

# PITCH PATTERN SEQUENCE AND DURATION PATTERN TESTS IN BRAZIL: LITERATURE REVIEW

## *Testes tonais de padrão de frequência e duração no Brasil: revisão de literatura*

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### ABSTRACT

This study has as a theme the pitch pattern and duration tests in Brazil and as a purpose to review and explain the temporal auditory processing evaluation in Brazil, specifically the temporal ordering tasks (pitch pattern and duration pattern tests). In order to achieve this objective was performed a systematic literature review on national journals, electronically accessed on the Scielo and Lilacs database, no restrictions related to year of publication. The research was structured using the descriptors: temporal processing, auditory temporal processing, temporal tests, pitch pattern sequence test, duration pattern test, auditory perception and auditory tests. The survey returned 33 national publications including 28 articles from journals, a master thesis and four doctoral theses. Thus, it can be seen that the use of the tests to assess the ability of temporal ordering in Brazil are recent and it's remarkable the significant increase of publications over the last past years. The emerging knowledge in Brazil made possible by the access to the tests allows extending a research field to all professionals committed to this issue.

**KEYWORDS:** Hearing; Auditory Perception; Hearing Tests

### ■ INTRODUCTION

Central auditory processing is currently defined as the "perceptual processing of auditory information in the central nervous system"<sup>1</sup>. This processing involves the auditory system mechanism responsible for the following behavioral phenomena: sound localization and lateralization; auditory discrimination; auditory pattern recognition; temporal aspects of audition including, temporal

resolution, temporal masking, temporal integration, and temporal ordering; auditory performance with competing acoustic signals; and auditory performance with degraded acoustic signals<sup>2</sup>.

As for temporal processing, author<sup>1</sup> states that temporal ordering ability to sound stimuli is, undoubtedly, one of the most important functions of central auditory nervous system. Assessment of auditory processing involving temporal ordering tasks uses behavioral measures to analyze central auditory system. This ability allows the listener to discriminate based on ordering and sequencing of auditory stimuli<sup>1</sup>.

In Brazil, assessment of temporal ordering tasks is recent. Over the past decade, there has been a variety of studies, which used diverse methodologies and clinical populations.

Thus, it is necessary to conduct a literature review that outlines an overview about the status of publications on this topic in order to guide researchers on previous studies and new research perspectives.

Regarding the above, the aim of this study was to review and explain auditory temporal processing

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Conflict of interest: non-existent

assessment in Brazil, specifically temporal ordering tests (frequency patterns and duration patterns test).

## ■ METHODS

This is a systematic review of the literature in national journals, accessed electronically on data basis Lilacs and SciELO, no restriction related to the year of publication. This research structured via the following descriptors: auditory perception, temporal processing, auditory temporal processing, auditory tests, temporal tests, and frequency and duration pattern standard tests.

This review evaluated and selected only those studies whose title, abstract or article were related to the objective of this study. The various studies found were filtered according to the line proposed by this review, and excluded those that were duplicated in databases. Relevant references cited in the selected databases were also included. Thus, the survey was composed by 33 national publications and 28 articles in journals, a master's dissertation and four PhD theses. It were also included six essential international publications for the description and understanding of the theme and assessment.

## ■ LITERATURE REVIEW

### Temporal Aspects of Audition

All functions of the central auditory nervous system are somehow influenced by time. In this system, the pattern of neural activity mediated by temporal information with an accuracy of micro-seconds. Speech and language comprehension, the most complex function of the human central nervous system, depends on the ability to deal with sound sequences<sup>3</sup>.

The processing acoustic cues of speech sounds depends on the proper perception of the frequency and duration of stimuli as a sequence of events<sup>4</sup>.

The importance of auditory perception of temporal patterns and sounds' sequence in the acquisition and understanding of the symbolic components of language is recognized, and the acoustic properties of speech may be limited to the basic components of duration and frequency<sup>1</sup>.

