

Applicability of the P300 frequency pattern test to assess auditory processing

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Abstract

Temporal ordering and auditory attention are important skills in information processing, being evaluated by a behavioral test, as the frequency pattern test (FPT) in temporal ordering (TO) and electrophysiological testing, as the P300 in auditory attention.

Objective: To analyze the applicability of FPT and P300 as testing for auditory processing.

Method: We performed an integrative literature review, with papers that met the inclusion criteria, using the MedLine, LILACS and SciELO databases, with the keywords: hearing attention, P300 evoked potential, P300 and electrophysiology, temporal ordering, processing and FPT. We found 13 papers concerning the use of the TPF and 16 regarding the use of P300.

Results: The TPF was the most used test in the evaluation of TO, presented in a diotic way in individuals with language disorders, musicians, blind people, rural workers and different age groups. The P300 is used in the frequency of 1000 Hz in the frequent stimulus and 2000 Hz for the rare stimulus, applicable in individuals of both genders, different age groups, and in patients with Down syndrome, liver cirrhosis, AIDS and Sleep Apnea Syndrome.

Conclusion: The FPT and P300 are efficient instruments used to assess the intended skills.

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INTRODUCTION

The Auditory Nervous System (ANS) is a highly complex system that plays a relevant role in the correct recognition and discrimination of auditory events, from the very simple - like a nonverbal stimulus, to the more complex - such as speech and language.

The brain is responsible for most of the speech auditory processing (AP), which begins in the cochlea, where the mechanical activity is transformed into nerve impulses. Physiologically, our hearing integrates three components: peripheral activity, central auditory activities and the Central Nervous System (CNS) processes¹. When there is a break in any of these factors, there is a deficit in speech recognition.

The cerebellum is also involved in auditory processing and collaborates in several cognitive functions such as memory, language processing and linguistic operations, among others¹. In addition to these functions, it also participates in temporal organization, maintenance and monitoring², intensifying neural response and coordinating the direction of selective attention, being active in short and long term memory tests³.

While the peripheral auditory system receives and analyzes the auditory stimuli from the environment, the central auditory system and the brain analyze the internal representations of these acoustic stimuli and a response is programmed by the individual. The construction made from the auditory signal in order to make the information functionally useful is called auditory processing (AP) and constitutes a series of mental operations that the individual performs when dealing with information received via the sense of hearing, relying on an innate biological capacity, the maturation process, experience and the stimuli from the acoustic environment². Therefore, normal hearing is necessary, but the acoustic signal has to be analyzed and interpreted in order to be transformed into a meaningful message.

AP involves a series of auditory skills such as location, detection, background information, binaural separation and others and, among them, we have temporal ordering, which can be simple when the individual identifies non-verbal sounds in the silence; and complex, when he/she identifies competitive verbal sounds, maintaining the order of presentation⁴. This ability can be analyzed by the frequency pattern test - which is behavioral, it depends on the individual's response and shows the operating mode of the subject. Another skill that makes up the AP, working in an integrated way with other skills, is auditory attention. This is made by the ability to stay focused, alert towards an auditory stimulus⁵ and can be analyzed by the P300 - an objective and physiological test capable

of showing changes not yet observable in the functioning of the individual.

Other skills are involved In the assessment of temporal ordering and auditory attention, such as frequency discrimination and memory. Thus, the tests can be used together as complementing each other, bringing additional information and with greater or lesser participation of the assessed individual.

These tests are just some of the tests used to assess the ANS, specifically the complex AP, event in its struggle to elucidate its associations with other changes, but mostly with language changes.

ANS functions are influenced by the sequence of sound events that occur in time, setting the processing of temporal information⁴. The temporal AP, which serves as the basis for auditory processing is a key skill in the auditory perception of verbal and non-verbal sounds, music, rhythm and punctuation; pitch discrimination, duration and phonemes⁶.

Differences in emphasis, prosodic cues - such as pauses and speech rate, allow the listener to identify the key word and determine the semantic content⁶.

Among the temporal processing skills, we have temporal ordering, that is directly related to phonemic perception and discrimination needed to make up the phonological system of the target language⁴.

