P300 auditory cognitive evoked potential as an indicator of therapeutical evolution in students with developmental dyslexia

ABSTRACT

Purpose: To verify the effectiveness of the Cognitive Auditory Evoked Potential-P300 (CAEP-P300) for monitoring the therapeutic evolution of students with developmental dyslexia. Methods: Twenty students diagnosed with developmental dyslexia, of both genders, aged between 8 and 14 years, divided into two randomized groups, one of them submitted to a phonological remediation program associated with reading and writing (GI), and the other one representing the control group (GII), participated in the study. The groups were paired up, and the individuals were submitted to two evaluations of the CAEP-P300 and the same interval was kept for both. Paired Student’s $t$-test, ANOVA test, and Pearson’s correlation coefficient were used, adopting 5% significance level. Results: The statistical comparison of the pre and post evaluations of each group demonstrated difference in the Phonological Awareness Test ($p=0.000$) and in the P300 latency ($p=0.005$) only for GI. Conclusion: CAEP-P300 use for monitoring the therapeutic evolution of children with developmental dyslexia is possible and represents a viable option for intervention programs.

RESUMO

Objetivo: Verificar a eficácia do Potencial Evocado Auditivo Cognitivo-P300 (PEAC-P300) para monitoramento da evolução terapêutica de escolares com Dislexia do Desenvolvimento. Métodos: Participaram 20 escolares, com diagnóstico de Dislexia do Desenvolvimento, de ambos os gêneros, com faixa etária entre 8 e 14 anos, divididos em dois grupos randomizados, um deles submetido a um programa de remediação fonológica associado à leitura e escrita (GI) e o outro representando um grupo controle (GII). Os grupos foram pareados e os indivíduos foram submetidos a duas avaliações do PEAC-P300, mantendo o mesmo intervalo para ambos. Utilizou-se o teste $t$ de Student pareado, a análise de variância ANOVA e o coeficiente de correlação de Pearson, adotando nível de significância de 5%. Resultados: A comparação estatística das avaliações pré e pós de cada um dos grupos demonstrou diferença na Prova de Consciência Fonológica ($p=0,000$) e na latência do P300 ($p=0,005$) apenas para o GI. Conclusão: A utilização do PEAC-P300 para o monitoramento objetivo da evolução terapêutica de crianças com Dislexia do Desenvolvimento é possível e representa uma opção viável para os programas de intervenção.
INTRODUCTION

Developmental dyslexia consists in a range of specific symptoms that imply in sub-cortical and cortical dysfunctions, which frequently have a constitutional origin and may affect reading and writing learning processes\(^1\). In order to comprehend dyslexia manifestations, the literature focuses on the phonological deficit\(^2\) hypothesis; however, there is still no consensus about it. One of the hypotheses is that the phonological deficit happens due to changes in the auditory processing, i.e. children with dyslexia present an altered sound discrimination ability, therefore the quick fusion of stimuli is compromised, resulting in the temporal processing alteration\(^3,4\).

Taking into account this assumption, intervention programs have been focused on the maximization of phonological abilities, with satisfactory results\(^5\). However, the efficacy verification of such programs as well as the therapeutic evolution monitoring have been restricted to behavioral measures, with a limited quantity of studies in the national and international literatures that use methods aimed for this purpose.

Thus, auditory evoked potentials are well-recognized, since neurophysiological changes tend to happen before the behavioral ones\(^6\). The Cognitive Auditory Evoked Potential-P300 (CAEP-P300) has been used to measure and monitor neurophysiological modifications of the central auditory nervous system\(^7,8\). Also known as a potential associated with events, it is an endogenous potential elicited by auditory discrimination, when the subject reacts to rare stimuli randomly presented between frequent stimuli (Oddball paradigm)\(^9,10\).

The P300 component happens when the subject consciously recognizes the presence of a change in the auditory stimulus; however the exact generators are unknown, but it includes reticular formation, lemniscus, inferior colliculus, thalamus, primary cortex, frontal cortex, centro-parietal cortex, temporal cortex, and hippocampus\(^11,12\). On the other hand, the N200 component is associated with perception, discrimination, recognition, and classification of an auditory stimulus and has multiple generators, among which is the supratemporal cortex\(^13\). Thereby, its use can be investigated in students with developmental dyslexia, once they present alterations in their phonological aptitudes.

