Rev Bras Otorrinolaringol.
V.70, n.6, 780-5, nov./dec. 2004

ORIGINAL ARTICLE

P300 Cognitive potential in free field: test applicability

Josilene Luciene Duarte[1], Kátia de Freitas Alvarenga[2], Orozimbo Alves Costa[3]

Key words: event-related potentials, P300, cognition, auditory.

Summary

Evaluation of the hearing function in individuals wearing electronic hearing aids is very important for the rehabilitation process. However, in these subjects, the procedures should be conducted in free field. Aim: To analyze the applicability of P300 cognitive potential investigated in free field. Study design: Clinical prospective. Material and Method: Thirty-three subjects of both genders were evaluated, aged 7 to 34 years, with normal hearing and no risk for mental disorders. P300 cognitive potential was performed with equipment Biologic's Evoked Potential System (EP), with insertion phones (3A) under free field (0º Azimuth and 45º Azimuth). Results: There were no statistically significant differences for latency of N2 and P300 and amplitude of P300 with regard to gender and conduction of the test (phone and free field), as well as for comparison of the measurements in free field at 0º and 45º Azimuth. Conclusion: Investigation of P300 cognitive potential in free field is a viable procedure.

[1] Speech and Hearing Therapist – Specialist in Audiology, FOB/USP.
[2] Ph.D., Speech and Hearing Therapist, Professor, Course on Speech and Hearing Therapy FOB/USP.
[3] Otorhinolaryngologist, Full Professor, Course on Speech and Hearing Therapy, FOB-USP; Vice-coordinator of CPA, HRAC-USP.
Affiliation: Department of Speech and Hearing Therapy, School of Dental Sciences, Bauru – USP
Address correspondence to: Kátia de Freitas Alvarenga – Departamento de Fonoaudiologia da Faculdade de Odontologia de Bauru – USP. Al. Doutor Otávio Pinheiro Brizola, Nº 9-75, Vila Universitária Bauru SP 17012-901.
Tel (55 14) 235-8332 – E-mail: katialv@fob.usp.br
Article submited on May 26, 2004. Article accepted on November 10, 2004.

INTRODUCTION

Among cerebral electrical phenomena, there are those that are spontaneous, measured by electroencephalogram, and those provoked by stimuli, which are called evoked potentials. The evoked potentials are classified according to type (Visual evoked potentials, auditory evoked potentials, somatosensorial evoked potentials), time (short, medium, long), distance (close or distant field), and sites where they are generated (sensorial, subcortex or cortex organ). They are obtained by recording and promeasuring responses to sensorial stimuli captured on the brain surface (Franco, 2001[1]).

P300 cognitive potential is long-latency auditory evoked potential generated from the discrimination of a rare auditory stimulus, among other frequent ones of the same modality and different physical characteristics, also called Oddball Paradigm. It is considered a cognitive potential, or event-related response, since it depends on the attention and discrimination of the patient to the rare stimulus that occurs in random intervals. It takes place at about 300 msec after stimulus presentation, with positive voltage and amplitude of 5-20 μvolt.

P300 cognitive potential is generated by a complex neural network, which presents afferent and efferent connections between the thalamus and the temporal-parietal cortex and pre-frontal cortex and the thalamus to the hippocampus and limbic region. In addition to cortical and subcortical areas involved in the formation of P300 cognitive potential, there are connections between the brainstem and reticular formation, responsible for detection, sensation and discrimination of acoustic stimuli and attention states to sensorial stimuli (Chermak; Musiek, 1997[2]). To Buchwald[3] (1990), the exact sites of P300 generators are unknown, but it is evident that it is not mature up to adolescent years, at about the age of 17 years.

At birth, latency of P300 cognitive potential occurs at about 500ms, going to 300ms at puberty (at about 15 years) and reaching 450ms in subjects aged over 65 years (Diniz Junior et al. 1997[4]). Most of the studies showed 1 to 2msec/year linear increase with aging, whereas amplitude reduces on average 0.2¼V/year (Goodin et al. 1978[5]).

As to gender influences in generation of these potentials, Colafêmina et al. (1999)[6] did not detect difference for P300 components, but only for component N2, whose values were higher in male subjects.