Temporal processing is the fundamental component of most auditory processing abilities; however, their underlying neural mechanisms are not well understood<sup>5</sup>.

The neural basis for human perception of frequency, even in individuals without any sensory abnormalities, is not entirely known and always wondered if the right auditory cortical region has greater specificity for frequency resolution compared to its homologous region on the left side<sup>6</sup>.

Individuals that failed to recognize temporal patterns have difficulty to extract and use prosodic aspects of speech such as rhythm, stress and intonation, which allow the listener to identify keywords within a sentence and interpret emphases and sarcasm<sup>7</sup>.

Temporal processing tests should compose the battery of special auditory tests that assess central auditory processing in children because they are fast to apply, easy to understand and to accomplish<sup>8</sup>.

Several precautions should be taken before applying the tests. Research showed that variables such as stimulus duration and requested command might interfere with individual's performance in auditory temporal tests. So, in relation to the stimulus duration, higher the duration, better the performance. Concerning the type of task, in tests that involves frequency, the ordering ability had a greater difficulty degree when compared to discrimination. It was concluded that is necessary a greater concern with the temporal parameters found in each test, since these tests influence the performance of the individual and, perhaps the diagnosis<sup>9</sup>.

### Frequency Patterns Test and Duration Patterns Test

Behavioral tests of temporal ordering have been developed in the 1960, in order to evaluate the dysfunction of the auditory nervous system central<sup>3</sup>.

Temporal tests are those that request the listener the ability of temporal sequence patterns recognition and temporal ordering of non- verbal stimuli<sup>7</sup>.

In 1976, Frank Musiek and colleagues proposed a test to assess temporal ordering tasks, "Pitch Pattern Sequence Test" or "Frequency Patterns Test- FPT"<sup>10</sup>.

Frequency Patterns Test consists of 60 sequences that contains three tones bursts composed of low (880 Hz) and high (1122 HZ) frequencies. Each of the tones has 10 milliseconds (ms) rise-fall time and a duration of 150 ms. The interval between the tones within each sequence is 200 ms. This permits the generation of six different tone sequences: HHL, HLH, HLL, LLH, LHL and LHH<sup>10</sup>.

Frequency Pattern Tests assesses frequency pattern recognition and temporal ordering task of different stimuli, and involves both hemispheres<sup>11</sup>.

The neurophysiological mechanism that explains the Frequency Patterns Test standard test sequence was described in earlier studies of the test<sup>12,13</sup>.

This model proposes that the integrity of both brain hemispheres is important for perception and nomination of tonal pattern. The non-dominant hemisphere (usually right) related to the perception of pitch and recognition of auditory contour. The

dominant hemisphere (usually left) is important for the nomination of tonal pattern (example: low, high, and low). The nomination of a tonal pattern initially requires the processing of acoustic boundary that, according to authors' proposition, occur in the right hemisphere, and will then transfer via the corpus callosum to the left hemisphere when the response requires verbalization of the tonal pattern. In cases where the response requires humming, there will be only participation of the right hemisphere. Therefore, when the response to the frequency pattern test requires verbalization of tonal pattern, the integrity of the right temporal lobe, the pathways of the corpus callosum and the left temporal lobe is essential to obtain an adequate response to the test.

In 1990, the authors described the Duration Pattern Test - TPD consist of sequences of three tones, one of which differs from the other two in the sequences by being either longer or shorter. The frequency of the test tone is held constant at 1000 Hz, with the duration on the tone either 500 ms (L) or 250msec (S). Each tone has a rise-fall time of 10 ms and the interval between tones is 300 ms. Six different sequences are possible: LLS, LSL, LSS, SLL, SLS, and SSL<sup>4</sup>. The authors assessed the performance of three groups on Duration Patterns Test: Group I: no hearing loss or lesions of the central nervous system; Group II: cochlear hearing loss and Group III: lesions in the central auditory nervous system determined by other neurological, radiological and / or surgical methods. The authors reported that this test is highly sensitive (86 %) and specific (92%) to detect cerebral lesion<sup>14</sup>.