In the light of what has been exposed, the objective of this study was to verify the CAEP-P300 effectiveness for monitoring the therapeutical evolution of students with developmental dyslexia that were submitted to phonological remediation associated with reading and writing.

METHODS

The study was approved by the Ethics Committee of Human Beings Research from Faculdade de Odontologia de Bauru at São Paulo University (FOB-USP), process number 008/2011. All participants and people in charge were aware of the procedures, received the information letter, and signed the Free Informed Consent.

From 2008 to 2010, 350 children complaining about learning difficulties were sent to the Speech Therapy Clinic of FOB-USP. Among them, only 20 were diagnosed with developmental dyslexia, forming the casuistry of this study. Diagnosis was carried out by an interdisciplinary team in the Speech Therapy Clinic of FOB-USP, following DSM-IV (2002) and ICD-10 criteria. As part of the protocol from the Speech Therapy Diagnostic Clinic of the institution, neuropsychological, neurological, psychopedagogical, and speech therapy evaluations were performed. Furthermore, the school is contacted in order to obtain relevant data for the final diagnosis.

The age range of these children varied from 8 to 14 years old, of both genders, and they were regularly enrolled in public and private schools. Regardless of age, all children presented the same level of reading difficulties, which was proved by previous diagnosis evaluation.

The inclusion factors included absence of recent or previous complaints about visual and hearing acuity, normal cognitive performance, and absence of genetics or neurological syndromes. The casuistry was randomly divided into two groups: Group I (GI) included 10 students, who were submitted to a phonological remediation program associated with reading and writing, and Group II (GII) was composed of 10 students, who initially did not receive any intervention, they became the control group of the study in order to demonstrate the variation test–retest.

The program used for this study was based on Salgado\(^16\) and structured in three different stages, with 24 cumulative sessions, twice a week, lasting around 45 minutes each. The original program proposed by Salgado\(^16\) has 20 sessions; however, this study added other four sessions in order to better develop the abilities under work. The sessions were divided into three different stages, with eight each, being:

1. Phonological (eight sessions), which includes hearing discrimination; sum and subtraction of phonemes and syllables; syllabic and phonemic manipulation; rhyme and alliteration.

2. Phonological and Reading (eight sessions), which encloses hearing discrimination; sum and subtraction of phonemes and syllables; syllabic and phonemic manipulation; rhyme; alliteration; letters and phonemes identification; fast nomination: letters–digits; visual discrimination; silent story reading–oral comprehension; and oral story reading–oral comprehension.

3. Phonological, Reading, and Writing (eight sessions), which include hearing discrimination; sum and subtraction of phonemes and syllables; syllabic and phonemic manipulation; rhyme; alliteration; letters and phonemes identification; fast nomination: letters–digits; visual discrimination; silent story reading–oral comprehension; oral story reading–oral comprehension; dictation of syllables, real words and pseudowords; dictations of sentences; dictation of texts; and written storytelling.

Pertinent ludic activities were created according to the objective of each stage. The family was present throughout the program, and they were given orientations about similar activities that can be performed in the students’ daily tasks.
The objective evaluation of Phonological Awareness (PA) was performed for this study through the Sequential Evaluation Instrument (Confias)\(^{17}\), which has the aim of verifying the child’s PA level, at the syllabic and phonemic levels, using specific tests. It is composed of two parts; the first one corresponds to the syllabic awareness that has nine items: synthesis, segmentation, initial syllable identification, rhyme identification, word production with the given syllable, medial syllable identification, rhyme production, exclusion, and transposition. The second part corresponds to phonemes awareness with seven items: production of a word that begins with the given sound, initial phoneme identification, final phoneme identification, exclusion, synthesis, segmentation, and transposition. The test is graded in a specific protocol, and the correct answers score one point and the incorrect ones have no points. In the syllable part, the maximum grade is 40 points and in the phonemes part it is 30, together they sum 70 points, i.e. 100% correct ones.

