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## Auditory temporal processing assessment in rural workers exposed to organophosphate pesticides

### *Avaliação do processamento auditivo temporal em trabalhadores rurais expostos a agrotóxicos organofosforados*

### ABSTRACT

**Purpose:** To evaluate the auditory temporal processing in workers occupationally exposed to organophosphate pesticides. **Methods:** Cross-sectional study in which 43 rural workers of both genders with bilaterally normal auditory thresholds that were occupationally exposed to organophosphates were assessed. The procedures included the following items: questionnaire regarding personal and professional background, period of exposition to organophosphates, otoscopy, pure-tone audiometry. Auditory temporal processing was tested through: the Frequency Pattern Test, the Duration Pattern Test and the Gaps-In-Noise Test. Performance on the tests were analyzed, as well as differences between left and right ears on the Gaps-In-Noise Test, and education level in all tests. **Results:** In great part of the subjects, auditory temporal processing performance was below normal standards. There was no difference between ears on the Gaps-In-Noise Test ( $p=0.33$ ). Additionally, no differences were found on any of the tests according to education level (Gaps-In-Noise:  $p=0.21$  on the right ear, and  $p=0.053$  on the left ear; Frequency Pattern Test:  $p=0.37$ ; Duration Pattern Test:  $p=0.84$ ). **Conclusion:** Temporal resolution and temporal order abilities were altered in individuals occupationally exposed to organophosphate pesticides, even when they showed normal peripheral auditory thresholds.

### RESUMO

**Objetivo:** Avaliar o processamento auditivo temporal em trabalhadores expostos ocupacionalmente a agrotóxicos organofosforados. **Métodos:** Estudo descritivo transversal. Foram avaliados 43 trabalhadores rurais, de ambos os gêneros, expostos ao organofosforado, com limiares audiométricos normais bilateralmente. Os procedimentos realizados incluíram os seguintes itens: questionário sobre a história pessoal e laboral, período de exposição ao organofosforado, meatoscopia, e audiometria tonal liminar. Para avaliação do processamento auditivo temporal foram utilizados os seguintes testes: Teste de Padrão de Frequência, Teste de Padrão de Duração e *Gaps-In-Noise*. Além do desempenho, estudou-se a diferença entre as orelhas direita e esquerda no *Gaps-In-Noise* e a faixa de escolaridade em todos os testes. **Resultados:** O desempenho da maior parte dos trabalhadores nos testes de processamento auditivo temporal foi inferior em relação aos padrões de normalidade. No teste *Gaps-In-Noise*, não houve diferença entre as orelhas ( $p=0,33$ ). Em relação à escolaridade, não houve diferença em nenhum dos testes (*Gaps-In-Noise*:  $p=0,21$  na orelha direita e  $p=0,053$  na orelha esquerda; Teste de Padrão de Frequência:  $p=0,37$ ; e Teste de Padrão de Duração:  $p=0,84$ ). **Conclusão:** As habilidades auditivas de resolução temporal e ordenação temporal mostram-se comprometidas em indivíduos expostos ao organofosforado, mesmo estes apresentando audição periférica normal.

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## INTRODUCTION

Some scientific studies have recently focused on the issue of the exposure to chemical substances and its effect on the central and peripheral auditory system. The clinical manifestations caused by organophosphate pesticides (OP) include damages to the central and peripheral nervous system. Its neuropsychological effects cover a variety of cognitive and affective disorders such as loss of concentration, memory, and information processing<sup>(1)</sup>.

The Central Auditory Nervous System (CANS) is a complex center of neural pathways that can be affected by a great sort of development and pathological conditions<sup>(2)</sup>. The integrity of afferent and efferent auditory pathways is essential for a good information processing.

The auditory processing refers to the mechanisms and processes performed by the CANS, which are responsible for many different auditory abilities needed for a good speaking discernment such as temporal ordering. The auditory processing disorder is a deficiency in one or more behaviors of the auditory abilities<sup>(5)</sup>.

The auditory processing can be evaluated by temporal auditory processing tests. Those tests are related to the perception of sound or its alteration within a limited gap of time<sup>(6)</sup> or to the ability of perceiving or distinguishing stimulus presented in a fast sequence<sup>(7)</sup>.

There are few researches that describe the auditory damages caused by the OP and its effects on the CANS. For this reason, the purpose of this study was to evaluate the performance of workers that have been exposed to the OP in the tests of temporal resolution and ordination.

## METHODS

The study has been approved by the Research Ethics Committee of the Universidade Federal do Rio de Janeiro under process number 143/2009, and considered the ethical aspects recommended by resolution 196/96 (BRAZIL. Resolution MS/CNS/CNEP n° 196/96 of October 10th, 1996) about research involving human beings. The participants signed the Term of Free and Informed Consent (TFIC).

