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P_{300} - long-latency auditory evoked potential in adolescents

Potencial evocado auditivo de longa latência (P_{300}) em adolescentes

Potencial evocado auditivo de larga latencia (P_{300}) en adolescentes

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Abstract

Introduction: The P_{300} is an objective procedure for assessment of hearing function. The elicitation of its components involves cortical areas related to perception, attention, auditory memory and cognition mechanisms. **Objective:** To evaluate the latencies of N_1, N_2, P_1, P_2 and P_3 in adolescents according to nutritional status and social, economic, demographic and educational variables **Methods:** A case series study was carried out involving 32 adolescents aged 13-18 years of both sexes attending public schools in Recife - PE. The P_{300} components were analyzed with 200 stimuli by using the Ep Smart Intelligent Hearing Systems (IHS) device. **Results:** It was observed that adolescents with records of class repetition had higher (p= 0.04) extension of P_1 component latency when compared to adolescents without class repletion records, as well as adolescents from higher social-economic profile had better P_3 component latency, when compared with those situated in lower socio-economic level. **Conclusion:** Prolongation in latency of P_1 and P_3 components were found in adolescents with class repetition records and lower socioeconomic status.

Keywords: Electrophysiology; Attention; Event-Related Potentials P_{300}; Hearing; Speech, Language and Hearing Sciences; Social Class.

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Resumo

Introdução: O P_{300} é um procedimento objetivo para avaliação da função auditiva. O eliciar de seus componentes envolve áreas corticais relacionadas à percepção, atenção, memória auditiva e mecanismos de cognição. **Objetivo:** avaliar as latências dos componentes N_1, N_2, P_1, P_2 e P_3 em adolescentes segundo variáveis sócio-econômico-demográficas, educacionais, e estado nutricional. **Método:** Estudo do tipo série de casos envolvendo 32 adolescentes de 13 a 18 anos, de ambos os sexos, das escolas públicas do Recife - PE. Foram analisados os componentes do P_{300} com 200 estímulos mediante uso do equipamento *Smart Ep Intelligent Hearing Systems* (I.H.S). **Resultados:** Observou-se que os adolescentes com repetência escolar apresentaram prolongamento da latência do componente P_1 maior (p= 0,04), quando comparados aos adolescentes sem registro de repetência escolar, assim como adolescentes da maior classe social apresentaram melhor latência (p= 0,03) no componente P_3, quando comparados com aqueles de menor classe social. **Conclusão:** Prolongamento na latência dos componentes P_1 e P_3 foram encontrados em adolescentes com repetência escolar e com nível socioeconômico mais baixo.

Palavras-chave: Eletrofisiologia; Potencial evocado P300; Audição; Fonoaudiologia; Nível socioeconômico.

Resumen

Introducción: El P_{300} es un procedimiento objetivo para la evaluación de la función auditiva. El provocador de sus componentes implica áreas corticales relacionadas con los mecanismos de percepción, atención, memoria auditiva y cognición. **Objetivo:** Evaluar las latencias de los componentes N_1, N_2, P_1, P_2 y P_3 en adolescentes de acuerdo a las variables socioeconómicas y demográficas, educacionales y estado nutricional. **Método:** Estudio de tipo serie de casos involucrando 32 adolescentes de 13 a 18 años de edad, de ambos sexos, de las escuelas públicas de Recife - PE. Los componentes P_{300} fueron analizados con 200 estímulos mediante el uso del equipo *Smart Ep Intelligent Hearing Systems* (I.H.S). **Resultados:** Se observó que los adolescentes con fracaso escolar presentaron prolongación de la latencia del componente P_1 mayor (p = 0,04) en comparación con los adolescentes sin antecedentes de fracaso escolar, y adolescentes de clase social más alta mostraron una mejor latencia (p = 0,03) en el componente P_3 cuando comparados con los de clase baja. **Conclusión:** Prolongación de la latencia de los componentes P_1 y P_3 se encontraron en los adolescentes con fracaso escolar y con nivel socioeconómico más bajo.

Palabras claves: Electrofisiología; Potencial evocado P300; Audición; Fonoaudiología; Nivel socioeconómico.

