Original Article

Artigo Original

Temporal auditory processing in rural workers exposed to pesticide

Processamento auditivo temporal de trabalhadores rurais expostos a agrotóxico

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Keywords

Hearing
Auditory perception
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ABSTRACT

Purpose: The objective of this research was to assess the ordering and temporal resolution auditory abilities in rural workers exposed to pesticides and compare them with laborers exposure index. **Methods:** A sectional study assessed 33 individuals of both genders, aged 18-59 years, who were exposed to pesticides during their daily routine. The procedures were: questionnaire, meatoscopy, basic audiological evaluation and Temporal Auditory Processing tests: pattern test duration and Gaps-in-Noise. In order to analyse the results, a variable called 'index of exposure' was set up through a simple sum of variables present in the questionnaire. The tests' results on Temporal Auditory Processing were categorized according to the tercis of distribution, based on the results observed – in this study, tertile 1, tertile 2, and tertile 3 – and then compared with the exposure index. **Results:** Difference was verified in all tertiles, with a dose-response relationship, i.e. increased average exposure was associated to worse performance on pattern test duration (p=0.001) and Gaps-in-Noise (p=0.001) in all tertiles. The highest correlation was observed between tertiles 3 and 1. **Conclusion:** Workers exposed to pesticide performed bellow average on Temporal Auditory Processing tests. There was association between the index of exposure to pesticides and worse performance in Temporal Auditory Processing tests, suggesting that the pesticides may be harmful to central auditory pathways.

Descritores

Audição
Percepção auditiva
Praguicidas/efeitos adversos
Trabalhadores rurais
Saúde do trabalhador

RESUMO

Objetivo: Investigar as habilidades auditivas de ordenação e resolução temporal, em trabalhadores rurais expostos ocupacionalmente a agrotóxicos, e correlacionar estes resultados com o grau de exposição dos laboriosos a estas substâncias. **Métodos:** Foi realizado um estudo seccional, por meio da avaliação de 33 indivíduos de ambos os gêneros, com idades entre 18 e 59 anos, expostos ocupacionalmente a agrotóxicos. Aplicou-se os seguintes procedimentos: questionário, meatoscopia, audiometria, imitanciometria e testes do Processamento Auditivo Temporal: Teste de Padrão de Duração e *Gaps-in-Noise*. Para análise dos resultados criou-se uma variável denominada índice de exposição, por meio de um somatório de variáveis presentes no questionário. Os resultados dos testes de Processamento Auditivo Temporal aplicados foram categorizados segundo os tercis de distribuição, de acordo com o resultado observado - sendo neste estudo denominado de Tercil 1, Tercil 2 e Tercil 3 - e então, comparado com o índice de exposição. **Resultados:** Verificou-se diferença em todos os tercis, havendo relação dose-resposta: conforme foi aumentada a média de exposição, pior foi o desempenho no Teste de Padrão de Duração (p=0,001) e no *Gaps-in-Noise* (p=0,001), em todos os tercis. A maior correlação foi observada entre o Tercil 3 e o Tercil 1. **Conclusão:** Os trabalhadores expostos ao agrotóxico apresentaram desempenho inferior ao esperado para os padrões de normalidade nos testes de Processamento Auditivo Temporal. Houve associação entre o índice de exposição a agrotóxico e pior desempenho nos testes de Processamento Auditivo Temporal, sugerindo que o agrotóxico pode ser uma substância nociva às vias auditivas centrais.

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INTRODUCTION

There has been steady increase in the use of pesticides in agricultural environment. The agricultural production process has shown significant technological and organizational changes, resulting in production gain. On the other hand, the increasing exposure to these substances causes damage to human health, which has become subject of Public Health research[1-3]. Data from the National System of Toxic-Pharmacological Information show that in Brazil, in 2008, there were 2754 reported cases of poisoning under occupational circumstances. Of these, 1082 (40%) were caused by exposure to pesticides and 1672 (60%) to other chemical products[4].

Many chemicals, such as pesticides, are known to be neurotoxic[5], which may affect the hearing, acting primarily in the central auditory pathways. Thus, when selecting the method of hearing assessment of exposed individuals, one should consider tonal and vocal audiometry as a starting point. In order to achieve this objective, it is necessary to apply tests that assess the full extension of the auditory system, such as electrophysiological tests and auditory processing tests[6].

Central auditory processing refers to what we do with what we hear[7]. Therefore, possessing normal hearing thresholds is not enough. It is also necessary that the acoustic signal be analyzed and interpreted in order to be transformed into a meaningful message[8]. Temporal auditory processing is defined as the perception of sound or sound changes within a restricted and defined period of time, i.e., it refers to the ability to perceive or distinguish stimuli presented in rapid succession[9].

