Original Papers

Polish Psychological Bulletin
2013, vol. 44(1), 92-101
DOI -10.2478/ppb-2013-0010

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ELECTROCORTICAL CORRELATES OF TEMPERAMENT

Abstract *The aim of this study was to investigate the relationship between three temperament dimensions: strength of excitation, strength of inhibition and mobility measured by Pavlov's Temperament Survey (PTS), and amplitudes and latencies of evoked brain potentials (N1, P2, N2, P3 & SW) measured by a visual oddball paradigm in two blocks. The participants were female psychology students (N=54) with mean age of 20.*
Significant positive correlations were determined between amplitudes of N1-P2-N2-P3 components and strength of excitation and mobility in the first and second block, mostly on parietal electrodes, as well as significant negative correlations of amplitudes of N1-P2-N2-P3 components and strength of inhibition. Considering measurement limitations important future study directions have been given.

Key words: *Pavlov's typology of temperament, evoked potentials, students*

Introduction

The discussion about clear distinction between temperament and personality has a long history (Rathee & Singh, 2001). The main characteristics of temperament are that it: a) is relatively strongly biologically based; b) tends to appear early in life; c) exerts broad effects upon behaviour; d) concerns behavioural characteristics such as tempo and endurance rather than the specific content of behaviour (Newberry, Clark, Crawford, Strelau, Angleitner, Jones & Eliasz, 1997). In other words: *"Temperament refers to basic, relatively stable personality traits which have been present since early childhood, occur in man, and have their counterparts in animals. Being primarily determined by inborn neurobiochemical mechanisms, temperament is subject to slow changes caused by maturation and individual-specific genotype-environment interplay"* (Strelau, 2001, p. 312). Strelau (1983) considered that temperament traits were primarily biologically based while personality traits were primarily socially based, even though the narrow range of traits heritability does not allow for a distinction on this basis alone (Zuckermann, 1992). This distinction is not supported by the current personality theories (Canli, 2006) which emphasize that structure of temperament and personality consists of a relatively small number (4 or 5) of higher-order traits (Depue, 2006) which do not exist detached from basic brain-behaviour systems, but rather are defined by them (Corr, 2007). "*Eysenck argued, and Gray showed, that the science of behaviour is best achieved by exploring multiple levels of analysis"* (Corr, 2007, p. 669). So, research presented in this paper contributes to understanding relationship between temperamental traits and biological processes as it examines biological basis of temperament by analysing self-assessed dimensions of temperament and EP-measurement within correlational study design.

I. P. Pavlov (1935) has conducted the first empirical studies on temperament within his investigation of different aspects of classical conditioning in dogs. Those studies presented the basis for his hypothesis that observed individual differences could be explained by individual-specific properties of the central nervous system (CNS), such as strength of excitation or strength of inhibition (Strelau, Angleitner & Newberry, 1999). Pavlov based his approach on the so-called "nervism" paradigm according to which any behaviour is governed and regulated by the CNS. The theory has been modified later by many Russian and War-

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saw researchers (Strelau, Angleitner & Ruch, 1990), but the last and the most influential one has been made by Jan Strelau (1983). Strelau (1983) kept Pavlov's basic CNS-properties (strength of excitation, strength of inhibition, mobility and balance) which represent the neurophysiologic characteristics that underlie individual differences in behaviour (Gray, 1964). Different configurations of the CNS-properties result in different types of CNS and they present the physiological basis of temperament (Strelau et al., 1999). CNS properties have been conceived with focus on the individual's ability to adapt. Thus strength of excitation (SE) refers to the functional capacity of the nervous system that reflects in the ability to endure intense or long-lasting stimulation without development of protective or transmarginal inhibition. In other words, SE represents efficiency in conditions of high level of stimulation and preference for such situations. Since individuals in their everyday lives are confronted with stimuli of great intensity, Pavlov (1951-1952) considered SE to be the most important CNS-property. Strength of inhibition (SI) refers to conditioned inhibition and the ability to maintain a state of conditioned inhibition. In behavioural terms, it represents the person's ability to stop or delay a given behaviour and to refrain from certain behaviours and reactions when required. In individuals with strong inhibitory process, prolonged conditioned inhibition does not cause disturbances. Mobility of nervous processes (MO) manifests in the ability to quickly and adequately react to changes in the environment. So, mobility refers to the ability to give way -according to the external conditions, to give priority to one impulse before the other (Pavlov, 1951-1952). The last CNS-property is balance of nervous system (BA) or equilibrium which is defined as the ratio of strength of excitation and strength of inhibition. The functional meaning of BA consists of the ability to inhibit certain excitations when required in order to evoke other reactions according to the demands of the surroundings.