One of the leading causes of school failure among children is lack of attention⁷. This problem can be the manifestation of a number of diseases, including Attention Deficit and Hyperactivity Disorder (ADHD) and Auditory Processing Disorder (APD), among others. However, there is still no consensus on whether the difficulty in auditory attention is a component associated with the APD or if it merely reflects an isolated deficit in attention processes⁷. Auditory attention is essential for the acquisition of acoustic and phonetic aspects of language patterns - essential in the learning process of reading and writing^{5,7}.

Inattention is a problem that causes a person to lose or not record the information in their working memory for later processing. This disorder causes the need for more time in performing work or school tasks, since one is always seeking the information lost because of inattention, and as a result, information processing is delayed⁵. Thus, a learner with APD may demonstrate problems with understanding, discrimination and auditory memory, language deficits, background information and their learning is affected, because it depends on the degree of attention⁸. Among AP skills, hearing attention deficit is the most prevalent among school-aged children⁹.

AP assessment encompasses the listener's skill in identifying, discriminating and perceiving speech's

segmental and suprasegmental aspects, and this skill is directly associated with auditory temporal aspects¹⁰.

Verbal and non-verbal stimuli are recommended in this type of assessment, using electrophysiological and behavioral tests to assess auditory skills⁸.

Behavioral tests are considered as key in AP diagnosis in adults and children¹¹.

Among the most used behavioral tests for the detection and identification of temporal ordering are the Frequency Patterns Test (FPT) and the Duration Patterns Test (DPT)¹².

Technically, these tests can be applied in an open field, since normative studies showed no significant difference between the right and left ears¹².

It is observed that more than 60% of examiners in this field use the FPT, and the DPT is less frequently used¹³.

In assessing the auditory attention skill one can utilize the long-latency auditory potential, also called P300.

P300 is a positive component with a peak around 300 ms or more after the stimulus onset. It is generated using a series of sound stimuli (frequent) and different stimuli (rare) which appear at random. The test result is obtained as a function of focusing attention on the rare stimulus¹⁴.

The different stimulus (rare) occurs between 15 and 20% of the time, and the subject must identify it by silently counting how many times the stimulus occurs. The auditory system becomes used to hearing the frequent stimulus, and therefore fewer neurons respond to it. Rare stimuli that are heard fewer times causes the system to respond with more neurons, and therefore the curve generated by these neurons is higher than that generated by a frequent stimulus. Subtracting the rare stimulus from the frequent one we obtain the P300¹⁵.

The delay in P300 latency was related to a possible deficit in cognitive processing, since the triggering of this potential involves cortical areas of auditory memory, attention and perception, as well as cognition mechanisms^{14,15}.

The AP assessment, with the use of the mentioned tests, also aims at monitoring hearing rehabilitation through auditory training (AT), aiming at minimizing altered auditory skills, as these are necessary for the understanding of speech¹². This technique is based on neural plasticity, which is the change in nerve cells occurring in accordance with the environmental influences and which considers young brains, such as children and adolescents with a higher plasticity which can, therefore, change¹².

The aim of this study was to examine the applicability of the FPT and the P300 for the evaluation of temporal ordering and auditory attention, respectively, by means of a literature review.

METHOD

We did an integrative literature review (evidence based) to find papers indexed in the following databases: Medical Literature Analysis and Retrieval System Online (MedLine, USA), Latin American and Caribbean Health Sciences (LILACS, Brazil) and the Scientific Electronic Library Online (SciELO, Brazil). To search for papers we used the following keywords: electrophysiology and P300, auditory attention, P300 evoked potential, temporal ordering, processing and FPT. The inclusion criteria were: published and indexed full-text papers, available in the aforementioned databases in Portuguese and/or English, between 2006 and 2011, discussing FPT and P300 being used to assess temporal ordering and auditory attention skills, respectively (Figure 1).

