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Original Article

P3 cortical potential: difficulty level for different stimulus

Potencial cortical P3: nível de dificuldade para diferentes estímulos

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ABSTRACT

Purpose: Evaluating the level of difficulty of identifying verbal and non-verbal stimuli, according to the classification of the participants, as well as comparing the latency of the P3 cortical potential. **Methods:** Thirty subjects, with a mean age of 23 years and normal hearing, were evaluated. The P3 potential was performed with non-verbal stimuli (tone burst) and verbal (/ba/ x /di/, /ba/ x /ga/, /ba/ x /da/). Each subject had to classify stimulus in "the easiest" and "the most difficult". **Results:** Most subjects rated the /ba/ x /di/ contrast as the easiest to identify and the contrast /ba/ x /ga/ the most difficult. The subjects reported that the speech stimulus were easier to identify when compared to tone burst. The difficulty level described by the subjects influenced the latencies of stimuli /Di/ and /Da/, ranked as the easiest and they were evidenced in the lowest latency of P3. **Conclusion:** The /Ba/ x /Di/ contrast was considered the easiest for perception, being evidenced by the lowest latency of P3. The speech contrasts were classified as the easiest when compared with the tonal stimuli. These comparisons help the clinician in selecting the stimuli and in the correct audiological diagnosis.

Keywords: Evoked potentials, Auditory; Event-related potentials, P300; Auditory perception; Auditory cortex; Adult

RESUMO

Objetivo: Avaliar o nível de dificuldade de identificação dos estímulos verbais e não verbais, segundo classificação dos próprios participantes, e comparar com a latência do potencial cortical P3. **Métodos:** Foram avaliados 30 sujeitos, com média de idade de 23 anos, normo-ouvintes. O potencial P3 foi pesquisado com estímulos não verbais (*tone burst)* e verbais (/ba/ x /di/, /ba/ x /ga/, /ba/ x /da/). Cada sujeito classificou os estímulos em "mais fácil" e "mais difícil". **Resultados:** A maioria dos indivíduos classificou o contraste /ba/ x /di/ como sendo o mais fácil de identificar e o contraste /ba/ x /ga/, como o mais difícil. Os sujeitos referiram que os estímulos de fala foram mais fáceis de identificar quando comparados com *tone burst*. O nível de dificuldade descrito pelos indivíduos influenciou nas latências dos estímulos /Di/ e /Da/, classificados como mais fáceis, e evidenciados na menor latência do P3. **Conclusão:** O contraste /Ba/ x /Di/ foi considerado o de maior facilidade de percepção, sendo evidenciado pela menor latência do P3. Os contrastes de fala foram classificados mais fáceis quando comparados com os estímulos tonais. Essas comparações auxiliam o clínico na escolha do estímulo utilizado e no correto diagnóstico audiológico.

Descritores: Potenciais evocados auditivos; Potencial evocado P300; Percepção auditiva; Córtex auditivo; Adulto

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INTRODUCTION

Auditory Evoked Potentials (AEP) are objective methods of hearing evaluation, and, when associated with behavioral methods, they contribute to the increase in accuracy in the diagnosis of central auditory disorders.

The AEP reflect neuroelectrical alterations in the auditory pathway, from the cochlea and auditory nerve to the cerebral cortex in response to an acoustic stimulus, permitting the investigation of the integrity of central auditory pathways, its maturation during the process of development and dysfunctions caused by several diseases(1). The Long Latency Auditory Evoked Potentials (LLAEP), specifically the P3, stand out in the investigation of some cognitive skills involved in information processing, such as attention, discrimination and auditory memory(2).

The P3, cognitive potential or endogenous potential, is a positive component peaking around 300 ms (milliseconds), influenced by the functional use that the brain makes from the sound stimulus, as well as by the level of attention of the subject during the examination(3-5). Through this potential, we can evaluate abilities such as attention and recent memory, both dependent on the discrimination between stimuli, whether verbal or non-verbal(6,7).

