P300 AND EXTRAVERSION IN THE VISUAL ODDBALL PARADIGM

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Abstract: The aim of this study was to investigate the relationship between P300, evoked by a standard visual oddball paradigm, and extraversion measured by the Eysenck Personality Questionnaire (EPQ-RA). The sample consisted of 54 subjects, all female, right-handers, in the age range 19-23 years. P300 was measured using occipital and parietal electrodes in two repeated trials for each subject. Regardless of the trial block, the electrode site effect was significant for both latencies and amplitudes. A tendency towards lower P300-amplitudes emerged in the second trial, implying a habituation effect. Subjects with higher extraversion showed significantly shorter P300-latencies recorded on the parietal group of electrodes (P_3 and P_4). However, as a more prominent relationship in the same direction was determined between the extraversion subtrait adventurousness and P300-latency, the effect of extraversion could be mainly attributable to adventurousness. The findings are discussed in terms of arousal theory and task demands.

Key words: P300, extraversion, visual oddball paradigm

INTRODUCTION

The psychophysiology of personality includes all studies of the biological basis of personality exploring the physiological processes underlying trait-like differences in psychological functioning (Fulgosi, 1994). In order to analyze the correlation between the psychological and the physiological aspects of human behavior, various methods of measuring ANS or CNS activity have been used (Hugdahl, 1995). This relation has been established and investigated ever since methods for measuring brain activity were discovered and the first proposal that individual differences in brain activity could be related to personality traits was made long ago (Lemere, 1936). Among the numerous analytical approaches in research into abilities and personality, the type of analysis studying phenotypic surfaces in an attempt to identify their biological basis is called *top-down analysis* (Nyborg, 1997). Within this field of research there have been many disagreements both about the traits that could best serve as the putative correlates of the measured brain activity and the measures of brain activity that could best serve as the biological markers of a certain personality trait. With the development of psychophysiology in the last four decades the emerg-

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ing literature can be seen to be increasingly focused on extraversion in the former role (Stenberg, 1994). Many researchers have agreed on extraversion's having a major place in the theoretical framework of basic personality dimensions (Costa, McCrae, 1992; Eysenck, 1992) as well as on its being genetically based (Eysenck, 1967; Zuckerman, 1991).

The clearest explanation of the relationship between extraversion and its biological basis is found in Eysenck's theory of personality (1957, 1967). Eysenck made the assumption that extraversion was related to cortical arousal, with introverts having chronically higher levels of arousal than extraverts - low amplitudes and high frequencies of alpha rhythm as measured by EEG. Although Eysenck's assumption has been basically supported within EEG research, there are still many inconsistencies left to be cleared up (Gale, 1983; Gale, Edwards, 1983). They concern not only the limitations of EEG use or the interaction effects with the intensity of the given stimuli, showing faster habituation and faster decline of alpha rhythm in extraverts (Stelmack, 1997), but also the personality measure used (O'Gorman, 1984). The evidence has shown the trait of impulsivity to be more strongly related to low arousal than is extraversion (Stenberg, 1992, 1994). Also, it was determined that those subjects who got bored easily and to a greater extent (which has been defined as adventurousness) also showed significantly higher EP-amplitudes (Rust, 1975) and, more specifically, higher P300-amplitudes (Hansenne, 1999), which showed a significant relationship between those two variables. Because of the more significant relationship between impulsivity and psychoticism on the one hand, and stronger, clearer and more stable relationship between adventurousness and extraversion on the other, greater emphasis was put in this study on this second relationship (Stenberg, 1994).

A relatively new measure of brain activity - event-related potentials - has recently been used to investigate the heightened perceptual sensitivity in introverts found in various studies (Siddle, Moorish, White, Mangan, 1969; Stelmack, Campbell, 1974). The event-related potentials (ERPs) are time-locked, i.e. they appear in a precisely determined period after the given stimulus that has been determined by the nature of the cognitive task used, and mostly in one part of the human cortex, in contrast to spontaneous EEG waves (Polich, 1993). As predicted by arousal theory, introverts showed higher amplitudes in both auditory (Bruneau et al., 1984; Stelmack, Campbell, 1974; Stelmack et al., 1977; Stelmack, Michaud, 1985; Stelmack, Geen, 1992) and visual ERPs (Soskis, Shagass, 1974; Stenberg, Rosen, Risberg, 1988; Stenberg, Rosen, Risberg, 1990). However, the obtained effects have been significantly modified by psychological factors such as attention and habituation (Stelmack, Michaud, 1985; Stenberg et al., 1990; Stenberg, 1994).