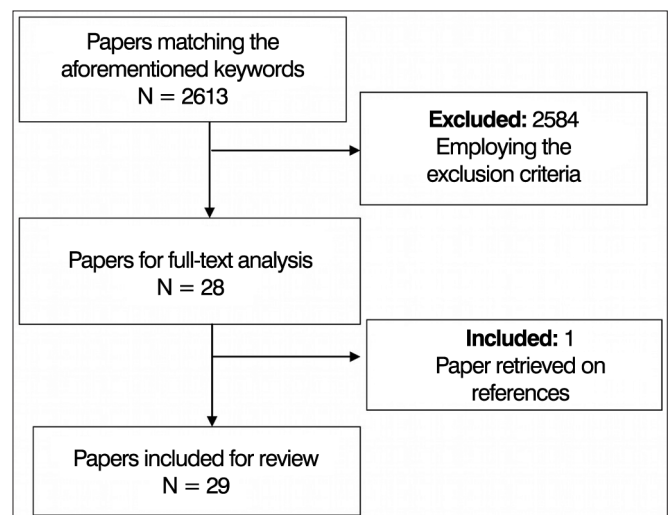


Figure 1. Diagram explaining the process of paper selection.

The exclusion criteria were: papers addressing the skill in individuals with hyperactivity and attention deficit disorder, neurological diseases or injuries, psychiatric diseases, peripheral auditory disorders, stuttering, study papers involving only one case, duplicate papers in the databases and literature reviews.

We found 13 papers addressing the frequency pattern test for evaluating the temporal ordering and 16 papers using the P300 for the analysis of auditory attention.

RESULTS

We noticed that the FTP can be used to evaluate temporal ordering in various situations. Most of them in individuals with language disorders, but it can also be used for musicians, blind people, rural workers, mouth breathers and in various age groups - children, adolescents, young people and adults (Chart 1).

Chart 1. Applicability of the frequency pattern test in the assessment of temporal ordering: 2006-2011.

Study	Sample/age range	Study type	Applicability	Results
1. Frederigue-Lopes et al., 2010 ¹⁶	43 school-aged (7 to 11 years)	Cross-sectional	Stimulus presentation by age	Performance was significantly higher in murmur in relation to naming ($p = 0.0001$), with significant FPT performance increase in relation to age in the naming mode (0.0491).
2. Santos et al., 2010 ¹⁷	12 school-aged (5 to 13 years)	Case series	Phonological change	FPT incremental change with an increase in the severity of the phonological disorder ($p = 0.011$).
3. Caumo et al., 2009 ¹⁸	15 school-aged (7 to 12 years)	Cross-sectional	Phonological change	Increase in FTP change <i>pari passu</i> to the increase in phonological change ($p = 0.041$).
4. Simões & Schochat, 2009 ¹⁹	40 school-aged (7 a 12 anos)	Cross-sectional	With and without dyslexia, both with APT without reading and writing complaints	Processing disorder without a reading complaint in the group with and without dyslexia changes the temporal ordering in the same proportion (5%) ($p = 1.0$).
5. Murphy & Schochat, 2009 ²⁰	63 school-aged (9 to 12 years)	Cross-sectional	With and without dyslexia	Dyslexia changes the FPT ($p < 0.05$).
6. Soares et al., 2011 ²¹	12 school-aged (8 to 12 years)	Case series	Reading and writing changes	FPT changed in 7 school-aged children, but this does not necessarily alter the P300 ($p = 0.19$).
7. Correa et al., 2011 ⁸	102 school-aged (8 to 12 years)	Cross-sectional	Mouth and nasal breathers	Mouth breathers underperform in murmur (RE - $p = 0.0152$, LE - $p = 0.0015$) and naming (RE - $p = 0.0045$), (LE - $p = 0.0282$) in FTP when compared to nasal breathers.
8. Fortunato-Tavares, 2009 ²²	23 school-aged (8 to 10 years)	Cross-sectional	Children with and without a specific language impairment (SLI)	Children with SLI have poor performance in FPT, with a correlation coefficient between FTP and language comprehension test with high syntactic complexity (LCT - HSC) of 0.97, indicating an almost perfect positive correlation (Pearson's correlation coefficient value 1).
9. Onoda et al., 2006 ²³	60 adolescents-adults (17 to 40 years)	Cross-sectional	Portuguese speakers (PL) or not of Japanese descent speakers of Japanese (JL) or not x Brazilians PL Speakers and not JP speakers	Portuguese speakers (PL) or not of Japanese descent have better performance in FPT than Brazilians ($p = 0.001$).
10. Nascimento et al., 2010 ²⁴	40 adolescents (< 20 years) and adults (> 30 years)	Cross-sectional	Musicians and non-musicians	Musicians have higher FPT performance for the right ($p = 0.003$) and left ($p = 0.002$) ears.
11. Boas et al., 2011 ²⁵	12 youngsters and adults (older than 18 years)	Cross-sectional	Blindness	Good FPT performance in 1 youngster (95 to 100% of correct answers).
12. Camarinha et al., 2011 ²⁶	43 youngsters and adults (18 to 59 years)	Cross-sectional	Rural workers exposed to organophosphate	In FPT, the rate of correct answers ranged from 0 to 96.6%, averaging 47.2%, and in regards of schooling $>$ or \leq 3 rd year there was no difference in the test ($p = 0.37$), i.e., education did not influence the test.
13. Ishii et al., 2006 ¹⁰	78 adults (18 to 55 years)	Cross-sectional	Professional singers x tuned and untuned amateurs	The FPT was sensitive to distinguish professional singers (97.7%) from tuned amateurs (93.1%) ($p = 0.004$) and those untuned (83.7%) ($p < 0.01$).