Regarding psychophysiology studies of temperament, especially those which used neo-Pavlovian concept of CNS-properties, Strelau (1991) emphasized that psychophysiological and psychophysical measures may be used in temperament research only under very strict requirements and limited circumstances. Within studies of construct validity and biological determinants of CNS-properties no significant correlation was found between strength of excitation measured by the STI (Strelau Temperament Inventory; Strelau et al., 1990) and strength of excitation measured by two laboratory measures: the laboratory scores of arousability – the slope of the reaction time curve in auditory and visual version. Strelau (1991) concluded that psychophysiological measures of SE were not comparable to the psychometric scores of this CNS property measured by questionnaires. Since then, psychophysiological methods have been developed further, as well as the psychometric measures of Pavlovian CNS-dimensions. Strelau, Angleitner and Newberry (1999) constructed the Pavlovian Temperament Survey with intention to facilitate cross-cultural studies of Pavlov's dimensions of temperament. One of the progressive and most frequently used psychophysiological methods is the evoked brain potentials method. Picton (1980) defined the evoked potentials (EPs) or event-related potentials (ERPs*) as changes in the electrical activity of the nervous system recorded in response to physical stimuli, in association with psychological processes, or in preparation for motor activity. Alternatively, they represent voltage fluctuations that are associated in time with some physical or mental occurrence (Picton et al., 2000). ERPs are time-locked, i.e. they appear in a precisely determined period after the given stimulus (Polich, 1993). Compared to EEG, the time resolution of EPs presented its great advantage in psychophysiological studies. From two main groups of EP-components: evoked potentials (those which follow the external physical stimuli) and emitted potentials (those which are connected with the processes of preparing for some cognitive or motor activity) (Sutton et al., 1965), the EPs: P1, N1, P2, N2, P3 and Sw have been measured in this study. Long Latency Exogenous Components (P1, N1, P2) occur after the stimulus, from 100 msec and up to 200-300 msec, and they are called transient since they share characteristics with endogenous components. The P1 usually peaks at about 50 msec, N1 at about 80-100 msec, and P2 at about 170-200 msec (Hugdahl, 1995). Although not all authors are of the same opinion, it is generally assumed that these waves are generated in the cortex of the temporal lobe (Hugdahl, 1995). N1 is related to the selective attention; therefore it is not an exclusively exogenous component. P2 is related to the early information processing, and together with N1 encodes the physical characteristics of stimuli. Furthermore, N2 component occurs always when a rare and unexpected stimulus appears, and it is connected with perceiving the stimulus in the periphery of subject's attention and reaction time. It occurs around 200 msec after given stimulus and its amplitude is in reverse proportion to the probability of stimuli emersion. If a certain change in the surroundings is relevant to the given task, N2 should be followed by P3 (Donchin et al., 1978). P3 component has been considered as a cognitive component since its main psychological correlates are attention allocation and changes in working memory. It manifests as a big positive wave with latency of 250-600 msec and it appears while subject is actively focused on a given stimulus and/or when a novel or surprising stimulus appears. Within personality research, P300 has been the most studied EP. Generally it manifests as fronto-parietal activation (Polich & Kok, 1995; Polich, 2004). In this research Slow wave activity (Sw) was measured. This component appears while subjects wait for the task to begin, it lasts for 3-4 sec and has a long latency – longer than 1 sec. It was determined that same variables that influence P3, influence this wave, but with rather different distribution on the scalp (Hugdahl, 1995).

There are a number of studies that tried to understand and clarify the complex relationship between personality and electrocortical activity. Majority of these used the Eysenck's model of personality. Eysenck's personality theory (1967) attempted to explain biological mechanisms potentially responsible for the personality dimensions and has produced many empirical findings and psychometric data on measures of personality. On the other hand, existing data on EP-components and personality dimensions is mostly limited to PEN definition of personality. In order to further the knowledge on biological underpinnings of personality and temperament, we considered a study on relationship between earlier mentioned EPs and a somewhat different theoretical model: Pavlov's CNS-properties useful. Since PTS scales consist of items that refer to typical behaviours that reflect dimensions of temperament and Pavlovian dimensions are supposed to be largely biologically determined it was assumed that CNS-properties would demonstrate a more consistent and solid relationship with electrocortical indexes than was the case with Eysenck's dimensions. In first electroencephalographic studies of temperament that were conducted during 1960s (Nebylitsin, 1961, 1963) it was determined that individuals with strong CNS had significantly higher variance of EEG-amplitude than the individuals with weak CNS (Klyagin, 1974). Larger EEG-amplitude variance has been operationalized as the person's ability to save energy and to endure in certain activity. Regan (1972) has found significant correlation between EP-amplitudes and stimuli intensity. Bazylevich (1974) pointed out that the strength of CNS is manifested when the increasing stimulus intensity cases to evoke increased reaction, he named this effect the law of strength and he used somatosensory potentials to measure the strength of nervous system. Chuprikova (1977) suggested the use of early evoked potentials amplitude (N1 & P2) to different intensities of stimuli for determining strength of CNS. Decrease of EP amplitudes in response to stronger stimuli is indicative for a weaker nervous system. Danilova (1986) investigated the evoked brain potentials and heart rate in subjects with strong and weak CNS (N=10; subjects were divided by their score on STI) during task performance in general and learning in particular. The procedure consisted of three sessions: 1) first four blocks with different light flashes were presented; 2) subjects were required to differentiate the blocks by frequency and to react with a movement of hand; 3) the subjects were instructed to react to nontarget stimuli. Overall, strong nervous system subjects have been superior in both speed and efficiency at the beginning and at the end of the experiment. At the beginning of the task, subjects with a strong CNS (N=5) showed significantly lower amplitudes of N150 and P200. Also, they had increased heart rate and increased EP-amplitudes parallel with the decreased errors. In the weak group, however, the decrease in errors was accompanied by a reduction in heart rate and a decrease in the positive amplitude of P200 and the negative amplitude in N150. Successful learning in strong subjects has been associated with an increase in arousal level, whereas the reverse was true for weak subjects. These findings were in accordance with the results of De Pascalis (1993), who investigated the relationship between hemispheric asymmetry, personality and temperament. 60 subjects were measured on N1-P2-N2-P3 components in auditory and visual modality and afterwards they completed personality questionnaires of Eysenck and Strelau. Author found weak but significant negative correlation between strength of excitation and N1-amplitude posterior, P3-amplitude anterior in auditory modality, and P2-amplitude anterior in visual modality. He concluded that higher levels of strength of excitation were related to a decrease in EP-amplitude. On the other hand, strength of inhibition was significantly positively correlated only with behavioural measure of time reaction in both modalities. Overall, SE and SI were in higher correlations with behavioural performance than with electrocortical activity (De Pascalis, 1993). Those results were confirmed in the second study of the same author (De Pascalis, 1994), where in the no-stress situation strong type subjects had faster reaction time, which was in agreement with Strelau's (1983) hypothesis. He postulated that the amplitude of the averaged evoked potentials (AEPs) may be considered as an example of electrophysiological phenomena related to arousal. After considering different personality operationalizations, Strelau (1985, 1987) pointed out that augmenters, sensation seekers, the weak type of NS, high-impulsive individuals and introverts have a higher EP-amplitude, whereas reducers, sensation avoiders, strong type of NS, extraverts and low-impulsive had lower EP-amplitudes. In the situations of high-intensity stimulation EP-amplitude will be decreased in reducers, and they will probably be able to endure rather intense stimulation before reaching their threshold of transmarginal inhibition, which is also the main characteristic of the strong nervous type. This is consistent with Eysenck's hypothesis that introverts are more cortically aroused, and that reflects in their higher EP-amplitudes (Stenberg, 1994), but only in highly demanding tasks, where there is no habituation effect. Recent studies showed that differences in personality affect the intra-block changes especially for the P3-amplitude when the target stimulus is repeated. This reflects different processing strategies in response to monotonous situations used by introverts and extraverts (Lindin, Zurron & Diaz, 2007; Tatalović Vorkapić, 2010; Tatalović Vorkapić, Tadinac & Rudež, 2010).