Introduction

Auditory processing involves a set of abilities on which the people depends to understand what they hear. Auditory evaluation is important to investigate whether the individual has an integrate auditory system or if the auditory system has any damage, making it possible to analyze the need for clinical assistance in relation to the neurophysiological aspects involved in sound interpretation[1,2].

Auditory evoked potentials (AEP's) can be classified into short-latency auditory evoked potentials such as brainstem auditory evoked potentials (BAEP), into Auditory Middle Latency Responses (AMLR) such as Medium Latency Auditory Response (MLAR) and Long Latency Auditory Evoked Potentials (LLAEP) such as the P_{300}[1].

Long Latency Auditory Evoked Potentials (LLAEP) make it possible the accurate measurement of the processing of auditory information as a function of time and objectively is related to the cognitive level[3,4,5,6,7,8,9]. It is generated when the patient pays attention and detects rare stimulus (RS), infrequent and random stimulus (20% of stimuli) among a series of frequent stimuli (FE) (80% of the stimuli). The elicitation of P_{300} involves cortical areas related to perception, discrimination, attention and auditory memory and mechanisms of cognition[5,7,9]. It is possible that the latency values of LLAEP can be influenced by factors such as sex (male or female), age, attention level, nutritional

status, socioeconomic status and school repetition[1,9,11,12,13].

The LLAEP allows to evaluate how long it takes for sound to be perceived and interpreted by the auditory cortex, so, it is possible to identify individuals with cognitive dysfunctions[1,6]. This test reflects the ability of cognitive performance and it is possible to determine if there is alteration in cortical auditory pathways of association[14] and latency is the best parameter for data analysis.

The LLAEP presents the components P_1, N_1, P_2, N_2 e P_3. These are subdivided into exogenous potentials (P_1, N_1, P_2, N_2) as they are strongly influenced by the physical characteristics of the stimulus (intensity and frequency, among others)[1,9] and endogenous potentials (P_3) predominantly influenced by internal events related to cognitive abilities[14].

The components N_2 e P_3 represent physiological phenomena associated with mental events related to memory and learning, N_2 is related to the perception and discrimination of the stimuli and P_3 with the capacity to consciously recognize the presence of a change in the auditory stimulus, in other words, the auditory attention beyond the discrimination[15,16] and the prolongation in the latency of this component suggests a delay in the cognitive processing of acoustic information[17].

Considering that LLAEP is a useful test in the study of memory disorders, sequential information processing and in decision making, it is important to obtain the standardization of responses for adolescents with normal hearing, being a protocol of clinical investigation in the difficulties of the school learning and attention deficit.

Therefore, the aim of this article is to verify if there is a significant difference between the latencies of components N_1, N_2, P_1, P_2 e P_3 and P_3 in the adolescents according to nutritional status, demographic socioeconomic level and educational variables (schooling and school repetition).

Method

The sample of this study was derived from a cohort of adolescents, designed to investigate the influence of excess body weight on the occurrence of dyslipidemia in the city of Recife, begun in 2007. This is a case-series study involving 32 adolescents aged 13 to 18 years, both sex (male and female), regularly enrolled in municipal and state public schools of the official teaching network of the city of Recife - PE, developed from June 2011 to September 2012.

We excluded adolescents who presented any physical deficiency that compromised the anthropometric evaluation, cognitive deficit, alteration in audiometric and tympanometric tests, adolescents who knew how to play any musical instrument or practice singing and who were using neuroleptic medication.

All the audiological exams were performed in the public clinic of the city of Recife -PE. Information on personal data, socioeconomic situation, and anthropometric data were obtained in the schools or in home visits and recorded in specific forms.

The latencies of the N_1, N_2, P_1, P_2 e P_3 waves of the LLAEP were evaluated, as well as the nutritional status. A survey of the socioeconomic demographic and educational information of adolescents was made, too.