It appears that most studies with FPT are cross-sectional, with the test being done in a soundproof booth through headphones^{9,10,16-19}.

FPT was employed in all studies, but in six of them, the DPT was also used to assess temporal

ordering^{16,18,20,21,23,26}, being used in the children's Autitec¹⁶ or infant and adult version depending on the subject's age¹⁷.

One should notice that there is no uniformity in the application of the test's intensity, since it was employed at the intensity of 50 dBHL^{20,27}, 60 dBHL¹⁸, 70 dBHL^{22,23}, or at

50 dBHL in the three-tonal mean value²⁴ or above Speech Reception Threshold (SRT)²¹.

We employed 60 stimuli in two studies^{16,19}, but many did not describe this figure in the methodology, although it is known that in six studies^{16,17,20,21,23,24} the FPT was diotic - the stimulus was given to both ears simultaneously and in two, it was monotic^{8,24}. Regarding the classification for the correct answers pattern, when mentioned, we used the one recommended by Musiek (2002)^{26,28} or Balen (2001)^{16,22,27}.

On how to answer the test, either naming or murmur (humming) it appears that the studies apply one of the forms, naming^{18,20,24} or murmur^{24,25}, but most of those which described the methodology applied, used both ways or let the individual choose how best to answer^{8,16,17,23}.

There is a relationship between reading and writing and temporal processing in dyslexic individuals^{19,20}.

Of the 52 school-aged kids with mouth breathing and normal hearing, we found that the temporal ordering skill performance was lower than expected for their age in half of the students evaluated in both ears in the form of naming (Right ear (RE) = 29; Left Ear (LE) = 30), and in almost half of the students in the form of murmur (right ear (RE) = 22, Left Ear (RE) = 26), as well as attention and memory, since mouth breathing alters the hematological system of the individual, affecting the overall health; and daytime sleepiness can interfere with the child's attention, impairing learning⁸.

The standard test frequency is sensitive (83%) to identify auditory processing disorders resulting from brain disorders, but is not as sensitive vis-à-vis brainstem lesions (45%) or cochlear damage (12%), although it has a high specificity of 82%²⁹. Recognition of the pattern as a whole would be done by the right hemisphere and the pattern sequencing by the left hemisphere, requiring an inter-hemispheric communication done by the corpus callosum. Before being decoded or sequenced by the left side it is stored in the short-term memory - and this is a brain function. The verbal response would require a subcortical neural sequence decoding of the posterior temporo-parietal area, through the intra-hemispheric tract white matter all the way to the the frontal region of the brain, within the central fissure, where the motor response would be organized and started²⁹.

As for auditory attention, it is known that among the various long latency auditory evoked potentials (LLAEP), the P300 or cognitive potential is the most widely used in clinical practice and it is largely useful in the study of cognitive functions, attention and recent memory¹⁵.

It is known that the P300 has already been experienced in various situations, seeking to obtain parameters for certain age ranges³⁰⁻³⁶ and male latencies are larger than that of females³² (Chart 2).