In the research of cortical potentials, there is the possibility of using verbal and nonverbal stimuli(8). The difference of response between stimuli has already been described in the literature and the authors highlight that the P3 latency increases when the "targets" for discrimination are more difficult than the standard, in other words, latency is sensitive to the demand of task processing(9). In contrast, the amplitude of P3 is greater for easier tasks and it decreases as the task becomes more difficult. Furthermore, there is a difference in cortical processing for verbal and nonverbal(10).

The different stimuli used in the research LLAEP, besides contributing to the evaluation of different brain areas, they may influence the audiological diagnosis in cases of auditory processing disorders. Frequently, the clinician is faced with a great variety of stimuli present in the equipment, not knowing the difference among them and what, behaviorally, may interfere with the response of the subject.

What is observed in the literature specialized in cortical potential is the extensive use of stimuli, whether tonal, vowels or consonants-vowels. In many studies, the researchers aim to observe the behavior of the P3 in relation to acoustic stimulation, without giving importance to the subjectivity of the signal processing by the evaluated subject. The perception of the subject is not always consistent with certain latencies and amplitudes of cortical potentials(11). In lots of cases, the patient has appropriate behavioral responses (discrimination and counting of stimuli) and altered electrophysiological responses, which may occur because of the acoustic stimulus parameters.

The aim of this research was to evaluate the difficulty level of identification of verbal and non-verbal stimuli, according to the classification of the participants themselves, and to compare with the latency of the P3 cortical potential in order to identify whether the central nervous system processes this information according with the perception of the participants, that is, if there is a correlation of subjective responses reported by the subjects with the electrophysiological responses.

METHODS

It is a cross-sectional, observational and contemporary study.

This research was approved by the Research Ethics Committee (REC) of *Universidade Federal de Santa Maria* (UFSM), under the protocol 25933514.1.0000.5346.

The participants signed the Informed Consent (IC), agreeing with the aims of this study and with the participation on it.

A total of 30 individuals aged from 18 to 32 years, being 15 women and 15 men, with normal hearing and without risk history for hearing, neurological and language changes.

Initially, the visual inspection of the external auditory canal was performed by using the Klinic Welch-Allyn® clinical otoscope, to rule out any changes that could influence the audiometric thresholds.

The pure tone audiometry was carried out in a soundproof booth, with Itera II Madsen® audiometer. They searched the airway thresholds at 250, 500, 1000, 2000, 3000, 4000, 6000 and 8000 Hz. The used technique was descending-ascending. We considered as normal hearing subjects those ones with tritone mean (500, 1000 and 2000 Hz) less than or equal to 25 dBHL (decibel hearing level)(12).

The acoustic immittance measurements were performed by the AT235 middle ear analyzer of Interacoustics®, for the search of the tympanometric curve and the acoustic reflexes. The reflections were investigated in the frequencies of 500 to 4000 Hz, bilaterally, in the contralateral way. We only included in the sample the subjects with tympanogram type "A" and with acoustic reflex (if present)(13).

For the research of the P3 cortical potential, we used the Intelligent Hearing Systems® equipment, SmartEP module, two channels. The skin cleaning was performed with abrasive paste and the fixing of electrodes with electrolytic paste and adhesive microporous tape, in the M1 (left mastoid) and M2 positions (right mastoid), Cz (vertex), being the ground electrode (Fpz) on the forehead. The value of the electrode impedance should be less than or equal to 3 kohms.

Patients were instructed to pay attention to different stimuli (rare stimulus) that appeared randomly within a series of equal stimuli (frequent stimulus). The requested cognitive task was to count the rare stimuli for different pairs of stimuli. Then, the examiner should report the number of rare stimuli between the series of frequent stimuli. After hearing the sequences of verbal stimuli, we asked the patients to inform what was the easiest verbal stimulus and what was the most difficult to identify and, after hearing the sequence of tone burst, comparing the easiness/difficulty between the tone burst with the verbal stimuli. The percentage of rare presentation of stimuli was 20%, while for frequent stimuli, it was 80%.