The main objective of this study was to examine the relationship between CNS-properties: strength of excitation, strength of inhibition and mobility and amplitudes and latencies of evoked potentials (N1, P2, N2, P3 & Sw) elicited by the visual oddball paradigm in two blocks. According to the previous findings, it was expected that the subjects with the higher levels of strength of excitation would show significantly lower EP-amplitudes considering their more pronounced ability to preserve the energy. Similar results are expected within the relationship of mobility and evoked potentials, because of its significant positive correlation with strength of excitation. If pronounced habituation effects occur, it is possible that no significant correlation will be found, or even that determined correlations will be in the opposite direction. Also, no significant correlation between SI and evoked potentials is expected. Finally, although currently there are no previous empirical studies on relationship of mobility and EP-latencies, since mobility refers to ability to react quickly and adequately to changes in the surroundings, it could be expected that mobility and EP-latencies will be in significant negative correlations.

Method

Subjects

Fifty four female subjects participated in this study (*M*=20.5 years, *SD*=1.28, with age range 19-23). All were undergraduate psychology students from the Department of Psychology, Faculty of Humanities and Social Sciences, University of Rijeka in Croatia. They were also right-handed, naive to electrophysiological studies, and reported no visual or neurological/psychiatric problems. All subjects read and signed a written consent stating that their participation in the study was voluntary, and were informed they will receive course credit for their participation.

Questionnaire

Pavlov's CNS-dimensions were measured by self-rated questionnaire, i.e. standardized Croatian version of Pavlov's Temperament Survey (Lučev, Tadinac, Tatalović, 2002) which measures Strength of excitation (SE), Strength of inhibition (SI), Mobility (MO) and Balance (BA). The questionnaire consists of 69 items – 23 items for each subscale. Typical item of the Strength of excitation subscale is: *"I like very demanding jobs"*; for Strength of inhibition subscale: *"I can hide my anger if needed"*; and for Mobility subscale: *"When my job changes, I'm quick to adjust"*. Balance is the secondary CNS property (SE/SI) and results of this scale were not taken into account in this study. Subjects answered questions on the Likert's 5-point scale (1-totaly disagree to 5-totaly agree). Item analysis confirmed satisfactory levels of reliability of PTS scales found in previous studies (Lučev, Tadinac, Tatalović, 2002; Lučev, Tadinac, Tatalović Vorkapić, 2006; Strelau et al., 1999). Cronbach Alpha coefficient obtained in this study was α=.86 for SE; α =.78 for SI and α=.89 for MO.

Evoked potentials' measurement and procedure

Evoked potentials have been widely measured by an auditory or visual oddball paradigm – the task of simple stimuli discrimination. During such a task the subject listens (looks) to a sequence of tones (visual stimuli), where one tone (visual stimulus) is usually the target. The subject's task is to press the button on hearing (seeing) the target stimulus (Polich, 2004).

After they were given general instruction students completed PTS and were informed of schedule of EP-measurement at the EP-laboratory, Department of Neurology at Clinical Hospital Centre in Rijeka. Each subject underwent a measuring of previously described evoked brain potentials: N1, P2, N2, P3 & Sw in two repeated blocks with the inter-block interval of 2 minutes. All recordings were made in the course of four months, always on Wednesdays and always at the same time – noon, to avoid the time-of-day-effect on evoked potentials. Because of the limited time laboratory was available to us, subjects were coming to complete their measurements according to their schedule in groups of 4-6. Evoked potentials were elicited by the standard visual oddball paradigm, chosen because of its less pronounced monotonous effect on the subjects. A Medelec/TECA Sapphire[II] 4E, Vickers Medical device with five Ag/AgCl disc electrodes was used. The standard recording procedure for visual ERPs uses two groups of active electrodes: two occipital (O_1 & O_2) and two parietal (P_3 & P_4) electrodes according to 10-20 system, and referred to Fz. 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. In each block, 40 visual stimuli were presented to one subject, i.e. for two blocks 80 stimuli. The total number of target stimuli was 16 (8+8) and non-target 64 (32+32). The ratio of target and non-target stimuli was 16:64, or 1:4. In other words, 20% of stimuli were rare (target) checkerboards and they were consisting of the small quadrangles, whereas the remaining ones were frequent (nontarget) checkerboards that were consisting of the big quadrangles, presented in the random order. The rhythm of stimuli alteration was 1/1 sec. With the inter-stimulus interval of 1 sec, EP-measuring for one subject was short, about 5 minutes for both blocks. Subjects were instructed to look at the red circle in the centre of the monitor and to react to the target stimuli by pressing the pen. Unfortunately, due to technical limitations there was no possibility to measure reaction time of the subjects.