Most studies analyze latency and amplitude; nonetheless, latency is a more reliable indicator than amplitude, since this is difficult to be changed because of attention³⁷ (Chart 2).

In some studies we see that as the age of the subjects increase, P300 latency values also tend to raise^{35,38}, but in others the latency is stable^{33,38,39}.

The N2-P3 amplitude has a large variability in P300, as seen in the study with its reassessment during a three-month period⁴⁰ and in cases in which the gender and menstrual cycle period influence it³⁶ (Chart 2).

In patients with sleep apnea syndrome (OSAS), there is a reduction in the P300 amplitude, suggesting cognitive dysfunction induced by auditory memory impairment³⁹.

Adults with AIDS have alterations in their cognitive potential, suggesting auditory pathway involvement in cortical regions and a deficit in the cognitive processing of auditory information in this population⁴¹.

In general, according to the studies found in the literature, we notice that in patients with Down syndrome³⁴, AIDS⁴¹ and phonological impairment⁴², amplitude and latency parameters were altered; however, in OSAS patients³⁹, only amplitude was altered; and in those cases of liver cirrhosis without encephalopathy⁴⁰, only latency was altered.

The equipment used in most studies for P300 implementation were the Biologic Equipment's Evoked potential System version 6.1.^{32,33,39} and the two-channel MK 22 Amplaid^{36,42}.

All the P300 tests found in the literature used the oddball paradigm, with 80% of frequent stimuli (FS) and 20% of rare stimuli (RS). The frequency used for the FS was 1000 Hz^{14,21,30,35,38,39-44} and 2000 Hz^{14,30-34,39,40,42-44} was used for the RS with four studies using 1500 Hz^{21,36,38,43}.

To implement the test, we mentioned the use of the Nuprep Abrasive Skin Gel cleaning paste on the skin³², the OMNI³⁴ abrasive paste and the Every Per La Pulizia Della Cute³⁶ - electrolytic paste for better electric current conductivity^{32,33} and the electrode was secured with micro-pore tape^{31,33,41,42}. To facilitate relaxation during the exam, he had a quiet^{21,36,41}, semi dark^{14,34,36} room, with a reclining chair^{21,41,43} or a stretcher^{14,36,42}.

The electrodes were placed on the mastoid and vertex⁴³, but also placed on the vertex (Cz), frontal (Fz) and mastoid (A1 and A2)^{21,30,31,33,39,41}, yet a considerable part of the studies used the international system¹⁰⁻²⁰ in which the electrodes are placed on the forehead (Fz), vertex (Cz), parietal (Pz) and earlobes (A1 - left, A2 - right)^{14,34-36,42-44}. In one study they added to the international way of electrode placement¹⁰⁻²⁰, one electrode above the right eyebrow and one in the left corner of the eye to control the electrooculogram⁴⁰.

It is suggested that the use of two active electrodes positioned at Fz and Cz can be considered one more resource to assist in the analysis of the P300 recording³³.

The individual with 3A headphones^{14,33,39,44} or TDH39^{21,30,38,41}, was trained on the exam^{14,33,35,36}, after explaining that he should keep his attention focused on

Chart 2. P300 applicability in the evaluation of auditory attention: 2006-2011.

