

ELECTROPHYSIOLOGICAL DIFFERENCES IN SANGUINE, CHOLERIC, PHLEGMATIC AND MELANCHOLIC

Sanja Tatalović Vorkapić

Department of Preschool Education, Faculty of Teacher Education

University of Rijeka

Address for correspondence:

Sanja Tatalović Vorkapić, PhD

Department of Preschool Education, Teacher Education College, University of Rijeka

University Campus, Slavka Krautzeka bb, 51000 Rijeka, Croatia

E-mail: sanjatv@ufri.hr

ABSTRACT

The aim of this study was to examine the relationship between latencies and amplitudes of evoked potentials (N1, P2, N2, P3 & Sw) and four temperament types defined on the basis of Eysenck's E and N dimensions: phlegmatic (E-N-), choleric (E+N+), melancholic (E-N+) and sanguine (E+N-). It was expected that choleric would be characterized by least inhibition, the lower arousability or the lowest EP-amplitudes, melancholic by most inhibition, the greater arousability or the highest EP-amplitudes, and sanguine and phlegmatic by an intermediate degree of inhibition. Furthermore, phlegmatic and melancholic types should have the longer EP-latencies, due to lower degree of extraversion.

A sample consisted of N=54 female psychology students, within the age range 19-23 years, all right-handers. Evoked potentials were measured by using the standard visual oddball paradigm in two trials. All participants have completed EPQ/R and afterwards were divided in the four groups according to the median on Extraversion and Neuroticism subscales.

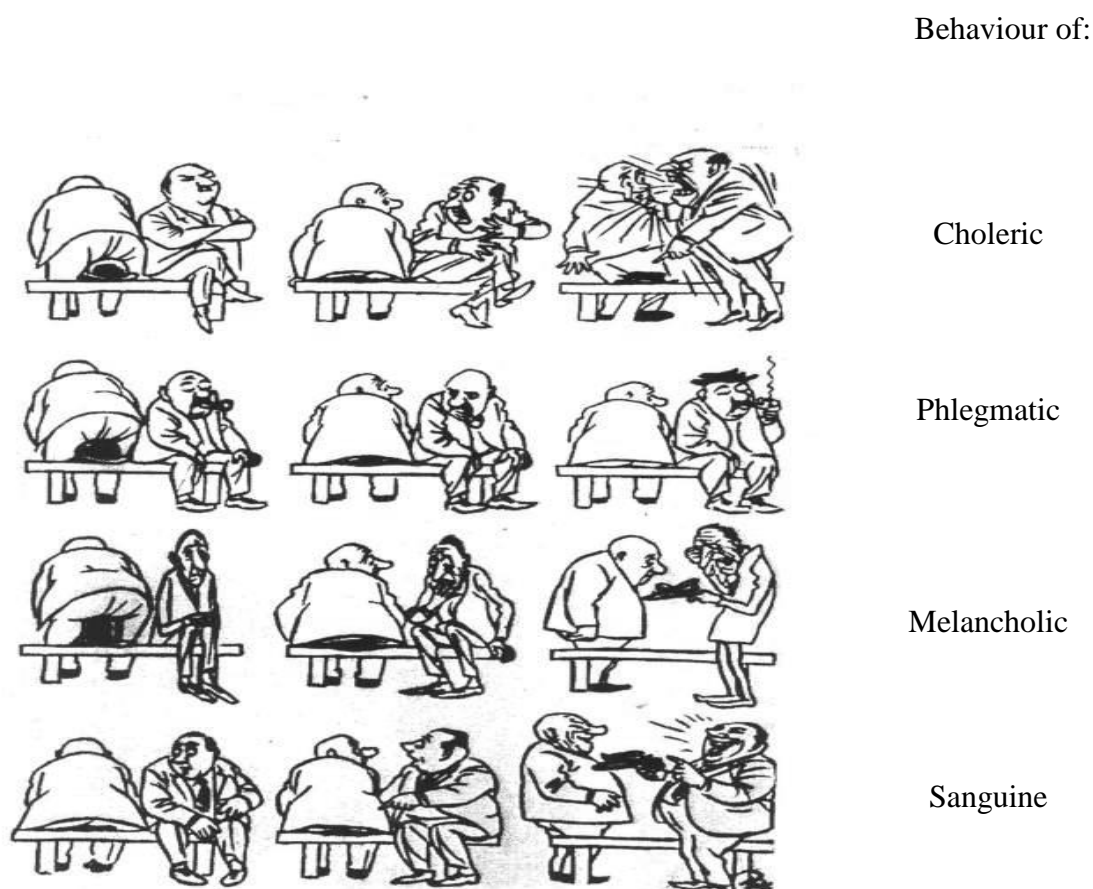
The analysis of EP amplitudes mostly showed the opposite pattern than expected: the lowest amplitudes were found in phlegmatic and the highest in choleric, with the sanguine and melancholic in between. The longest N2-latencies were determined in phlegmatic, and the longest P2- and Sw-latencies in melancholic, what was expected considering their low position on the E dimension. The electrophysiological differences among the four temperament types were clearly demonstrated, but the direction of their relationship has been discussed according to the mediate role of the attention and habituation effect variables.