Considering that P300 wave latency is an indicator of cortical processing speed, it is markedly prolonged in cases of cognitive deterioration (Oken, 1990[7]; Polich; Kok, 1995[8]). Therefore, the application of P300 cognitive potential is important for the diagnosis and follow up of many different affections to the central nervous system, owing to the changes in how the wave is recorded, specifically of latency and amplitude (Martinez Barros; Marlon Igor, 1998[9]). Goodin; Aminoff (1992)[10] reported use of this potential in cases of diagnosis of dementia and pseudo-dementia owing to high sensitivity and specificity in these cases, characterized by increase in latency of P300 wave. However, it is important to point out that this method does not investigate structural alterations, but rather underlying neurophysiological processes (Franco, 2001[1]).

The first reports of this cognitive potential date from 1965. Since then, many different research studies have been conducted. In Brazil, there are few studies that showed normal range in different age ranges, comparing P300 with other diagnostic procedures (imaging exams), hormone and psychological disorders, and the main assessment parameters and distribution of electrodes used.

There is the need to assess the auditory function in users of electronic devices applied to deafness (hearing aids, cochlear implants, etc.), to check how these subjects are processing the acoustic signal (environmental sounds and speech); however, most existing tests are subjective. P300 is an objective test and it can be applied in all age ranges provided that the subjects understand the required task. However, in hearing impaired subjects users of electronic devices, the test should be conducted in free field. In the Brazilian literature, there are no published studies showing application of P300 in such circumstances. Internationally, there are studies that assessed users of cochlear implant, but not all of them had control group to be used as comparison parameter. Moreover, assessment parameters used to record P300 cognitive potential, age of tested subjects and normal range values for the control group varied a lot in these studies, which hindered the comparative analysis between them (Kaga et al.,1991[11]; Groenen et al.,1996[12]; Kileny et al., 1997[13]; Okusa et al. (1999)[14]; Beynon et al., 2002[15]).

The purpose of the present study was to analyze the applicability of P300 cognitive potential investigated in free field.

MATERIAL AND METHOD

The present study was conducted at the Division of Speech and Hearing Therapy, School of Dental Sciences, Bauru, University of Sao Paulo (FOB/USP).

The study comprised 33 volunteer subjects, 19 female and 14 male, ages ranging from seven to 34 years. All subjects were submitted to clinical history, and we excluded data on risk factor for hearing loss and neurological problems, as well as subjects with confirmed hearing loss in pure tone audiometry, acoustic immittance measures, and ipsilateral and contralateral acoustic reflexes. In this situation, subjects were referred to specific treatment in the clinical division of the Course of Speech and Hearing Therapy, FOB/USP.

The project was approved by the Ethics Committee, School of Dental Sciences, Bauru; patients and responsible guardians received a letter with information and signed the informed consent term to participate in the study.

ELECTROPHYSIOLOGICAL ASSESSMENT PROCESS

P300 COGNITIVE POTENTIAL

The text was conducted in a silent room with insertion phones 3A and acoustic room (free field).

We used disposable electrodes for ECG AG/AGCL with gel and clamped wire to allow the use of this type of electrode. To start the electrophysiological assessment, the electrodes required individual impedance below 5 KΩ and impedance between them of less than 2KΩ. The subjects were comfortably seated with closed eyes (elimination of the artifact caused by eye movement), and the loudspeaker was placed 1m from the subject, in two positions: 0º Azimuth and 45º Azimuth from the right ear.

Active electrodes were placed in Cz and Fz and connected to the input of channels 1 and 2 of the pre-amplifier, respectively. The reference electrode was positioned in the right mastoid, in input 2 of channel 1 interconnected to channel 2 by the jumper, to the pre-amplifier, and the ground electrode was positioned in Fpz position.

We used rare tone burst stimulus in the frequency of 2000Hz, with non-frequent presentation (*oddball paradigm*), unpredictably and randomly, with 20% likelihood of presenting another frequent tone burst stimulus in the frequency of 1000Hz, which was presented in the likelihood of 80%, moderate intensity of 70dB and speed of 1 stimulus per second, using low-pass filter from 1 to 125Hz. The initial record was filtered through a low-pass digital filter with cut-off frequency of 25Hz.

We asked the subjects to identify the rare stimuli, counting them in loud voice.

Assessment Parameters

From the identified findings, the ones that are specifically directed to the objective of the present study are absolute latency of components N2 and P300 and amplitude (amp) of P300 studied with insertion phone and free field conditions, and loudspeaker positioned at 0º Azimuth and 45º Azimuth, recorded in Fz and Cz. We considered the presence of P300 wave when it was simultaneously recorded in Fz and Cz.

Equipment

For the procedure above described, we used the device Biologic's Evoked Potential System (EP).

