RESEARCH ARTICLE

ACTA Vol. 14, No. 3, 2016, 241-254
NEUROPSYCHOLOGICA

Received: 11.04.2016
Accepted: 28.09.2016

A – Study Design
B – Data Collection
C – Statistical Analysis
D – Data Interpretation
E – Manuscript Preparation
F – Literature Search
G – Funds Collection

DOI:10.5604/17307503.1222838

THE RELATIONSHIP OF NEUROTICISM, PSYCHOTICISM AND DEPRESSION WITH VISUAL EVOKED POTENTIALS

Sanja Tatalović Vorkapić[1(A,B,C,D,E,F)], Meri Tadinac[2(A,D,E)]

[1] The Faculty of Teacher Education, The University of Rijeka, University Avenue 6, 51000 Rijeka, Croatia

[2] The Faculty of the Humanities and Social Sciences, The University of Zagreb, I. Lučića 3, 10000 Zagreb, Croatia

SUMMARY

Background: The aim of this study was to investigate the relationship between visual evoked potentials (N1, P2, N2, P3 and Sw) and levels of neuroticism, psychoticism and depression. Based on previous research, longer EP-latencies were expected in more depressed subjects, and smaller EP-amplitudes in subjects with higher levels of neuroticism and psychoticism.

Material/ Methods: The sample consisted of female psychology students (N=54), age 19-23, all right-handed. After measuring Eysenck's personality dimensions with EPQ/R, and depression with D-92, evoked potentials were measured in two trials by means of the EMG/EP device Medelec/TECA Sapphire[II], 4E. Significantly lower P2-amplitudes, reflecting early stimuli processing, and lower N2-amplitudes, reflecting stimuli characteristic assignment, were found in subjects with higher neuroticism.

Results: The most stable relation, determined in both trials, was the one between P2-amplitude and neuroticism. Higher amplitudes of N2 and P3, representing attention allocation and memory updating, were significantly correlated with higher psychoticism. Finally, as expected, slow wave latency was significantly prolonged in more depressed subjects. Eysencks' personality theory and over-arousal hypothesis are used as theoretical frames for discussing the results and future research guidelines.

Conclusions: The research findings significantly contribute to the understanding of biological determination within rarely explored personality traits, such as neuroticism, psychoticism and depression. However, since the research has some limitations, concrete guidelines for future electrophysiological studies in the field of human personality have been recommended.

Key words: students, brain electrophysiology, neuromarkers, personality traits

INTRODUCTION

There is an almost universal agreement as to neuroticism being one of the most important human personality traits (Mathews, 2004). A person with a high level of neuroticism is prone to anxiety, depression, and other negative emotions, along with concern, frequent and sudden changes of mood, and a vulnerability to stress. In contrast, a low degree of neuroticism is a characteristic of an emotionally stable person who is calm and unconcerned. This personality trait is associated with individual differences in excitability and emotional reactivity, as reflected in the autonomous activation (Eysenck & Eysenck, 1985). It has been found that neuroticism is largely inherited, and Zuckerman's (1991) estimate of its heritability was 0.40-0.60. In this study, neuroticism and psychoticism are operationalized within Eysenck's personality theory (1967), which linked neuroticism with the arousability of the emotional system, located in the reticular, limbic, and cortical structures. Therefore, in stressful conditions neuroticism should be positively correlated with autonomic and cortical arousal, but some empirical findings have not supported this hypothesis (Coles, Gale & Kline, 1971; Matthews & Gilliland, 1999, 2001). Although some authors (Winter, Broadhurst & Glass, 1972; Gale et al., 2001) found a certain trend towards a high cortical arousal in the EEG data in highly neurotic persons, a great number of well-designed studies failed to establish such a connection, due to the complex interaction effects of neuroticism, extraversion and situational factors. Furthermore, findings on correlations between neuroticism and evoked potentials are inconsistent. Some studies showed no correlation (Rust, 1975; Golding et al., 1986; De Pascalis & Montirosso 1988; De Pascalis, 1993; Lolas, Camposano & Etcheberrigaray 1989; Fjell et al., 2005), while others found significant correlations between neuroticism and P3 latency (Plooy-out Görsel, 1981; Pritchard, 1989; Stelmack, Houlihan & McGarry-Roberts, 1993; Stelmack & Houlihan, 1995), significant negative correlations of neuroticism with P3 amplitudes and positive correlations with P3 latency (Polich & Martin, 1992; Gurrera et al., 2001; Momirović, 2008). All these studies used a complex task for inducing evoked potentials, and all of them were conducted in the auditory modality. The authors' explanation of their findings was that reduced EP amplitude, especially P3 amplitude, might not be specific for a mental disorder, but that it certainly indicated the vulnerability for psychological dysfunction. A number of clinical studies using evoked potentials found prolonged latency and reduced amplitudes, especially those in the cognitive domains, in a variety of psychological disorders (Polich, 1999).