Key words: four Eysenck's temperament types, evoked potentials, students

INTRODUCTION

The typological system that prevailed for almost two millennia was based on the everyday observation that personality traits occur in clusters that can be used to define Choleric, Melancholic, Sanguine and Phlegmatic temperament types (Figure 1).

Figure 1. The picture of the four behavioural reaction in the same situation which corresponded to the four temperament types: choleric, phlegmatic, melancholic and sanguine



In the past, a several significant individuals have defined them. Two Greek physicians: Hippocrates (c.460-c.370 B.C.) and Galen (AD 130-200) differentiated personalities according to the dominant bodily fluids: Choleric personality type has dominating yellow bile, so reactions are quick-tempered; Melancholic personality type has dominating black bile,

so acted dejected; Sanguine personality type has dominating blood and react as buoyant type; and Phlegmatic personality type has dominating phlegm and act like sluggish type. W. Wundt (1903) defined personality types according to a dimensional system of emotional strength and emotion change speed. He differentiated people with strong emotions and fast emotion change as choleric (SE/FC), people with strong emotions but slow emotional change as melancholic (SE/SC), people with weak emotions and fast emotional change as sanguine (WE/FC), and people with weak emotions but slow emotional change as phlegmatic (WE/SC). I. Kant (1912) divided personality according to two temperaments: temperament of emotions that included melancholics and sanguine and temperament of activity that included phlegmatics and choleric. Even though everyone of the mentioned temperament typology classification had not had a solid scientific ground and we know today that human behaviour is not connected with our bodily fluids (even this concept could be easily connected with the impact of a various hormones in human behaviour), the first one has been very influential through the years and have had a great influence on many personality theorists.

Modern temperament theories have been developed from two streams: the theories that were influenced by eastern and western traditions. The western tradition has not made a strict distinction between temperament and personality traits, so it equalized the personality dimensions with temperament dimensions (Casimjee, 2003). The eastern tradition emphasized the biological determination of temperament, so more often it has been using in its research experiment than questionnaires measures. One significant part of the eastern tradition is the Russian school with its creator I. P. Pavlov. After numerous studies about conditioning laws, Pavlov (1951-1952) has developed two theories: a) the theory of three CNS-properties: the strength of nervous system, equilibrium and mobility; and b) the theory of four basic CNS-types. The connection between those two theories lies in the fact that different configurations of the three CNS-properties constitute the four CNS-types namely the: a) weak type, b) strong

and unbalanced type, c) strong, balanced and slow type, and d) strong, balanced and mobile type (Strelau, 1983). Those four NCS-types corresponded to the four classical types of temperaments as proposed by Galen and Hippocrates (Table 1; Ruch, 1992).

Table 1. The four Hippocrates-Galen temperaments as characterized by the Pavlovian NSPs and the Eysenckian superfactors E and N (adapted from Ruch, 1992; p. 1262)

| Hippocrates-Galen typology | Pavlov's TNS | Eysenck's superfactors |
|----------------------------|------------------------|---------------------------|
| Melancholic | Weak | Unstable introvert (N+E-) |
| Choleric | Strong unbalanced | Unstable extravert (N+E+) |
| Phlegmatic | Strong balanced slow | Stable introvert (N-E-) |
| Sanguine | Strong balanced mobile | Stable extravert (N-E+) |

Within that frame (Strelau, 1997), melancholic types are characterized by weak processes of excitation and inhibition with a narrower range of action. Pavlov thought they were not adaptive temperaments due to their non-functional CNS. Choleric have been characterized by strong excitation and inhibition processes, with an excitation and unbalance dominance. The most adaptive temperaments are thought to be phlegmatic and sanguine. Therefore, Pavlov sought to distinguish those four temperament types in terms of CNS processes of excitation and inhibition. However, his dilemma was that his measures identified two dimensions of temperament variation what he sought to explain in terms of a single neurophysiologic dimension contrasting predominance of excitation and predominance of inhibition.