Study	Sample/age range	Study type	Aplicability	Results
1. Advíncula et al., 2008 ⁴²	20 school-aged (7 to 14 years)	Cross-sectional	With and without phonological impairment	The mean amplitude values from N2 were lower in the group with phonological disorders in both ears (RE - $p = 0.0047$, LE - $p = 0.0003$).
2. Soares et al., 2011 ²¹	12 school-aged (8 to 12 years)	Case series	Reading and writing alteration	No differences in latencies between the RE and the LE ($p = 0.151$) and only 17% had altered P300.
3. Della Coletta et al., 2007 ⁴³	36 school-aged (9 to 10 years)	Cross-sectional	With and without Duchenne syndrome (DS)	Although patients with DS showed a worse performance when compared with the control group, there was no statistical difference regarding latency ($p = 0.14$) and amplitude ($p = 0.17$) values between the groups.
4. Duarte et al., 2009 ³³	33 school-aged to adults (7 to 34 years)	Case series	Age and gender	There were no differences between N2 and P3 wave latencies, both in positions Fz ($p = 0.95$ and $p = 0.92$, respectively) and Cz ($p = 0.94$, $p = 0.69$, respectively) with respect to gender, and P3 amplitude, no correlation was found for age ($p > 0.05$) in all positions.
5. Machado et al., 2009 ³⁶	22 youngsters and adults (18 to 31 years)	Case series	Gender and menstrual cycle	Amplitude values were influenced by gender ($p = 0.049$) and menstrual cycle ($p = 0.016$).
6. Simões et al., 2009 ³⁰	25 youngsters and adults (18 to 30 years)	Cross-sectional	With and without a masking noise	No differences in latency (RE - $p = 0.59$; LE - $p = 0.872$) and amplitude (RE - $p = 0.241$, LE - $p = 0.236$) between the with and without noise situations for the P300, but in the P200 wave there was a difference in amplitude between the with and without noise situations ($p < 0.001$).
7. Matas et al., 2011 ³⁸	49 youngsters and adults (18 to 40 years)	Cross-sectional	Gender and auditory training	There was no difference in P300 latency between genders ($p = 0.49$ and 0.12 , respectively for females and males) even after auditory training, but the N2-P3 amplitude decreased for both genders ($p = 0.03$ and 0.003 , respectively) after auditory training.
8. Silva et al., 2007 ⁴¹	42 youngsters and adults (19 to 48 years)	Cross-sectional	With and without HIV/AIDS	The group with HIV/AIDS had higher latencies ($p = 0.010$) and lower amplitudes ($p = 0.021$).
9. Crippa et al., 2011 ³²	33 youngsters and adults (18 to 55 years)	Cross-sectional	Gender	Latency for males was higher than for females for both RE ($p = 0.002$) and in LE ($p = 0.008$).
10. Martins et al., 2011 ³⁹	66 youngsters and adults (22 to 59 years)	Cross-sectional	Patients with OSAS and primary snorers	The P300 amplitude was lower in patients with OSAS ($p = 0.003$), but the latency was similar ($p = 0.089$) in both groups.
11. Teodoro et al., 2008 ⁴⁰	85 youngsters and adults (20 to 65 years)	Cross-sectional	With and without liver cirrhosis/age	There was an increase in P300 latency in the cirrhotic group, both in the 25-45 years group ($p = 0.03$), as for the 46-65 years group ($p = 0.014$).
12. Cesar et al., 2010 ³⁴	51 youngsters and adults (19 to 38 years)	Cross-sectional	With and without Down syndrome	We found prolonged P300 (N1, P2, N2 and P3) latencies ($p = 0.0088$, $p = 0.0032$, $p = 0.000$, $p = 0.000$, respectively) and lower N2 - P3 ($p = 0.0023$) amplitude in individuals with Down syndrome.
13. Sá, Pereira, 2011 ⁴⁴	45 adult women (20 to 36 years)	Clinical prospective	Exposure to music	The employed test had fast and slow songs or no music, depicted similar latency and amplitude performances in all evaluations ($p > 0.05$).
14. Rezende et al., 2008 ⁴⁴	60 adult women (21 to 46 years)	Case series	With and without systemic lupus erythematosus	There were no differences in latency and amplitude between the presence/absence of the syndrome (RE - $p = 0.762$, LE - $p = 0.890$).
15. Massa et al., 2011 ³¹	15 adult men (22 to 55 years)	Case series	Verbal and non-verbal stimulus	P300 latencies with verbal stimuli were significantly higher than those from non-verbal stimuli ($p = 0.001$), but the amplitude mean values were lower for verbal stimuli when compared to their non-verbal counterparts ($p = 0.004$).
16. Coser et al., 2010 ³⁵	62 seniors (60 to 74 years)	Cross-sectional	Age	P300 latency increases with age at a rate of 2.85 ms per year between the ages of 60 and 74 years ($p < 0.0001$).

the rare stimulus, and he should count silently and raise his hand upon hearing it^{36,38,39,42,44} or count out loud^{21,31,33}, thereby avoiding keeping the patient wide awake, being instructed to keep the eyes closed^{31,36,42,44}.

