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Random Gap Detection Test (RGDT) performance of individuals with central auditory processing disorders from 5 to 25 years of age

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ABSTRACT

Objective: The aim of the present study was to assess the auditory temporal resolution ability in individuals with central auditory processing disorders, to examine the maturation effect and to investigate the relationship between the performance on a temporal resolution test with the performance on other central auditory tests.
Methods: Participants were divided in two groups: 131 with Central Auditory Processing Disorder and 94 with normal auditory processing. They had pure-tone air-conduction thresholds no poorer than 15 dB HL bilaterally, normal admittance measures and presence of acoustic reflexes. Also, they were assessed with a central auditory test battery. Participants who failed at least one or more tests were included in the Central Auditory Processing Disorder group and those in the control group obtained normal performance on all tests. Following the auditory processing assessment, the Random Gap Detection Test was administered to the participants. A three-way ANOVA was performed. Correlation analyses were also done between the four Random Gap Detection Test subtests data as well as between Random Gap Detection Test data and the other auditory processing test results.
Results: There was a significant difference between the age-group performances in children with and without Central Auditory Processing Disorder. Also, 48% of children with Central Auditory Processing Disorder failed the Random Gap Detection Test and the percentage decreased as a function of age. The highest percentage (86%) was found in the 5–6 year-old children. Furthermore, results revealed a strong significant correlation between the four Random Gap Detection Test subtests. There was a modest correlation between the Random Gap Detection Test results and the dichotic listening tests. No significant correlation was observed between the Random Gap Detection Test data and the results of the other tests in the battery.
Conclusion: Random Gap Detection Test should not be administered to children younger than 7 years old because other reduced capacities might influence their performance. Also, Random Gap Detection Test assesses a specific auditory ability, different than the one evaluated with the other auditory tests. Finally, it is suggested to test individuals at only one frequency of the Random Gap Detection Test because results provide similar information than when assessing them on all subtests.

1. Introduction

Individuals with central auditory processing disorders (CAPD) are as vulnerable as those having a sensory hearing loss when listening to speech in acoustically degraded environments. Even with normal hearing sensitivity, they report having more difficulties then their peers without CAPD when in a group conversation or surrounded by noise. Basically, they have a listening problem [1]. This problem could have a neurological source – i.e. tumors in the central auditory nervous system (CANS), epilepsy, head trauma [2], but for most individuals with CAPD the etiology of the disorder is unknown.

Little is known about temporal processes in individuals with CAPD. When assessed with a central auditory test battery, children with CAPD displayed the highest percentage of failure with a temporal processing test [3]. In fact, 64% of the 48 children with CAPD tested failed the Pitch Pattern Sequence Test, a temporal ordering test [3]. So far, there is little data to comprehend how these

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individuals perform in auditory temporal resolution tests. Auditory temporal resolution ability enables the detection of changes in the duration of a sound stimulus and/or the detection of gaps inserted in an auditory stimulus. Currently, the tests commercially available to assess temporal resolution in clinical settings are the Auditory Fusion Test-Revised (AFT-R) [4], the Random Gap Detection Test (RGDT) [5] and the Gaps in Noise (GIN) [6].

The AFT-R entails two stimuli at specific frequencies (500 Hz, 1 kHz, 2 kHz and 4 kHz) that are presented with inter stimulus intervals (ISI) varying from 2 to 300 ms. There are also trials with no ISI – i.e. only one stimulus is presented. The person tested has to report if one or two stimuli were heard. The RGDT is an adapted version of the AFT-R. However, this one presents the stimuli in a randomized ISI duration order. The ISI duration is limited to nine steps between 0 and 40 ms as a series of nine pairs of pure tones (500 Hz, 1 kHz, 2 kHz and 4 kHz) or clicks with variable ISI durations. The person tested has to indicate if one or two sounds were heard. The Gaps-In-Noise (GIN) Test can be used with both adult and pediatric populations [6–8] and is composed of six-second long segments of broadband noise that may contain none or up to three gaps, presented in a pseudorandom order that may last from 2 to 20 ms. The tested person is required to press a button each time a gap in the noise is detected.