To verify normal hearing, the condition of inclusion of this study, tonal and vocal audiometries were performed. In the tonal audiometry, auditory thresholds equal to or lower than 20 dB NA for the frequencies performed (500 Hz, 1000 Hz, 2000 Hz and 4000 Hz) were considered normal, and the vocal audiometry normality was considered when recognition thresholds (LRF) equal to or near the arithmetic mean of the frequencies of 500 to 2000 Hz per ear (equal to or less than 20 dB NA) (assuming a change of 5 dB NA for more or less). The test was performed in an acoustic booth, using the AC 40 audiometer [Interacoustics, Kansas City, MI, USA] with TDH-39 headphones [Telephonics, Huntington, NY, USA], calibrated according to the international ISO standard 8253-1 (1989) and Resolution 364/09 of the Federal Council of Speech and Hearing Therapy.

In addition to audiometry, immitanciometry was used for the exclusion of the subjects in case of middle ear alterations. In this procedure it was considered normal to present Type A tympanogram with stapedial reflexes present or partially absent, that is, present in some frequencies and absent in others. The reflexes were tested at frequencies of 500 Hz, 1000 Hz, 2000 Hz and 4000 Hz on the contralateral side and 1000 Hz and 2000 Hz on the ipsilateral side. The immitanciometer model AZ 7 [Interacoustic, Kansas City, MI, USA] was used in this evaluation.

Both audiometry and immitanciometry (tympanogram and reflexes) were performed after an

evaluation performed by an otolaryngologist. The physician examined the absence of external ear pathology with a otoscope [*Welch Allin Inc., Skaneateles Falls, NY, USA*]. These procedures lasted approximately ten minutes.

In order to evaluate the P300, the Smart Ep (Intelligent Hearing Systems (IHS), Miami, FL, USA] was used. This equipment is composed of a signal mediator, which adds up and gives the mean of the recorded electrical activities. This equipment also includes an amplifier, a preamplifier, a coupled notebook for wave viewing and a signal generator properly calibrated by the manufacturer and standardized for the acquisition and analysis of the recordings.

The exams were performed with the adolescents lying on a stretcher located in a semi dark room. Initially, the skin was cleaned with 70% alcohol and the disposable surface electrodes [Meditrace, São Paulo, SP, Brazil] were placed in the following locations: Fpz (front-ground) for the ground electrode, Fz (vertex) for the inverted electrode, M_1 (mastoid) for the reference electrode in the left ear and M_2 (mastoid) for the reference electrode in the right ear and they were connected to the preamplifier, which captured the responses of the LLAR. All electrodes were fixed to skin with electrolytic paste [Nuprep, Aurora, CO, USA]. ER-3A insert headphones [Acustic Orlandi Indústria, Comércio e Serviços Audiológicos Ltda., Bauru, SP, Brazil] were also used to send the rare and frequent stimuli. The adolescent, after the initial preparation, was instructed to stay awake, well relaxed, for the examination.

To obtain the response curve, 200 stimuli were presented in the intensity of 70 dBNA (70 decibels of hearing level), at the frequency of 1000 Hz for the rare stimuli (RSs), and 80 dBNA (80 decibels of hearing level) in the frequency of 4000 Hz for frequent stimuli (FSs). The odd ball paradigm was used, in which 80% of stimuli were FSs and 20% were RSs. Adolescents were also asked to mentally count the RSs in the set of stimuli presented, raising the finger when they identified it and reporting the number of them at the end of the exam.

Measures were taken to control the artifacts such as the sound insulation of the room where the examination was performed, with the concern of keeping the fluorescent lights off, thus avoiding any interference produced by this electric light. Another control factor was the impedance between the electrode and the skin that should be less than 3000 *ohms*.

The following equipment parameters were used: filter between 0.5 and 30 Hz, monoaural stimuli, *tone burst* with 20 ms *plateau* (rise / fall of 5 ms), with interval between stimuli of 1.1 ms, analysis time of 500 ms, sensitivity of 160 microvolts, alternating polarity, lowpass 30 Hz and high pass filter of 1 Hz, window 512 ms. The procedure lasted 45 minutes, on average, between the placement of the electrodes and the examination. As the stimulus was monaural, the arithmetic mean between ear latencies was calculated to analyze the LLAEP.

The latencies of the LLAEP components P_1, N_1, P_2, N_2 e P_3 were marked, following the appearance of the waves, in the positive - negative - positive polarities, respectively when they occurred, occurring in the replication of the "frequent" and "rare" tracing between 55 and 380 *ms*. The normal patterns for the components were: P_1: 55 to 80 ms, N_1: 80 to 150 ms, P_2: 145 to 180 ms, N_2: 180 to 250 ms and P_3: 220 to 380 ms[18] and marking of the sites of positive and negative polarities of the tracing was made in consensus by two speech therapists.