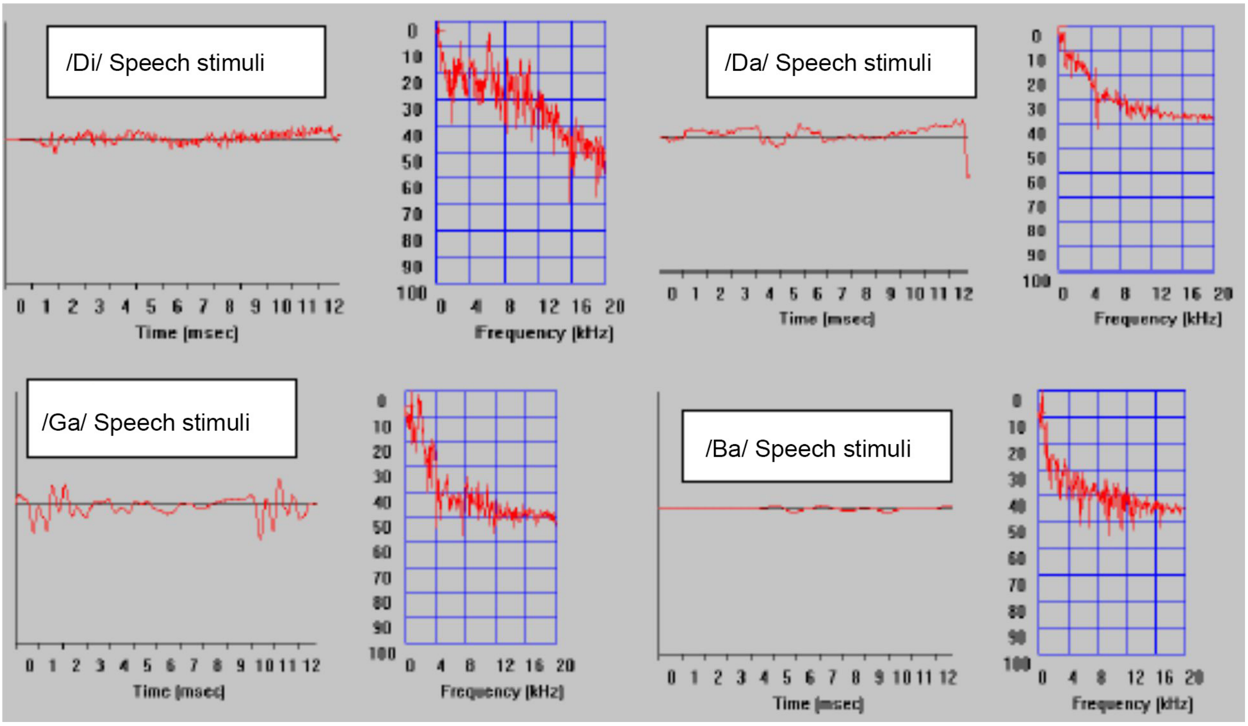
Non-verbal stimuli were used (tone burst), in the frequencies of 1000 Hz (frequent stimulus) and 4000 Hz (rare stimulus), and verbal (/Ba/ syllables as frequent stimulus and /Ga/, /Da / e / Di / as rare stimuli). Speech stimuli are synthetic, non-natural, generated in the used equipment. Figure 1 shows the difference presented by the equipment in every contrast of speech. All stimuli were presented through the insertion phones, binaurally, at an intensity of 75 dBPe (decibel equivalent peak). For each type of contrast, 300 stimuli were used (approximately 240 frequent stimuli and 60 rare stimuli), for obtaining P3. The tracings were not replicated due to the total procedure time with different stimuli, once replication might let the participants tired and this could influence the answers. The survey with different pairs of stimuli lasted approximately one hour, with rest intervals of approximately ten minutes between the series of stimuli. The parameters used in this study are described in Chart 1.