The GIN test and the RGDT are sensitive to lesions in the CANS and might have a clinical use to assess individuals with CAPD [6,9]. RGDT was also used in workers exposed to solvent [10], in individuals with auditory neuropathy [11] or CAPD [12,13]. Results revealed longer gap detection thresholds for the experimental group when compared to the gap for the control group [10–12]. However, in Yalçinkaya et al.'s study [11], participants with auditory neuropathy had sensorineural hearing loss that could have influenced the results since the test presentation level was between 55 and 65 dB HL. In fact, two participants had moderate to severe hearing loss and one had severe hearing loss. Also, in Sharma et al.'s study [13], 25% of those having a diagnosis of CAPD failed the RGDT. However, there was no specific information regarding the age of those who failed the RGDT. Furthermore, results showed that RGDT test performance did not have any significant correlation with language and cognitive test performance. They did not report any correlation between performances at the different auditory tests.

The present study uses the RGDT to examine: (1) the auditory temporal resolution ability in individuals with CAPD; (2) the effect of maturation on temporal resolution ability and (3) the relationship of performance of individuals with a CAPD on RGDT with their performance on clinical central auditory tests.

2. Methods

The study was approved by the ethic committee of the.... Adults participants and children's parents signed the consent form and the children gave their assent.

2.1. Participants

Participants were referred by different professionals (physicians, speech-language pathologists, psychologists) because CAPD was suspected. Following the assessment, they were divided in two groups: 131 with CAPD and 94 with normal auditory processing (C). Table 1 presents the study sample according to the age.

Prior to the auditory processing assessment, participants met the following criteria: (1) pure-tone air-conduction thresholds no poorer than 15 dB HL bilaterally at octave frequencies between .25 and 8 kHz; (2) normal admittance measures (middle ear pressure + −100 daPa and compliance of .2 ml or above); and (3) presence of ipsilateral and contralateral acoustic reflexes at expected levels for octave frequencies between .5 and 4 kHz.

Table 1
Number of subjects in the Central Auditory Processing Disorders (CAPD) group and the control (C) group divided by age from 5 to 25 years old.

Age groups	CAPD	C
5–6 years	29	11
7–8 years	46	28
9–11 years	43	28
12–25 years	14	27
Total	131	94

2.2. Procedures

Several auditory processing tests were grouped under four categories and selected according to participants' age and answering capabilities. The normative values for each of the administered tests followed the criteria described by Pereira [14]. The four groups were as follows:

(1) Binaural interaction, including the localization test [15];
(2) Temporal processing, including the Pitch Pattern Sequence test (PPST) [16,17], the Duration Pattern Sequence test (DPS) [18], the memory sequence verbal test (MSV) and the memory sequence non-verbal test (MSNV) [15];
(3) Monaural low redundancy, including the Synthetic Sentence Identification test with ipsilateral competing message (SSI-ICM) [15], the Pediatric Speech Intelligibility test with ipsilateral competing message (PSI-ICM) [15] and the Speech in noise test (S in N) [15];
(4) Dichotic listening, including the Staggered Spondaic Word (SSW) [15], the Dichotic Digits test (DDT) [15], the Nonverbal Dichotic test-free recall (DNVT-F) and the directed attention (DNVT-D) [15] as well as the Dichotic Consonant-Vowel test (DCVT) [15].

When one task in a test or more was altered, the presence of CAPD was confirmed based on the normative criterions in Brazilian Portuguese [14,15]. Participants with normal performance in all auditory processing tests were included in the control group.

Following the auditory processing assessment with the previous tests, the RGDT was administered [5], in a sound-proof booth. On the RGDT, a series of pure tones was presented and for each frequency (500 Hz, 1000 Hz, 2000 Hz and 4000 Hz), there were two versions of the test based on the ISI duration. One version consisted of 9 trials: 8 pairs of 17 ms pure tones with a randomized ISI with 0, 2, 5, 10, 15, 20, 25, 30 or 40 ms long. The other version contained 10 trials: 9 pairs of 17 ms pure tones with ISÍs with 50, 60, 70, 80, 90, 100, 150, 200 or 300 ms. Stimuli were presented in both ears at 55 dB above the mean of the hearing thresholds measured at 500 Hz, 1000 Hz and 2000 Hz. After each trial presentation, participants indicated if they had heard one stimulus or two stimuli.