The storage of measured EP-data included automatic averaging procedure and artefacts' rejection due to eye-blinks or something else (8 artefacts were rejected). Since there were no possibility for differentiating the EPs according to frequent standards vs. infrequent deviants and for automatic marking of the measured evoked potentials, marking was done manually using a cursor, with baseline correction or sharpening the EP-curve, by the same medical technician for both blocks. In the first block, the marking criterion was the peak amplitude based on the defined amplitude parameters for each evoked potential. After marking the peak amplitude, the software automatically marked the relevant latency. So, peak-to-peak amplitude and absolute latency to

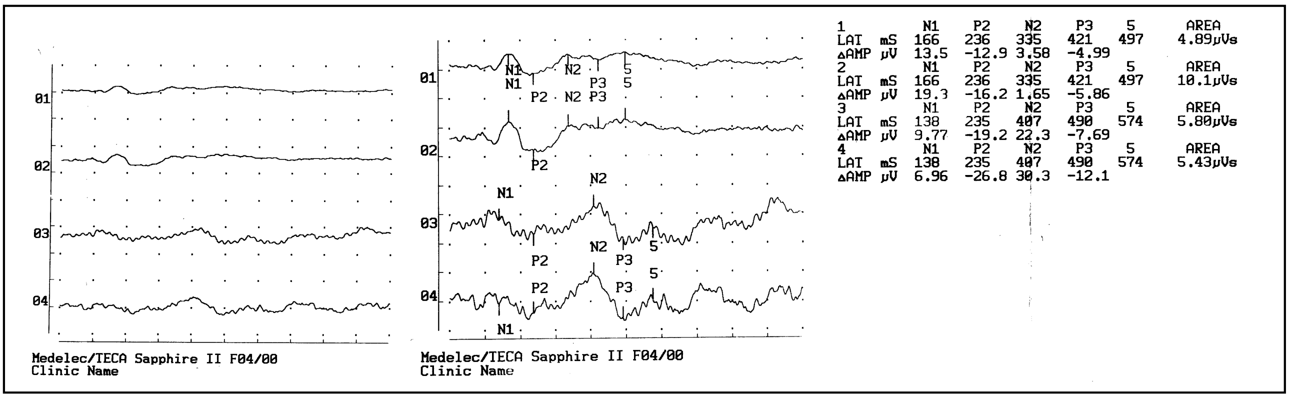

Figure 1. The example of unmarked (left) and manually marked and sharpened (right) EP-curve with all amplitudes and latencies of measured evoked potentials in the first block

wave peak were marked. To avoid the effect of the latency jitter (Coles, Gratton, Kramer, & Miller**,** 1986; Hoormann, Falkenstein, Schwarzenau, & Hohnsbein, 1998), and to make evoked potentials more stable over blocks, in the second block all evoked potentials were marked by the same latencies as in the first block. For each subject there was the same P300-latency (determined in the first block) in both blocks and different P300-amplitudes. An example of the averaged and artefact-corrected unmarked and then manually marked ERP curves for one subject in the first block are shown in Figure 1.

Results

Descriptive statistics for PTS-dimensions and evoked potentials

The group averages for three PTS-dimensions (Table 1): Strength of excitation (*M*=53.8; *SD*=8.7), Strength of inhibition (*M*=65.1; *SD*=6.9) and Mobility (*M*=66.2; *SD*=9.4) did not substantially differ from the results obtained on the Croatian standardization sample (Lučev, Tadinac & Tatalović, 2002).

Table 1. Means (M), standard deviations (SD), results' range and K-Sz (p-values) for the Strength of excitation (SE), Strength of inhibition (SI) and Mobility (MO) with their intercorrelations (r, p-values) for the whole sample (N=54)

		M	SD	Range	K-Sz	p	SI	MO
CNS-properties	SE	53.8	8.7	34-72	.70	.72	.33 (p=.02) [.06/.57]	.68 (p=.00) [.55/.79]
	SI	65.1	6.9	50-82	.82	.51		.36 (p=.01) [.08/.59]
	MO	66.2	9.4	45-89	.72	.68		

Legend: K-Sz=Kolmogorov-Smirnov test for testing the normality of distribution

As it can be seen in Table 1, this sample of psychology students showed more pronounced ability to inhibit their reaction if there was a need for that, and the ability to quickly and adequately react to changes in the environment. Furthermore, distributions of results on PTS scales were not significantly different from normal distribution, and we could justly apply parametric statistical procedures on this sample of data.

All intercorrelations found between PTS-dimensions were statistically significant (see Table 1) and in agreement with results of other studies with PTS (Strelau et al., 1999). All PTS-dimensions correlate positively with each other, with the highest correlation between strength of excitation and mobility. Individuals with higher levels of strength of excitation also have more pronounced strength of inhibition, as well as higher results on mobility, which is in accordance with the Strelau's theoretical model (1983). Confidence intervals of correlation coefficients could be observed in Table 1, too. The smallest range of correlation confidence intervals is determined concerning the relationship between strength of excitation and mobility, which is in accordance with the highest determined intercorrelation between those two PTS-dimensions (see Strelau et al., 1999).