Both tests allow two distinct patterns of response: humming and nomination. In humming, there is great involvement of the right hemisphere and, in nomination of the left hemisphere. Patients with right unilateral lesion would present alterations on both patterns of response since this hemisphere would be responsible for identifying the acoustic pattern. Lesions on the left hemisphere, would present adequate response to humming and, decrease to nomination due to the dependence of this hemisphere for language labeling<sup>11</sup>.

In United State, in 1997, began the marketing of the Frequency Patterns Test and Duration Pattern Test developed by Auditec®. Frequency Patterns Test differs from that proposed by Musiek, where the frequencies are centered at 880Hz and 1430Hz. The test is available in two versions: the adult and infant, @the difference between them is the duration of the stimulus (300 ms for the adult version and 500 ms for infant) and the interval between the sequences (6 seconds for the adult version and,9 seconds for the infant). DPT version proposed by

Auditec® presents similar features to that proposed by Dr. Frank Musiek<sup>15</sup>.

Descriptions, differences, similarities, patterns of response and neurophysiological mechanisms involved in Frequency Patterns Test and Duration Patterns Test are well defined in the literature.

In Brazil, in 1998 a study conducted with 80 young adults, normal hearing, using Frequency Patterns Test and Duration Patterns Test, as described by its creators<sup>10,13,14</sup>.

In another study, the tests were performed monaurally and it was found that the variables ear side (right and left) and intensity level (50 dBSL and 20dBSL) did not influence the results. The author reported that the performance of males was higher than females. The reference criterion for young people with normal hearing was a value equal to or greater than 76 % accuracy for Frequency Patterns Test and a value equal to or greater than 83 % accuracy for Duration Patterns Test. The study concluded that the use of these two behavioral auditory tests are important in the set of procedures that assess the neural pattern for processing nonverbal sounds. The authors reported that these non-verbal procedures are quick and easy to apply and may be included in the test battery of auditory processing to verify interhemispheric integration and integrity of the each hemisphere<sup>16</sup>.

Aiming at the tests' standards, a study was conducted to establish the performance profile of 229 children with no language, speech, hearing and / or learning, age range between seven to 11 years from public schools, for temporal patterns 'recognition. The tests used were Frequency Patterns Test and Duration Patterns Test commercialized by Auditec®<sup>15</sup>and applied monaurally. For Frequency Patterns Test, nomination response, the authors found that the mean score for correct answers at 10 years was 75.9 % and at 11 years was 83 %. For Duration Patterns Test, nomination response, the research found that the average was 58.33 % accuracy at 10 years and 64 % accuracy at 11 years<sup>17</sup>.

Study in a population of 155 subjects of both genders, aged between 7 and 16 years, normal hearing, found an average of 30 % of alteration for behavioral tests (Frequency Patterns Test and Duration Patterns Test). The comparison between the results of two tests, FPT (880 Hz Hz/1122) and DPT (250/500 ms.) for right and left ears showed that even at 12 years the two tests are concordant. At 13 years, however, it was noted that they do not coincide, i.e. the result of one cannot be the same as the other. In this age group, a greater number of changes was observed at the FPT than the DPT.

In this study, the authors did not specify the type of response required of the individuals<sup>3</sup>.

When analyzing the publications that aim to establish the normal range for the tests, there was no publication with the normal range for the adult version of the Frequency Patterns Test from Auditec®, with the parameters of normality for the other tests are well defined.

Initially the tests applied with supra-aural headphone, but new research demonstrated the applicability in soundfield, as the ear factor does not influence the behavior of subjects with temporal processing disorders.