Anthropometry was performed in the schools or in home visits with a double take of the weight and height of the adolescents, using the mean values. The measurements that presented differences greater than 100 g for weight and 0.5 cm for height were ignored. Body weight was obtained in a digital electronic scale [Omron, Kyoto, Japan], with a maximum capacity of 150 kg and a precision of 100 g. The adolescents were weighed barefoot with no objects in their hands and pockets and no head adornments. The height was measured using the portable stadiometer [Alturexata, Belo Horizonte, MG, Brazil], with an accuracy of 1 mm and 0.5 cm. The adolescents were placed upright, barefoot, with their upper limbs hanging over their bodies, their heels, their backs and their head touching the wall and looking forward. The measurements of weight and height followed the recommendations of Lohman et al.[19]. The body mass index for age (BMI), expressed as z scores, was used according to the recommendations of the World Health Organization to classify the nutritional status[20].

Some demographic and educational socioeconomic data were collected through interviews such as: sex (biological), age group - from 13 to 15 years and 11 months and from 16 to 18 years

and 11 months, schooling, classified in primary education (6th to 9th grade) and high school (1st to 3rd year) and the record of school repetition.

For the purposes of socioeconomic classification of families, the Brazilian Economic Classification criteria, established by the Brazilian Association of Research Companies[21] were used and for this study it was classified as: ≥ R$ 1391.00 (Class B_2 and C_1) and < than R$ 1391,00 (Class C_2 and D).

Data analysis

The data were typed in double entry and the *Validate*, module of the Epi-Info program version 6.04 (WHO / CDC, Atlanta, GE, USA) was applied to identify possible typing errors. Statistical analysis was performed with the *Statistical Package for Social Science* (SPSS) for *Windows*, version 13.0 (SPSS Inc. Chicago, IL, USA). There was no statistically significant difference regarding the latency between the ears for the LLAEP latencies ($p > 0.05$), using, therefore, the mean latencies between the ears of the LLAEP for data analysis.

Continuous variables were tested for normality of distribution by the Kolmogorov Smirnov test. All of the latencies of the LLAEP presented normal distribution and the results were expressed in the mean and standard deviation forms. In the comparison between means, the homogeneity tests of the variance (Levene test) and Student's t-test were applied for unpaired data. The significance level of 5% (confidence interval - CI equal to 95%) was adopted for rejection of the null hypothesis.

Ethical aspects

The research protocol was approved by the Research Ethics Committee of the Hospital de Cancer de Pernambuco (nº 02/2010). All the adolescents who participated in the study were previously informed about the objectives of this research, as well as the methods to be adopted so that, through their permission, the data were collected. Each parent or guardian signed a free agreement form according to Resolution 196/1996.

Results

The sample consisted of six male adolescents [17.6% $CI_{95\%}$ 6.76 - 34.53] and twenty-six females [82.4% $CI_{95\%}$ 65.46 - 93.24].

In Table 1 the latency values N_1, N_2, P_1 and P_2 were arranged according to the nutritional status and the socioeconomic, demographic and educational variables. It was observed that adolescents with school repetition had significantly higher latency of the P_1 component when compared to adolescents with no school repetition record.

The Table 2 presents the latency values of P_3 according to the nutritional status, socioeconomic, demographic and educational variables. A significant association was observed only with the variable socioeconomic level, where adolescents of higher social class presented better latency in the P_3 component when compared with those of lower social class.

Discussion

The specialized literature presents few studies addressing the use of LLAEP in adolescence. Among these studies, there is a predominance of papers that evaluate the latency behavior according to the age progression, specifically from the second decade of life and in the same way as other studies, the components were evaluated by means between the ears[1,22].

A positive correlation between P_3 latency and age has been reported, where the advancement of age causes increased P_{300} latency from 15 years of age[6,23]. In this sense, age should be taken into account in the interpretation of the values obtained in different age groups, although, in our series, there were no latency differences in any of the components of the LLAEP among the age groups.