It is a transversal descriptive study. Participants were 43 rural workers of both genders, with ages ranging from 18 to 59 years. Data collection was carried out in Sapucaia, state of Rio de Janeiro, a geographically isolated municipality where workers are occupationally and environmentally exposed to OP.

The research included people with no history of otological surgery, psychiatric diseases and which had never before been exposed and/or worked with other kinds of chemical products. Furthermore, people should present normal otoscopy and auditory thresholds under or equal 25 dB NA in the frequencies from 250 Hz to 8 kHz. All individuals reported to work from four to eight hours every day exposed to the substance. Most part of them declared exposition to OP since childhood.

A questionnaire was applied to evaluate occupational and life history of each worker, with questions related to personal data, general health, and the labor itself, such as time of ser-

vice, use of protection equipments, use of drugs, and details regarding the exposure to OP. Auditory tests were also carried out in soundproof booths. Workers were submitted to anamnesis, otoscopy, basic auditory evaluation and tests to evaluate temporal auditory processing.

In order to evaluate the temporal processing, we used the equipment *Processamento Auditivo 2004* (Auditory Processing 2004), from Acústica Orlandi®, attached to a CD player Phillips®. Recorded stimulus were played for the Frequency Pattern Test (FPT), the Duration Pattern Test (DPT), and the Gaps-in-noise Test (GIN). The FPT and DPT were performed in both ears simultaneously.

In order to evaluate FPT, we have used the stimulus of low tones (880 Hz) and high tones (1122 Hz) with the duration of 500 ms, diotically transmitted at 50 dB NS. Individuals were asked to identify each item from the series through oral responses, classifying them as bass and treble, or thin and thick for each one of the stimuli. The tests were considered normal when they obtained over 75% correct answers<sup>(8)</sup>.

In order to evaluate the DPT, a long sound of 500 ms and a short one of 250 ms, both in the frequency of 1 kHz was diotically transmitted at 50 dB NS, totalizing 30 items of the test, bilaterally presented. The frequency was kept constant at 1 kHz. Individuals were asked to identify each item from the series through oral responses, classifying them as short or long. The tests were considered normal when they obtained over 75% correct answers<sup>(8)</sup>.

The GIN test was carried out with monaural presentation beginning with the right ear, following the protocol, with zero to three gaps and duration between zero and 20 ms, inserted in segments of six seconds of white noise. For the accomplishment of this test we used the test tracks numbers three and four of the CD, which correspond to the tests of the right and left ear, respectively. The tests were considered normal when they obtained thresholds less or equal to 4 ms<sup>(9)</sup>.

Statistical analysis used the following tests:

- To verify whether there is a significant variation of GIN measures between left and right ears, it was used the Wilcoxon signed-rank test;
- To verify whether there is a significant variation in measures between age groups ( $\leq 31$  years old and  $> 31$  years old) or between education levels ( $\leq 3^{\text{rd}}$  grade and  $> 3^{\text{rd}}$  grade), it was used the Mann-Whitney test.

Non-parametric methods were used because the variables did not present normal distribution (data dispersion, ordinal nature and/or lack of distribution symmetry). The significance level adopted was 5%. Statistical analysis was processed by the SAS® System software, version 6.11 (SAS Institute, Inc., Cary, North Carolina).

## RESULTS

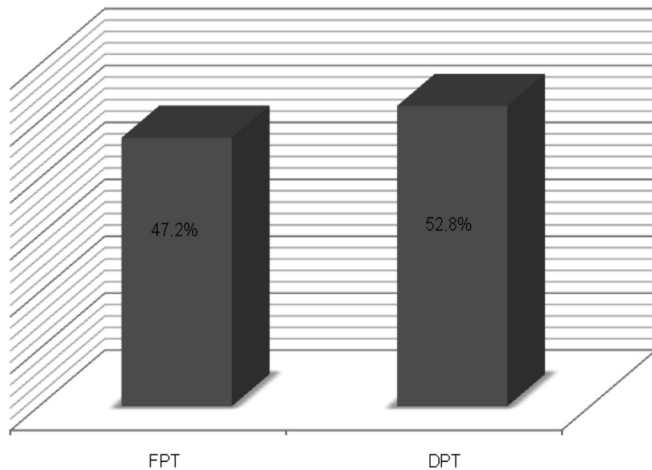
Data regarding average, standard deviation (SD), median of measures according to education level ( $\leq 3^{\text{rd}}$  grade and  $> 3^{\text{rd}}$  grade), and the corresponding descriptive level (p-value) of the Mann-Whitney test were calculated for FPT, DPT, and GIN (Table 1). No difference was observed in the performance of individuals according to their education level.