Recently, a research used children's version of Auditec® to characterize the performance profile of children with normal hearing in detection and identification of temporal ordering tasks, the stimuli presented in soundfield. The assessment of 43 children, aged between seven and 11 years and five months, showed that: (1) children's performance for Frequency Pattern Test when the answer required was humming was significantly higher than for nomination; (2) significant improvement of performance for Frequency Patterns Test for nomination's answers, Duration Patterns Test for humming and nomination, with increasing age; (3) performance on Frequency Patterns Test was higher than Duration Patterns Test<sup>18</sup>. These findings may contribute to the clinical routine and researches that involves temporal ordering tasks on deaf individuals that uses electronic devices as well as for situations which the use of supra-aural earphones is not indicated.

Based on the possibility of applying temporal ordering tests in soundfield it may be considered auditory processing tests' inclusion, as a new feature, in hearing aids selection and fitting, considering that in some cases, this step may result in hearing aids rejection because it not address the needs of individuals. There was a study aiming to evaluate the performance of patients in Duration Patterns Test during hearing aids selection and adaptation. Then, it was evaluated seven adults, aged 34 to 71 years, with bilateral hearing loss ranging from mild to moderate, with medical indication for hearing aids fitting. Methodology consisted of the inclusion of DPT, humming answer, performed before and during the fitting, using two hearing aid models, one with analog and other with digital technology. The authors observed that the temporal ordering ability was slightly better with the analog device in both ears, but with a digital device, there was a significant improvement in the right ear and no improvement in the left ear<sup>19</sup>. When analyzing this publication, were noticed the absence of description about the level of stimulus presentation, assessment of separate ears and test version used (Auditec® or Musiek).

In the literature, there are reports that two languages exposure and musical training can influence the test performance.

A study with 60 individuals divided into the following subgroups: Japanese descendants that spoke Brazilian Portuguese and Japanese, Japanese descendants that spoke Brazilian Portuguese and did not speak Japanese and individuals that did not descend from Oriental and spoke Brazilian Portuguese speakers. The researchers applied the FPT and DPT at 70dBNA, but they did not referred the version that they used. They observed a better performance at FPT compared to the DPT for the first two groups when compared to native group. It seems that auditory experience provided by exposure to Japanese language facilitated the recognition of sound frequency pattern<sup>7</sup>.

To assess the influence of musical training, researchers compared the ability of temporal sequencing between 20 violinists and 20 non-musicians applying the Frequency Patterns Test (Auditec® version), presented monaurally, and the expected answer was humming. The results showed that violinists' performance was better on both tests when compared to non-musicians; it can be justified by the fact that musical training enabled greater insight for frequency discrimination whereas that musical practice provides this ability<sup>20</sup>.

Also this theme, another study assessed the effect of auditory training on individuals performance using for assessment Frequency Patterns Test and Duration Patterns Test. It were evaluated 20 individuals of both genders, aged between 17 and 30 years, among these 10 had musical training, and 10 did not have. The authors concluded that musical training influenced the individuals' performance, which was higher than expected for individuals without central disorders<sup>21</sup>.

Another factor that should be considered in this topic is the aging of the central auditory pathways, as well as cognitive decline of elderly. Considering these aspects, it would be interesting to determine normality criteria for the elderly population in auditory processing tests<sup>19</sup>.

Aiming to assess auditory sensitivity in this population, a study conducted with 25 elderly, with normal hearing. For the assessment were used the version proposed by Musiek, applied monaurally and the required answer was nomination. The authors reported that the mean percentage of correct answers was 49.2 % At Frequency Patterns Test and 67.5 % at Duration Patterns Test, and these values were lower than those obtained in normal young adults. The relationship between DPT and FPT and individual age was inversely proportional, i.e., higher the age, worst the performance<sup>22</sup>.

Aging can bring a decline in the ability of temporal ordering, which may be related to reduction of effective communication. A study conducted to assess auditory processing, aimed to investigate the influence of age and hearing loss in 65 elderly. They used the DPT, diotic presentation, and they found that the mean score (63.1%) was lower than that found in young adults with normal hearing. Thus, it can be inferred that aging brings harm to temporal ordering ability, and in this study, the hearing loss did not influence test's results<sup>5</sup>.