In the Table 2 mean amplitudes and latencies of all evoked potentials (N1, P2, N2, P3 and Sw) measured in two blocks are presented. They were determined according to their points of maximum negativity or positivity – latency. Due to the technical limitations of the device used, a possibility of a latency jitter could not be avoided by using the Woody filter method, and therefore the P300-latencies were made constant over blocks and used for marking the EPs in the second block. Although a lot of valuable information has been lost in this way, the additional reason for using this method was the evidence of a very small impact of habituation on latencies (Polich, 1989; Lin & Polich, 1999; Bruin, Kenemans, Verbaten, & Van der Heijden, 2000), especially when pauses between the blocks are very short (1-2 minutes).

Table 2. Means and standard deviations for the EPs: N1, P2, N2, P3 and Sw (amplitudes and latencies) measured in the first and the second block for the whole sample (N=54)

Electrode	Mean (Standard Deviation)					
	EP	**N1**	**P2**	**N2**	**P3**	**SW**
O_1	**latency**	143.3(29.5)	220.8(20.1)	300.6(36)	412.8(42.9)	495.8(58.2)
	amplitude1	10.2(5.3)	9.2(5.1)	4.5(4.2)	4.5(2.9)	
	amplitude2	10.4(5.4)	8.9(4.6)	4.6(4.8)	3.7(3.2)	
O_2	**latency**	143.3(29.5)	220.4(19.9)	300.6(35.9)	413.7(44.3)	499.2(58)
	amplitude1	12.4(6.4)	10.8(6.1)	4.9(5.3)	4.6(3.2)	
	amplitude2	12.1(6.3)	10.4(5.6)	4.9(5)	3.5(2.7)	
P_3	**latency**	138.1(30.1)	209.4(24.7)	291.5(51.5)	389.1(65.5)	480.6(77.6)
	amplitude1	13.4(7.5)	13.6(8)	8.9(6.1)	9.2(7)	
	amplitude2	13.1(7.2)	11.7(8.3)	8.5(6.3)	8.9(6.8)	
P_4	**latency**	137.7(30.3)	209.9(24.9)	291.4(51.5)	388.8(65.7)	480.9(78.3)
	amplitude1	15.4(8.5)	14.7(9.1)	8.1(5.2)	9.2(7.3)	
	amplitude2	14.7(7.8)	13(8.3)	7.7(5.7)	9(7)	

Legend: Electrode sites: two occipital (O1 and O2) and two parietal (P3 and P4)
EP (evoked brain potentials): N1, P2, N2, P3 & SW
Amplitude1: amplitude measured in the first block
Amplitude2: amplitude measured in the second block

Table 3. The correlations (r), their significance levels (p) and confidence intervals [CI] between PTS-dimensions: Strength of excitation (SE), Strength of inhibition (SI) and Mobility (MO) and amplitudes in the first (amplitude1) and second block (amplitude2) of N1, P2, N2 and P3 on all electrodes (O1, O2, P3 & P4)

EP-amplitudes			SE	SI	MO
Elektrode O_1	N1	Amp1	.06 (p=.69) [-.27/.34]	.23 (p=.10) [-.10/.53]	.00 (p=.98) [-.32/.28]
		Amp2	.10 (p=.46) [-.22/.37]	.15 (p=.29) [-.14/.43]	-.07 (p=.63) [-.36/.22]
	P2	Amp1	.08 (p=.57) [-.24/.38]	.12 (p=.38) [-.22/.44]	.08 (p=.58) [-.20/.35]
		Amp2	.19 (p=.17) [-.14/.46]	.26 (p=.06) [-.05/.504]	.15 (p=.28) [-.12/.37]
	N2	Amp1	.08 (p=.59) [-.24/.38]	-.11 (p=.42) [-.29/.12]	.06 (p=.69) [-.32/.42]
		Amp2	.02 (p=.90) [-.33/.34]	-.22 (p=.12) [-.39/-.02]	.04 (p=.79) [-.37/.44]
	P3	Amp1	-.03 (p=.83) [-.30/.27]	.16 (p=.23) [-.11/.42]	.10 (p=.48) [-.15/.37]
		Amp2	-.01 (p=.94) [-.33/.31]	-.12 (p=.39) [-.33/.13]	.08 (p=.56) [-.23/.39]
Elektrode O_2	N1	Amp1	.04 (p=.77) [-.23/.33]	-.07 (p=.60) [-.31/.17]	-.01 (p=.96) [-.26/.26]
		Amp2	.03 (p=.84) [-.25/.32]	-.22 (p=.11) [-.41/-.01]	-.08 (p=.58) [-.31/.20]
	P2	Amp1	.13 (p=.35) [-.17/.40]	.00 (p=.98) [-.35/.34]	.23 (p=.09) [-.11/.52]
		Amp2	.12 (p=.37) [-.18/.38]	.08 (p=.57) [-.25/.35]	.19 (p=.17) [-.17/.47]
	N2	Amp1	.11 (p=.41) [-.19/.40]	-.22 (p=.12) [-.45/.10]	.08 (p=.54) [-.26/.46]
		Amp2	.08 (p=.59) [-.26/.40]	-.26 (p=.06) [-.47/-.01]	-.02 (p=.90) [-.40/.39]
	P3	Amp1	.00 (p=.97) [-.28/.29]	.16 (p=.26) [-.10/.38]	.06 (p=.68) [-.19/.36]
		Amp2	.10 (p=.47) [-.38/.25]	-.15 (p=.27) [-.39/.16]	-.04 (p=.77) [-.31/.27]
Elektrode P_3	N1	Amp1	**.32** (p=.02) [.05/.54]	.14 (p=.33) [-.13/.41]	.17 (p=.21) [-.07/.44]
		Amp2	**.27** (p=.05) [.03/.49]	.21 (p=.13) [-.06/.46]	.26 (p=.06) [-.02/.51]
	P2	Amp1	**.36** (p=.01) [.18/.55]	.04 (p=.75) [-.20/.28]	**.29** (p=.03) [.02/.55]
		Amp2	.20 (p=.14) [-.09/.46]	.12 (p=.37) [-.11/.37]	**.33** (p=.01) [.08/.55]
	N2	Amp1	.11 (p=.42) [-.13/.32]	.01 (p=.92) [-.28/.30]	.16 (p=.25) [-.10/.40]
		Amp2	**.30** (p=.03) [.02/.56]	-.05 (p=.72) [-.29/.21]	**.40** (p=.00) [.15/.64]
	P3	Amp1	-.06 (p=.66) [-.36/.23]	-.16 (p=.26) [-.37/.09]	.10 (p=.48) [-.34/.20]
		Amp2	.24 (p=.08) [-.04/.48]	**-.28** (p=.04) [-.50/-.03]	.20 (p=.15) [-.13/.52]
Elektrode P_4	N1	Amp1	-.06 (p=.69) [-.34/.24]	-.16 (p=.23) [-.41/.08]	.02 (p=.92) [-.24/.29]
		Amp2	.01 (p=.95) [-.22/.25]	-.01 (p=.95) [-.28/.27]	.14 (p=.30) [-.05/.33]
	P2	Amp1	.23 (p=.10) [-.01/.45]	.03 (p=.82) [-.24/.30]	.19 (p=.16) [-.09/.46]
		Amp2	.20 (p=.14) [-.07/.44]	.16 (p=.26) [-.13/.41]	**.28** (p=.04) [.03/.51]
	N2	Amp1	.20 (p=.14) [-.01/.40]	**.35** (p=.01) [.03/.57]	.26 (p=.06) [.02/.50]
		Amp2	.23 (p=.09) [.00/.46]	.17 (p=.21) [-.06/.41]	**.28** (p=.04) [.03/.51]
	P3	Amp1	.06 (p=.66) [-.23/.33]	-.12 (p=.41) [-.30/.10]	-.05 (p=.70) [-.28/.20]
		Amp2	**.31** (p=.02) [.03/.55]	**-.28** (p=.04) [-.49/-.04]	.12 (p=.40) [-.19/.44]

