuli there may occur one to three gaps (silent intervals), while in other stimuli no gap was inserted[2-4].

The gap detection threshold is obtained through the GIN test, i.e., the smallest gap perceived by the individual, at least 66.6% of the time it was presented (that is, four times once each gap appears six times in each test range) is considered the threshold[2-4].

Statistical analysis was performed using the Mann-Whitney, Wilcoxon, and Kruskal-Wallis tests as well as the Spearman correlation test. The significance level adopted was of 0.05 (5%).

Table 1. Gap detection thresholds of students from private and public schoolsfor right and left ear (in ms)

Ear	School	n	Mean	SD	p-value
Right	Private	20	4.90	0.72	0.618
	Public	17	5.12	0.99	
	Total	37	5.00	0.85	
Left	Private	20	5.35	0.88	0.245
	Public	17	5.00	0.71	
	Total	37	5.19	0.81	

Mann-Whitney test ($p<0.05$)
Note: SD = standard deviation

Table 2. Gap detection thresholds for each ear according to age group (in ms)

Ear	Age range (in years)	n	Mean	SD	p-value
Right	7	10	5.60	0.97	0.076
	8	4	5.25	0.50	
	9	4	4.75	0.96	
	10	5	4.80	0.45	
	11+	14	4.64	0.75	
	Total	37	5.00	0.85	
Left	7	10	5.70	0.95	0.144
	8	4	5.00	0.82	
	9	4	5.00	0.00	
	10	5	5.40	0.89	
	11+	14	4.86	0.66	
	Total	37	5.19	0.81	

Kruskal-Wallis ANOVA ($p<0.05$)
Note: SD = standard deviation

Table 3. Correlation between age group and test performance on GIN

Ear	Statistics	
Right	Correlation coefficient	-0.399
	p-value	0.015*
	n	37
Left	Correlation coefficient	-0.234
	p-value	0.163
	n	37

* Significant values ($p\leq0.05$) – Spearman Correlation

RESULTS

There was no difference between the performance of public and private school children on the gap detection threshold (Table 1). Thus, for the other comparisons, the two groups were combined.

No difference between age groups for gap detection thresholds was observed (Table 2). However, there was a negative correlation between age and gap detection threshold, indicating that the higher the age, the lower the threshold. This correlation was significant only for the right ear (Table 3)

The Mann-Whitney test revealed no difference for any of the ears on the between-gender comparison (right ear p=0.241; left ear p=0.369; Mann-Whitney test).

Considering that there was no difference between age group and gender with regard to the gap detection thresholds, all children were grouped for the between-ear comparison. This analysis also revealed a non-significant difference, indicating similarity between gap detection thresholds of the right (5.00 ± 0.85 ms) and left ears (5.19 ± 0.81 ms) (p=0.153; Wilcoxon test).

Thus, the mean value for the 74 ears was defined: 5.09 ms (±0.83). This range represents the average gap detection threshold for the children between 7 and 12 years of age evaluated in this study. The cut off value of 6.75 ms is found if two standard deviations are added to the mean – this is a clinically used parameter to define the cut off criterion between normal and a typical performance.

DISCUSSION

The auditory temporal processing comprises four subprocesses: ordering or sequencing; integration or summation;

masking; resolution, discrimination or acuity. The auditory ability of temporal resolution refers to the minimum time required to segregate or solve acoustic events[1-5].

The procedure known as gap detection is a relatively simple psychoacoustic method to evaluate temporal resolution[2,3,5]. Several stimuli can be used on gap detection tests, including pure tones, narrowband and broadband noise. In addition, there are several ways of presenting these stimuli (with variation in frequency, intensity, duration of the stimulus or the gap, gap position within the stimulus, etc.). These variables can result in different gap detection thresholds[3,4].

In addition, other variables such as age[12-14], hearing loss[15-17] or neurological injuries[2,18] can influence the determination of gap detection thresholds.

The maturation of temporal resolution is also an important variable to be considered and the development period of this auditory skill in children remains unclear. Previous studies report different ages in which the temporal resolution reaches adulthood standards: 9[19], 10[20] or 12[21] years. It should be noted that different test parameters were used in the studies and this may have influenced the diversity of results[8].

Given the importance of temporal resolution for auditory and speech perception[22], language[2,23], and reading[9-11], the need of including a gap detection test in the battery tests for evaluation of auditory processing is evident, especially for pediatric assessment[5].