All body structures are modified in aging process, what causes hearing and understanding difficulties. The hearing loss that occurs as a result of this process leads to a decrease of communicative function, also causes withdrawal from social contact. A study performed with 21 elderly compared the temporal processing (FPT and DPT – Auditec®, dichotic presentation) in individuals with normal hearing and sensorineural hearing loss. It was observed that FPT performance was higher than DPT performance and, these results showed no significant relationship between the individuals with and without hearing loss. This finding suggests that aging process influenced the results and the peripheral hearing loss did not. The men's lower performance may be associated with the hearing loss, as well as the number of males who participated of the study<sup>23</sup>.

In the revised publications we found that temporal ordering tests could be applied in soundfield<sup>18,19</sup>, which can contribute to study this ability on users of electronic devices. It was also observed that peripheral hearing loss<sup>5,23</sup> did not influence this ability, which can be modified by musical training<sup>20,21</sup>, fluency in more than one language<sup>7</sup> and aging<sup>5,22,23</sup>.

### **Clinical applications of Frequency Patterns and Duration Patterns Test**

Several studies are being performed to investigate temporal ordering tasks in neurological disorders.

One of these studies investigated the performance in musical frequency (low tone - 440Hz / high tone - 493Hz) and duration (short – 59ms / long - 161 ms) tests in 10 subjects, aged between 50 and 70 years diagnosed with Parkinson's disease. The stimuli were presented in soundfield, and researchers observed changes on both tests. The authors explained this performance based on the influence of environmental factors, age, and developmental level of the disease<sup>1</sup>.

A study developed with 18 subjects of similar age, of which eight had temporal lobe epilepsy and ten without cortical damage, it was observed that individuals with epilepsy had more deficits in auditory

processing than those without cortical damage. The difficulty of temporal ordering evidenced by the duration pattern test can be associated with problems in speech recognition. The temporal lobe epilepsy was a factor that differentiated sound processing, whereas, individuals with this change showed impairment in the ability to analyze verbal and nonverbal sounds received auditorily. This cortical region is responsible for processing acoustical information<sup>24</sup>.

The same authors complemented that auditory pathway ends at temporal lobe (primary and secondary auditory cortex), after going through various structures of the peripheral and central auditory system. For a proper analysis and interpretation of information received auditorily (auditory processing) it is required anatomical and functional integrity of these structures. The electric discharges caused by seizures can cause neuronal loss in the region where the auditory processing occurs, these arose the hypothesis that there are difficulties to process mental information received auditorily, which might worsen the communication skills of these patients<sup>24</sup>.

A case study described a male child with cerebrovascular disease (involvement of cortical and perforating branches of the middle cerebral artery ischemic type with hemorrhagic transformation) that occurred when he was four years and ten months old. The cortical-subcortical lesion in the left hemisphere compromised structures related to auditory processing, affecting the temporal lobe, parietal areas, insular and subcortical structures. To assess temporal ordering was applied Frequency Patterns Test (Auditec® version) test, binaural mode, on two occasions (when he was 8 and later at 11 years), appropriate response for this test was observed in two applications. The authors explained that the lack of alteration might be due to the time elapsed between the acute event and the assessment. They also said that on extensive injuries on left hemisphere, verbal function can be rearranged on the opposite hemisphere, and as a result, new patterns establishes and there is an exchange of the direction advantage<sup>11</sup>.

In analyzing the temporal ordering publications on neurological disorders it was verified that the use of a single test to assess this skill and a reduced number of subjects.

The relationship between temporal processing and language disorders has received little attention in national and international literature. The associations between deficits in auditory tasks and language disorders are not clear and must be explained<sup>25</sup>.

It was observed that, in most studies of individuals who had speech pathology, the temporal ordering ability was impaired, and FPT was the test most frequently used to assess this ability.