The relationship between evoked potentials and Pavlov's CNS-properties

To analyse the relationship between evoked potentials and PTS-dimensions, Pearson's correlation coefficients were calculated for every electrode (O_1, O_2, P_3 & P_4) in the first and second block. In addition, since PTS scales of SE and MO are highly intercorrelated and it is unclear whether significant correlations are specific for SE or MO scores, a set of regression analyses which the accent on SE and MO semi-partial correlations was conducted. Furthermore, in the Table 3, the correlation coefficients between EP-amplitudes from the first and second block at all electrodes for the evoked potentials: N1, P2, N2 & P3 and PTS-dimensions are presented, along with confidence intervals of calculated correlation coefficients.

N1-P2-N2-P3-amplitudes measured in the first and second block were in significant positive correlations with strength of excitation and mobility which was not in accordance with the first hypothesis. High intercorrelation of MO and SE make it harder to interpret the significant correlations between these PTS scales and EP-amplitudes. It could be that these significant correlations are more specific for SE or MO scores, than for the SI scores. In addition, significant correlations between EP-amplitudes and SE/MO dimensions are positive (from r=.27 to r=.40), while significant correlations between EP-amplitudes and SI are mostly negative (r=-.28). Since PTS-subscales had very high significant intercorrelations, a set of multiple regression analyses was conducted in order to clarify this relationship. Regression analyses were performed (Table 4) only for those EP-amplitudes (as criterion variables) which showed significant relationships with SE, SI or/and MO (as predictor variables) (see Table 3), i.e. for: N1-amplitude in the first and second block on P3-electrode; P2-amplitude in the first and second block on P3-electrode; N2-amplitude in the second block on P3 and P4 electrodes and in the first block at P4 electrode; P2-amplitude in the second block on P4-electrode; and P3-amplitude in the second block on P3 and P4 electrodes. Overall, it was determined that PTS-dimensions were significant predictors only for P3-amplitude in the second block at both parietal electrodes, for N2-amplitude in the second block at P3-electrode, and in the first block at P4-electrode. Significant changes from zero-order correlations to partial correlations could be observed between PTS-dimensions and: N1-amplitude in the second block at P3-electrode; P2-amplitude in the first block at P3-electrode and in the second block at P4-electrode; N2-amplitude in the second block at both parietal electrodes; and P3-amplitude in the second block at P4-electrode (Table 4).

Table 4. Partial correlation coefficients for those EP-amplitudes that significantly correlated with PTS-dimensions as results of conducted regression analyses

EP-amplitudes			SE	SI	MO	R	R2	F(p)
Elektrode P_3	N1	Amp1	.26	.05	-.06	.32	.10	1.89 (.14)
		Amp2	.12	.11	.08	.31	.10	1.78 (.16)
	P2	Amp1	.02	.01	.19	.28	.08	1.41 (.25)
		Amp2	-.03	.01	.26	.33	.12	2.10 (.11)
	N2	Amp2	.07	-.24	.33	.46	.21	**4.38 (.01)**
	P3	Amp2	.20	-.40	.14	.46	.21	**4.49 (.01)**
.Elektrode P_4	P2	Amp2	-.01	.06	.19	.29	.08	1.53 (.22)
	N2	Amp1	.00	.28	.12	.38	.14	**2.81 (.05)**
		Amp2	.05	.07	.16	.30	.09	1.59 (.20)
	P3	Amp2	.38	-.41	-.05	.50	.26	**5.71 (.01)**