There was no relationship between the latencies of the LLAEP components regarding gender (male or female), these findings corroborate with similar results described in recent studies with children and elderly[9,16,23]. Nevertheless, it is important to have more detailed investigations to increase the level of understanding of this potential association among adolescents, since some authors have already observed that young and adult men presented higher latency values[1,15].

Regarding schooling, the influence of this variable on the latencies of the LLAEP components was not observed, since it would be possible to suggest that individuals with a higher level of education understand better the commands to perform the exam and if they were more attentive; however, this relationship was not verified. Most of the studies with this test are paired samples in relation to schooling[5], and those studies that aren't

Table 1. Mean of absolute latency of components N_1, N_2, P_1 and P_2 according to nutritional status, socio-economic-demographic and educational variables in adolescents aged 13 to 18 years of public school in Recife, PE. 2011 - 2012.

VARIABLES	N_1[1]				N_2[2]				P_1[3]				P_2[4]			
	n*	$\bar{X}$	SD	p[5]	n*	$\bar{X}$	SD	P[5]	n*	$\bar{X}$	SD	p[5]	n*	$\bar{X}$	SD	p[3]
Nutricional Status[6]																
Eutrophic	24	148,1	43,5	0,38	25	261,6	33,2	0,89	23	109,3	43,6	0,69	24	210,9	43,1	0,35
Overweight	6	165,5	38,9		7	263,6	28,4		6	117,2	42,9		6	228,6	30,0	
Sex																
Male	5	163,6	34,9	0,50	6	254,8	24,9	0,54	5	122,1	41,4	0,53	5	212,4	35,7	0,90
Female	25	149,2	44,2		26	263,8	33,4		24	108,6	43,6		25	214,8	42,7	
Age (years)																
13 ⊢ 15	16	145,1	39,2	0,38	18	259,3	29,2	0,59	15	98,4	37,1	0,10	16	209,9	41,3	0,53
16 ⊢ 18	14	158,9	46,5		14	265,6	35,6		14	124,4	45,8		14	219,6	41,6	
School Grade																
Elementary school	16	149,2	40,6	0,75	18	256,6	28,4	0,28	15	107,7	37,7	0,68	16	212,1	37,0	0,75
High School	14	154,3	46,1		14	269,1	35,5		14	114,5	48,9		14	217,1	46,4	
School Repetition[7]																
≥ R$ 1391,00	15	156,1	35,5	0,97	17	258,0	28,6	0,31	14	120	39,3	0,51	15	214,9	39,0	0,59
< R$ 1391,00	12	156,7	50,1		12	270,9	38,6		12	108,7	48,1		12	223,6	44,9	
School Repetition																
Yes	15	161,9	45,1	0,19	17	259,3	35,6	0,61	14	127,7	47,0	0,04	15	222,2	40,0	0,31
No	15	141,3	38,7		15	265,2	27,8		15	95,3	32,8		15	206,7	41,9	

[1] Component N_1,[2] Component N_2, [3] Component P_1, [4] Component P_2, [5] Student's t-test for unpaired data, [6] Eutrophy: ≥ Score Z -2 and ≤ 1; Overweight: > Score Z +1, [7] Brazilian Association of Research Companies, 2010: ≥ R$1391 (class B_2 and C_1), < R$ 1391 (class C_2 and D).
*There are groups of components N_1, N_2, P_1 and P_2 that are without recording latency information or of nutritional status and socioeconomic variables.

Table 2. Mean of absolute latency of the P_3 component according to nutritional status, socioeconomic-demographic and educational variables in adolescents aged 13 to 18 years of the public school system in Recife, PE. 2011 - 2012.

Va	P_3 [1]			
	n	$\overline{X}$	SD	p [2]
Nutritional Status [3]				
Low weight	25	335,7	31,8	0,52
No Low weight	7	344,4	29,7	
Sex				
Male	6	328,9	16,7	0,46
Female	26	339,6	33,5	
Age (years)				
13 ├ 15	18	339,6	23,8	0,69
16 ├ 18	14	335,0	39,4	
School Grade				
Elementary School	18	341,6	19,9	0,45
High School	14	332,3	41,6	
Socioeconomic level [4*]				
≥ 1391	17	326,8	30,2	0,03
< 1391	12	352,6	30,9	
School Repetition				
Sim	17	334,2	32,9	0,52
Não	15	341,4	29,5	

[1] Component P_3, [2] Student's t-test for unpaired data, [3] Eutrophy: ≥ score Z -2 and ≤ 1; Overweight> Score Z +1, [4] Brazilian Association of Research Companies, 2010: ≥ R$1391 (class B_2 and C_1), < R$ 1391 (class C_2 e D).
*Group without recording of information

paired samples[15] don't show a correlation between schooling and latencies.