In Robinson's work (1982, 1983, 1986, 1996, 2001) it could be seen that there are two distinct excitation-inhibition dimensions rather than the single one proposed by Pavlov, by

which his dilemma could be resolved. In Robinson's research (1982, 1983, 1996) EEG responses were evaluated in terms of AEP (auditory evoked potential) and personality measures that related in a meaningful way to the physics of oscillating systems, to the anatomy and physiology of the diffuse thalamocortical system, and finally to the theories of both Pavlov and Eysenck. That research has given the answer on the question about understanding how the reciprocal interaction of excitatory and inhibitory neurons can generate wave phenomena. Robinson (1983, 1996) concluded that oscillatory activity is often caused by the reciprocal interaction of two opposed elements (inhibitory and excitatory elements) and that the "natural frequency" (it manifests as the particular frequency at which a particular system will oscillate freely following any disturbance) is determined by the relative influence of these elements. In addition, Robinson (1983) stated that the functional character and reciprocal interaction of these neurons within "feedback" circuits is precisely what is required to cause the oscillatory electrophysiological activity as CNS in general and arousal system in particular. To conclude, natural frequency is not only a superior index of "cerebral arousability" but it is also an index of the relative influence of cerebral excitation and cerebral inhibition. Robinson (1982, 2001) confirmed Eysenck's arousability hypothesis since introverts had higher natural frequency than extraverts and Pavlov's excitation-inhibition hypothesis because melancholics (E-N+) had the highest natural frequencies (predominance of excitation) whereas sanguine (E+N-) individuals had the lowest natural frequencies (predominance of inhibition). Since this presents the main hypothesis in this study too, the term natural frequency must be better explained. It could be more clearly presented as: greater "reactivity", shorter "response latencies", greater "arousability" and as manifestation of faster "transmission times".

Furthermore, within Eysenck's personality model (Eysenck & Eysenck, 1985) the four temperaments result from combinations of the well-known super-factors extraversion (E) and

Neuroticism (N), as it could be also seen in the Table 1. Therefore, the introverts could be recognized within melancholic and phlegmatic type but in the first one with the higher level of neuroticism and in the second with the lower level of neuroticism or greater emotional stability. On the other side, extraverts could be recognized within choleric and sanguine, but in the first one with a greater level of neuroticism, and in the second with a greater stability. So, unstable introverts, i.e. melancholic are described as moody, anxious, rigid, sober, pessimistic, reserved, unsociable and quiet; choleric (unstable extraverts) as touchy, restless, aggressive, excitable, changeable, impulsive, active, optimistic; sanguine (stable extraverts) as sociable, lively, carefree, leadership, outgoing, talkative, responsive and easygoing; and phlegmatic (stable introverts) as passive, careful, thoughtful, peaceful, controlled, reliable, even-tempered and calm (Revelle, Wilt & Condon, 2011). This classification is especially interesting for this study, since has been recently received support from empirical studies of mood states (Howarth, 1988; Howarth & Zumbo, 1989). Besides, brain systems underpinning neuroticism have profound influences on behaviour, controlling the individual's ability to learn through conditioning, to function effectively in society, and to manage stressful encounters (Matthews, 2004). In addition, the second reason to explore the electrocortical correlates of the four temperament types according to Eysenck's empirical verification of Hippocrates-Galen typology is the fact that any significant analyses of extraversion in any methodological context has no serious meaning if it has been studied isolated from neuroticism (Eysenck, 1967; Eysenck & Eysenck, 1985). Well, one of the very significant questions for ontogenesis of neuroticism, which has been analysed within several studies is related to whether psychometric independence of extraversion and neuroticism has been accompanied with the same independent physiological processes suggested by Eysenck (1967) or not? This scientific field has been created as the result of numerous findings of determined psychophysiological correlates of neuroticism and extraversion. Claridge &