**Table 1.** Statistical analysis of central tendency measures of the FPT, DPT and GIN according to education level

Variable	Group ≤3rd grade (n=22)				Group >3rd grade (n=21)				p-value
	Mean	±	SD	Median	Mean	±	SD	Median	
FPT	45.3	±	26.0	36.6	49.2	±	20.8	43.3	0.37
DPT	51.6	±	19.2	51.7	54.0	±	25.1	56.6	0.84
GIN RE (ms)	7.3	±	1.8	8	6.7	±	1.7	6	0.21
GIN LE (ms)	7.3	±	1.8	8	6.3	±	1.4	6	0.053*

\* Significant values (p<0.05) – Mann-Whitney test

**Note:** SD = standard deviation; FPT = frequency pattern test; DPT = duration pattern test; GIN = gaps-in-noise; RE = right ear; LE = left ear



**Note:** FPT = Frequency Pattern Test; DPT = Duration Pattern Test

**Figure 1.** Distribution of correct answers of FPT and DPT (in percentage)

The mean scores for FPT and DPT were 47.2% and 52.8%, respectively. Such result is below normal standards (Figure 1).

Table 2 shows the measures of central tendency for correct answers in FPT and DPT expressed as percentage. In the FPT, score varied between 0% and 96.6%, and in the DPT, between 3.3% and 100%. In both tests, only seven workers presented responses within normal standards.

Results allow the observation of mean, standard deviation or pattern error (SD/PE), median, minimum and maximum of the measures in right (RE) and left (LE) ears, absolute delta (RE-LE), and the corresponding descriptive level (p-value) of the Wilcoxon signed-rank test for the GIN test, analyzing the smallest gap detected (Table 3).

No differences were detected between thresholds and percentage of correct answers in the GIN test in both ears (Table 3). Nevertheless, the responses for gap detection are worse than the expected responses, according to normal standards.

**Table 2.** Central tendency measures of the FPT and DPT expressed in percentage of correct answers

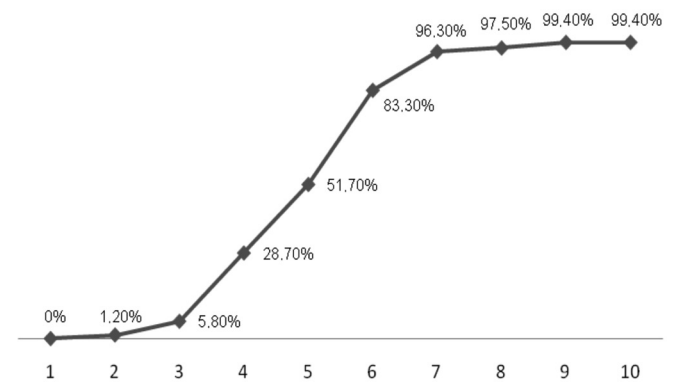
Test	n	Mean	SD	Median	Minimum	Maximum
FPT	43	47.2	23.4	39.9	0	96.6
DPT	43	52.8	22.0	53.3	3.3	100

**Note:** SD = standard deviation; FPT = frequency pattern test; DPT = duration pattern test

It is observed that the studied rural workers presented, in average, thresholds of 7.0 ms for RE and 6.8 ms for the LE.

It was verified the performance for gap interval in the mean number of correct answers, considering both test tracks and right and left ears (Figure 2). It can be noted in the present research that the workers presented a detection rate equal or over 67% only after the gap interval of 8 ms.

Results also show the mean, standard deviation (SD) and median of the measures according to age groups (≤31 years old and >31 years old), and the corresponding descriptive level (p-value) of the Mann-Whitney test for the GIN test (Table 4). There was no difference in the measures for the GIN test between age groups.



**Figure 2.** Performance curve on the GIN test by gap interval

**Table 3.** Variation analysis of central tendency measures of the smallest detected gap in the GIN test between RE and LE

Threshold (ms)	n	Mean	SD/PE	Median	Minimum	Maximum	p-value
GIN RE	43	7.0	1.7	8	4	10	
GIN LE	43	6.8	1.7	6	5	12	
delta	43	0.16	0.19	0	-3	2	0.33

Wilcoxon signed-rank test (p<0.05)

**Note:** SD = standard deviation; PE = pattern error; GIN = gaps-in-noise; RE = right ear; LE = left ear

**Table 4.** Statistical analysis of the GIN test measures according to the age group

GIN	Group ≤31 years (n=14)		Group >31 years (n=29)		p-value
	Mean ± SD	Median	Mean ± SD	Median	
Threshold - RE (ms)	6.3 ± 1.7	6	7.3 ± 1.7	8	0.066
Threshold - LE (ms)	6.5 ± 2.1	6	7.0 ± 1.5	8	0.12

\* Mann-Whitney test (p<0.05)

**Note:** SD = standard deviation; GIN = gaps-in-noise; RE = right ear; LE = left ear

## DISCUSSION

The aim of the FPT and the DPT is to evaluate temporal ordination and the recognition of acoustic contours<sup>(10,11)</sup>. Temporal ordination refers to the perception of multiple auditory stimuli on its occurrence order, which is recommended as an important tool to complement the diagnosis of auditory processing disorders.