Previous studies suggest a correlation between central auditory disorders and occupational exposure to pesticides[10,11].

Bearing this in mind, the aim of the present study was to assess the temporal auditory processes (ordering and temporal resolution) of rural workers from the city of Campos dos Goytacazes (RJ), who were occupationally exposed to pesticides, and match the results with the level of exposure of those workers.

METHODS

A cross-sectional epidemiological study was conducted. This research was reviewed and approved by the Research Ethics Committee at the Institute for Studies in Public Health, Universidade Federal do Rio de Janeiro (UFRJ), memorandum 113/2009.

The city of Campos was chosen due to its large agricultural production, and consequently the widespread use of pesticides. Initially, a partnership with the rural workers union of Campos dos Goytacazes was determined, aiming to motivate workers' participation and adherence to the research.

The rural workers invited to take part in the research sought the rural workers union within the period of March 8-19, 2010, and complied with the inclusion criteria required for the study: age range between 18 and 59 years, prior occupational exposure to pesticides and ability to understand the purpose of the research.

All individuals who agreed to participate in the study signed the consent form.

All participants filled in a questionnaire which included personal and occupational data, as well as questions about general and auditory health. The following exclusion criteria were adopted: evidence of neurological disorders and exposure to occupational noise – so that these factors would not function as a confounding factor.

Otoscopy was performed to exclude individuals who presented wax stopper or any foreign body in external auditory meatus. Impedance test was also performed – using the Interacoustics® Mini-Tymp – to exclude workers with audiological pathologies in the outer ear (LE) and/or middle ear (ME); and tonal and vocal audiometry to exclude individuals with neurosensorial hearing loss[12]. The latter procedure was carried out with the Amplaid® 309 audiometer.

Initially, 38 individuals were assessed, one person was excluded from the study for having evident cognitive disorders and other four because they had sensorineural hearing loss.

The profile of the studied group was then outlined. Out of the 33 rural workers, 24 (72.7%) were male and nine (27.3%) were female. Their educational background ranged from illiteracy to high-school, the sample consisting of five (15.2%) illiterate individuals, 25 (75.8%) with elementary school level and only three who had finished high-school. The average age was 45.3 years; the minimum age was 26 years and the maximum 59. The individuals were exposed to various types of pesticides, the most widely used type was the herbicide, especially *roundup*®, and in a smaller amount insecticides and fungicides.

The Duration Pattern Test (DPT) was used to assess the function of sequencing or temporal ordering, which involves perception and processing of two or more auditory stimuli in its order of occurrence in time. The function of this ability is to enable the listener to recognize acoustic contours such as intonation, tone and rhythm[13]. The test was performed monaurally at 50 dB above the average hearing thresholds of frequencies 500 Hz, 1k and 2 kHz and naming was the type of answer required. Before the beginning of the test, three standard sequences were applied as trials, to guarantee that the individual clearly understood what was going to be done.

The Gaps-in-Noise test (GIN) was applied in order to assess the ability of temporal resolution. This can be defined as the capacity to detect the time interval between sound stimuli or to perceive the shortest time in which an individual can discriminate two audible signals[14], i.e., it is related to the ability to detect changes in sound stimuli over time[15].

The GIN test was applied monaurally at 50 dB NS, based on the average value of hearing thresholds for 500 Hz, 1k and 2 kHz. There was no previous training to the task.

Attempting to create a scale measuring the level of occupational exposure of workers to pesticide, a variable called exposure index was determined, calculated by the sum of the following variables presented in the questionnaire (Appendix 1): Number of years of exposure – from the age when the contact with pesticides began until current age; number of days of use of the pesticide during the latest season; number of times the pesticides were applied each month; age when the contact with pesticides began; number of working hours with pesticides per day and distance from home to farming land. This index of exposure was obtained using a scoring system (Appendix 2), which ranged from 0 to 20 points, with heavier weight assigned to the answer choice in which the individual had a greater exposure.