Herrington (1963) were the first authors who have investigated the separate neurological paths within studies of individual differences in sedations thresholds, additional spiral effects and blood pressure. It has been determined that neuroticism is significantly related to a higher levels of a cortical arousal (Winter, Broadhurst & Glass, 1972) and also with lower levels of cortical arousal (Coles, Gale & Kline, 1971). Those various psychophysical correlates of neuroticism have been explained in detail by Zuckermann (1991, 1992). Besides, the psychometric independency between neuroticism and extraversion has been often related with the absence of significant correlations between neuroticism and EEG-measures of cortical arousal. Therefore, if the expected significant correlation between extraversion and neuroticism has been determined, the significant relationship between neuroticism and electrocortical measures could be expected to be determined (Stelmack, 1981). Finally, Robinson (2001; p. 1255-1256) emphasized “...that all of the major dimensions of personality are determined by the four basic temperament types” and “...that the widely accepted E and N coordinates should be used to identify the temperament types, and that it is these types that should be studied not the constantly shifting patterns of correlations in questionnaire data.” So, to analyse electrocortical correlates of the four combinations of extraversion and neuroticism seems to be not only interesting way to explore the psychophysiology of personality, but the needed one due to empirical validation.

With the aim of improving Pavlov's hypothesis, Robinson (2001) has used the measures of auditive evoked potentials (N2 & P2) and the factorization of sum values in three categories: waves of 4Hz, 7Hz and 10Hz what corresponded to characteristic frequencies of brain stem, limbic and thalamocortical system. He determined that the greatest balance between excitatory and inhibitory effect had the sanguine (N=41) and phlegmatic types (N=28); that choleric (N=16) showed the proposed predominance of excitation and melancholics (N=8) showed the predominance of inhibition. According to that, Buckingham

(2002) has investigated the relationship between four temperament types (ES/sanguine, (N=16); EN/choleric (N=16); IS/phlegmatic (N=8) and IN/melancholic (N=16)) and evoked potentials (P1N1 & N1P2). In this study, two different EP-answers were evoked by the tasks in which the subjects must react on three different tone intensity (auditive modality) and flashlights (visual modality). The results showed the statistically significant difference between melancholic and sanguine types. The melancholic types showed significantly steeper and higher amplitudes of P1N1 and N1P2, but only in auditive modality, what has confirmed the optimal level of arousability hypothesis and proposed higher cortical arousal and reactivity in melancholic. In visual modality, no significant differences have been determined. Buckingham (2002) has concluded that auditive EP-amplitudes presented more appropriate index for cerebral activity than visual EP-amplitudes.

Even though this study had a certain limitation since the only possibility of measuring evoking potentials was in the one – visual modality, it was interesting to conduct such research that provide one more insight in electrocortical correlates of the four temperament types. Using the standard visual oddball paradigm for evoking the potentials, the changes in the electrical activity of the nervous system as a response to physical stimuli, in association with psychological processes could be recorded. During such a task, the participant looks to a certain visual stimuli (checkboard), where one visual stimulus is usually the target. The participant's task is to press the button or just quietly count seeing the target stimulus (Polich, 2004). Taking into account the context in which a stimulus occurs (Brinar, Brzović, Vukadin & Zurak, 1996), two EP groups can be distinguished: *evoked (sensory or exogenous) potentials* represent the brain's reaction to some specific sensory stimulus, and *event-related potentials (cognitive or endogenous)* represent the same reaction, but one that is time-locked with specific physical or psychological event. The P1 (at 50 msec) has been used for non-invasive assessment of functional state of visual fields and visual cortex (Dabić-Jeftić &

Mikula, 1994). N1 (80-100 msec) is related to selective attention (Polich, 1993). P2 (170-200 msec) is related to the early information processing, and together with N1 encodes the physical characteristics of stimuli (Hugdahl, 1995). N2 (after 200 msec) is related to the process of discrimination and stimulus novelty (Näätänen, 1992). Cognitive wave P3 (300-600 msec) does not reflect the physical parameters of stimuli, is not always connected to the appearance of the stimulus, is being evoked by the unexpected stimuli and does not appear if the stimuli are not relevant for the subject (Polich, 1998). As for its neural model, P300 shows a fronto-parietal activation (Polich & Kok, 1995; Polich, 2004) and it appears when there is a need to update the internal model of the environment in the working memory. Finally, the Slow wave activity (longer than 1 sec, and lasts for 3-4 sec) appears even before the stimulus presentation, while participants wait for the task to begin (Hugdahl, 1995). For detailed study, sensory same as cognitive EP-components were measured here. In this way, the amplitude and latency of these components reflect, in a robustly systematic manner, variations in the underlying psychological substrate (Donchin, Ritter & McCallum, 1978).