There are studies that show that obesity may be related to cognitive dysfunction in adolescents and adults[12] with prolongation of P_3 latency in obese adolescents but as reported in another study[24], this relationship was not found and therefore it is interesting to see more studies that verify the exact mechanism of cognitive impairment in obese children[24], since excess weight is also a nutritional disorganization.

It was noted that adolescents with a school repetition record showed a prolongation in the latency of the P_1 component, as evidenced in a study[11], in which adolescents with a repetition record presented prolongation in the latencies in comparison to those who didn't have this kind of record.

The fact that we don't have recordings of all the latencies in the components P_1, N_1 e P_2 in sixteen adolescents aged fifteen years, in only one ear, may be related to the maturational process of the structures involved in the appearance of the cortical auditory evoked potential[16], since It is possible to notice the influence of the age group with an increase in the latency values in waves N_1 and P_2, although there were no significant differences between the age groups[16].

N_2 and P_3 components assess auditory attention[22,25], but although no major changes have been observed, prolonged latencies in the N_2 component are observed in all study variables, suggesting a slow response with impairment of the integration of the auditory association area with the cortical and subcortical areas of the central nervous system[13].

Conclusion

There was influence of school repetition and socioeconomic level in the latency of the long-latency auditory evoked potential in the adolescents of this study.

References

1. Crippa BL, Aita ADC, Ferreira MIDC. Padronização das respostas eletrofisiológicas para o P300 em adultos normouvintes. Distúrb. Comum. 2011; 23(3): 325-333.

2. Wiemes GM, Kozlowski L, Mocellin M, Hamerschmidt R, Schuch LH. Potencial evocado cognitivo e desordem de processamento auditivo em crianças com distúrbios de leitura e escrita. Braz J Otorhinolaryngol. 2012; 78(3): 91-7.

3. Didoné DD, Garcia MV, Silveira AF. Long latency auditory evoked potential in term and premature infants. Int Arch Otorhinolaryngol. 2014; 18: 16-20.

4. Ozdemir HH, Demiroren K, Demir C.F., Serin M.H. Potenciais auditivos evento-relacionados à P300 em crianças com Coreia de Sydenham. Arq. Neuro-Psiquiatr. 2014; 72(8): 603-08.

5. Miranda E.C., Pinheiro M. M.C., Pereira L.D, Iorio M.C.M. Correlation of the P300 evoked potential in depressive and cognitive aspects of aging. Braz J Otorhinolaryngol. 2012; 78(5): 83-9.

6.Alvarenga KF, Araújo ES, Ferraz E, Crenitte PAP. P300 auditory cognitive evoked potential as an indicator of therapeutical evolution in students with developmental dyslexia. CoDAS. 2013; 25(6): 500-05.

7. Perez AP, Ziliotto K, Pereira LD. Test-Retest of Long Latency Auditory Evoked Potentials (P300) with Pure Tone and Speech Stimuli. Int Arch Otorhinolaryngol [serial on the Internet]. [cited 2016 October 01]; 20(4):[about 6 p.]. Available from: https://www.thieme-connect.com/products/ejournals/pdf/10.1055/s-0036-1583527.pdf

8. Regaçone SF, Gução ACB, Giacheti CM, Romero ACL, Frizzo ACF. Potenciais evocados auditivos de longa latência em escolares com transtornos específicos de aprendizagem. Audiol Commun Res. 2014; 19(1): 13-8

9.Bruno RS, Oppitz SJ, Garcia MV, Biaggio EPV. Potencial evocado auditivo de longa latência: diferenças na forma de contagem do estímulo raro. Rev. CEFAC. 2016; 18(1): 14-26.