The results of the tests were categorized according to the value observed in the distributing tertiles which, in this study, were called Tertile 1 (T1), Tertile 2 (T2) and Tertile 3 (T3) and then compared to the exposure index. In the DPT, values greater than 43.3% were considered T1; values between 36.6% and 43.3%, T2; values under 36.6%, T3. In the GIN, values less than 5.0 ms were considered Tertile1 (T1); values between 5.1 and 6.0 ms, Tertile 2 (T2); values greater than 6.0 ms, Tertile 3 (T3)

Descriptive statistics was used to outline the profile of the population studied according to the variables: gender, age and education. To measure the correlation between the tests applied and the exposure index in a continuous way the Spearman's correlation test was used. In order to analyze the relation between the tests performed in tertiles and the exposure index, we used the analysis of variance associated to Scheffer's test. Furthermore, to analyze the influence of variables in the tests results, we used the Spearman's correlation and logistic regression, in order to neutralize the confounding factor, since the test results did not present a normal distribution. The logistic regression was used merely to determine the risk of the individual to present worse performance when controlled by the confounding factor. In order to apply logistic regression, the values of the DPT and GIN results were divided by the median so that groups with the same number of individuals could be formed. In this study, a worse performance was ascertained in the DPT with values below 40%, in both ears; and in the GIN, the occurrence above 5 ms in the right ear (RE) and 6 ms in the left ear (LE).

The statistical analysis was performed using the computer program Statistical Package for Social Sciences (SPSS), version 17.0.

RESULTS

Duration pattern test

When statistics for the measures of central tendency were done, an exposure mean of 8.33 (SD=3.35) was observed and the mean for DPT in the right ear was 43.7% (SD=10.53) and in the left ear it was 40% (SD=9.34) (Table 1).

We found correlations between SDT performance and the exposure index, considering $p<0.05$. There was an average negative correlation for the RE (R=-0.615) and a high negative correlation for the LE (R=-0.715).

We compared the mean exposure index among the tertiles of the SDT. There was a difference in the mean of exposure between tertiles 3 and 1. Although there was no difference between tertiles 1 and 2, we observed that there was an increasing rise in the mean of exposure in the DPT, with the presence of a dose-response relationship, i.e., as the mean of exposure increased, the worse was the performance in the test, in both ears (Table 2).

When analyzing the influence of variables: gender, age and education, the only association found in the results of DPT was with the variable age.

A logistic regression, controlled by age, was used to determine the odds of an individual to present a worse performance in the DPT due to a higher exposure index.

In both ears, it was observed that the higher the exposure index, the greater the chance of rendering a worse performance (less than 40%) in the DPT, even when the influence of the age factor was controlled (Table 3).

Gaps-in-Noise test (GIN)

The mean, the median, the standard-deviation, the minimum and maximum values of Gaps-in-Noise (GIN) test and exposure index were exposed, as well as the correlation coefficient of performance at GIN in both ears, according to the exposure index and the p-value. The GIN test presented an average of 5.82 (SD=2.17) for RE and 6.25 (SD=2.06) for LE (Table 1).

A significant correlation was found, considering $p<0.05$ for the GIN test in both ears. The GIN threshold in the RE presented a high positive correlation (R=0.713) and in the LE an average positive correlation (R=0.566) (Table 1).

We compared the average of the exposure index among the tertiles at GIN, and there was difference between tertiles 3 and 1. However, although there was no difference between tertiles 1 and 2, we observed that there is a growing increase in the mean of exposure among the tertiles of performance at GIN, and there is also a dose-response relationship: as the mean of exposure increases, the worse the performance of the test is, in both ears (Table 2).

Table 1. Descriptive analysis of the Duration Pattern Test (DPT) and Gaps-in-Noise Test (GIN), in correlation with the exposure index to pesticides among rural workers

Test	Mean	Median	SD	Minimum	Maximum	R	p-value
DTP RE	43.7	40.0	10.53	30.0	66.6	-0.615	0.000*
DTP LE	40.0	40.0	9.34	30.0	66.6	-0.713	0.000*
GIN RE	5.82	5.0	2.17	2.0	12	0.713	0.000*
GIN LE	6.25	6.0	2.06	4.0	12	0.566	0.001*
Exposure	8.33	8.00	3.35	1.0	17.0	-	-

* Significant values ($p<0.05$) – Spearman Correlation

Note: R = correlation coefficient; SD = standard deviation; RE = right ear; LE = left ear

Table 2. Comparison between exposure index and the tertiles in the Duration Pattern Tests (DPT) and Gaps-in-Noise (GIN) test amid the rural workers