As the evoked potentials have been served widely like a fine tool for investigating the psychophysiological background of personality, it was assumed to analyse the electrocortical correlates of the four temperament types using the EP-method would be more than justified. According to the previously described theoretical frames, it was expected that choleric would be characterized by least inhibition, the lower arousability or the lowest EP-amplitudes, melancholic by most inhibition, the greater arousability or the highest EP-amplitudes, and sanguine and phlegmatic by an intermediate degree of inhibition. Furthermore, phlegmatic and melancholic should have the longer EP-latencies, due to lower degree of extraversion (Brebner, 1983; Tatalović Vorkapić, Tadinac & Rudež, 2010). Since none of the theoretical presumptions did not take into account possible mediate effects of attention and different habituation effects on extraverts/introverts (Sternberg, 1994; Tatalović Vorkapić, 2005, 2010;

Tatalović Vorkapić et al., 2010), they must be mentioned. Different habituation rates in introverts/extraverts influenced on the correlation directions between EPs and personality dimensions, so they must be taken into account concerning the research findings. Therefore, if relevant, they would be discussed later.

METHOD

Subjects

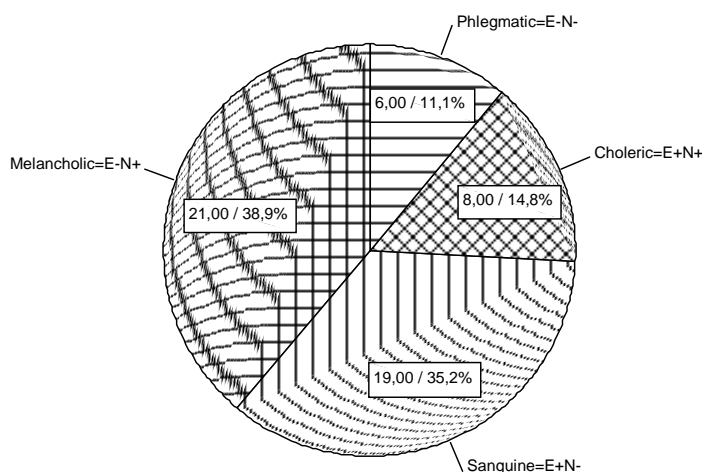
A total number of 54 female students of psychology (M=20.50 years, SD=1.28, range: 19-23) were participated in this study. They were all undergraduates studying at the Department of Psychology, University of Rijeka. To have more homogenous sample they have been all right-handed with no neurological/psychiatric or visual problems. In addition, students out of age-range between 19-23 years were excluded from the research because of previous research findings concerning the age effect on measured evoked potentials that was determined in the age-range more than four (Polich & Kok, 1995). Finally, they were naive to electrophysiological studies and received course credits for their partaking in the study.

Personality measurement: The four temperament types

To determine the four temperament types that correspond to the four classical temperament types, personality traits of extraversion (E) and neuroticism (N) were measured by the Eysenck's Personality Questionnaire-Revised (Eysenck & Eysenck, 1994). After completing the questionnaire, the subjects were divided in the four groups on the basis of their Extraversion and Neuroticism results, following the criterion of median for Extraversion $C=17$ and for Neuroticism $C=8$ (Figure 2). So, the groups were defined as: Sanguine (E+N-) = ($E > 17$ i $N < 8$); Melancholic (E-N+) = ($E \leq 17$ i $N \geq 8$); Phlegmatic (E-N-) = ($E \leq 17$ i $N < 8$); and

Choleric (E+N+) = (E>17 i N \geq 8). The difference significance in evoked potentials between those four groups was computed by a t-test.