N1-amplitude at the P3-electrode in the first block showed lower but not significantly different correlation with SE, but even N1-amplitude in the second block showed significant zero-order correlation with SE (r=.27, p=.05), its partial correlation was very low ($r_{partial}$=.12) and pretty much the same as partial correlations with SI ($r_{partial}$=.11) and MO ($r_{partial}$=.08). Although we found statistically significant positive correlations between P2-amplitude in the first block on P3-electrode and SE (r=.36, p=.01) and P2-amplitude in the first block on P3-electrode and MO (r=.29, p=.03), when we analyse partial regression coefficients we can see that specific amount of variance of P2-amplitude in the first block on P3-electrode (criterion variable) explained by MO is higher than specific amount of variance explained by SE. Semi-partial correlation between SE and P2-amplitude in the first block on P3-electrode is $r_{partial}$=.02, while semi-partial correlation between MO and P2-amplitude in the first block on P3-electrode is r_{partia}=.19. Furthermore, semi-partial correlation between N2-amplitude in the second block at P3-electrode and SI ($r_{partial}$=.-.24) was much higher than with SE ($r_{partial}$=.07). Therefore, the specific amount of variance of N2-amplitude in the second block on P3-electrode (criterion variable) explained by SI is higher than specific amount of variance explained by SE, which could not be detected from their zero-order correlations. Finally, even though zero-order correlation between P3-amplitude in the second block at P4-electrode and SI (r=-.28, p=.04) was lower than with SE (r=.31, p=.02), their relationship with aspects of EP potentials was slightly changed when semi-partial correlations were analysed, i.e. semi-partial correlation between P3-amplitude and SI ($r_{partial}$=-.41) is higher than between P3-amplitude and SE ($r_{partial}$=.38).

Discussion

Descriptive statistics confirmed previous findings on PTS-dimensions in student samples, and determined latencies and amplitudes of evoked brain potentials measured were in accordance with results of earlier research (Tatalović Vorkapić, 2010). Values of intercorrelations between PTS-subscales that were determined in this study were in the range that could be expected according to results of studies with different versions of PTS (Strelau et al., 1999). Furthermore, determined EP amplitudes and latencies were within the expected ranges, regardless of the electrode or the block (Table 2). There was a tendency of shortening the latencies from occipital to parietal electrodes on all evoked potentials. Considering the differences between EP-amplitudes from the first and second trial block, there was only one significant decrease determined: in the P300-amplitude on the O_2 electrode in the second trial block (t=2.32; p=.02). This finding indicates a tendency toward habituation effect, since the change was determined only for one evoked potential and only on one electrode. This suggests that a high level of monotony was induced by the employed visual task, a finding that should be taken in consideration when interpreting results on relationship between evoked potentials and PTS-dimensions.

To analyse the relationship between evoked potentials and PTS-dimensions, relevant correlation analyses were conducted. Apart from theoretical assumptions of Pavlov, who emphasized that higher strength of nervous system is closely connected with pronounced ability to conserve the energy, which can be operationalized as increased EEG-variance (Klygin, 1974) or as decreased EP-amplitudes (Strelau, 1983a; De Pascalis, 1993), there are but a few relevant studies that examined relationship between EPs and dimensions of temperament. However, considering the definition of mobility as ability to quickly and adequately react to the environmental changes, it could be expected that subjects with pronounced MO will have shorter EP-latencies. The rationale for expecting negative correlations between mobility and EP-latencies was grounded on psychological-functional role of evoked potentials in perception of new stimuli in surroundings, their selection and categorization of their physical characteristics (Donchin et al., 1978), with the accent on the differentiation of early and late information processing. Nevertheless, the majority of those correlations between EP-latencies and PTS-dimensions were negative, and it could be concluded that there is a small tendency toward negative relationship. If the sample of subjects used in this study was larger perhaps this correlation would be stronger. In the future, it would be useful to closely investigate the relationship between MO and EP-latencies using a greater number of subjects of different age, sex and professions, so that larger variability of results on mobility dimension could be included. Greater number of electrodes with more advanced ERP-apparatus would also result in a valuable improvement in validity of data obtained in future studies.

Coefficients of correlations were obtained in order to examine assumptions about higher CN-strength and greater ability to conserve energy in individuals with strong nervous system and lower cortical arousal (Strelau, 1985). The significant increase in all EP-amplitudes that reflects selective attention, early processing, extraction of stimuli characteristics and changes in working memory was related to higher scores of two PTS-dimensions: strength of excitation and mobility. On the other hand, the relationship between strength of inhibition and EP-amplitudes was rather complex. Significant correlations were found only on parietal electrodes, which in the case of middle and late EP-components could be explained by the fact that they had their neural generators localized fronto-central and fronto-parietal. This should be taken into consideration in planning of future research.