In relation to the maturation of the auditory system, the auditory cortex has been investigated from the human fetal period to adulthood. The study is based on brain samples analyzed by different histological and immunohistochemical procedures. The authors found that at five years of age, the expression of neurofilaments, which precedes myelination, is still confined to the deeper auditory cortical layers. After the age of five, matured axons begin to appear in cortical layers II and III, and around 11 to 12 years of age, its density is equivalent to that of adults. This last step represents the maturation of cortico-cortical connections, which interconnect the two hemispheres as well as different cortical areas in the same hemisphere. These intra and inter-hemispheric axons form the morphological basis for the greater complexity of the cortical auditory processing. This process is accompanied by improved behavioral performance in more complex listening skills which reaches values similar to adults at this age[24].

Although the neurophysiological studies evidence the rostral-caudal maturation of the auditory system and the progressive development of listening skills, the exact timing of development of temporal resolution is still uncertain. However, it is known that this ability continues to develop during the process of language acquisition[5]. Previous studies on the topic have yielded conflicting results regarding the age at which the temporal resolution reaches thresholds similar to adults[19-21], although the different parameters used in these studies may have influenced the results[8].

The results of the present study suggest that although with increasing age there is improvement in gap detection thresholds; this improvement is minimal since there was no difference among the analyzed age groups. This finding is in agreement with those of a standardization study of GIN results for the ages between 7 and 18 years[5] carried out in the United States. Given these results, the authors indicated that the temporal resolution reaches adulthood values at least 7 years of age.

Moreover, findings of the present study showed no difference between right and left ears, indicating symmetrical maturation between ears for temporal resolution[5]. This finding has also been observed in several studies with adults[2-5, 18,25].

Likewise, no significant difference in gap detection thresholds between genders was observed, which corroborates another study on temporal resolution[26]. Most studies on temporal resolution do not analyze gap detection thresholds by gender[2,5,12,27-29], which interferes on the discussion of this variable.

The gap detection thresholds obtained by each age group, without considering the ears, were: 7 years (5.65 ms); 8 years (5.12 ms); 9 years (4.87 ms); 10 years (5.1 ms); and above 11 years (4.75 ms). These values were very close to those obtained by another study[5]: 7 years (5.18 ms); 8 years (4.86 ms); 9 years (4.85 ms); 10 years (5.1 ms); and above 11 years (4.45 ms). Similarly, the mean threshold of the present study (5.09 ms) was very close to the one obtained by another study carried out in the United States[5] (4.9 ms), which suggests that American and Brazilian children exhibit similar performance with respect to the temporal resolution assessed by the GIN test.

In another study[30], the GIN was administered to ten typically developing children from 6 to 14 years of age and found thresholds similar to those described in this study (right ear: 5.7 ms and left ear: 5.4 ms). It should be noted that the above mentioned study assessed 6-year old children and the sample was smaller, which may explain the slight increase of the GIN threshold when compared with the present study.

The previously presented cut off criterion of 6.75 ms (mean +2 SD) does not constitute a normative value for the application of the GIN test in Brazilian children. This value serves as a reference for future comparisons since additional studies with a representative sample for the standardization of GIN in the pediatric population in Brazil are needed. However, it is noteworthy that this value is consistent with that proposed for the United States pediatric population[5].

Future studies with application of the GIN test in children with speech, language, and writing alterations are necessary so that this test can be a part of the routine clinical assessment of (central) auditory processing.

CONCLUSION

The performance of children with no hearing complaints with seven to 12 years of age on the GIN test was: average gap detection threshold of 5 ms in the right ear and 5.19 ms in the left ear. There was no age, gender, and ears effect in the gap detection thresholds assessed by the GIN test.

RESUMO

Objetivo: Investigar o desempenho de escolares de 7 a 12 anos de idade, sem queixas auditivas, no teste *Gaps-in-Noise* (GIN). **Métodos:** Todas as crianças foram submetidas à otoscopia, audiometria tonal, logoaudiometria, medidas de imitância acústica e teste dicótico de dígitos. Somente realizaram o teste GIN os escolares com resultados dentro do esperado nos referidos testes (37 crianças, sendo 20 de escola particular e 17 de escola pública). Uma vez que não houve diferença entre o desempenho das crianças de escola pública e escola particular, o grupo foi tratado como único. **Resultados:** Foram encontrados os seguintes valores médios no GIN por faixa etária: 7 anos (5,65 ms); 8 anos (5,12 ms); 9 anos (4,87 ms); 10 anos (5,1 ms) e acima de 11 anos (4,75 ms). **Conclusão:** O limiar médio de detecção de gap na orelha direita foi de 5 ms e na orelha esquerda foi de 5,19 ms. Não houve diferença entre as diversas faixas-etárias, orelhas e gêneros, no que se refere aos limiares de detecção de *gap* avaliados pelo GIN.

Descritores: Estimulação acústica; Percepção auditiva; Testes auditivos; Audição; Criança; Questionários

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