The individuals who achieve a high score on the psychoticism scale display high levels of loneliness, cruelty, callousness, and indifference to others, behave aggressively, even to members of their family, show an absence of fear, and love to make fun of others and harass them. They are characterized by stubbornness in thinking and behaviour, their socialization is very weak, and they have no empathy and understanding of others or feelings of guilt. During the validation of the P-subscale of EPQ (Eysenck & Eysenck, 1994) a significant correlation be-

tween the degree of masculinity and psychoticism was found, indicating that the biological basis of psychoticism could be related to androgen hormones. The concept of psychoticism (Eysenck, 1997) could be described as a continuum ranging from an altruistic, socialized, empathic, conventional and conformist person to an impulsive, hostile, aggressive, psychopathic, schizoid person. A high degree of psychoticism indicates a greater likelihood for the development of psychotic symptoms. EP research of psychoticism could be divided into three main categories: a) EP studies of schizophrenia; b) EP studies of alcoholism and antisocial personality disorder; and c) EP research on healthy human personalities. Within the first category it was found that P3-amplitude was reduced in schizophrenia (Ford, Pfefferbaum & Roth, 1992; Turetsky, Colbath & Gur, 1998). Findings suggest that the P3 amplitude represents a significant neurobiological marker for psychopathology (Ford et al., 1999). In addition, several studies (Pfefferbaum et al., 1984; Blackwood, Erbmeier & Muir, 1994; Souza, Muir & Walker, 1995) found significantly prolonged P3 latency in schizophrenic patients. Some types of schizophrenia are attributed to dopaminergic hyperactivity in different parts of the limbic system, (Lloyd, 1978; Reynolds, 1983, 1987) leading to an over-arousal hypothesis. On the other side, EP studies of antisocial personality disorder or alcohol dependency have used an under-arousal hypothesis. Low levels of arousal lead to involvement in activities that bring excitement (often involving crime, risk-taking, and violent behaviours) in order to raise the arousal to an optimal level. EP studies of antisocial behaviour and alcohol dependency found significantly lower EP amplitudes (Golding et al., 1986), especially the P3 amplitude, supporting the under-arousal hypothesis (Porjesz & Begleiter, 1990; O'Connor et al., 1994; Polich, Pollock & Bloom, 1994; Bauer & Hesselbrock, 1999a,b; Bauer et al., 2001), whether it be of prisoners (Barrat et al., 1997) or adolescents with conduct disorders (Porjesz & Begleiter, 1998). Finally, EP studies on healthy human personality showed a significant relationship between psychoticism and various EP components (Rust, 1975; Pritchard, 1989; Lolas et al., 1989; De Pascalis, 1993; Robinson, 2001). Stelmack and Houlihan (1995) found a significant negative correlation between psychoticism and P3 amplitude, while Polich and Martin (1992) found a significant positive correlation, but only in female participants. Golding et. al. (1986) found a significant negative correlation between psychoticism and early somatosensory evoked potentials (N21-P27). Momirović (2008) analysed the tendency for aggressive and impulsive reactions, psychotic symptoms of dissociation, psychotic regression, and low ego strength in relation to the P3 wave in samples of healthy (N=15) and clinical (N=21) subjects. He found a significant negative correlation between P3 amplitude and psychoticism, but no significant correlations between psychoticism and P3 latency, thus only partially supporting the assumption of reduced P3 amplitude and prolonged P3 latency as indicators of vulnerability for psychological dysfunction (Gurrera et al., 1991).

Neurophysiological bases of depression were often studied by using the evoked potentials, specifically the P3-wave, resulting in inconsistent findings (Houston, Bauer & Hesselbrock, 2004). Although the prolonged latency and re-

duced amplitude were expected in more depressed individuals, some studies did not find a significant association between depression and EP-amplitude (Bange & Bathien, 1998; Bruder et al., 1991, 1998; Giedke, Thier & Bolz, 1981; Patterson, Michalewski & Starr, 1988; Roth et al., 1981; Sara et al., 1994), and some resulted in unambiguous findings regarding the relationship of depression and EP-latency (Bange & Bathien, 1998; Blackwood et al., 1987; Bruder et al., 1991; Diner, Holcomb & Dykman, 1985; Gangadhar et al., 1993; Giedke, Thier & Bolz, 1981; Gordon et al., 1986; Muir, St Clair & Blackwood, 1991; Vandoolaeghe et al., 1998). However, the majority of studies confirmed the expected lower P3-amplitudes in more depressed subjects (Baribeau-Braun & Leserve, 1983; Pfefferbaum et al., 1984; Diner et al., 1985; Thier, Axmann & Giedke, 1986; Blackwood et al., 1987; Muir, St Clair & Blackwood, 1991; Gangadhar et al., 1993; Santosh et al.,1994; Bruder et al., 1995; Defrance et al., 1996; Yanai et al.,1997; Kaustio et al., 2002; Roschke & Wagner, 2003; Houston, Bauer & Hesselbrock, 2003; Urretavizcaya et al., 2003). The possible explanation for the heterogeneity of P3 findings in relation to depression could be the heterogeneity of the samples and measurements.

Therefore, with the aim of a better understanding of the electrophysiology of various psychopathological difficulties, it is very important to investigate the biological background of related personality traits in normal, healthy subjects. Scientists have mostly studied traits operationalized within Eysenck's personality theory, such as neuroticism and psychoticism. Within the domain of emotions and moods, depression and anxiety have been mostly examined among healthy and clinical samples. Therefore, our research has focused on three personality variables: neuroticism, psychoticism and depression in healthy students, with the aim of exploring their relationship with visual evoked potentials. Based on theoretical assumptions and earlier findings we expected significantly longer EP-latencies in more depressive participants, and lower EP-amplitudes in those with higher levels of neuroticism and psychoticism.