Test	Alteration degrees according to tertiles	Mean of exposure index	p-value[a]	p-value[b]
DPT RE	T1 (greater than 43.3%)	5.3	----	0.001*
	T2 (36.6-43.3%)	8.6	0.129	
	T3 (less than 36.6%)	10.3	0.001*	
DPT LE	T1 (greater than 43.3%)	5.4	----	0.001*
	T1 (36.6-43.3%)	7.7	0.191	
	T2 (less than 36.6%)	10.5	0.001*	
GIN RE	T1 (less than 5 ms)	5.8	----	0.001*
	T2 (5.1-6.0 ms)	7.7	0.003*	
	T3 (greater than 6.0 ms)	10.3	0.003*	
GIN LE	T1 (less than 5 ms)	7.3	----	0.001*
	T2 (5.1-6.0 ms)	7.7	0.003*	
	T3 (greater than 6.0 ms)	11.0	0.044*	

[a] In relation to the reference tertile (T1), calculated by Scheffe's test
[b] ANOVA
* Valores significativos ($p<0.05$)
Note: RE = right ear; LE = left ear

Table 3. Logistic regression adjusted by age in order to evaluate the odds of worse performance in Duration Pattern Tests (DPT) and Gaps-in-Noise (GIN) test, according to exposure index among rural workers

Test	Odds ratio (OR)	CI (95%)
DPT RE	2.020	1.108 – 3.683
DPT LE	1.879	1.157 – 3.050
GIN RE	2.038	1.218 – 3.409
GIN LE	1.203	0.948 – 1.526

Note: RE = right ear; LE = left ear; CI = confidence interval

When analyzing the influence of variables: gender, age and education, the only significant association found in the results at GIN was with the variable age.

An analysis of logistic regression controlled by age was performed in order to verify the odds of the individual to obtain a worse performance at GIN when presenting a higher exposure index. In both ears, it was ascertained that the higher the exposure index, the greater the chance of the individual present a worse performance at GIN, i.e., the greater the chance of presenting results above 5 ms and above 6 ms, in RE and LE respectively, even when the influence of age was controlled (Table 3).

DISCUSSION

The studied population was predominantly composed by male adult subjects (72.7%), with similar results found in other studies[16,17].

In the population studied, all the results (100%) found for the DPT indicated worse performance when compared to normal conditions, i.e., hit rate equal to or above 83% for both ears[18] (Table 1). Therefore, we may suggest that pesticides may harm the capacity of temporal ordering as assessed by the SDT.

Nowadays, there is a standardization for the GIN test until the age of 31, and the criterion of normality is a general average in the gap thresholds of 4.19 ms[19]. In the workers in this study, it was observed that approximately 51.5% of the GIN results were altered in the RE and 54.5% in the LE, with the possibility that this percentage indicates that pesticide is harmful to the auditory ability of temporal resolution.

However, it is important to point out that the population studied probably has socioeconomic status and education level inferior to those of the populations used in the standardization of the Temporal Auditory Processing Tests, which makes it difficult to compare data obtained with the values described as normality.

Comparing the results at DPT with the ones at GIN, it was observed that performance was relatively worse at DPT. Perhaps this finding may be attributed to the fact that DPT, unlike GIN, involve not only the auditory ability of temporal ordering, but also memory – which may contribute to a greater variability in the performance on tests involving discrimination of duration[20]. The same comparison was made in another study, where similar results were found. In the analysis of the researchers, the fact was justified by the task requested at DPT, in which the type of answer used was naming, requiring inter-hemispheric transfer, i.e., with both brain hemispheres were involved. The recognition of contour pattern occurs in the right hemisphere and the information is transferred through the corpus callosum to the left hemisphere, where the signal's naming is done. Thus, in cases where there are poor verbal responses, it is likely that there is a disorder in the inter-hemispheric transfer. On the other hand, at GIN, the requested task does not require naming, but the identification of the silence interval, by raising a hand, not demanding inter-hemisphere transfer [21].

In the DPT and GIN tests categorized in tertiles with exposure index (Table 2), differences were found in all tertiles, with a dose-response relationship, i.e., as the average of exposure increased, the worse was the performance in the tests. The greatest correlation was found between T3 and T1. Perhaps, in studies with the same goal and with a larger number of participants a stronger correlation among all tertiles could be identified.

When analyzing the influence of the variables of gender, age and education, a significant relationship was found only with the variable age. Both in DTP and GIN, the individuals included in T3 had a higher exposure index, however, they were also the ones with the highest age average. Therefore, age could be a confounding factor for the research. When carrying out logistic regression (Table 3) to neutralize the possible bias of age, we found positive results in relation to the hypothesis initially raised: Individuals with higher exposure index presented worse performance at DPT and GIN tests, regardless of their age. Other current studies indicate that there is a relationship between auditory processing and ageing(22). This studies, however, were done with an elderly population, over 60 years-old, unlike our present research, which included individuals aged 59 at the most, with the objective of trying to avoid that age could influence the temporal auditory processing test results.