Figure 1 presents the publications<sup>25-35</sup> which employed Frequency Patterns Test and / or Duration Patterns Test to assess temporal ordering ability in individuals with communication disorders.

Author	Year	Speech TherapyDiagnosis	Test	Results
Fortunato-Tavares et al <sup>25</sup>	2009	Specific Language Impairment	FPT Auditec	Abnormal
Abdo, Murphy e Schochat <sup>26</sup>	2010	Attention Deficit/Hyperactivity Disorders and Dyslexia	FPT Musiek	Abnormal
Simões e Schochat <sup>27</sup>	2010	Dyslexia	FPT Musiek	Abnormal
Frota <sup>28</sup>	2003	Specific Reading and Writing Impairment	FPT/DPT Musiek	Abnormal
Silva, Oliveira e Cardoso <sup>29</sup>	2011	Developmental Stuttering	FPT/DPT Auditec	Abnormal
Santos, Pereira e Leite <sup>30</sup>	2010	Phonological Disorder	FPT Auditec	Appropriate
Correa et al <sup>31</sup>	2011	Oral Breather	FPT *	Abnormal
Dias <sup>32</sup>	2005	Asperger Syndrome	PFT/DPT Musiek	Appropriate
Engelmann e Ferreira <sup>33</sup>	2009	Learning Disabilities	FPT Auditec	Abnormal
Machado et al <sup>34</sup>	2011	Reading and Writing Disorders	FPT/DPT (melodic)	Abnormal
Soares et al <sup>35</sup>	2011	Reading and Writing Impairment	FPT/DPT *	Abnormal

Legend: FPT – Frequency Patterns Test; DPT – Duration Patterns Test.

\*The authors did not specified in the publication the test version used.

### Figure 1 – Studies of literature describing the applications of temporal ordering tests in communication disorders

To investigate the performance of children with dyslexia and attention-deficit/ hyperactivity disorders in behavioral tests of auditory processing, were applied the Frequency Patterns Test (Musiek version), binaural mode, in 30 children (aged between 7 and 12 years) divided into three groups: control group, dyslexia group, and attention deficit hyperactivity disorder group. It was observed that children with dyslexia showed statistically worse performance than the control group on the test, suggesting the existence of relationship between temporal ordering skills and reading disorder. The group of children with attention deficit/ hyperactivity disorder showed statistically worse performance than the control group in all tests, suggesting the existence of relation between the tested ability and attention deficit/hyperactivity disorder<sup>26</sup>.

Another study that enrolled 40 children with auditory processing disorder associated or not with dyslexia. They applied the FPT (Musiek version), and it was observed that the individuals with dyslexia show, mostly, different patterns of auditory processing disorder, with greater changes in temporal processing tests when compared to tests that assessed other auditory skills<sup>27</sup>. A limitation of this study is the lack of reference regarding stimuli presentation.

The association of specific language impairment to auditory processing disorders was suggested in a study, which hypothesized that the discrimination of brief stimuli would be compromised in children with specific language impairment. This deficit would lead to difficulties in developing phonological skills necessary to map phonemes, to decode and encode words and phrases effectively and

automatically. The poor performance on Frequency Patterns Test observed in children with specific language impairment seems to be related to difficulty in process rapid auditory sequences of various stimuli. A better understanding of this association may provide important information for both differential diagnosis as to most effective language intervention<sup>25</sup>.

In order to assess the performance of children with specific disorders of reading and written verbal and nonverbal auditory processing tests were applied. Sixty children divided into two groups, one without and the other with specific disorders of reading and writing were evaluated. The author found different performance and statistically significant between the two groups studied On Frequency Patterns Test and Duration Patterns Test, and concluded that auditory skills impairment was associated with specific disorders of reading and writing<sup>28</sup>.