The temporal auditory acuity threshold was determined as the shortest ISI when it was consistently indicated that two stimuli were heard at the tested frequency. The mean from the four frequencies tested was calculated and a composite temporal auditory acuity threshold was obtained. The expanded version was applied only when the temporal auditory acuity threshold for each frequency was greater than 40 ms.

3. Results

Fig. 1 displays the central auditory tests and the percentage of participants who failed each one of them. The temporal ordering

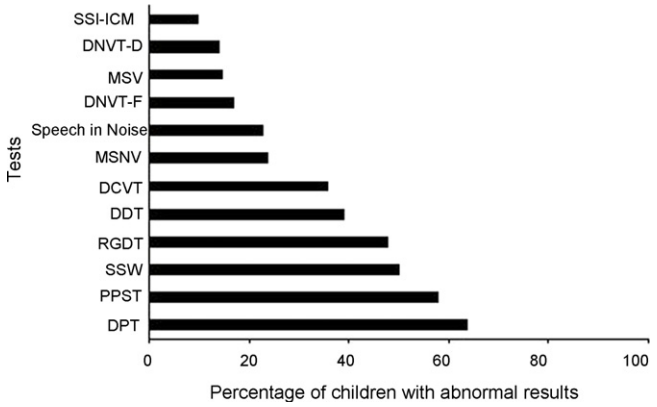

Fig. 1. Percentage of the participants with central auditory processing disorder who failed the tests on the Brazilian central auditory assessment battery.

tests – PPS and DPS – were those for which abnormal results were the highest (64% and 58%, respectively) followed by the SSW test (50%) and the RGDT, that displayed a 48% failing rate. Results showed that 86% of the 5–6 year-olds, 49% of 7–8 year-olds and closed to 30% of the individuals of 9 years old and older with CAPD had abnormal results on the RGDT (gap detection over 20 ms). The monaural low redundancy tests used, i.e. SSI-ICM or PSI-ICM tests, displayed a 10% failure rate.

A three-way ANOVA, with two between-subject factors (Group-two levels; Age-four levels) and one repeated factor (Frequency-four levels) was performed. Results showed that the effect for two out the three main factors was significant: group [$F(1, 217) = 47.17$, $p < .001$] and Age [$F(4, 217) = 4.99$, $p < .01$]. The effect of the Frequency factor [$F(2.6, 570.88) = .82$, $p > .05$] was not significant. There was a statistical significant interaction for group × age [$F(3, 217) = 3.87$, $p = .01$]. The two-way interactions group × frequency [$F(3, 651) = 1.41$, $p > .05$] and Age × frequency [$F(9, 651) = .56$, $p > .05$] as well as the three-way interaction group × age × frequency [$F(9, 651) = .71$, $p > .05$] were not significant (Fig. 2).

The group × age interaction was decomposed and a univariate ANOVA was performed for each group. Results showed a significant difference between the age groups with CAPD [$F(3, 127) = 7.32$, $p<.001$] and without CAPD [$F(3, 90) = 2.9$, $p<.05$]. *T* tests revealed that the 5–6 year-olds with CAPD had significant lower performance than those of the 9–11 year-olds [$t(70) = 5.6$, $p < .001$] and of the 12–25 year-olds with CAPD [$t(41) = 3.76$, $p = .001$]. For the control group, the 5–6 year-olds had significant lower performance only with those of the 12–25 year-old participants [$t(36) = 2.86$, $p = .007$] (see Table 2).

Table 2
Results of the *T* test comparisons between age groups for subjects in both groups.

Age groups difference (year-olds)	CAPD			C		
	df	T	p	df	t	p
5–6 and 7–8	72	1.69	.09	37	1.43	.16
5–6 and 9–10	70	5.6	.000*	37	1.83	.08
5–6 and 12–25	41	3.76	.001*	36	2.86	.007*
7–8 and 9–10	86	2.39	.02	54	.26	.79
7–8 and 12–25	57	1.55	.13	53	1.65	.11
9–10 and 12–25	55	.25	.80	53	.11	.11

* Significant $p < .008$ with Bonferroni corrections.