Figure 2. Eysenck's Temperament Typology: Frequency and percentage of subjects divided in four temperament groups



Evoked potential measurement: Apparatus and procedure

After the general instruction was given to participants, EPQ/R was administered first, and then, each participant underwent the measurement of the evoked brain potentials (N1, P2, N2, P3 and SW) in two trials according to the EP-measurement schedule. In cooperation with the Department of Neurology in Clinical Hospital Centre in Rijeka and according to the availability of EP-laboratory, all recordings were made in the course of four months, always on Wednesdays and always at the same time – noon. In addition, with this schedule the relevant EP-variables of the time of the day and the season were controlled. EP-responses were elicited by the standard visual oddball paradigm, chosen according to the possibilities of the device. The available apparatus was the model of a Medelec/TECA SapphireII 4E device (1996) with five Ag/AgCl disc electrodes. The active electrodes were placed on O1, O2, P3

and P4 (according to the 10-20 system), and referred to Fz. The electrode impedance was kept below 5k Ω and the filter bandpass was 0.1-50 Hz. A pattern reverse binocular full-field stimulation was performed in a dark, quiet room using a 16x16 checkerboard pattern, 70 cm away from the nasion, with 1Hz frequency and 100% contrast. Fifteen percent of stimuli were rare checkerboards (consisting of the smaller quadrangles) and presented the target stimuli, whereas the remaining ones were frequent checkerboards (consisting of the larger quadrangles) presented in random order and they were the nontarget stimuli. Participants 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, because there was no possibility of the time reaction measurement. Since the apparatus software had the possibility only to store the measured evoked potentials, the marking procedure of the amplitudes and latencies of the evoked potentials (N1, P2, N2, P3 and SW) was performed manually, using a cursor, by the same medical technician for both trials. In the second trial the evoked potentials were marked by the same latencies as those from the first trial, so the effect of the latency jitter could be avoided (Coles, Gratton, Kramer & Miller, 1986; Hoormann, et al., 1998), and to make evoked potentials more stable over trials. Therefore, for each participant there was a same EP-latency (as measured only in one trial) for both trials, but different EP-amplitudes.

RESULTS AND DISCUSSION

The relationship between four temperament types and evoked potentials

To analyse relationship between four temperament types and measured evoked potentials, t-tests were conducted. No determined result distributions have significantly differed from the normal distribution, so parametric statistics could be applied. The possibility of generalization of the determined results must be taken with a precaution due to two sample characteristics. First, after division of 54 subjects in the four groups of temperament types a

rather small number of subjects have left (Figure 2). Nevertheless, this study has been conducted with this number of subjects since there was no possibility to examine more than 54 subjects. Besides, the EP-studies are generally very specific, expensive and long lasting, so employ a smaller number of subjects than other psychology studies. However, this sample characteristic must be taken as a limitation of the determined results. Second, in this study only psychology students were the subjects, who were open enough to participate in EP-research. But, it is well-known that examine psychology students in the personality research of any kind or within any theoretical model has its limitation since there is no enough heterogeneity according personality traits or dimensions. In other words, the temperament differences among them are rather small, so that could influence on determined difference effects, what will be mentioned later. According to extraversion and neuroticism levels, this sample showed a rather similar pattern as the subjects from the original research (Eysenck & Eysenck, 1994): a little higher extraversion levels and a little smaller neuroticism levels have been determined on this sample.

The difference between four temperament types in EP-latencies

The means and standard deviations for Eysenck's temperament typology groups and latencies of EPs: N1, P2, N2, P3 and Sw on the four electrodes (O1, O2, P3 and P4), same as the t-tests results were shown in the Table 2, Figure 3.

Table 2. Means (M), Standard deviations (SD) and t-test results for Eysenck's temperament typology groups and latencies of EPs: N1, P2, N2, P3 and Sw on the four electrodes (O1, O2, P3 and P4)

| EP-latencies | N1 | P2 | N2 | P3 | Sw |
|---------------------|--------------|-----------|-----------|-----------|-----------|
| Types | M(SD) | | | | |