Statistical Analysis

The results were analyzed by descriptive analysis to calculate mean and standard deviation, paired t Student test to compare gender and variance analysis with repeated measures considering how the test was conducted (insertion phone, field at 0º and 45º Azimuth) and recording of Fz-Cz.

Considering the values obtained with insertion phone (reference pattern) we took descriptive measures of each one of the variables (latency of components N2 and P300 and P300 amplitude), obtained by subtracting values obtained with insertion phone and free field (0º and 45º). These variables were defined as follows:

- FZP3'(0°) = FZP3 (0°) – FZP3(phone); FZP3'(45°) = FZP3(45°) – FZP3(phone); CZP3'(0°) = CZP3(0°) – CZP3(phone); CZP3'(45°) = CZP3(45°) – CZP3(phone); FZaP3'(0°) = FZaP3(0°) – FZaP3(phone); FZaP3'(45°) = FZaP3(45°) – FZaP3(phone); CZN2'(0°) = CZN2(0°) – CZN2(phone); CZN2'(45°) = CZN2(45°) – CZN2(phone).

RESULTS

The comparison of latency values of components N2 and P300 and amplitude P300 using paired t Student test to each test situation (with insertion phones and free field), considering gender, is presented in Table 1. We can observe that there were no statistically significant differences in gender, comparing latency of N2 and P300 and amplitude of P300 to each test situation.

Table 2 presents the descriptive analysis (mean, standard deviation, maximum and minimum values) of latency of components N2 and P300 and amplitude of component P300, when they were investigated with insertion phones and in free field (0º Azimuth and 45º Azimuth).

Table 3 presents likelihood values (p) for latency of components N2 and P300 and amplitude of P300, measured with analysis of variance with repeated measures, in which sound source mode of presentation were the criteria (insertion phone and free field).

Tables 4 and 5 presented descriptive measures of latency for components N2 and P300 and P300 amplitude and inferential analysis using variance analysis tests with repeated measures, respectively, considering the difference between insertion phone and free field (0º Azimuth and 45º Azimuth), measured in Cz and Fz.

DISCUSSION

The study of auditory evoked potential has been increasingly used in clinical practice because it is an easy to apply procedure with high diagnostic value. P300 cognitive potential is a test that assesses cognitive processes of hearing and serves to inform the clinician about the integrity of central auditory nervous pathways.

Some authors reported that the central nervous system is mature only at the age of 17 years, owing to the process of neurological maturation (Buchwald, 1990[3]), in which there is increase in intra and inter-cortical connectivity, as reported

Table 1. Results of paired t student test comparing latency (ms) and amplitude (µV) values for components N2 and P300 conducted with in situ earphone and free field (0° and 45° Azimuth), considering gender.

	Long latency potential P300					
	FzN2	FzP300	FzP300 amp	CzN2	CzP300	CzP300 amp
Phone	0.95	0.92	0.17	0.94	0.69	0.14
0º Azimuth	0.41	0.40	0.51	0.64	0.53	0.28
45º Azimuth	0.25	0.32	0.08	0.28	0.28	0.29

$p < 0.05$ – statistically significant.

Table 2. Descriptive analysis (mean, standard deviation, maximum and minimum values) of latency (ms) of components N2 and P300 and amplitude (µV) of components P300, when investigated for the use of insertion phones and in free field (0° Azimuth and 45° Azimuth).

	Long latency auditory evoked potentials								
		Phone			0º Azimuth		45º Azimuth		
	X ± DP	Minimum	Maximum	X ± DP	Minimum	Maximum	X ± DP	Minimum	Maximum
CzN2	228 ± 31	183	273	235 ± 28	177	275	230 ± 26	189	275
CzP300	341 ± 23	301	371	346 ± 22	307	391	346 ± 21	307	383
CzP300-amp	2,12 ± 1,07	0,3	3,9	2,47 ± 2,05	0,2	11	1,96 ± 1,10	0,3	4,6
FzN2	230 ± 31	183	275	237 ± 27	177	275	230 ± 26	189	269
FzP300	339 ± 20	301	369	347 ± 22	311	391	346 ± 21	309	383
FzP300-amp	1,81 ± 1,06	0,1	4,3	2,08 ± 1,41	0,3	8,1	1,76 ± 0,96	0,1	4,7

Table 3. Values of likelihood (*p*) for latency of components N2 and P300 and amplitude of P300, measured with analysis of variance with repeated measurements, in which criteria were sound source presentation mode (insertion phone and free field), recorded in Fz and Cz.

	Long latency auditory evoked potentials – P300		
Factors	Latency N2	Latency P300	Amplitude P300
Sound source presentation	0.23	0.16	0.30
Sound source X Fz-Cz	0.27	0.07	0.68

$p < 0.05$ – statistically significant.