Correlation analyses were performed to examine the relationship between the RGDT results and those obtained at other clinical central auditory tests and also between the RGDT subtests' results. These results are presented in Table 3 and they revealed a strong significant correlation between the four RGDT subtests (*r* between

Table 3
Results of the correlation analysis between the performance obtained at the four subtests of RGDT.

($n = 131$)	Gap 500 Hz	Gap 1 kHz	Gap 2 kHz	Gap 4 kHz
Gap 500 Hz	1			
Gap 1 kHz	0,672 $p < .001$	1		
Gap 2 kHz	0,75 $p < .001$	0,732 $p < .001$	1	
Gap 4 kHz	0,655 $p < .001$	0,722 $p < .001$	0,826 $p < .001$	1

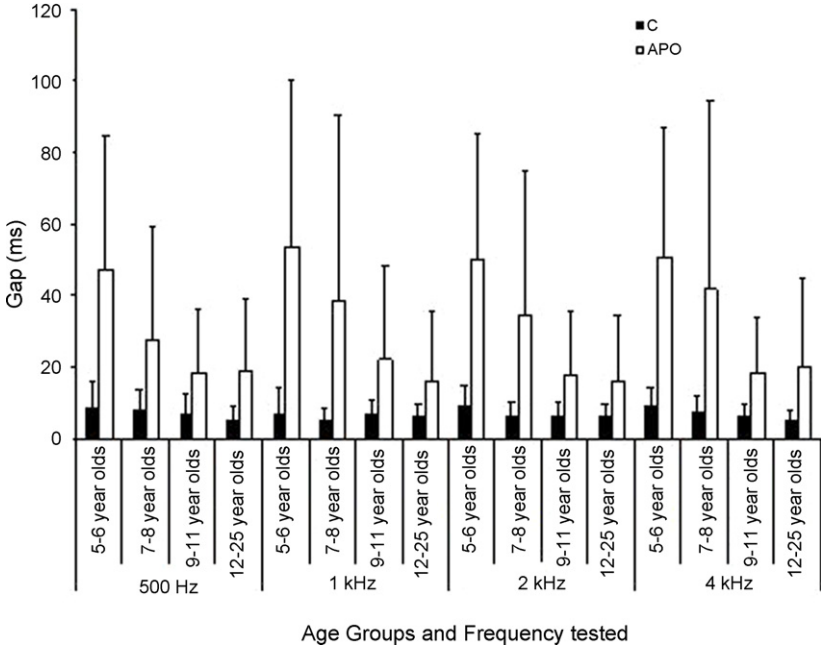

Fig. 2. Mean of the gap detection measures of participants with central auditory processing disorder (CAPD) and participants without CAPD (C) as a function of four age groups and the four RGDT pure-tone frequencies.

Table 4
Results of the correlation analysis between the average performance of participants with CAPD at the four RGDT subtests and those obtained by other tests in the Brazilian central auditory assessment battery.

	SSI-ICM ($n=131$)	DNVT-D ($n=103$)	DNVT-F ($n=103$)	MSV ($n=131$)	S in N (131)
RGDT vs	$r=-0{,}122$ $p>.05$	$r=-0{,}436$ $p<.001$	$r=-0{,}215$ $p<.05$	$r=-0{,}093$ $p>.05$	$r=0{,}05$ $p>.05$
MSNV ($n=131$)	DCVT ($n=92$)	DDT ($n=69$)	SSW ($n=108$)	PPST ($n=69$)	DPT ($n=29$)
$-0{,}163$ $p>.05$	$r=-0{,}225$ $p<.05$	$r=-0{,}327$ $p<.01$	$r=-0{,}316$ $p=.001$	$r=-0{,}217$ $p>.05$	$r=0{,}013$ $p>.05$

.6 and .8). In addition, results showed that the correlation between the RGDT results and those of the five dichotic listening tests (NVDT-FR, NVDT-DA, DCV, DDT, and SSW) was statistically significant (Table 4), even though, this correlation was modest (r between .2 and .5). There was no significant correlation between results obtained with the RGDT and those displayed for the monaural low redundancy tests (S in N, SSI-ICM, PSI-ICM) and the temporal ordering tests (MSV, MSNV, DPS, PPS).