P300, which accompanies cognitive processing, including the activation of attention mechanisms and changes in working memory, is the most widely investigated of the psychologically important ERP components (Picton, 1980). P300 does not reflect the physical parameters of stimuli, is not always connected to the appearance of the stimulus, is evoked by unexpected stimuli and does not appear if the stimuli are not relevant for the subject (Polich, 1998). As regards its neural model, P300 shows a fronto-parietal activation, where its subcomponents P3a and P3b can be measured using a more precise and sophisticated apparatus (Polich, Kok, 1995; Polich, 2004). However, its functional significance and role remain unsolved. Donchin and Coles (1988) propose that P300 appears when there is a need to update the internal model of the environment in the working memory. Verleger (1988), on the other hand, has suggested, within his context closure hypothesis, that P300 appears when the perceptual epoch is closed, being a reflection of confirmation rather than of revised, subjective expectancies. The dominant view today is the hierarchical model of a P300 psychological-functional role, where P300 does not reflect one psychological process but rather the interrelation between activation and deactivation - processes that have impact on only some of the regulatory mechanisms in the brain (Portin et al., 2000). Therefore, P300 does not present a unique component, but the activity of more neural generators that are simultaneously active.

Within the physiology of extraversion P300 has been proved to be an adequate measure of cortical activity (Stelmack, 1981, 1990). It has been widely measured by an auditory or visual oddball paradigm - the task of simple stimulus discrimination. During such a task the subject listens to (looks at) a sequence of tones (visual stimuli), where one tone (visual stimulus) is usually the target. The subject's task is to press a button on hearing (seeing) the target stimulus (Polich, 2004). The rationale for expecting differences between extraverts and introverts to emerge in the oddball task has its basis in the finding that extraverts have a faster habituation rate (O'Gorman, 1977; Ditraglia, Polich, 1991) and a more rapid decline in vigilance tasks demanding sustained attention (Keister, McLaughlin, 1972). Therefore it is expected that introverts will better sustain their attention during an oddball task that induces monotony, resulting in higher amplitudes in the averaged ERPs. This assumption has been confirmed in some studies (Daruna, Karrer, Rosen, 1985; Wilson, Languis, 1999; Polich, Martin, 1992), but if habituation was avoided or response requirements were kept high, the P300 differences between extraverts and introverts disappeared or even changed direction (Cahill, Polich, 1992; Orlebeke, Kok, Zeillemaker, 1989; Stenberg, 1994).

The aim of this study was to examine the relationship between P300 and extraversion in a visual oddball paradigm. The first problem was to compare P300-amplitudes and P300-latencies between extraverts and introverts in the first trial block. Considering the above-mentioned habituation effects, our second problem was to explore their role on the basis of the comparison between the first and the second trial block results. Additionally, as some of the evidence suggested a significant positive relationship between P300-amplitude and impulsivity (Stenberg, 1994), this relationship was also examined.

METHOD

Subjects

A total of 54 female subjects (M = 20.5 years, SD = 1.28, range: 19-23) were selected from a preliminary sample of 91 undergraduate students from the Department of Psychology in Rijeka. They were all right-handed, naive to electrophysiological studies, and reported no visual or neurological/psychiatric problems. The subjects received course credit for their participation in the study.

On the basis of their scores on the EPQ R/A Extraversion scale, the subjects were divided by the Median criterion in two groups: the first one with low results on the Extraversion scale (<17, N = 27) and the second one with high results on the Extraversion scale (≥17, N = 27). A similar division was made for the Impulsivity (≤6, N = 29; >6, N = 25) and Adventurousness scales (<10, N = 26; ≥10, N = 28).