Similar studies that correlated the exposure index to pesticides and temporal auditory processing were not located.

One of the possible limitations of this study is the number of subjects studied and the fact that the sample is composed by volunteers, which makes it a non-probabilistic sample, apart from being too small to allow the detection of subtle differences in changes on the temporal auditory processing in relation to the exposure index. Nevertheless, it should be pointed out that although the studied population was small, statistically significant results show the relevance of this pioneering study in Brazil.

Another possible limitation is the fact that the study is sectional, which could hinder the assessment of the causal relationship (the exposure precedes de outcome). However, the use of a previous exposure index minimized such a limitation.

According to specialized literature, the adverse effects that chemical exposure may cause to the central nervous system are recognized(23-25). However, the effects of these substances in the central auditory pathways are still poorly explored. Therefore, there is a need for studies that make use of tests to deepen the knowledge of toxicity of pesticides in the auditory system.

Results point out to an association between pesticide exposure and changes in the skills of ordering and temporal resolution in the Temporal Auditory Processing, and it was ascertained that it is important to consider central auditory issues in procedures that aim at preventive measures for the rural workers exposed to these substances.

CONCLUSION

Rural workers occupationally exposed to pesticides present a performance that is poorer than expected when compared to patterns of normality in temporal auditory processing. There is an association between exposure to pesticide and poorer performance on the tests applied, indicating that the exposure to pesticides may affect the central auditory pathways, impairing the capacity of ordering and temporal resolution.

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Appendix 1. Questionnaire

1. General information
Name:
Sex: ( ) F ( ) M Age: ___________________________
Address: ____
District:___________________________ City:____________________________
Phone number: ____________________ Postal Code:_____________________
Marital status: ____

Education:
( ) Illiterate
( ) Incomplete elementary school
( ) Complete elementary school
( ) Incomplete high school
( ) Complete high school

2. Health records
( ) High-blood pressure ( ) High cholesterol ( ) Diabetes ( ) Cancer ( ) AIDS ( ) Neurological alterations
Are you currently taking any medications? ( ) yes ( ) no
Which one(s)? ____

3. Hearing Information
Have you ever noticed fluid coming out of your ears? (otorrhea)? ( ) yes ( ) no
Have you ever undergone:
Ear surgery? ( ) yes ( ) no
Tympanic perforation? ( ) yes ( ) no
Exposure to very loud noise? ( ) yes ( ) no
Which?____

4. Information about the use of pesticides
How long have you worked with pesticides (poison/medicine for plants)?
( ) less than a year ( ) 11-20 years
( ) 1- 5 years ( ) 21-30 years
( ) 5- 10 years ( ) over 30 years

During the latest season, how many days did you apply (poison/medicine for plants)?
( ) never
( ) 1 - 5 days
( ) 6 - 25 days
( ) 26 - 50 days
( ) less than 50 days

How many times a month do you apply pesticide? (poison/medicine for plants)?
( ) once ( ) 5- 10 times
( ) 1-5 times ( ) more than 10 times

How old were you when you got into contact with pesticide? (poison/medicine for plants)?
( ) 21 years-old or older
( ) 15-20 years-old
( ) 10-15 years-old

5. Working habits
How many hours a day do you work?
( ) 4 to 6 hours
( ) 8 hours
( ) 10 hours
( ) 12 hours or more

What is the distance from your home until the place where you apply/mix pesticide? (poison/medicine for plants)?
( ) less than 50 meters ( ) 100-200 meters
( ) 50-100 meters ( ) over 200 meters

Appendix 2. Criteria used for scoring exposure index

Variable	Answers	Scoring
Exposure time	Less than 1 year	0 points
	1-5 years	1 point
	5-10 years	2 points
	11-20 years	3 points
	21-30 years	4 points
	Over 30 years	5 points
Days of use during latest season	Never	0 points
	1-5 days	1 point
	6-25 days	2 points
	26-50 days	3 points
	More than 50 days	4 points
Number of times of use per month	Once	0 points
	1-5 times	1 point
	5-10 times	2 points
	More than 10 times	3 points
Age when contact with pesticide started	21 years or older	0 points
	15-20 years	1 point
	10-15 years	2 points
Hours of work per day	4 to 6 hours	0 points
	8 hours	1 point
	10 hours	2 points
	12 hours or more	3 points
Distance from home to farm	Over 200 meters	0 points
	100-200 meters	1 point
	50-100 meters	2 points
	Less than 50 meters	3 points