METHODS

Subjects

A total of 54 female participants (*M*=20.5 years, *SD*=1.28, age range:19-23), all undergraduate students from the Department of Psychology, Faculty of the Humanities and Social Sciences, the University of Rijeka, Croatia, participated in the study. They were all right-handed, naive to electrophysiological studies, and reported no visual or neurological/psychiatric problems. The students received course credits for their participation in the study.

Questionnaires for measuring neuroticism, psychoticism and depression

The Neuroticism subscale (24 items) and the Psychoticism subscale (32 items) of the Eysenck Personality Questionnaire (EPQ-R), i.e., its standardized

version (Eysenck & Eysenck, 1994) were used for measuring neuroticism and psychoticism. Students answered the questions dichotomously, i.e. by choosing between YES and NO. The level of a measured personality dimension was determined as the sum of the relevant answers on each EPQ-subscale. The levels of reliability were similar to those determined in previous studies: for Neuroticism, Cronbach's alpha was r=0.89, and for Psychoticism r=0.61.

The Depression Scale (D-92, Krizmanić & Kolesarić, 1994) was used for measuring depression, operationalized as a temporary, lasting or permanent condition, triggering a series of changes in the experience and expression of emotion, cognitive processes, meeting basic needs (sleep, diet, activity, sexuality) and behaviour. The scale consists of 22 items, intended for determining the global level of depression in individuals older than 16. For each item the subject has to choose one from four answers. The scale showed satisfactory internal consistency (Cronbach's alpha 0.88).

Apparatus and procedure

The EP-measurement (N1, P2, N2, P3 and Sw) in two trials took place after subjects had been given general instructions and had filled-out the personality scales. Considering the sensitivity of EP-measurement it is important that all recordings are done in the same conditions. Therefore, evoked potentials were measured for four months, always on Wednesdays at noon. Following the EP-device manual instructions (Sapphire^{II} User Manual 003W009A, 1996), standard visual oddball paradigm and the device Medelec/TECA Sapphire^{II} 4E device with five Ag/AgCl disc electrodes were used. Two occipital (O1 and O2) and two parietal (P3 and P4) electrodes were used as active and referred to Fz. The electrodes were placed according to the 10-20 system. The filter bandpass was 0.1-50 Hz and the electrode impedance was kept below 5kΩ. The recording was made in a dark, quiet room using a 16 x16 checkerboard pattern, 70 cm away from the nasion, with a 1Hz frequency and 100% contrast. Two visual stimuli patterns were used: 15% of stimuli were rare (target) checkerboards (consisting of the smaller quadrangles), whereas the remaining ones were frequent (non-target) checkerboards (consisting of the larger quadrangles), presented in a random order. 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, since there was no possibility of measuring the reaction time.

The same medical technician marked all the EP amplitudes and latencies manually using a cursor, for both trials. For each subject there was the same EP-latency (as measured only in one trial) for both trials, but different EP-amplitudes, due to the marking procedure. In the first trial, the first major negative peak between 80-100 msec for the rare stimuli was identified as the N1 response and was marked. Other evoked potentials were marked accordingly: P2 as major positive peak between 170-200 msec; N2 as a major negative peak between 200-300 msec; P3 as a major positive peak between 300-600 msec; and SW as a major negative peak between 600-800 msec. To avoid the effect of the latency

jitter (Coles et al., 1986; Hoormann et al.,1998), and to make the evoked potentials more stable over trials, in the second trial they were marked by the same latencies as those from the first trial. An example of the averaged and artefact-corrected ERP curves for one participant in the first and the second trial block is presented in Tatalović Vorkapić, Tadinac & Lučev (2013).

RESULTS AND DISCUSSION

The mean results on the neuroticism (*M*=9.2; *SD*=5.62) and psychoticism (*M*=8.44; *SD*=9.3) scales were very similar to the norms for the relevant age groups (Eysenck & Eysenck, 1994). The comparison of the means on the depression scale with those obtained in the validation study (Krizmanić & Kolesarić, 1994) showed that our participants' scores (*M*=40.09, *SD*=7.52) were somewhat lower than those in the validation sample (*M*=44.16). Overall, it can be concluded that the results are expected for the sample of healthy students that participated in the research.

The relationship between EP-latencies and personality measures

The correlation analysis of relation between neuroticism, psychoticism and depression with EP latencies and amplitudes on all four electrodes (O1, O2, P3 and P4) in the first, and the EP amplitude in the second trail, was performed. No significant correlations were found between personality traits and latencies on the occipital electrodes. The correlations of neuroticism, psychoticism, and depression with EP latencies on parietal electrodes are shown in Table 1.

No significant correlations were found between the EP-latency and neuroticism, therein confirming some previous findings (Rust, 1975; Golding et al., 1986; de Pascalis et al., 1988, de Pascalis, 1993; Lolas et al., 1989; Fjell et al., 2005), although in other studies a certain trend toward elevated cortical arousal in the EEG data in a highly neurotic person (Winter et al., 1972, Gale et al., 2001), and a negative correlation between neuroticism and P3-latency (Plooy-out Görsel, 1981; Pritchard, 1989; Stelmack, Houlihan & McGarry-Roberts, 1993; Stelmack

Table 1. Correlation matrix of neuroticism, psychoticism and depression with latencies of N1, P2, N2, P3 & Sw on parietal electrodes (P_3 & P_4)