In this study, the general mean of correct answers in the FPT and DPT (Figure 1) corroborate the findings of a study<sup>(12)</sup> that evaluated the effects of mercury in adolescents that had been exposed to this substance and found responses worse than expected, according normal standards<sup>(8)</sup>. Another study<sup>(13)</sup> evaluated workers exposed to OP using FPT and DPT, and found significant alterations in central level. These tests presented unsatisfactory results on individuals exposed to solvents<sup>(14)</sup>.

Some studies<sup>(15-17)</sup> have reported that auditory processing disorders and altered cognitive tests might be related to intellectual level, poor language, and reading difficulties. As our research was composed by people with low education levels and residents in a rural area, we had the curiosity to evaluate this influence. For this purpose, workers were split into two groups: ≤3<sup>rd</sup> grade and >3<sup>rd</sup> grade. No significant differences were found between these education levels for both FPT and DPT. It was observed that the number of correct answers was lower than expected, according to normal standards<sup>(8)</sup> (Table 2). One of the possible hypotheses that may explain the low performance in the FPT and DPT may be the low education level or low cultural level in both groups.

During the realization of the tests, the procedure were explained several times. However, it was common to find random and imprecise responses, even after training sections.

In another study<sup>(17)</sup>, 226 adult and elderly individuals were selected, according to their professional occupations. The aim was to characterize the auditory processes of memory, interaction and integration of different occupational levels in the simplified evaluation of central auditory processing and in the dichotic digits tests. The authors concluded that individuals that make a daily use of their mental skills present better performances when compared to those whose occupations do not demand a daily use of these same skills.

Therefore we suggest further studies in order to analyze whether education and/or cultural levels can interfere on the performance in tests that evaluate temporal resolution and ordination.

The GIN test has been studied since 2003 and it is a tool used for the diagnosis temporal auditory processing disorders in adult and children populations<sup>(18)</sup>. It evaluates the temporal

resolution ability, which is fundamental for the perception of complex stimuli, such as speech<sup>(19)</sup>.

The studied rural workers presented, in average, thresholds higher than normal standards<sup>(9)</sup> (Table 3). These data are similar to the results of another study<sup>(20)</sup>, conducted with elderly people.

Regarding the differences between ears, no differences were found. This data corroborates a study<sup>(21)</sup> that also did not find differences in GIN between RE and LE.

It is worth noting that there is only one study in Brazil about normal standards of the GIN test in adults. Moreover, that study was carried out with individuals up to 31 years of age. For this reason, in our study, we cared to analyze the results of this test by splitting the subjects into two groups: people younger than 31 years and people with 31 years or older. Based on this division, it was observed that age difference did not interfere in the results, a reason that allowed us to use the GIN test in both studied groups.

Another hypothesis for these results is the exposition of these workers to OP, affecting their concentration, memory, and information processing<sup>(1)</sup>. This affirmative corroborates a study<sup>(22)</sup> that concluded that neurotoxic products can damage the central nervous system.

Another research<sup>(23)</sup> performed cognitive tests in 127 ovine breeders exposed to OP and 78 not exposed individuals. The breeders that had been exposed presented results worse than individuals not exposed in tests of memory, response rate, fine motor control, and strategy elaboration. The results suggested that there might be a relationship between exposition to OP and neurobehavioral alterations.

Given the above, it is observed that the exclusive use of pure tone threshold audiometry may be insufficient to evaluate auditory aspects in populations exposed to OP. The inclusion of temporal resolution and ordination tests in the group of audiological evaluation tests allowed a broader evaluation of both peripheral and central hearing of these workers.

Considering the discussed studies and the results of the present research, it is emphasized the need for more attention to environmental and occupational health surveillance. This will allow the development of training programs so that those substances can be replaced by ecological and sustainable alternatives, such as organic agriculture, in order to protect the human health and the environment.

## CONCLUSION

The workers exposed to organophosphate pesticides present performances lower than the expected in tests of temporal auditory processing. It is observed an unsatisfying performance

in the Frequency Pattern Test, Duration Pattern Test and in the Gaps-in-noise test. The altered auditory abilities are ordination and temporal resolution.

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