Even though N1-P2-N2-P3-amplitudes measured in the first and second block were in significant positive correlations with strength of excitation and mobility was not in accordance with the first hypothesis, Danilova (1986) reported similar results. In her study, the direction of the relationship direction was changed during the learning process of differentiating the light flashes. At first, the inverted relationship was determined between SE and EP-amplitudes, but at the end of learning task, the increased EP-amplitudes were significantly correlated with higher levels of SE. Although the tendency of habituation effect was established in this study as well, it would be very interesting to conduct a similar research with the possibility of more than two measuring blocks. Another similarity with this research is that Danilova (1986) used a discrimination task with a rather similar level of difficulty as the discrimination task that was used in this study. Both tasks were quite easy, and therefore had a high probability of inducing monotony in subjects. Task difficulty represents a very significant variable to be controlled or varied in the EP-research (Sternberg, 1994), and this as well should be taken into consideration in future studies. The low level of task difficulty could be the main reason for the positive relationship between strength of excitation and EP-amplitudes that was found in this study. De Pascalis (1993) in his research obtained inverse relationship between SE, MO and EP-amplitudes due to the characteristics of task. He used the discrimination task in audio and visual modality, but the level of difficulty was varied in order to keep the highest level of attention in subjects, so that correct answers and reaction time could be measured. There are many indices that show that the level of task difficulty influences findings in studies on relationship between PTS-dimensions and evoked potentials. Difficulty of task was also a relevant factor in studies that investigated the relationship between evoked potentials and extraversion (Sternberg, 1994; Tatalović Vorkapić, 2010; Tatalović Vorkapić, Tadinac & Rudež, 2010). Finally, calculated confidence intervals of all correlation coefficients (Table 3) showed rather wide ranges, which imply great variability in relationship between EP-amplitudes and PTS-dimensions. This variability could be the results of specific measurement of evoked potentials. Generally, evoked brain potentials showed great sensitivity toward influence of numerous, internal and external factors (Dabić-Jeftić & Mikula, 1994), that could be avoided or minimize if technically advanced EP-apparatus has been used. Unfortunately, this was not the case in this study. Therefore, more technically advanced EP-apparatus could avoid or minimise the measurement error, and enable researchers to more accurately investigate the relationship between evoked potentials and personality.

Furthermore, results of regression analyses show the significance of calculating partial correlations. High intercorrelation between all three PTS-scales, especially between MO and SE, make it harder to interpret the significant correlations between PTS dimensions and EP-amplitudes. Even though zero-order correlations indicated a certain pattern of correlations between PTS-dimensions and EP-amplitudes, the partial correlation coefficients showed a rather different findings. Overall, it could be seen (Table 4) that although the same directions and similar levels of zero-order correlations of some EP-amplitudes with SE and MO were determined, the majority of these relationships should be attributed to the independent contribution of mobility, not strength of excitation. This study demonstrated that if intercorrelations between temperament dimensions are high, it is necessary to compute and examine semi-partial correlations with relevant variables since effect of intercorrelations can distort the “real” relationship between variables.

Finally, findings on relationship between CNS-properties and EP-s could be discussed regarding the relationship between extraversion and EPs. Even though EP-researchers of personality mostly tried to confirm the arousal hypothesis made by Eysenck (1967), with introverts having chronically higher levels of arousal than extraverts – higher amplitude in both auditory (Stelmack & Michaud, 1985; Stelmack & Geen, 1992) and visual EPs (Stenberg, Rosen & Risberg, 1988, 1990), some recent studies showed that obtained effects have been significantly modified by attention and habituation (Stenberg et al., 1990; Stenberg, 1994; Tatalović Vorkapić, 2010). For a broader perspective it is interesting to mention the results of correlational analyses on the same sample but between EPs and extraversion (Tatalović Vorkapić, 2010). Even though the higher arousal level in introverts was expected, due to habituation effect the significant correlation between extraversion and EP-amplitudes has not been determined. But, in that research, a significant correlation between shorter P3-latencies and extraversion was found. When reviewing pattern of correlations, it could be noticed that different direction of relationships with electrocortical correlates was found for Eysenck’s personality traits and Pavlovian temperament dimensions. Pavlovian temperament dimensions have shown a more consistent and more significant correlations with EPs.

Earlier mentioned more complex findings on the relationship between SI and EP-amplitudes, could not be easily interpreted due to correlational nature of this study and other relevant variables that could not be controlled or varied. High scores on SI scale that reflect pronounced ability to inhibit or delay a certain behaviour in accordance with demands of situation is significantly correlated with higher N2-amplitude but lower P3-amplitude measured on parietal electrodes. Therefore, it would seem that early EP-components had an opposite relationship with the SI than the later EP components, which implies that this specific PTS-dimension indeed has a complex relationship with EPs. Even more, this study indicated that the established relationship between N2-P3-amplitudes and SI is stronger than the one between N2-P3 amplitude and other two PTS-dimensions, since partial correlation coefficients showed that SI explained the majority of variance in those EP-amplitudes. Due to SI- operationalization it would be very interesting to experimentally examine task-difficulty-variation and its influence on the relationship between SI and EP-amplitudes. However, at this moment, we do not have enough of empirical data to further explain this finding, but future research with certain methodological modifications could help resolve this problem. Some of the methodological limitations of this study were: a) since only two occipital and two parietal electrodes were used, there was no information about fronto-central activation of measured EP-components; b) the use of Medelec/TECA Sapphire^{II} 4E device (1996) in this research which is old type of EP-device and the subjectivity of manually EP-marking and greater measurement error which could lead to greater EP-variability. In future investigations greater number of subjects of different sex, age and profession should be included in order to gain a greater variability of the PTS-dimensions. Also, tasks from different modalities should be used, task difficulty and number of blocks should be varied, and finally, possibility of measuring the correct answers and reaction time would be a valuable improvement in research design.

Conclusion

It could be concluded that the main hypothesis of this study was partially confirmed. Correlations between N1-P2-N2-P3-amplitudes from first and second blocks and strength of excitation and mobility were positive and statistically significant, but only on parietal electrodes, most likely due to the habituation effect. On the other hand, it could be speculated that the first hypothesis would be confirmed if a more difficult task was applied, and this should be investigated further in future studies. Significant negative correlation between mobility and EP-latencies that we expected was not found in this study. In order to explain the intricate relationship between different EP-amplitudes and strength of inhibition further investigations with the research modifications mentioned earlier are necessary. Nevertheless, this study represents an interesting contribution to understanding the complex relationship between personality and evoked potentials. Also, it could be concluded that even within studies using the same Pavlov CNS-properties model of personality, different information processing and different reactions to the easy/hard tasks represent significant moderating factors of the relationship between temperament and evoked potentials.

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