EP-latencies		Neuroticism	Psychoticism	Depression
Electrode P_3	N1	.03	-.05	-.04
	P2	.10	-.12	.16
	N2	-.07	-.16	.19
	P3	.09	-.26	.24
	SW	.18	-.20	**.33****
Electrode P_4	N1	.02	-.06	-.04
	P2	.10	-.12	.17
	N2	-.07	-.16	.19
	P3	09	**-.26***	.25
	SW	.18	-.21	**.34****

**p<0.05, **p<0.01*

& Houlihan, 1995) were found. These findings are close both to the theoretical models and hypothesis of this research, given the increased reactivity due to anticipation in a highly neurotic person as opposed to a low neurotic. It should be noted that the variability of neuroticism in our sample was quite small, as could be expected in a sample of healthy and young subjects. Therefore, the correlation of neuroticism and EP-latency should be examined in a larger and more heterogeneous sample. Our findings support the arguments concerning the methodology of exploring neuroticism, as emphasized by Zuckerman (1991) and Matthews (1999). Since neuroticism is a personality trait associated with individual differences in excitability and emotional reactivity, as reflected in the autonomous nervous activation (Eysenck & Eysenck, 1985), the researchers have recommended that a large number of psychophysiological paradigms on various levels should be used.

Apparently, the bottom-up model could be considered too simplistic and inadequate for explaining the biological basis of neuroticism. Taking into account Zuckerman's (1991) assumptions about the several sources of neurotic emotionality (biochemical effects, subcortical structures such as the amygdala, cortical emotional-control systems such as the orbitofrontal cortex, and different higher order cognitive processes) and the relationship with these sources being not linear and singular, a single method, such as EP, is definitely not enough. The combination of EP and some autonomous psychophysiological measures could contribute to a better understanding of neuroticism.

A small but significant correlation was determined at one parietal electrode between higher psychoticism and shorter P3-latency, similarly to other EP-studies (Golding et al., 1986; Pritchard, 1989). There are currently no viable explanations of these findings. An attempt to explain them could be through the argument of a common correlate. High levels of intelligence are often correlated with shorter EP-latencies, especially P3-latency. It is possible that participants with a shorter P3-latency and higher psychoticism, who quickly focus attention and quickly evaluate the target stimuli, have higher levels of intelligence. It is possible that some characteristics of psychoticism that are not part of the pathology in certain combinations could contribute to the cognitive efficiency of the individual, It would therefore be very interesting to further examine the electrophysiological bases of psychoticism in a more heterogeneous sample, comprising participants with different levels of intelligence.

Significant correlations were found between depression and EP-latency: higher depression was related to prolonged slow wave latencies measured at parietal electrodes. This is an expected finding, considering the presumed vulnerability to a psychological dysfunction reflected in prolonged latency (Bruder et al., 1995; Hansenne et al., 2000) and reduced amplitude (Diner et al., 1985; Gangadhar et al., 1993, Muir et al., 1991; Bruder et al., 1995) among more depressive individuals. Psychomotor and cognitive deceleration are the main properties of increased depression in humans, and they are reflected in prolonged EP-latencies. Our finding supports previous results (Austin et al., 2001; Ottowitz et al., 2002).

We found the significant correlations only between slow wave latency and depression, although they were also expected for other EP-latencies. This is probably due to the fact that the depression levels in our healthy sample were very low compared to the clinical samples used in other studies, and this should be taken into account in future studies.

The relationship between EP-amplitudes and personality measures

To examine the relations between personality measures and EP-amplitudes on four electrodes, the correlation analysis was performed. As no significant correlations were found between personality traits and amplitudes on the occipital electrodes, only the correlations for the parietal electrodes are shown in Table 2. A significant negative correlation was established between neuroticism and the P2- N2-amplitude on both parietal electrodes in both trials. On the other hand, the significant correlation of neuroticism with a cognitive evoked potential P300 on one parietal electrode was positive, indicating that higher neuroticism is related to the increase in the P3-amplitude. This finding certainly indicates a different relationship between neuroticism and the automatic vs. controlled information processing: a lower cortical arousal during early information processing, and a higher one during voluntary, deeper cognitive information processing. This finding is quite interesting and could be explained by the difficulty level of the task used. Studies which have used more complex tasks for evoking evoked potentials (Polich & Martin, 1992; Gurrera et al., 2001; Momirović, 2008) have resulted in significantly reduced P3 amplitudes among highly neurotic persons, while a very simple discrimination task in this study could have evoked a significantly lower cortical arousal in participants with a higher neuroticism. This notion should be investigated in future studies using the experimental variation of task difficulty levels. Another possible explanation of this finding could be the potentially large range of reactions in highly neurotic individuals on different levels of information processing measured by the EP-method. In other words, the increased P3-amplitude in college students with higher neuroticism could support the hypothesis of higher cortical arousal in highly neurotic individuals (Eysenck, 1967). Highly neurotic people could be characterized by inadequate access and response to a specific task, in line with the definition of neuroticism as associated with individual differences in excitability and emotional reactivity (Eysenck, 1967). This assumption would be very interesting to investigate by exploring the relationship of EPs and neuroticism by varying the difficulty/modality/trials of the tasks for evoking EPs, and with a larger sample of participants, heterogeneous in gender, age, occupations, as well as through varying levels of neuroticism and stress situations, and using the additional psychophysical measures of ANS activity.