The motor act of lifting the hand associated with counting the rare stimuli is reported as being easier and so it is believed that this methodology may be adopted for patients with difficulties in performing the test only counting in sequence³⁶.

The parameters used in most studies with P300 were: simultaneous binaural^{32,35,36,39,40,42}, monaural^{14,38,41,44} or 100 ms rise/fall³⁶ or 5 ms rise/fall⁴² e 10 ms rise/fall⁴³ 20 ms plateau^{36,42}, at 70 dBHL^{14,30,32,33,43,44}, 75 dBHL^{31,32,41} or 80 dBHL^{21,35,36,42} with 300^{14,21,31,35,38,41,44} tone burst-type stimuli^{21,30,32,33,35,36,38,39,41,42} at the speed of 1 s^{14,30,32,33,36,39} alternating polarity⁴², rarefied³² or positive³¹, with a high pass of 1 Hz³⁸, 2 Hz³¹ or 20 Hz⁴ and low pass at 0.5 Hz³⁶, 1.5 Hz³¹ or 30 Hz³⁸.

There was no latency difference between the ears^{21,31} as well as between the genders^{33,36}.

The P300 was employed twice in two studies^{14,30}. However this causes fatigue and compromises the outcome of the evaluation, since it depends on attention³¹. Some authors chose to perform the electrophysiological test between 8 and 10 am⁴⁵ or at 9 am to avoid the circadian cycle³².

The classifications, when referred to, were the ones recommended by Junqueira (2002)⁴⁵, McPherson (1996)¹⁵ and Pfefferbaum (1984)⁴⁶.

We notice that the different methodologies are different vis-à-vis the parameters employed and the P300 wave shape. As it turns out, the P300 latencies with verbal stimuli were significantly larger and the amplitudes were smaller for the P300 with nonverbal stimuli³¹. This probably happened because the verbal stimuli, which in this study were formed by the syllables /ba/ and /da/, are more complex, thus more difficult to hear when compared to nonverbal stimuli discrimination.

DISCUSSION

As to the easiest test between the FPT or DPT, the FPT test is indeed considered the easiest test by 80% of the individuals²³.

The FPT, which evaluates temporal ordering, depends on several central auditory processes, such as the recognition of the whole, inter-hemispheric transfer, linguistic qualification, sequencing of linguistic elements and evidence of memory use⁴⁷.

One should consider that in some studies the ages of the individuals ranged from age 5 to 59 years and it is known that performance in any temporal ordering test,

being it the FPT and/or DPT has a quantitative improvement in responses as age increases, especially between eight and ten years^{24,47}, since the corpus callosum maturation starts at seven years of age²⁸ and reaches adult levels of performance on auditory processing tests at around ten or eleven years of age²⁴.

We noticed that in subjects with phonological disorder^{17,18}, temporal ordering is changed, because the difficulty in perception of stimuli that change rapidly interferes with the phonological processing of language sounds, interfering with speech understanding and therefore in the acquisition of the target phonological system⁶ and yielding verbal language problems⁴.

The finding of a superior performance in nonverbal FPT (murmur) proves the ease of detection, recognition and retention of frequency patterns related to the execution of the murmur. Murmur does not involve memory, discrimination and awareness of the sound sequence, characterized by an imitative activity, apparently less complex⁴⁸.

The verbal response task is more complex, indicating the need for a nervous system learning or neuromaturation. Naming as a linguistic activity, requires processes depending on more connections between thought and language¹⁶.

The task of temporal sequencing involves both brain hemispheres, each with a different task, but working together, regardless of the stimulated ear. The structures involved in tonal testing of auditory patterns would involve each hemisphere and the structure that connects both hemispheres is the corpus callosum. The right hemisphere would be in charge of recognizing the acoustic contour and the left one would be responsible for temporal sequencing and naming what was heard^{4,29}. Thus, the difficulty in the naming mode, can be explained by the need for inter-hemispheric integration (via the corpus callosum) of the stimuli in requesting a verbal response, which does not occur in the nonverbal request²⁸.

Exposure to music theory and ear training are important factors in FPT performance, since they enable a greater perception in frequency discrimination, and musical practice provides this skill, making clear this association between music education and competence in frequency pattern recognition^{10,24}.