One study evaluated 15 patients with persistent developmental stuttering and 15 with normal hearing and no language disorder, the authors found a poor performance on temporal ordering tests (FPT and DPT - Auditec® version). The tests applied binaurally and the answer required was humming. The authors emphasized the importance of including temporal ordering test on stuttering diagnosis. Also highlighted the need to train auditory in therapeutic intervention in order to promote acquisition, maintenance and transfer of fluency for children who stutter<sup>29</sup>.

In a study with cochlear implant users, the authors found that these individuals had a similar performance in the temporal ordering tests when compared to the group of individuals with normal hearing. The tests used were Frequency Patterns Test and Duration Patterns Test (Musiek version), applied on soundfield. They concluded that cochlear implant provided favorable performance in tasks that require temporal ordering skills<sup>4</sup>.

Research conducted with 12 children diagnosed with phonological disorders reported the integrity of temporal ordering skills (Frequency Patterns Test - Auditec® version) and temporal resolution. The analysis of the ability of temporal resolution showed that these children need a longer time interval to perceive differences between sounds. Children with phonological disorders seem to have difficulties in phonological organization and proper sound sequencing<sup>30</sup>.

Assuming that hearing plays an important role in development and social adjustment of blind patients, were conducted a study with 12 blind individuals. Frequency Patterns Test and Duration Patterns Test were applied in a binaural mode, but the authors did not specify the version used. The

performance of most individuals ranged from 95 to 100 %, which showed that the ability to process auditory information and to order temporal stimuli is preserved. The fact that the visual sensory disabilities require other strategies can help the development of auditory skills, which would justify a good performance in tests that involves attention and memory, such as FPT. In general, blind and listeners need a suitable temporal processing, to not only find himself in space but also develop oral language<sup>6</sup>.

By applying Frequency Patterns Test in 28 children and adolescents post-meningitis, hearing within normal pattern, the authors found 25 % of disorders in the cases evaluated, and this disorder was often associated with complaints of reading and listening in noise situations<sup>36</sup>.

The literature showed that workers are a susceptible population to impairments in peripheral and central auditory pathways. Thus, it is important to include central auditory tests in audiological assessment of this population in order to complement the pure tone audiometry.

Due to the importance of this issue, a study conducted with 41 military aimed to evaluate their auditory processing. The individuals divided into two groups, one composed of 16 military without hearing loss and the other composed of 25 soldiers with hearing loss. Auditory processing assessed using FPT (Auditec® version). The results showed that 68.75% of the group without hearing loss and 48 % of the group with hearing loss had abnormal results on at least one of the conditions (humming or nomination) in at least one ear, no statistically significant difference was observed between the average of the test results between the left and right ear. The findings of this study concludes that exposure to occupational noise impacts the auditory processing of military personnel, and alterations in the central auditory pathway was observed regardless the presence of peripheral hearing impairment<sup>37</sup>.

Another study with workers evaluated the temporal auditory processing in individuals occupationally exposed to organophosphate pesticides. The researches applied Frequency Patterns Test and Duration Patterns Test (Musiek version) in 43 rural workers of both genders, exposed to organophosphate with normal audiometric thresholds bilaterally. They observed lower than expected performance in these tests, both the FPT and in DPT. Only seven workers showed responses within normal limits on both tests. The authors concluded that temporal ordering skills shown to be impaired in individuals exposed to the organophosphate, even in the presence of normal hearing. One of the hypotheses that may explain the low performance

in the FPT and DPT may be low education or low cultural level in both groups. This study stated that the exclusive use of pure tone audiometry might be insufficient to assess the auditory aspects in populations exposed to organophosphate. The inclusion of temporal ordering and resolution tasks in audiological assessment the battery allowed a broader assessment of hearing, since such tests evaluate the central auditory nervous system of these workers<sup>38</sup>.

It is known that the level of education may influence the results of the temporal ordering tests, as these tests are behavioral and the answers depend on cognitive level. The level of education would be beneficial for the intellectual improvement of the individual.