Higher levels of psychoticism were significantly related to higher P3-amplitudes on both parietal electrodes in the second trial, and with the higher N2-amplitude from the second trial on the P4 electrode only. In other words, students with elevated levels of psychoticism showed a significantly increased P3-amplitude reflecting the initial evaluation of stimuli and changes in immediate memory,

and an increased N2-amplitude reflecting the automatic extraction properties of the stimuli and control of the determination of the target stimuli properties. Our results are the opposite to earlier findings on the reduction in EP-amplitudes, especially the P3-amplitude, in schizophrenics and subjects with antisocial personality disorder, criminal behaviour and tendencies toward alcoholism, which is not surprising considering the differences in the sample characteristics – clinical and normal. Polich & Martin (1992) obtained results similar to ours only in female participants, but offer no interpretation of those results. Given that the dimension of psychoticism in the normal population is primarily characterized as stubbornness and persistence, indicating the increased cognitive engagement related to their own thinking and actions towards their environment, it would be logical to expect an elevation in the EP-amplitude.

A significant negative correlation was determined between depression and N2-amplitude in the second trial on both parietal electrodes, according to expectations based on earlier findings (Diner et al., 1985; Gangadhar et al., 1993; Muir et al., 1991; Bruder et al., 1995), although there was no significant relationship between depression and the P3-amplitude. More depressed subjects demonstrated reduced levels of N2-amplitude, which partly reflects the automatic extraction of stimuli properties, and partly determining the properties and selecting a target. This particular EP-component has a transitional character as its first part refers to automatic, and the other part to controlled information processing, and this EP-component is sensitive to changes in the depression level in healthy participant. Houston et al. (2004) emphasized that there were many inconsistent findings regarding the relationship of depression and evoked potentials, which are often just ascribed to the characteristics of the tested sample. It could therefore be concluded that the hypothesis of a reduced EP amplitude in subjects with

Table 2. Correlation matrix of neuroticism, psychoticism and depression with amplitudes of N1, P2, N2 and P3 on parietal electrodes (P_3& P_4) in the first (Amp1) and the second trial (Amp2)

EP-amplitude			Psychoticism	Neuroticism	Depression
Electrode P_3	N1	Amp1	.04	-.09	-.21
		Amp2	.02	-.02	-.07
	P2	Amp1	.12	**-.28***	-.22
		Amp2	.13	-.19	-.20
	N2	Amp1	.06	-.07	-.15
		Amp2	.10	-.25	**-.38****
	P3	Amp1	-.01	**.28***	.24
		Amp2	**.37****	.04	-.07
Electrode P_4	N1	Amp1	-.01	-.02	-.06
		Amp2	-.06	.04	.01
	P2	Amp1	.02	**-.31***	-.18
		Amp2	.06	**-.33***	-.19
	N2	Amp1	.21	-.23	-.12
		Amp2	**.37****	**-.31***	**-.27***
	P3	Amp1	.14	.18	.14
		Amp2	**.33***	-.04	-.07

*$p<0.05$, **$p<0.01$

higher depression is partly confirmed. However, it is necessary to examine the level of depression and its relation with EPs in healthy and clinical samples of different ages and genders, and with varying task difficulty.

CONCLUSION

Electrophysiological studies of personality, either on normal or clinical subjects, present a valuable way to explore the biological basis of human personality. Although this study resulted in some novel findings, it is important to mention its main limitations. Firstly, EP-measurement included only four electrodes and manual EP-marking. These two technical limitations should be taken into account in future research, since a greater level of reliability and validity could be reached with recordings on a larger number of electrodes, and automatic or software EP-marking. Regarding the sample properties, it should be emphasized that our sample was very specific (psychology students) and homogenous, resulting in a low variability of measured traits (equal by their psychological characteristics). Additionally, a very simple oddball task was applied. Therefore, in future studies it would be very important to use more heterogonous and larger samples, more complex tasks for evoking the EPs, and more adequate electrophysiological apparatus for EP-measurement.

Conflict of interest statement

There are no potential conflicts of interest or any financial/personal relationship with other people/organizations that could inappropriately bias the conduct and findings of this study.

REFERENCES

Austin, M., Mitchell, P., & Goodwin, G.M. (2001) Cognitive deficits in depression, British Journal of Psychiatry, 178, 200-206.

Bange, F., & Bathien, N. (1998) Visual cognitive dysfunction in depression: an event-related potential study, Electroencephalography and Clinical Neurophysiology, 108, 472-481.

Baribeau-Braun, J., & Leserve, N. (1983) Event-related potential assessment of psychomotor retardation in depressives, Advances in Biological Psychiatry, 13, 211-224.

Barratt, E.S., Stanford, M.S., Kent, T.A., & Felthous, A. (1997) Neuropsychological and cognitive psychophysiological substrates of impulsive aggression, Biological Psychiatry, 41, 1045-1061.

Bauer, L.O., & Hesselbrock, V.M. (1999a) P300 decrements in teenagers with conduct problems: Implications for substance abuse risk and brain development, Biological Psychiatry, 46, 263-272.

Bauer, L.O., & Hesselbrock, V.M. (1999b) Subtypes of family history and conduct disorder: Effects on P300 during the Stroop test, Neuropsychopharmacology, 21, 51-62.

Bauer, L.O., Costa, L., & Hesselbrock, V.M. (2001) Effects of alcoholism, anxiety and depression on P300 in women: A pilot study, Journal of Studies in Alcoholism, 62, 571-579.