Table 4. Descriptive analysis for latency of components P300 and N2 and amplitude of P300, respectively, considering difference between insertion phone and free field (0º Azimuth and 45º Azimuth), measured in Cz and Fz.

	Long latency auditory evoked potentials											
	Fz						Cz					
	Latency P300		Amplitude P300		Latency N2		Latency P300		Amplitude P300		Latency N2	
	45º – Phone	0º – Phone	45º – Phone	0º – Phone	45º – Phone	0º – Phone	45º – Phone	0º – Phone	45º – Phone	0º – Phone	45º – Phone	0º – Phone
n	33	33	33	33	33	33	33	33	33	33	33	33
Mean	8	10	-0.05	0.30	3	9	7	7	-0.26	0.21	0	6
standard deviation	17	20	1.35	1.46	27	22	18	23	1.54	1.94	36	33
Median	6	12	-0.27	-0.06	6	2	8	6	-0.2	0.21	6	2
Minimum	-34	-32	-2.87	-1.64	-72	-18	-30	-44	-3.26	-3.14	-136	-138
Maximum	36	48	2.59	5.78	64	82	38	50	3.26	8.42	70	82

Table 5. Values of likelihood (*p*) for latency of components N2 and P300 and amplitude of P300, measured through variance analysis with repeated measurements, in which criteria were sound source presentation mode in free field (0º Azimuth and 45º Azimuth), recorded in Fz and Cz and interaction of these criteria.

	Long latency auditory evoked potentials – P300		
Factors	Latency N2	Latency P300	Amplitude P300
Sound source presentation	0.136	0.795	0.201
Record in Fz-Cz	0.551	0.140	0.350
Sound source in X Fz-Cz	0.406	0.451	0.600

Values obtained with differences between 45º Azimuth and phone, and 0º Azimuth and phone.

by Kügler et al. (1993)[16]. However, it is believed that P300 may be carried out in children as of the age of 7. For this reason, this study was conducted in volunteers aged 7 on, within the age range in which presbyacusis was not a variable to be considered.

According to the study, we could notice that evoked p300 cognitive potential in free field with the loudspeaker positioned at 0º Azimuth and 45º Azimuth is a viable test to be conducted. All assessed subjects presented recording of components N2 and P300 in Fz and Cz, respectively.

The installation of the equipment in free field conducted by the specialized technician did not require complex procedure, despite the arrangement of auditory evoked potentials' output through the loudspeakers rather than the phones. Calibration was made in dBnHL.

As to patients' response, there were no differences in responses of the subjects concerning the test in free field and with phones. It is important to point out that it was easier for the examiner to correlate response of the subject to presentation of stimulus in free field, because the stimulus is audible to both.

Upon studying p300 cognitive potential, there was no statistically significant difference in latency of components N2 and P300 and amplitude of P300, recorded in Fz and Cz, when analyzing the variable gender (Table 1). This finding was not in accordance with what was described by Colafêmina et al. (1999)[6], who detected statistically significant differences between gender for latency of component N2. However, we should consider that this study was different in the age range of the sample and in type of transducer, in this case, surface phone TDH39.

According to mean and standard deviation values obtained and presented in Table 2, we can notice that latency values of components N2 and P300 and amplitude P300, recorded in Fz and Cz, in three modes of test conduction (phone, 0º and 45º Azimuth) were similar and that dispersion of latency and amplitude values of these components in each group seemed to be similar for all analyzed conditions, according to the standard deviation values. This fact can be visualized in Table 3, in which we can see that there were no indications of difference concerning the test conduction mode.

Considering the measurement obtained with insertion phone as reference, the analysis using differences between the measures with phone and 0º Azimuth, and phone and 45º Azimuth, showed that there were no statistically significant differences between free field measures (0º Azimuth and 45º Azimuth), latency for components N2 and P300 and amplitude of P300 (Tables 4 and 5).

Thus, results demonstrated that normal range determined by biological calibration made with phones for each device can be the reference for analysis when the test is conducted in free field under such conditions. Another important piece of data was that small variations in positioning of the loudspeakers in the angles between 0º and 45º Azimuth do not interfere in reliability of intra and inter-examiner procedure.

Upon studying P300 Cognitive Potential in free field with loudspeaker positioned at 0º Azimuth, values for normal latency for N2 were 235±28ms and 237±27ms, for P300 they were 346±22ms and 347±22ms and amplitude of P300 was 2.47±2.05µV and 2.08±1.41mV, recorded in Cz and Fz, respectively.