FPT is the most frequently used instrument in the assessment of temporal ordering, despite the existence of the Duration Pattern Test (DPT), from the age of 7, and it can improve quantitatively as we age²⁸.

As for auditory attention, it is known that the auditory evoked potentials (AEP) have been characterized as an important tool in neuroscience because of their

objectiveness in evaluating the structural and functional integrity of the central auditory nervous system. Besides the known clinical applications of the AEP in audiological diagnosis, intra-operative and cognitive function monitoring, its use has advantages in the assessment of language disorders, because it does not require a verbal response³⁸.

The long-latency auditory evoked potentials (LLAEP) depict the cortical electrophysiological activity involved in attention, discrimination, memory, integration and decision-making skills^{15,30}. These potentials are associated with recorded electrical responses, generated by the thalamus, auditory cortex and cortical association areas - structures involved in discrimination, memory, attention and integration tasks^{31,38}, are affected by sleep, sedation and by attention to acoustic stimuli, being therefore related to attention and cognition.

In the published studies, the ages of the subjects range from 7-74 years and it is known that the P300 starts to increase in the second or third decades of life, i.e. age should be taken into account in interpreting the values obtained at different ages, since the P300 latency increases by approximately one millisecond per year of life⁴⁹.

The decrease in P300 latency is related to increased cognitive ability; thus, following up individuals with cognitive disorders by means of the P300 can be beneficial, since this electrophysiological measure can provide information about behavioral changes of later manifestation³⁸.

Attention and recent memory are dependent on stimuli discrimination, either verbal or non-verbal.

The P300 is objective; however, its analysis is extremely subjective, depending on a good clinical experience to visually detect the waves³⁸.

Among the main P300 components, we list the N2 and P3 waves. N2 is a mixed - an exogenous and an endogenous - factor⁴⁵. The exogenous factor of N2 contributes to the physical discrimination of the stimulus^{37,45,50} as the acoustic characteristics of the stimulus and the endogenous factor reveal attention and perception⁴⁵, having automatic and passive responses that happen before the stimulus, elicited by the rare event, as in sound competitive situations⁴². The P3 component is an endogenous potential⁴⁶, occurring when the individual consciously recognize a change in the auditory stimulus. These components may change when there are deficits in the attentional mechanisms.

Studies with P300 associated with attention and memory deficit report the N2 and P3 components as being sensitive to these changes. The specificity and sensitivity of this instrument is approximately 80%⁵⁰.

Authors point out that the P300 latency increases as "targets" for discrimination are more "difficult" than the

standard, i.e. the latency is sensitive to the task processing demand. In contrast, the P300 amplitude is larger for easier tasks and decreases as the task becomes more difficult¹⁵.

It should be noted that exposure to music can be a facilitator for the examiner to assess the P300, as it facilitates the achievement and maintenance of attention during the exam⁴⁴, it assists in neural synchronicity and stimulates the tonotopic map of frequencies, which would facilitate the examination⁴⁰.

We noticed the need to obtain parameters in individuals from different age groups as youngsters and adults^{31-33,36,38}, and for healthy older adults³⁵ and we realized that the P 300 needs to be further studied.

The application of P300 in the evaluation of auditory attention is very common, however it is still an object to obtaining parameters as we seek to evaluate it in different age groups, healthy subjects and in cases with language disorders and there is no single methodology for use.

FINAL REMARKS

The FPT is an instrument most often used to assess temporal ordering, generally used with a CD Player connected to the audiometer, receiving the stimuli through a headphone, being applicable to individuals with phonological disorders, mouth breathing, language disorders and rural workers, performing well in blind adults and Japanese descendants - as a second language facilitates sound frequency pattern recognition.

The P300 can be used with various parameters, and latency is the best indicator for analyzing auditory attention, being applicable in patients with Down syndrome, AIDS, phonological disorder, OSAS and liver cirrhosis, in subjects of both sexes and different age groups.

Exposure to music is a factor that can help improve temporal ordering and P300 use to assess auditory attention, because this characteristic favors auditory memory training and frequency discrimination, abilities that help in processing the investigated skills.

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