Blackwood, D.H.R., Whalley, L.J., Christie, J.E., Blackburn, I.M., St Clair, D.M., & McInnes, A. (1987) Changes in auditory P3 event-related potential in schizophrenia and depression, British Journal of Psychiatry, 150, 154-160.

Blackwood, D.H.R., Erbmeier, K.P., & Muir, W.J. (1994) Correlation of regional cerebral blood flow equivalents measured by single photon emission computerized tomography with P300 latency and eye movement abnormality in schizophrenia, Acta Psychiatrica Scandinavica, 90, 157-166.

Bruder, G.E., Towey, J.P., Stewart, J.W., Friedman, M., Tenke, C., & Quitkin, F.M. (1991) Brain event-related potentials to complex tones in depressed patients: Relations to perceptual asymmetry and clinical features, Psychophysiology, 32(4), 373-381.

Bruder, G.E., Tenke, C., Stewart, J.E., Towey, J.P., Leite, P., Voglmaier, M., & Quitkin, F.M. (1995) Brain event-related potentials to complex tones in depressed patients: relations to perceptual asymmetry and clinical features, Psychophysiology, 32, 373-381.

Bruder, G.E., Tenke, C., Towey, J.P., Leite, P., Fonk, R., Stewart, J.E., McGrath, P.J., & Quitkin, F.M. (1998) Brain ERPs of depressed patients to complex tones in an oddball task: relation of reduced P3 asymmetry to physical anhedonia, Psychophysiology, 35, 54-63.

Coles, M.G.H., Gale, A., & Kline, P. (1971) Personality and habituation of the orienting reaction: Tonic and response measures of electrodermal activity, Psychophysiology, 8, 59-63.

Coles, M.G.H., Gratton, G., Kramer, A.F., & Miller, G.A. (1986) Chapter Ten: Principles of signal acquisition and analysis, In: M.G.H. Coles, E. Donchin & S.W. Porges (Eds.), Psychophysiology: Systems, Processes and Applications (pp. 183-221), The Guilford Press, New York, USA.

Defrance, J.F., Ginsber, L.D., Rosenber, B.A., & Sharma, J.C. (1996) Topographical analysis of adolescent affective disorders, International Journal of Neuroscience, 86, 119-141.

De Pascalis, V. (1993) Hemispheric Asymmetry, Personality and Temperament, Personality and Individual Differences, 14(6), 825-834.

De Pascalis, V., & Montirosso, R. (1988) Extraversion, neuroticism and individual differences in event-related potentials, Personality and Individual Differences, 9(2), 353-360.

Diner, B.C., Holcomb, P.J., & Dykman, R.A. (1985) P300 in major depressive disorder, Psychiatry Research, 15, 175-184.

Eysenck, H.J. (1967) Biological basis of personality, Charles C Thomas Publisher, Springfield, Illinois, USA.

Eysenck, H.J. (1997), Personality and Experimental Psychology: The Unification of Psychology and the Possibility of a Paradigm, Journal of Personality and Social Psychology, 73(6), 1224-1237.

Eysenck, H.J., & Eysenck, M.W. (1985) Chapter eight: The psychophysiology of personality. In: Personality and individual differences: A natural science approach (217-236), Plenum Press: New York & London.

Eysenck, H.J. & Eysenck, S.B.G. (1994) Priručnik za Eysenckove skale ličnosti: EPS-odrasli (Manual for Eysencks' personality scales: EPS-adults. In Croatian), Naklada Slap, Jastrebarsko.

Fjell, A.M., Walhovd, K.B., Meling, S., & Johansen, M.B. (2005) Basic information processing of neurotics and stables: An experimental ERP approach to personality and distractibility, Scandinavian Journal of Psychology, 46, 493-502.

Ford, J.M., Pfefferbaum, A., & Roth, W. (1992) P3 and schizophrenia, Annals of the New York Academy Sciences, 658, 146-162.

Ford, J.M., Mathalon, D.H., Marsh, L., Faustman, W.O., Harris, D., Hoff, A.L., Beal, M., & Pfefferbaum, A. (1999) P300 amplitude is related to clinical state in severely and moderately I11 patients with schizophrenia, Biological Psychiatry, 46, 94-101.

Gale, A., Edwards, J., Morris, P., Moore, R., & Forrester, D. (2001) Extraversion-introversion, neuroticism-stability, and EEG indicators of positive and negative empathic mood, Personality and Individual Differences, 30, 449-461.

Gangadhar, B.N., Ancy, J., Janakiramaiah, N., & Umapathy, C. (1993) P300 amplitude in non-bipolar, melancholic depression, Journal of Affective Disorders, 28, 57-60.

Giedke, H., Thier, P., & Bolz, J. (1981) The relationship between P3-latency and reaction time in depression, Biological Psychology, 13, 31-49.

Golding, J.F., Ashton, C.H., Marsh, V.R., & Thompson, J.W. (1986) Early and late SEPs – the later the potential the greater the relevance to personality, Personality and Individual Differences, 7(6), 787-794.

Gordon, E., Kraiuhin, C., Harris, A., Meares, R., & Howson, A. (1986) The differential diagnosis of dementia using P300 latency, Biological Psychiatry, 21, 1121-1132.

Gurrera, R.J., O'Donnell, B.F., Nestor, P.G., Gainski, J., & McCarley, R.W. (2001) The P3 Auditory Event-Related Brain Potential Indexes Major Personality Traits, Biological Psychiatry, 49(11), 921-929.