Questionnaires

Levels of extraversion and giving socially desirable answers were measured by Eysenck's Personality Questionnaire - Revised version, EPQ-RA (Eysenck, Eysenck, Barrett, 1985), its standardized version (Eysenck, Eysenck, 1994), to be precise. This instrument consisted of 106 items and has also measured psychoticism, neuroticism, addiction and criminality. Item analysis in this study confirmed earlier satisfactory levels of reliability: Cronbach Alpha for extraversion was 0.89 and for the social desirability scale 0.68.

Levels of impulsivity and adventurousness were measured by Eysenck's Personality Questionnaire - Impulsivity, Venturesomeness and Empathy, EPQ-IVE (Eysenck et al., 1985), its standardized version (Eysenck, Eysenck, 1994), to be precise. It consisted of 54 items and besides those two personality traits it has also measured empathy. Item analysis has also confirmed previous levels of reliability: Cronbach Alpha for impulsivity was 0.74 and for the adventurousness scale 0.79.

Finally, the control variable of depression was measured by the Depression scale D-92 (Krizmanić, Kolesarić, 1994). It consisted of 22 items and subjects answered on a four-point Likert scale. In this study computed Cronbach Alpha for this scale was 0.88.

Apparatus and Procedure

After the general instruction and filling out of the described questionnaires, each subject was measured for the evoked brain potential P300 in two repeated trials. All recordings were made in the space of four months, always on Wednesdays and always at the same time - noon. Because of the limited laboratory time at our disposal, subjects came to the laboratory once a week in groups of 4-6, and each of them underwent two repeated trials, with an intertrial interval of 2 minutes. P300 responses were elicited by the standard visual oddball paradigm, chosen because of its smaller monotonous effect on subjects. A Medelec/TECA Sapphire^{II} 4E device with five Ag/AgCl disc electrodes was used. The active electrodes were placed on O_1, O_2, P_3 and P_4 (according to 10-20 system), and referred to F_Z. The electrode impedance was kept below 5kΩ and the filter bandpass was 0.1-50 Hz. A pattern reverse binocular full-field stimulation was performed in a dark, quiet room using a 16x16 checkerboard pattern, 70 cm away from the nasion, with 1Hz frequency and 100% contrast. Fifteen percent of stimuli were infrequent (target) checkerboards (consisting of small quadrangles), whereas the remaining ones were frequent (nontarget) checkerboards (consisting of big quadrangles), presented in random order. Subjects were instructed to look at the red circle in the center of the monitor and to react to the target stimuli by pressing the pen.

The marking of the amplitudes and latencies of the P300-component was performed manually, using a cursor, by the same medical technician for both trials. In the first trial, the first major positive peak between 300-600 msec for the rare stimuli was identified as the P300 response and was marked. To avoid the effect of latency jitter (Coles et al., 1986; Hoormann et al., 1998), and to make the P300-component more stable over trials, the P300-component was marked in the second trial by the same P300-latency as the one from the first trial. Therefore, for each subject there was the same P300-latency (as measured in one trial only) in both trials and different P300-amplitudes. Examples of the averaged and artifact-corrected ERP curves for one subject in the first and the second trial blocks are shown in Figure 1.