The research started with /Ba/ and /Ga/ pair, followed by /Ba/ e /Di/, /Ba/ and /Da/ pairs and burst tone, and, prior to obtaining the tracings, all verbal stimuli and nonverbal were presented, so that the subjects could become familiar with the differences. After the search of the first two speech stimuli, the subjects were asked to rest so that fatigue would not interfere in the answers of the last two sequences of stimuli. Subsequently, each subject had to classify the degree of difficulty of each rare stimulus. Participants should answer the following questions: "among all sequences of verbal stimuli, which one do you

Chart 1. Parameters used for obtaining the P3 potential

Equipment	Intelligent Hearing System®
Module	SmartEP
Electrodes	M1, M2, Fpz e Cz
Impedance of electrodes	Less or equal to 3Kohms
Intensity	75 dBHL
Type of stimulation	Binaural
Number of stimuli	300 (80% frequente e 20% raro)
Channels	AB
Velocity	0.8 pps
Strength	2.0 ms
Phase	Alternated
Used stimuli	Ba (frequent) Ga (rare) Ba (frequent) Di (rare) Ba (frequent) Da (rare) 1Khz (frequent) 4Khz (rare)
Paradigm	Oddball paradigm
Type of transducer	Phones of insertion
Strength of stímuli	50.000 μs
Rise/Decay	20%
Envelope	Trapezoidal
State of the subject	Alert

Note: K ohms = kiloohms; dBHL = decibel hearing level; pps = pulses per second; ms = millisecond; KHz = kilohertz; μs = microseconds



Source: Intelligent Hearing System® equipment

Figure 1. Differences between the used contrasts

consider the easiest to identify?" "Among all sequences of verbal stimuli, which one do you consider the most difficult to identify?" And finally, "from the verbal and non-verbal stimuli, what kind of stimulation do you find the easiest to identify?". The objective was that individuals would identify the easiest verbal stimulus and they could compare verbal stimulus with nonverbal ones.

In this study, we considered only the latency values obtained through the identification of P3 wave at the peak of greater amplitude, considered only in tracing of the rare stimulus. The exogenous potentials were not evaluated, once the purpose of this study was to assess how the subjects were processing the stimuli, corresponding to the cognitive abilities that lead the P3 and not exogenous potentials.

The data were tabulated and analyzed statistically and, then, the level of difficulty reported by individuals and P3 latencies between the verbal and non-verbal were compared. The following statistical tests were used: Mann Whitney test, Kruskal Wallys test, Student's t test and Wilcoxon test, with significance level of 5%.

RESULTS

From the total of investigated subjects, 80% rated the /Di/ stimulus as being the easiest among verbal stimuli. In relation to the contrary classification, 90% reported greater difficulty in identifying the /Ga/ stimulus (Table 1). Comparing speech stimuli and tone burst, most subjects reported greater level of easiness of speech stimuli, compared to tonal ones (Table 2).

The comparison between the level of easiness or difficulty and the latencies of stimuli was carried out between the contrasts, in order to verify that the stimulus classified by the subject as the easiest or the most difficult was the lowest or the highest latency, respectively.

To compare the latencies compared to the stimulus classified as "the easiest", the contrasts that received this rating were compared with others, being detected significant difference to the indifference of easiness between /Di/ and Da/, in other words, the speech stimuli have been reported to be the easiest and had the lowest latency (Table 3).

Table 1. Descriptive measures for "the easiest" classification between speech stimuli

Stimuli	Classification			
	"The easiest"		"The most difficult"	
	n	%	n	%
/Ba/ x /Di/	24	80	0	0
/Ba/ x /Ga/	1	3.3	27	90
/Ba/ x /Da/	1	3.3	3	10
Indifferent between /Ba/ x /Di/ and /Ba/ x /Da/	4	13.3	0	0
Total	30	100	30	100

Considering the results for the most difficult classification, there were no statistically significant differences between the mean of P3, for different stimuli (Table 4).

Comparing all speech stimuli (/Ba/ x /Ga/, /Ba/ x /Di/ and /Ba/ x /Da/ means) with tone burst, there was no statistically significant difference, in other words, the level of easiness or difficulty reported by the subjects, in general, did not interfere with latencies of P3 (Table 5).

DISCUSSION

Although it is considered an objective method of evaluation, the P3 may be interfered with by some factors that contribute to the variability of its measures, including the type of stimulus[14,15]. The speed of detection and perception of the rare stimulus by the subject are directly related to the latency of P3 and they depend on the type of acoustic stimulation[16].