The groups were paired up according to their chronological age and all the students were submitted to two evaluations for the CAEP-P300 research. For the GI, evaluations happened before and after the phonological remediation program associated with reading and writing, with a 12-week interval; and for GII, although there was no intervention, the same interval was kept between the two evaluations. The same day in the week and time for the evaluation before and after the students’ program of GI was determined, since how the child is at the moment of the test may influence the results. Following the same reasoning, the times of GII evaluation were determined by their pair in the experimental group.

The CAEP-P300 test for speech stimulus was performed using the Biologic Evoked Potential System (EP) equipment, in a quiet room, with the student comfortably lay down on a stretcher, instructed to remain in alert state, paying attention to the rare stimulus, which was randomly presented to the frequent stimulus (Oddball paradigm). Also, when every discriminated rare stimulus was done, the patient was supposed to raise his index finger. The test parameters and electrodes positioning are described in Chart 1. Latency of N200 and P300 (ms) components and P300 (ΩV) amplitude, registered in Cz, were analyzed.

Data were submitted to descriptive and inferential statistics analysis through paired Student’s t-test, analysis of variance (ANOVA), and Pearson’s correlation coefficient. A 5% (0.05) level of significance was adopted.

**RESULTS**

In the PA Test, the GI presented improvement of the performance after the phonological remediation associated with reading and writing, with higher values of means in all items of the test, but with a more expressive one in the phonemic subtest. In GII, there was not quite a measure change of the scores, in any subtests, with absence of difference (Tables 1 and 2).

Table 3 presents the CAEP-P300 descriptive statistics analysis, of both groups, regarding the absolute latencies of N200 and P300 components in ms, and P300 amplitude, in mV, in the two evaluation moments (before and after).

Table 4 shows the statistic comparison of the two evaluations (before and after) of each group, through the paired Student’s t-test and ANOVA regarding absolute latencies of N200 and P300 components, in ms, and P300 amplitude, in mV. The absence of difference in GI, when analyzing the latency and amplitude measures of the considered components, demonstrates test–retest reliability of the procedure. In this table, there is also a comparison of the groups concerning N200 and P300 components, before and after the phonological remediation associated with reading and writing.

Correlation measures of the CAEP-P300 and the PA Test, on both evaluation moments, are presented in Table 5.

**DISCUSSION**

The PA, i.e. the metalinguistic skill that allows analyzing and reflecting consciously upon the phonological structure of the oral language, is settled as an important precursor for the development of reading and writing abilities\(^{18,19}\), therefore it is the focus of phonological remediation programs.

Students from GI, who were submitted to the phonological remediation program associated with reading and writing,

---

**Table 1. Mean scores before and after testing in the Phonological Awareness proof**

<table>
<thead>
<tr>
<th></th>
<th>Syllable</th>
<th>Phoneme</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
</tr>
<tr>
<td>GI – Before</td>
<td>30.1</td>
<td>6.47</td>
<td>12.6</td>
</tr>
<tr>
<td>GI – After</td>
<td>34.4</td>
<td>6.47</td>
<td>20.8</td>
</tr>
<tr>
<td>GII – Before</td>
<td>29.9</td>
<td>6.14</td>
<td>12.9</td>
</tr>
<tr>
<td>GII – After</td>
<td>30.5</td>
<td>5.61</td>
<td>13.3</td>
</tr>
</tbody>
</table>

**Caption:** SD = standard deviation; GI, submitted to a phonological remediation program associated with reading and writing; GII, control group.

**Table 2. Performance comparison in the Phonological Awareness proof, on both evaluation moments**

<table>
<thead>
<tr>
<th></th>
<th>Syllable</th>
<th>Phoneme</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
</tr>
<tr>
<td>GI – Before × After</td>
<td>0.000*</td>
<td>0.000*</td>
<td>0.000*</td>
</tr>
<tr>
<td>GII – Before × After</td>
<td>0.278</td>
<td>0.269</td>
<td>0.158</td>
</tr>
</tbody>
</table>

**Caption:** *p≤0.05 – statistically significant. Paired Student’s t-test.
demonstrated better performance in the PA test, both in the syllables and in the phonemes test. Increase in the average of hits on both tests was similar; however, in the phoneme test, students reached results that were closer to the test maximum scoring (Tables 1 and 2). Furthermore, it was possible to notice this improvement in a qualitative manner, which was evidenced by the increase of the student’s ability to deal with games about PA.