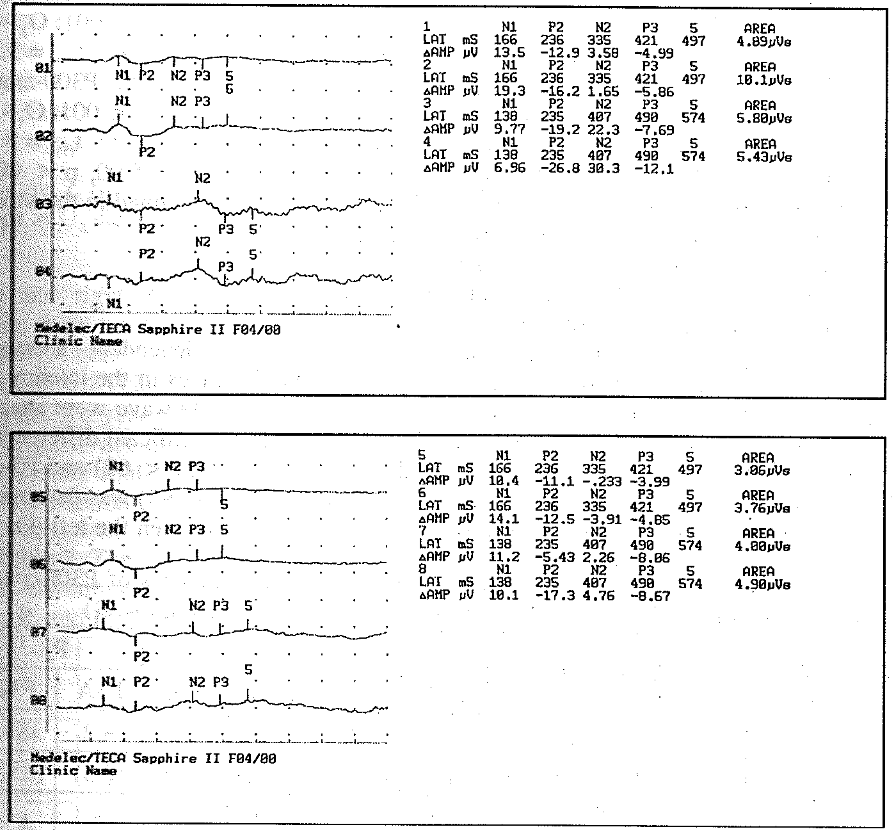


Figure 1. An example of a recorded P300-wave (above: a sharpened marked P3-wave measured in a first trial block; below: a sharpened marked P3-wave measured in a second trial block) in the visual oddball paradigm with intertrial interval of 2 minutes

RESULTS

Personality Variables

The group average for the EPQ R/A Extraversion (M = 15.5; SD = 5.4) did not substantially differ from the one obtained on the Croatian standardization group (M = 14.2; SD = 4.7), nor did those for EPQ IVE/A impulsivity (M = 7.0; SD = 3.4) and adventurousness (M = 9.2; SD = 3.6), (M = 9.0; SD = 4.2 and M = 8.7; SD = 3.9, respectively). According to the Kolmogorov-Smirnov test of conformity, the distributions of all personality variables were normal. There was no significant correlation between age and any of the personality variables.

ERP Results

Mean amplitudes and latencies of the P300 are shown in Table 1. They were determined for the point of maximum positivity in the 300-600 msec range. The basic principle for marking the P300-wave in the first trial block was the peak amplitude, which was marked only after marking all other ERP components. Due to the technical limitations of the device used, the possibility of a latency jitter could not be avoided by using the Woody filter method, and the P300-latencies were therefore made constant over trial blocks and used for marking the P300-wave in the second trial block. Although a lot of valuable information was lost in this way, an additional reason for using this method was evidence of a very small impact of habituation on latencies (Polich, 1989; Lin, Polich, 1999; Bruin et al., 2000), especially when pauses between the trial blocks were very short (1-2 minutes). The tendency of P300-amplitude decrease in the second trial block, indicating a habituation effect, can be seen in Figure 2.

The statistically significant differences between occipital and parietal electrodes in the first trial block were found in the P300-latencies (O_1 - P_3: $t_{(53)} = 2.96$, $p < .001$; O_1 - P_4: $t_{(53)} = 3.00$, $p < .001$; O_2 - P_3: $t_{(53)} = 3.11$, $p < .001$; O_2 - P_4: $t_{(53)} = 3.16$, $p < .001$), as well as in the P300-amplitudes (O_1 - P_3: $t_{(53)} = 5.36$, $p < .001$; O_1 - P_4: $t_{(53)} = 5.03$, $p < .001$; O_2 - P_3: $t_{(53)} = 5.27$, $p < .001$; O_2 - P_4: $t_{(53)} = 5.00$, $p < .001$). Similar results were obtained in the second trial block.