Researchers investigated the influence of educational level at Frequency Patterns Test and Duration Patterns Test, in a complementary way, in a study with workers that had lower education level and lived in the countryside. The sample divided into two groups, the first consisted of workers with educational level by the third grade of elementary school and the other with higher education level. No significant difference was found between the education level and the FPT and DPT performance<sup>38</sup>.

Another study investigates the influence of metallic mercury in central auditory processing of adolescents exposed to this agent, applying FPT and DPT (Musiek version). Twenty-one adolescents exposed to metallic mercury and 31 without exposure were evaluated. It can be observed that adolescents exposed had significantly lower performance than unexposed adolescents for most behavioral tests applied and the main damage on the exposed group found was on the processing of brief and successive sounds<sup>39</sup>.

The authors add that the pathophysiology of adverse health effects from chronic exposure to metallic mercury is not well defined, but data from the literature suggest that the main effects are damage to the central nervous system, and among the affected structures are the black substance, the occipital and temporal lobes. The latter structure has recognized relevance for auditory processing, auditory cortex location, and it is essential for the recognition of an organized succession of pure

sounds of different frequencies or durations and for the recognition of complex sound patterns. This relationship could explain the changes found in this study<sup>39</sup>.

The temporal ordering tests are widely used in assessment of auditory processing in different clinical populations, however there is variability of the version used, the presentation mode and the answer required. In compiled publications, more than half of them used both tests (FPT and DPT) to investigate this ability. There is no consensus in literature about the version used (Musiek or Auditec®), and the studies do not justify the reason for the version's choice. It is necessary to perform further studies in order to compare the sensitivity, specificity and concordance between the two versions in different clinical populations.

Most studies used only behavioral tests to assess temporal ordering, there were only two studies that associated behavioral and electrophysiological tests<sup>3,35</sup>. This finding suggests new research perspectives that associate behavioral and electrophysiological measures in the assessment of temporal ordering skills.

These new perspectives will contribute to scientific advance on this topic and enable a more accurate diagnosis of normal central auditory nervous system and on several diseases that affect.

## ■ CONCLUSION

In Brazil, the use of tests that assess temporal ordering ability is recent; however, it is possible to observe a significant publications' increase on the last five years. The emerging knowledge made possible by the access to tests battery in the country, allowed the expansion of this research area for all professionals committed to this theme.

In order to support the preventive actions, diagnosis, treatment and rehabilitation in different clinical populations suggest the expansion of knowledge on this topic. Currently there is a tendency to associate behavioral assessment with electrophysiological measures, which will contribute to increase the knowledge about central auditory system normal operation and on several diseases that affect.

**RESUMO**

Este estudo tem como tema o teste de padrão de frequência e de duração no Brasil e como objetivo revisar e explanar sobre a avaliação do processamento auditivo temporal no Brasil, mais especificamente sobre os testes tonais de ordenação temporal (teste de padrão de frequência e duração). Para atingir tal objetivo foi realizado um trabalho de revisão sistemática da literatura em periódicos nacionais, acessados eletronicamente na base de dado Scielo e Lilacs, sem restrição ao ano de publicação. A pesquisa foi estruturada por meio dos descritores: processamento temporal, processamento auditivo temporal, testes temporais, testes tonais de padrão de frequência e testes tonais de padrão de duração, percepção auditiva e testes auditivos. A pesquisa retornou 33 publicações nacionais sendo 28 artigos de periódicos, uma dissertação de mestrado e quatro teses de doutorado. Com isso, pode-se perceber que a utilização de testes que avaliem a habilidade de ordenação temporal no Brasil é recente, sendo notável o aumento significativo das publicações nos últimos cinco anos. Desta forma, o emergente conhecimento possibilitado pelo acesso aos testes no Brasil permite ampliar um campo de pesquisa a todos os profissionais comprometidos com este tema.

**DESCRIPTORIOS:** Audição; Percepção Auditiva; Testes Auditivos

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Received on: February 18, 2012

Accepted on: August 29, 2012

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