4. Discussion

The present study showed that almost half of the 131 subjects with CAPD failed the RGDT. This suggests that one out of two individuals with CAPD have reduced temporal resolution ability. Some of these subjects might experience difficulties in processing speech because of their limited capacity to perceive small silence interval in or between speech segments. Verbal speech processing relies, in part, on temporal processing abilities [19]. However, for other subjects, especially those in the youngest group, there might be other factors contributing to their poor performance on the RGDT test. Data showed that more than 80% of the youngest group studied, namely the 5–6 year-olds, obtained abnormal results. This is a tremendous percentage of children having difficulties with this test compared to older children – the 9 year-olds – that had 30% of results above 20 ms. This percentage of abnormality in older children is similar to the percentage in the 7–12 year-olds reported in Sharma et al.'s study [13]. The control peers in the present study presented a threshold of no more than 10 ms. Central noise, such as change in response bias or criteria, and motivation, attention or other non auditory factors might have influenced their results. As raised by Wightman et al. (1989) [20], the younger children might be disposed to guess on more trials than their older peers. This is supported, in part, by the intra-test variability in individuals with CAPD, where 62% of the 5–6 year-olds had a standard deviation over 10 ms from their performance across frequency. This result was reached by only 20% of the participants over the age of 8 years old.

Also, results showed an improvement of the temporal resolution threshold as a function of age in both groups. However, the difference between their performances was mostly between the youngest and the oldest groups. These results are compatible with those of previously conducted studies on temporal resolution measures [20–22]. They are also in agreement with Keith's results [5], showing no improvement in children's performance from ages 5 to 11. However, with the AFT-R, the youngest group – 5 and 6 year-olds – presented differences of respectively 5 and 4 ms in temporal resolution threshold when compared to their 8 to 50 year-olds [5], suggesting improvement in the threshold as a function of age.

Opposed to results reported in previous studies in adults [23,24], this study did not show any significant difference between the threshold obtained at the four frequencies tested, as also shown by Davis and McCroskey [21] on their temporal fusion test from 500 Hz to 4 kHz. Differences in procedure might explain the noted discrepancy between studies. As reported by Wightman et al. [20], using pure tone as in RGDT might let some spectral cues be perceived by the fact that the tones are abruptly presented (17 ms duration including 1 ms raise and fall time duration). In other studies [22–24], the stimuli were presented in noise to prevent the detection of spectral cues.

Based on the present study, the RGDT could be used to measure clinically the temporal resolution ability at only one frequency instead of presenting the four frequencies subtests. Results showed no significant difference between the performance obtained at the four test frequencies and also a high significant correlation between performances at these frequencies. However, testing on more than one frequency might provide valuable information on other capacities other than this ability, namely attention. It could be an indirect way to document an attention problem in some children, even if the aim of the evaluation with the RGDT is to measure the auditory resolution capacity.

Results from the correlation analyses did not show any strong relationship between the performance obtained with the RGDT and that on the other clinical tests. The only fair negative correlations were between the RGDT and the five dichotic listening tests. These results showed that as the gap detection threshold data increased, the number or percentage of correct responses decreased on the dichotic tasks. These results were applicable for the speech as well as for the non speech dichotic tests. These findings might suggest that there is some overlapping auditory capacities underlying temporal resolution and dichotic listening that were unveiled with the used tests. There was no significant correlation between the RGDT and the speech in noise test and the temporal ordering tests. These tests seem to assess different auditory abilities. This is in concordance with Bellis' [25] suggestion that a central auditory assessment battery should be composed of at least of four groups of tests, including auditory temporal processing tests. These comprised temporal integration, resolution and ordering tests.

5. Conclusion

Based on the present study, the RGDT is one of the tests that individuals with CAPD are inclined to fail. Results showed that almost half of the 131 subjects with CAPD had abnormal results on this test, mainly the 5–6 year-olds. Performance in the test is influenced by the age for those that present CAPD and those in the control group. It is suggested that the test should not be administered to subjects as young as 5 and 6 years of age because other reduced capacities might influence their performance, such as attention. Finally, testing individuals at only one frequency with the RGDT might provide the same information than assessing them on all four frequencies subtests, without loosing any valuable data. In addition, this suggested adapted procedure will reduce the duration of the evaluation which is an important factor to take into account in the process of assessing central auditory abilities in children.

Conflict of interest statement

There are no conflicts of interest.

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