Hemispheric Differences

Using t-test for dependent measures, hemispheric differences in the latency and amplitude of the P300-wave were studied. In the first trial no significant difference in P3-latency ($t_{(53)} = .49$, $p < .62$) and P3-amplitude ($t_{(53)} = .09$, $p < .93$) was determined in those variables between the left (O_1 and P_3) and right (O_2 and P_4) hemispheres. Also, there was no difference between left and right hemisphere for P3-amplitude ($t_{(53)} = .07$, $p < .94$) in the second trial.

In the analysis of the habituation effect, a significant decline in P300-amplitude in the second trial block was found only on the O_2 electrode ($t_{(53)} = 2.32$, $p < .05$).

Table 1. Means and standard deviations for amplitudes and latencies of P300-wave measured in the first and the second trial block for the whole sample (N = 54)

Electrode			O_1		O_2		P_3		P_4	
P300			P3A	P3L	P3A	P3L	P3A	P3L	P3A	P3L
Trial block	1.	M	4.5	412.8	4.6	413.7	9.2	389.1	9.2	388.8
		SD	(2.9)	(42.9)	(3.2)	(44.3)	(6.9)	(65.5)	(7.3)	(65.7)
	2.	M	3.8		3.5		8.9		9	
		SD	(3.2)		(2.7)		(6.8)		(7)	

Legend:
Electrode sites: two occipital (O_1 and O_2) and two parietal (P_3 and P_4)
P3A: P300 amplitude, P3L: P300 latency
M: Mean, SD: Standard deviation

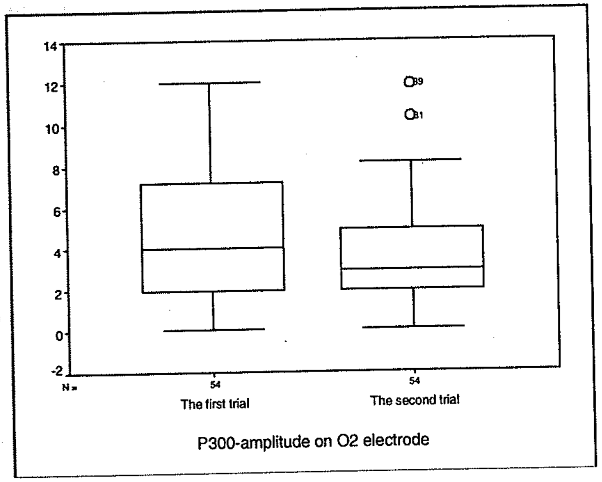


Figure 2. Stem-and-Leaf Plot of P300-amplitude measured in the first and second trial block at O_2 electrode - the habituation effect could be observed

The Relationship between P300 and Personality Variables

The correlations of P300-latencies and P300-amplitudes with personality variables are shown in Table 2. It can be seen that P300-latencies recorded on the parietal

Table 2. The correlations (r) between personality measures of Extraversion, Impulsivity, Adventurousness, and Latencies and Amplitudes of P300-wave on 4 electrodes (O_1, O_2, P_3 and P_4) in the first trial block on the whole sample (N = 54)