10. Mendonça EBS, Muniz LF, Leal MC, Diniz. AS. Aplicabilidade do teste padrão de frequência e P300 para avaliação do processamento auditivo. Braz J Otorhinolaryngol. 2013; 79(4): 512-21.

11. Oliveira JC, Murphy CF, Schochat E. Processamento auditivo (central) em crianças com dislexia: avaliação comportamental e eletrofisiológica. CoDAS. 2013; 25(1): 39-44.

12.Lokken KL, Boeka AG, Austin HM, Gunstad J, Harmon CM. Evidence of executive dysfunction in extremely obese adolescents: a pilot study. Surg Obes Relat Dis 2009: 5: 547–52.

13.Borja A, Ponde M. P300: avaliação do potencial evocado cognitivo em crianças com e sem TDAH. Rev Ciênc Méd Biol. 2009; 8(2): 198-205.

14 Simões HO, Frizzo ACF, Zanchetta S, Hyppolito MÂ, Reis ACMB. Variables in P300 recording: task type and electrode position.CoDAS 2016; 28(4): 355-61.

15. Gutiérrez GN, Rangel GCE, Tovar JR. Medición del potencial evocado cognitivo P300 em um grupo de individuos colombianos sanos. Rev Cienc Salud. 2013; 11(2): 231-236.

16. Alvarenga K.F., Vicente L.C., Lopes R.C.F., Silva R.A., Banhara M.R., Lopes A.C et al. Influência dos contrastes de fala nos potenciais evocados auditivos corticais. Braz J Otorhinolaryngol. 2013; 79(3): 336-41.

17 Almeida RP, Matas CG. Potenciais evocados auditivos de longa latência em crianças desnutridas. CoDAS. 2013; 25 (5): 407-12.

18. McPherson DL. Late Potentials of the Auditory System. San Diego (California): Singular Publishing Group; 1996.

19. Lohman TG, Roche AF, Martorell R, editors. Anthropometric standartization reference manual. Champaign (Illinois): Human Kinectics Books; 1988.

20. WHO (World Health Organization). Anthro for personal computeres, version 2, 2007: software for assessing growth and development of the word's children. Geneva; 2007.

21. .Associação Brasileira de empresa de pesquisa (ABEP). Critério Padrão de Classificação Econômica do Brasil. 2010 [Acesso em: 01 jul. 2010]. Disponível em: www.abep.org/codigosguias/Criterio_Brasil_2010.pdf.

22. Soares-Mendonça EB, Muniz LF, Leal MC, Arruda IKG, Diniz AS. Ordenação temporal e atenção auditiva e sua relação com concentrações de hemoglobina de adolescentes. Distúrbios Comun. 2016; 28(1): 50-61

23. Giraldo NG, Galvis CER, Tovar JR. Medição do potencial evocado cognitivo P300 em um grupo de indivíduos colombianos sadios. Rev. Cienc. Salud. 2013; 11 (2): 195-204.

24. Tacilar ME, Turkkahraman D, Oz O, Yucel M, Taskesen M, Eker I, et al. P300 auditory event-related potentials in children with obesity: is childhood obesity related to impairment in cognitive functions?. Pediatric Diabetes. 2011; 12(7): 589-95.

25. Romero ACL, Capellini SA, Frizzo ACF. Potencial cognitivo em crianças com transtorno do déficit de atenção com hiperatividade. Braz J Otorhinolaryngol. 2013; 79(5): 609-15.

26. Balen SA, Boeno MRM, Liebel G. A influência do nível socioeconômico na resolução temporal em escolares. Rev. Soc. Bras. Fonoaudiol. 2010; 15(1): 7-13.

27.Moraes AL, Guimarães LSP, Joanette Y, Parente MAMP, Fonseca RP, Almeida RMM. Efeitos da idade, escolaridade, hábitos de leitura e escrita, processamento semântico e sintomas de depressão na fluência verbal. Psicol.Reflex.Crit. 2013; 26(4): 680-690.

28. Lacerda ABM, Soares VMN, Goncalves CGO, Lopes FC, Testoni R. Oficinas educativas como estratégia de promoção da saúde auditiva do adolescente: estudo exploratório. Audiol. Commun. Res.2013; 18 (2): 85-92.