The results obtained after the test revealed that difficulties in PA were overcome, because, even if the standard deviations are considered, the GI students reached normality values.

Most researches about reading and writing have demonstrated the relationship between PA and progress in the reading and writing learning process, together with different factors that promote learning of spelling patterns associated with the pronunciation based on phonological aspects. Thus, with the continuous and progressive learning, the student reaches the orthographic stage in which recognition and reading of words happen via a direct lexical and semantic access from certain graphic characteristics of the word, which are orthographically stored(20).

Efficiency in the process of word decodification promotes increase of reading speed, which creates positive influences in reading comprehension. Increase of reading speed and ability is directly associated with PA skills, lexical access, and working memory. Therefore, as the remediation program associated with reading and writing provided an improvement in the phonological processing abilities, the impacts on reading speed became more perceptible.

Due to blood flow alterations in some areas of the temporal cortex, children with developmental dyslexia may present some flaws on the information neurological processing, causing difficulty in the hearing perception of phonological information about reading learning in a writing system with alphabetical base. Studies carried out in Brazil evidenced these alterations in the neurological functioning of children with such diagnosis(21,22).

Table 3. Descriptive statistics analysis of the Cognitive Hearing Evoked Potential-P300

<table>
<thead>
<tr>
<th>Cognitive Hearing Evoked Potential-P300 (ms/ΩV)</th>
<th>Before</th>
<th>After</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>SD</td>
<td>Minimum</td>
</tr>
<tr>
<td>Lat. N200 GI</td>
<td>271.53</td>
<td>43.30</td>
</tr>
<tr>
<td>Lat. P300 GI</td>
<td>431.22</td>
<td>29.69</td>
</tr>
<tr>
<td>Amp. P300 GI</td>
<td>7.85</td>
<td>2.77</td>
</tr>
<tr>
<td>Lat. N200 GII</td>
<td>267.57</td>
<td>44.13</td>
</tr>
<tr>
<td>Lat. P300 GII</td>
<td>398.33</td>
<td>48.22</td>
</tr>
<tr>
<td>Amp. P300 GII</td>
<td>7.25</td>
<td>4.94</td>
</tr>
</tbody>
</table>

Caption: SD = standard deviation; Lat., latency; GI, submitted to a phonological remediation program associated with reading and writing; Amp., amplitude; GII, control group.

Table 4. Comparison of the Cognitive Hearing Evoked Potential-P300 in the two moments of evaluation for each group and comparison between the groups

<table>
<thead>
<tr>
<th>Cognitive Hearing Evoked Potential-P300</th>
<th>GI – Before × After</th>
<th>GII – Before × After</th>
<th>Before – GI × GII</th>
<th>After – GI × GII</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lat. N200</td>
<td>p=0.487</td>
<td>p=0.453</td>
<td>p=0.842</td>
<td>p=0.992</td>
</tr>
<tr>
<td>Lat. P300</td>
<td>p=0.005*</td>
<td>p=0.321</td>
<td>p=0.083</td>
<td>p=0.889</td>
</tr>
<tr>
<td>Amp. P300</td>
<td>p=0.335</td>
<td>p=0.660</td>
<td>p=0.744</td>
<td>p=0.556</td>
</tr>
</tbody>
</table>

Caption: Lat. = latency; Amp., amplitude; GI, submitted to a phonological remediation program associated with reading and writing; GII, control group; ANOVA, analysis of variance.

Table 5. Correlation measures of the Cognitive Hearing Evoked Potential-P300 and of the Phonological Awareness proof in both evaluation moments

<table>
<thead>
<tr>
<th>Syllable</th>
<th>Before</th>
<th>After</th>
<th>Phoneme</th>
<th>Before</th>
<th>After</th>
<th>Total</th>
<th>Before</th>
<th>After</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lat. N200</td>
<td>r=0.703</td>
<td>Moderate negative</td>
<td>r=0.824</td>
<td>Strong negative</td>
<td>r=0.735</td>
<td>Moderate negative</td>
<td>r=0.845</td>
<td>Strong negative</td>
</tr>
<tr>
<td>Lat. P300</td>
<td>r=0.934</td>
<td>Strong negative</td>
<td>r=0.844</td>
<td>Moderate negative</td>
<td>r=0.949</td>
<td>Strong negative</td>
<td>r=0.872</td>
<td>Strong negative</td>
</tr>
<tr>
<td>Amp. P300</td>
<td>r=0.962</td>
<td>Strong positive</td>
<td>r=0.954</td>
<td>Strong positive</td>
<td>r=0.982</td>
<td>Strong positive</td>
<td>r=0.956</td>
<td>Strong positive</td>
</tr>
</tbody>
</table>