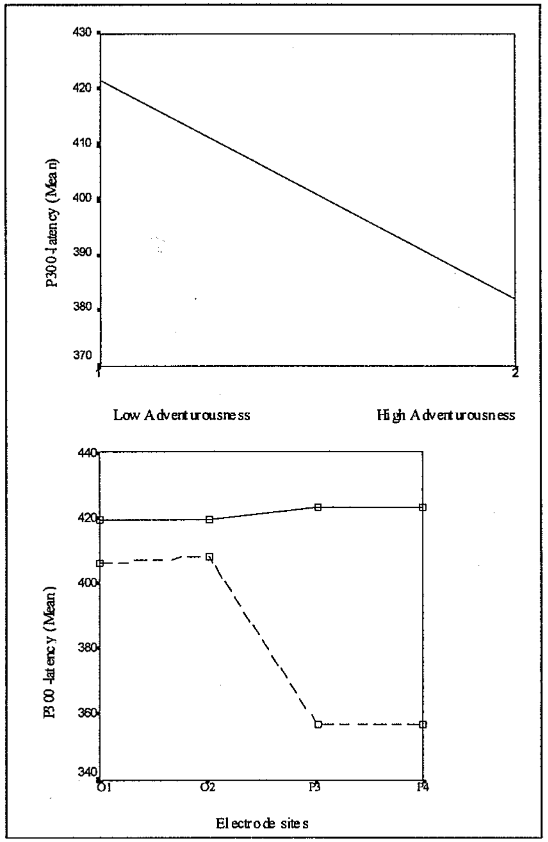
	P3L on O_1	P3A on O_1	P3L on O_2	P3A on O_2	P3L on P_3	P3A on P_3	P3L on P_4	P3A on P_4
E	-.19	-.10	-.20	-.10	**-.31***	.03	**-.31***	.04
I	-.16	-.05	-.16	-.04	-.23	.05	-.23	.09
A	-.11	-.23	-.09	-.23	**-.48****	-.18	**-.48****	-.08

Legend:
Electrode sites: two occipital (O_1 and O_2) and two parietal (P_3 and P_4)
P3A: P300 amplitude, P3L: P300 latency
E: extraversion, I: impulsivity, A: adventurousness
* $p < .05$; ** $p < .01$

electrodes showed a significant negative correlation with both extraversion and adventurousness. There was no significant correlation between the P300-amplitude and any of the personality traits, nor was there correlation between impulsivity and any of the P-300 measures.

A repeated measures ANOVA was performed to examine the differences in P300-waves between groups with high and low levels of extraversion and adventurousness. Significant main effects of extraversion were found neither for P300-latency (F(1) = 3.82, p = .06) nor for P300-amplitude (F(1) = 0.09, p = .76), while a significant effect of adventurousness was found only for the P300-latency (F(1) = 11.13, p = .002)

This finding, illustrated in Figure 3, is due to the P300-latencies recorded on the parietal electrodes, which were significantly shorter for subjects with a high level of adventurousness than those with a low level of adventurousness.



Legend:
1 - Low Adventurousness group of subjects

2 - High Adventurousness group of subjects

Legend:

——— A low level of Adventurousness

----------- A high level of Adventurousness

Figure 3. P300-latency in function of Adventurousness (up) and Adventurousness and four electrode sites (O_1, O_2, P_3 and P_4) (down)

DISCUSSION

ERP Results

The determined P300 amplitudes and latencies were within the expected range (amplitudes >10μV, latencies 300-600 msec), regardless of the electrode or the trial block (Table 1).

The statistically significant differences were obtained between the occipital and parietal electrodes: the P300-latencies were shorter, while the P300-amplitudes were higher on the parietal (P_3, P_4) than on the occipital (O_1, O_2) electrodes in both trial blocks. This finding has confirmed the expected P-300 topography, the expectation being based on the defined centro-parietal neural generators of the P300-wave, leading to the clearest recordings of the P3 on the parietal electrodes (Polich, 2004). No hemispheric differences in the P300-amplitudes have been determined, although the earlier findings had shown a greater activation of the right hemisphere than the left in the classical oddball task, recorded mostly on anteromedial locations (F_3, F_4, C_3, C_4) (Alexander, Polich, 1995; Alexander et al., 1995, 1996; Polich, Hoffman, 1998; Hoffman, Polich, 1999). This could be the consequence of recording the P-300 with only five electrodes: F_Z (ground electrode), O_1 and O_2 (occipital) and P_3 and P_4 (parietal), which is a standard procedure for recording the visual P300-wave with the device we have used (Sapphire[II] User Manual, 1996). We have, therefore, no recordings from the anterior electrodes, which usually reflect hemispheric differences in activation.

The significant decrease in the P300-amplitude only on the O_2 electrode in the second trial block, indicating a habituation effect, was expected, as the occipital electrodes are those corresponding to the neural basis of the visually evoked potentials (Dabić-Jeftić, Mikula, 1994). This finding suggests that a high level of monotony was induced by the employed visual task, leading to differences in P300-amplitudes between extraverts and introverts.