Hansenne, M., Pitchot, W., Pinto, E., Reggers, J., Papart, P., & Ansseau, M. (2000) P300 Event-related Brain Potential and Personality in Depression, European Psychiatry, 15, 1-8.

Hare, R.D. (1993) Without conscience: The disturbing world of the psychopaths among us, New York: Pocket Books.

Hoormann, J., Falkenstein, M., Schwarzenau, P., & Hohnsbein, J. (1998) Methods for the Quantification and Statistical Testing of ERP Differences across Conditions, Behavior Research Methods, Instruments, & Computers, 30(1), 103-109.

Houston, R.J., Bauer, L.O., & Hesselbrock, V.M. (2003) Depression and familial risk for substance dependence: A P300 study of young women, Psychiatry Research in Neuroimaging, 124, 49-62.

Houston, R.J., Bauer, L.O., & Hesselbrock, V.M. (2004) P300 evidence of cognitive inflexibility in female adolescents at risk for reccurent depression, Progress in Neuro-Psychopharmacology & Biological Psychiatry, 28, 529-536.

Kaustio, O., Partanen, J., Valkonen-Korhonen, M., Viinamäki, H., & Lehtonen, J. (2002) Affective and psychotic symptoms relate to different types of P300 alterations in depressive disorder, Journal of Affective Disorders, 71, 43-50.

Krizmanić, M., & Kolesarić, V. (1994) Priručnik za primjenu Skale depresivnosti D-92 (Manual for Depression Scale D-92 application. In Croatian),Naklada Slap, Jastrebarsko.

Lloyd, K.G. (1978) Observations concerning neurotransmitter interaction in schizophrenia, In: L.L. Butcher (Ed.), Cholinergic-Monoaminergic interactions in the Brain. New York: Academic Press.

Lolas, F., Camposano, S., & Etcheberrrigaray, R. (1989) Augmenting/reducing and personality: A psychometric and evoked potential study in Chilean sample, Personality and Individual Differences, 10(11), 1173-1176.

Mathews, G. (1999) Personality and skill: A cognitive-adaptive framework, In: P.L. Ackerman, P.C. Kyllonen & R.D. Roberts (Eds.), The future of learning and individual differences research: Processes, traits, and content (pp. 251-270), Washington, DC: American Psychological Association.

Mathews, G. (2000) A cognitive science critique of biological theories of personality traits, History and Philosophy of Psychology, 2, 1-17.

Matthews, G. (2004) Neuroticism from the Top Down: Psychophysiology and Negative Emotionality, In R.M. Stelmack (Ed.), On the Psychobiology of Personality: Essays in Honour of Marvin Zuckerman (pp. 249-266), Elsevier Ltd., UK.

Matthews, G., & Gilliland, K. (1999) The personality theories of H. J. Eysenck and J. A. Gray: A comparative review, Personality and Individual Differences, 26, 583-626.

Matthews, G., & Gilliland, K. (2001) Personality, biology and cognitive science: A reply to Corr (2001), Personality and Individual Differences, 30, 353-362.

Momirović, A. (2008) Povezanost evociranih kognitivnih potencijala s rezultatima psihologijskih testova (The relationship between cognitive evoked potentials and psychological testing results. In Croatian), In: A. Vulić-Prtorić, V. Ćubela-Adorić, A. Proroković, I. Sorić & P. Valerjev (Eds.), Paper summaries: 16th Psychology Days in Zadar, 29-31. /May, (p. 85), University of Zadar, Department of Psychology.

Muir, W.J., St Clair, D.M., & Blackwood, D.H.R. (1991) Long-latency auditory event-related potentials in schizophrenia and in bipolar and unipolar affective disorder, Psychological Medicine, 21, 867-879.

O'Connor, S., Bauer, L.O., Tasman, A., & Hesselbrock, V.M. (1994) Reduced P300 amplitudes of ERPs are associated with both a family history of alcoholism and antisocial personality disorder, Progress in Neuro- Psychopharmacology & Biological Psychiatry, 18, 1307-1321.

Ottowitz, W.E., Dougherty, D.D., & Savage, C.R. (2002) The neural network basis for abnormalities of attention and executive function in major depressive disorder: Implications for application of the medical disease model to psychiatric disorders, Harward Review of Psychiatry, 10, 86-99.

Patterson, J.V., Michalewski, H.J., & Starr, A. (1988) Latency variability of the components of auditory event-related potentials to infrequent stimuli in aging, Alzheimer-type demention, and depression, Electroencephalography and Clinical Neurophysiology, 71, 450-460.

Pfefferbaum, A., Wenegrat, B.G., Ford, J.M., Roth, W.T., & Kopell, B.S. (1984) Clinical application of the P3 component of event-related potentials, II: Dementia, depression, and schizophrenia, Electroencephalography and clinical Neurophysiology, 59, 104-124.

Plooij-van Gorsel, E. (1981) EEG and cardiac correlates of neuroticism: A psychophysiological comparison of neurotics and normal controls in relation to personality, Biological Psychology, 13, 141-156.

Polich J. (1999) P300 in clinical applications, In: E. Niedermeyer & F. Lopes de Silva (Eds.), Electroencephalography: Basic Principles, Clinical Applications and Related Fields, 4th edition (pp. 1073-1091), Baltimore-Munich: Urban & Schwarzenberg.