Conversely, when the loudspeaker was positioned at 45º Azimuth, values of normal latency for N2 were 230±26ms and 230±26ms, for P300 they were 346±21ms and 346±21ms and amplitude was 1.96±1.10µV and 1.76±0.96µV, recorded in Cz and Fz, respectively. Similarly to what is observed in p300 cognitive potential with earphones, there is no literature consensus on latency and amplitude reference values for N2 and P300 in free field, and there are different values presented in this study and in others (Beynon et al., 2002[15]; Groenen et al.,1996[12]). Probably, this fact also justifies the difference in age range of the studied population and assessment parameters.

It is important to emphasize that in subjects with cochlear implant, the loudspeaker should be positioned at 45º Azimuth from the implanted ear, allowing appropriate stimulation. This is different from the assessment made in subjects users of hearing aids or cochlear implant with binaural adaptation, in which the loudspeaker has to be positioned at 0º Azimuth. However, this indication does not occur in cochlear implants in Brazil owing to its high cost and because many international centers are still investigating it (Beynon et al. 2002[15]; Groenen et al., 1996[12]).

CONCLUSION

The present study led us to conclude that:

- Latency values of components N2 and P300 and amplitude of P300 did not differ depending on test conduction mode: phone and free field (loudspeaker at 0º and 45º Azimuth), and
- P300 Cognitive Potential in free field is a feasible procedure to be applied in normal subjects.

REFERENCES

1. Franco GM. O potencial evocado cognitivo em adultos normais. Arq Neuropsiquiatr 2001; 59 (2-A): 198-200.
2. Chermak GD, Musiek FE. Central auditory processing disorders: new perspectives. San Diego: California Singular Publishing Group. Inc; 1997.
3. Buchwald JS. Comparison of plasticity in sensory and cognitive processing systems. Clin Perinatol 1990; 17(1):57-66.
4. Diniz Junior J, Mamgabeira-Albernaz PL, Munhoz MS, Fukuda Y. Cognitive potentials in children with learning disabilities. Acta Otolaryngol 1997; 117 (2): 211-3.
5. Goodin DS, Squires KC, Hderson BH, Starr A. Age-related variations in evoked potentials to auditory stimuli in normal human subjects. Electroenceph Clin Neurophysiol 1978; 44: 447-58.
6. Colafênima JF, Fellipe ACN, Junqueira CAO, Frizzo ACF. Potenciais evocados auditivos de longa latência (P300) em adultos jovens saudáveis: um estudo normativo. Rev Bras de Otolaringol 2000; 66 (março-abril): 144-8.
7. Oken BS. Endogenous event-related potentials. In: Chiappa KH. (ed). Evoked potentials in clinical medicine. New York: Raven Press; 1990. p. 563-92.
8. Polich J, Kok A. Cognitive and biological determinants of P300: an integrate review. Biol Psychol 1995; 41: 103-46.
9. Martinez B, Marlon I. Introducción a los potenciales evocados de larga latencia: P-300. Acta Neurol Colomb 1998; 14 (3): 177-80.
10. Goodin DS, Aminoff MJ. Evaluation of dementia by event-related potentials. J Clin Neurophysiol 1992; 9(4): 521-5.
11. Kaga K, Kodera K, Hirota E, Tsuzuku T. P300 response to tones and speech sounds after cochlear implant: a case report. Laryngoscope 1991; 101 (8): 905-7.
12. Groenen PAP, Makhdoum M, Van Den Brink JL, Atollman MHP, Snik AFM, Van Den Broek P. The relation between electric auditory brain stem and cognitive responses and speech perception in cochlear implant users. Acta Otolaryngol 1996; 116: 785-90.
13. Kileny PR, Boerst A, Zwolan T. Cognitive evoked potentials to speech and tonel stimuli in children with implants. Otolaryngol Head Neack Surg 1997; 117: 161-9.
14. Okusa M, Shiraishi T, Kubo T, Nageishi Y. Effects of discrimination difficulty on cognitive event-related brain potentials in patients with cochlear implants. Otolaryngol Head Neck Surg 1999; 121: 610-5.
15. Beynon AJ, Snick AFM, Van Den Broek P. Evaluation of cochlear implant benefit with auditory cortical evoked potentials. Int J Audiol 2002; 41 (7): 429-35.
16. Kügler CFA, Taghavy A, Platt D. The event-related P300 potential analysis of cognitive human brain aging: a review. Gerontology 1993; 39: 280-303.