Caption: Lat. = latency; Amp., amplitude.
Results from the study of Kujala et al.\textsuperscript{(23)} indicated that training causes a change in the cortical hearing plasticity, which is a result from the increase of neuropsychological activities and time of reaction to alteration of sounds, accompanied by improvement in reading performance. A posterior study showed that there are changes in the brain activation of the posterior region of the middle temporal gyrus seen in the magnetoencephalography after the intervention through reading remediation\textsuperscript{(24)}.

CAEP-P300 reflects the electrical activity of brain areas that happens before a specific task that includes skills like attention, discrimination, integration and memory, which are also involved in the information phonological processing.

Thus, normal functionality of central hearing structures is fundamental in order that perceptual abilities are acquired in the expected pattern. According to literature of the area, neuropsychological changes are reflected on the hearing evoked potentials, both in their latency or amplitude; therefore, it is possible to determine the relationship between these changes and the behavioral hearing abilities.

Taking into account that children with developmental dyslexia present alterations in phonological abilities\textsuperscript{(3,4)}, the investigation of CAEP-P300 in the therapeutic processes, focusing on these skills, may provide additional information to the behavioral observation.

In the literature, CAEP-P300 use to assess neurophysiological changes that happened after the hearing training was seen in patients with hearing process disorder\textsuperscript{(10)}, in cases of disfluency\textsuperscript{(12)}, as well as a predictor of the results of chemical dependence treatment\textsuperscript{(11)}.

In this study, CAEP-P300 was analyzed in two moments, before and after the phonological remediation, associated with reading and writing. Initially, a strong correlation between the CAEP-P300 characteristics, latency and amplitude, and the performance in PA tests (Table 5) was seen, which shows the pertinence of using CAEP-P300 to monitor the therapeutical evolution in a phonological remediation program associated with reading and writing.

Hence, another important datum is that there was no difference in the latency and amplitude of P300 component when the two moments of the GI evaluation were compared (Table 4), which demonstrates the test–retest reliability of the procedure\textsuperscript{(13)}. Besides, the inexistence of difference between the groups regarding latency of N200 and P300 components and amplitude of P300 before remediation reinforces the control of variables that could influence on the obtained results.

On the other hand, if compared to the average of latency values of the P300 component, in the two evaluation moments of the group submitted to phonological remediation associated with reading and writing (GI), a decrease was seen in the latency with a significant difference (Table 4). No significant differences were found both in the GI and in the GII, for P300 amplitude and N200 latency.

Therefore, decrease in the P300 component latency for the GI demonstrates that work with phonological abilities induced to changes in the central hearing nervous system, which could be monitored through CAEP-P300. These physiological changes seen in the CAEP-P300 reflected on the child’s behavioral performance, because the same difference was observed in the PA test, in which a better performance was seen after the intervention. These findings showed the therapeutical evolution of students with developmental dyslexia that were submitted to therapies focused on the maximization of phonological abilities, which is in agreement with previous studies\textsuperscript{(5–8)}.

Based on the abovementioned results, P300 may provide pieces of information that help guiding the intervention process of students with developmental dyslexia, since the absence of changes in the P300 latency can be seen as a sign for the need to reassess the therapeutical approach that was used and if some appropriations are needed.

**CONCLUSION**

The use of CAEP-P300 for the aimed monitoring of the therapeutical evolution of developmental dyslexia children is possible and represents a viable option for intervention programs.

*KFA was in charge of outlining the study, she also monitored data collection and tabulation and collaborated on data analysis and manuscript elaboration; ESA was in charge of data collection and tabulation and collaborated on data analysis and manuscript elaboration; EF was in charge of outlining the study, she also monitored data collection and tabulation, and collaborated on data analysis and manuscript elaboration.

**REFERENCES**