In our study, there was a preference of the participants for speech stimulus /Di/, which suggests that the contrast with the frequent stimulus is higher (Figure 1), facilitating the processing of stimuli. /Ga/ was considered the most difficult stimulus, which does not differ significantly with the /Ba/ stimulus (Figure 1). These results are in agreement with another study[17], in which the

Table 2. Descriptive measures for "the easiest" classification between verbal and non-verbal stimuli

	Verbal stimuli		Non-verbal stimuli		Indifferent	
	n	%	n	%	n	%
The easiest contrast to identify	21	70	4	13.3	5	16.6

Table 3. Comparison of the latencies between stimuli classified as the easiest to identify

	/Ba/ x /Di/	/Ba/ x /Da/	Indifference between /Di/Da/	p£
	Mean (ms)	Mean (ms)	Mean (ms)	
/Ba/ x /Ga/	344.7	336.0	334.0	0.541
/Ba/ x /Da/	276.8	343.0	302.5	0.247
/Ba/ x /Di/	318.4	312.0	366.8	0.105
Tone burst	303.9	312.0	264.7	0.047

£: Mann Whitney test (p<0.05)

Table 4. Comparison of the latencies between stimuli rated as the most difficult to identify

	/Ba/ x /Ga/	/Ba/ x /Da/	p£
	Mean (ms)	Mean (ms)	
/Ba/ x /Ga/	340.1	368.7	0.192
/Ba/ x /Da/	281.9	300.7	>0.999
/Ba/ x /Di/	326.0	323.7	0.844
Tone burst	298.0	311.0	0.457

£: Mann Whitney test (p<0.05)

Table 5. Comparison between "the easiest" classification between speech stimuli and tone burst

	The easiest speech	The easiest tone burst	Indifferent	p£
	Mean	Mean	Mean	
All speech stimuli	317.1	327.9	365.1	0.076
Tone burst	297.6	299.5	311.3	0.804
p-value	0.141ŧ	0.322¥	0.158¥	
Difference [(1) – (2)]	19.5	28.4	53.8	

£: Kruskal Wallys test (p<0.05); ŧ: T-Student test for paired data (p<0.05); ¥: Wilcoxon test (p<0.05)

subjects judged that the easiest stimulus in terms of identification are those ones with higher contrast and low distortion. These authors reported that the degradation of speech signal perceived by the subject is directly associated to the features of P3, once stimuli without distortion and of easy identification cause greater amplitudes and lower latencies of cognitive potential.

In our study, the speech stimuli were considered easier to identify than the tonal stimuli. Although verbal stimuli are more complex[18], they are more familiar to the subjects as they are present in the mother tongue, while the tonal stimuli can have no meaning except for individuals with musical abilities[19].

Considering the results of the statistical analysis of this research, the P3 stimuli classified as the easiest (/Di/ and /Da/ stimulus presented lower latency, being statistically significant. This result is in agreement with other studies, which report that the perception of the subject and acoustic complexity is proportional to the P3 latency values[17,20]. On the other hand, this correlation was not significant for /Ga/ stimulus, which was reported to be the most difficult to identify, among the speech stimuli. We believed that this result could be significant with a more expressive sample.

In this study, there was no significant difference in the comparison between the level of easiness with latencies of pure tone stimuli or speech, when considering the overall mean of complex stimuli. The speech stimuli have been used to provide information about the processing of the signal in the auditory cortex, mostly in cases which behavioral evaluation is not possible, assisting in rehabilitation therapy of the patients[21]. This comparison assists the clinician in cases that the choices of the verbal stimuli are performed randomly.

The perception of the subject regarding sound stimuli becomes important in order to the attention skills and discrimination of stimuli could remain constant throughout the evaluation and also for its reliability. In our study, there was a preference of participants by the /Ba/ x /Di / and /Ba/ x /Da/ speech contrast, which evoked reliable answers and classified as of easy perception. When compared with other contrasts, it was highlighted the lower latency, demonstrating a correlation between the electrophysiological examination and the perception of the subject.

CONCLUSION

The /Ba/ x /Di/ contrast was considered the easiest for perception, being evidenced by the lower latency of P3. The speech contrasts were classified as the easiest when compared with the tonal stimuli. These comparisons help the clinician in selecting the used stimulus and correct audiological diagnosis.

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