Polich, J., & Martin, S. (1992) P300, Cognitive Capability, and Personality: A Correlational Study of University Undergraduates, Personality and Individual Differences, 13(5), 533-543.

Polich, J., Polock, V.E., & Bloom, F.E. (1994) Meta-analysis of P300-Amplitude from Males at Risk for Alcoholism, Psychological Bulletin, 115(1), 55-73.

Porjesz, B., & Begleiter, H. (1990) Event-related potentials in individuals at risk for alcoholism, Alcohol, 7, 465-469.

Porjesz, B., & Begleiter, H. (1998) Human evoked brain potentials and alcohol, Alcoholism: Clinical and Experimental Research, 5, 394-317.

Pritchard, W.S. (1989) P300 and EPQ/STPI Personality Traits, Personality and Individual Differences, 10(1), 15-24.

Reynolds, G.P. (1983) Increased concentrations and lateral asymmetry of amygdala dopamine in schizophrenia, Nature, 305, 527-529.

Reynolds, G.P. (1987) Post-mortem neurochemical studies in human postmortem brain tissue, In: H. Hafner, W.F. Gattaz & W. Janzarik (Eds.), Search for the Causes of Schizophrenia (pp. 236-240), Heidelberg: Springer.

Robinson, D.L. (2001) How brain arousal system determines different temperament types and the major dimensions of personality, Personality and Individual Differences, 31, 1233-1259.

Röschke, J., & Wagner, P. (2003) A confirmatory study on the mechanisms behind reduced P300 waves in depression, Neuropsychopharmacology, 28, S9-S12.

Roth, W.T., Pfefferbaum, A., Kelly, A.F., Berger, P.A., & Kopell, B.S. (1981) Auditory event-related potentials in schizophrenia and depression, Psychiatry Research, 4, 199-212.

Rust, J. (1975) Cortical evoked potential, personality, and intelligence, Journal of Comparative and Physiological Psychology, 89(10), 1220-1226.

Santosh, P.J., Malhotra, S., Raghunathan, M., & Mehra, Y.N. (1994) A study of P300 in melancholic depression: correlation with psychotic features, Biological Psychiatry, 35, 474-479.

Sapphire^{II} User manual 003W009A (1996) Medelec, Vickers Medical & Teca Vickers Medical, Medical Device Directive, Medelec Ltd, England.

Sara, G., Gordon, E., Kraiuhin, C., Coyle, S., Howson, A., & Meares, R. (1994) The P300 ERP component: An index of cognitive dysfunction in depression?, Journal of Affective Disorders, 31, 29-38.

Souza, V.B.N., Muir, W.J., & Walker, M.T. (1995) Auditory P300 event-related potentials and neuropsychological performance in schizophrenia, Biological Psychiatry, 37, 300-310.

Stelmack, R.M., Houlihan, M., & McGarry-Roberts, P.A. (1993) Personality, reaction time, and event-related potentials, Journal of Personality and Social Psychology, 65(2), 399-409.

Stelmack, R.M., & Houlihan, M. (1995) Event-Related Potentials, Personality, and Intelligence: Concepts, Issues, and Evidence, In: D.H. Saklofske, M. Zeidner (Ed.), International Handbook of Personality and Intelligence (349-365), Plenum Press, New York.

Tatalović Vorkapić, S., Tadinac, M., Kulenović, A., & Buško, V. (2008) Evoked potentials and abstract thinking, Review of Psychology, 15(1-2), 67-76.

Tatalović Vorkapić, S., Tadinac, M. & Lučev, I. (2013). Electrocortical correlates of temperament. Polish Psychological Bulletin, 44(1), 92-101.

Thier, P., Axmann, D., & Giedke, H. (1986) Slow brain potentials and psychomotor retardation in depression, Electroencephalography and Clinical Neurophysiology, 63, 570-581.

Turetsky, B., Colbath, E.A., & Gur, R.E. (1998) P3 subcomponent abnormalities in schizophrenia: II. Longitudinal stability and relationship to symptom change, Biological Psychiatry, 43, 31-39.

Urretavizcaya, M., Moreno, I., Benlloch, L., Cardoner, N., Serrallonga, J., Menchón, J.M., & Valleyo, J. (2003) Auditory event-related potentials in 50 melancholic patients: increased N100, N200 and P300 latencies and diminished P300 amplitude, Journal of Affective Disorders, 74, 293-297.

Vandoolaeghe, E., van Hunsel, F., Nuyten, D., & Maes, M. (1998) Auditory event-related potentials in major depression: prolonged P300 latency and increased P200 amplitude, Journal of Affective Disorders, 48, 105-113.

Winter, K., Broadhurst, A., & Glass, A. (1972) Neuroticism, extraversion and EEG amplitude, Journal of Experimental Research in Personality, 6, 44-51.

Yanai, I., Fujikawa, T., Osada, M., Yamawaki, S., & Touhouda, Y. (1997) Changes in auditory P300 in patients with major depression and silent cerebral infarction, Journal of Affective Disorders, 46, 263-271.

Zuckerman, M. (1991) Psychobiology of personality, Press Syndicate of the University of Cambridge, Cambridge University Press, USA.

Address for correspondence:
Sanja Tatalović Vorkapić
The Faculty of Teacher Education, The University of Rijeka
University Avenue 6, 51000 Rijeka, Croatia
e-mail: sanjatv@ufri.hr
phone: +385 51 265 830