The Relationship between P300 and Personality Variables

The finding of a significant correlation between extraversion and P300-latency confirms the theoretical assumption about introverts being more cortically aroused than extraverts, which is manifested in their faster cognitive processing and shorter P300-latencies. This hypothesis has been confirmed in the work of Brebner (1983, 1990), where introverts have also shown shorter P300-latencies compared with extraverts, while at the same time having longer reaction times. This was explained by the nature of introverts as *"geared to inspect"* and extraverts as *"geared to respond"* (Brebner, Cooper, 1985). Doucet and Stelmack (2000) have used the measures of P300-latencies, reaction time and movement time, while varying the type of task (four types made up of (in)congruent and (in)compatible characteristics). Their results showed significantly longer P300-latencies in extraverts than introverts in three types of task, but in the simplest one (congruent compatible) the extraverts showed shorter P300-latencies than introverts. This finding suggested that P300-latency was very sensitive to task demands - when they were very low and tended to induce monotony the differences between extraverts and introverts changed direction and P300-latency became shorter in extraverts. Our results support the notion about the effects of task demands: the classical visual oddball task we used was low demanding and the pause between the two trial blocks was very short, inducing monotony (as already shown by the observed habituation effect).

The analyses including advènturousness show that the observed weak relationship between extraversion and P300-latency could be attributed to this trait, which is subsumed under extraversion. The faster cognitive processing in highly adventurous subjects could be related to their characteristics of readiness and openness for new and unusual situations. They also exhibit the tendency to take risks while being completely aware of this risky behavior, which requires one to be highly focused and organized, and to take control in such situations. As highly impulsive subjects lack that kind of planning, advance organizing, and proactive behavior in general, it is not surprising that no correlation has been found between P300-latency and impulsivity.

CONCLUSION

The expected P300-topography was confirmed, as significantly longer latencies and significantly lower amplitudes were recorded on the occipital electrodes compared with those recorded on the parietal ones. A tendency of P300-amplitude decrease in the second trial block, indicating a habituation effect, has been determined only on the O_2 electrode. No significant correlations were established between either extraversion or adventurousness and P300-amplitude. But subjects with higher levels of extraversion and adventurousness showed significantly shorter P300-latencies recorded on the parietal electrodes (P_3 and P_4) compared with those with lower levels of these traits. The relationship between adventurousness and P3-latency was more prominent, so the effect of extraversion could be mainly attributable to adventurousness. Finally, there was discussion of how findings could be explained in terms of the variability in task demands used in the research, when clearer interpretation could be obtained by using more complex oddball tasks and technically more advanced devices for recording the evoked brain potentials. This could also enable researchers to explore the more specific functional role of P300-wave viewed either as a cognitive index or as a physiological index of certain personality traits.

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P300 A EXTROVERZIA VO VIZUÁLNEJ ODDBALL PARADIGME

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Súhrn: Cieľom výskumu bolo skúmanie vzťahu medzi P300, vyvolaným štandardnou vizuálnou oddball paradigmou a extroverziou meranou Eysenckovým osobnostným dotazníkom (EOD-RA). Výskumu sa zúčastnilo 54 žien, praváčok, vo veku od 19 do 23 rokov. U každej účastníčky sme P300 merali pomocou okcipitálnych a parietálnych elektród v dvoch opakovaných meraniach. Bez ohľadu na dané meranie bol účinok elektród signifikantný pre obe latencie a amplitúdy. V druhom meraní sa objavila tendencia k nižším P300 amplitúdam, čo poukázalo na efekt habituácie. Účastníčky s vyššou extroverziou prejavili signifikantne kratšie P300 latencie zaznamenané skupinou parietálnych elektród (P_3 a P_4). Keďže sme však zistili výraznejší vzťah medzi podčrtou extroverzie, dobrodružnosťou, a P300 latenciou, účinok extroverzie môžeme vo väčšej miere pripísať dobrodružnosti. Výsledky sme skúmali v kontexte arousal teórie a náročnosti úlohy.