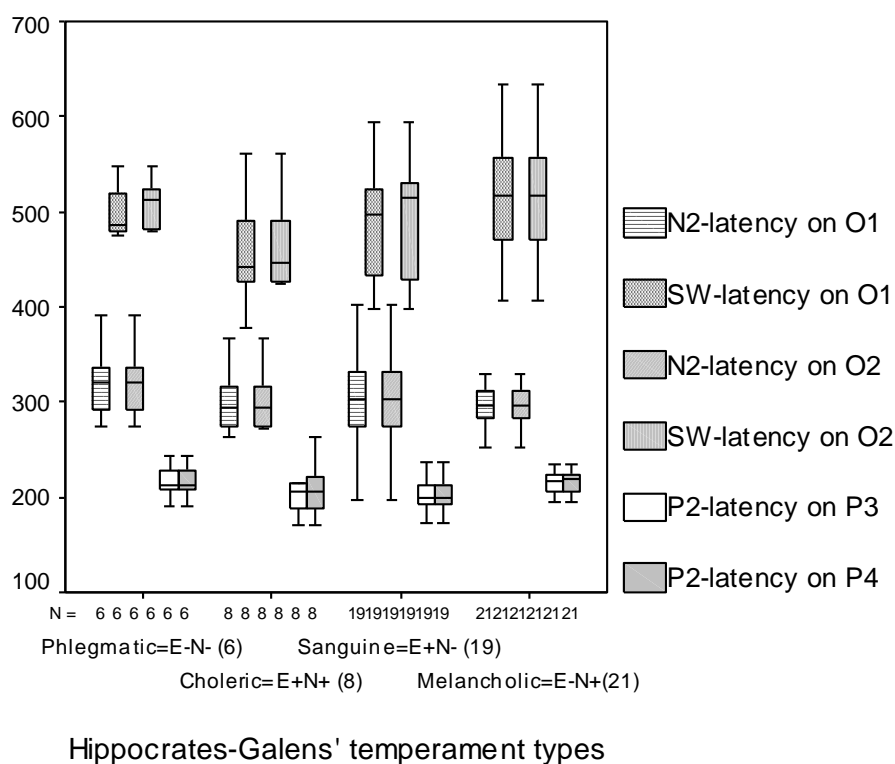
| | | | | | | |
|-----------------------|-----|---------------|----------------|----------------|---------------|----------------|
| 1. Melancholic | O1 | 142(30.8) | 218.38(17.45) | 295.81(22.03) | 419.14(36.68) | 514.52(53.65) |
| | O2 | 142(30.8) | 217.48(16.58) | 295.33(21.98) | 418.81(36.76) | 516.52(55.17) |
| | P3 | 145.09(36.19) | 216.62(27.7) | 300.19(57.08) | 404.38(62.38) | 502.95(65.31) |
| | P4 | 144.52(36.88) | 217.48(27.8) | 300.19(57.08) | 404.38(62.38) | 502.67(65.72) |
| 2. Choleric | O1 | 139.62(25.63) | 219.88(9.69) | 300(33.51) | 389.25(46.54) | 456.75(56.5) |
| | O2 | 139.62(25.63) | 219.88(9.69) | 301.12(32.22) | 389.75(46.78) | 463.75(49.48) |
| | P3 | 134.62(22.82) | 206.75(27.77) | 275.25(39.9) | 366.25(73.54) | 457.38(90.07) |
| | P4 | 133.12(23.91) | 208.25(28.59) | 274.62(40.16) | 366.25(73.54) | 460.62(93.25) |
| 3. Phlegmatic | O1 | 160.67(26.88) | 229(8.12) | 322.5(40.36) | 424.83(20.43) | 499.17(28.36) |
| | O2 | 160.67(26.88) | 229(8.12) | 322.5(40.36) | 432.5(22.7) | 509.67(29.16) |
| | P3 | 137.5(30.18) | 216(17.75) | 291(45.99) | 409.83(57.33) | 505.67(62.46) |
| | P4 | 137.5(30.18) | 216(17.75) | 291(45.99) | 409.83(57.33) | 507.83(64.75) |
| 4. Sanguine | O1 | 140.79(26.88) | 221.21(27.78) | 299.21(46.87) | 411.9(51.17) | 490.53(64.75) |
| | O2 | 140.79(30.62) | 221.1(27.75) | 299.32(46) | 412.26(53.68) | 491.79(66.07) |
| | P3 | 131.89(25.41) | 200.42(19.71) | 289(52.54) | 375.21(66.54) | 457.84(84.57) |
| | P4 | 132.16(25.03) | 200.42(19.72) | 289(52.54) | 374.32(66.92) | 457(84.52) |
| T-test, p | 1-2 | | | | | O1* O2* |
| | 1-3 | | | O1* O2* | | |
| | 1-4 | | P3* P4* | | | |
| | 2-3 | | | | | |
| | 2-4 | | | | | |
| | 3-4 | | | | | |

*p<.05 **p<.01

Overall, it could be seen that significant differences have been determined between melancholic and sanguine types at P2-latency on P3-electrode ($t_{(38)}=2.11$, $p=.04$) and on P4-electrode ($t_{(38)}=2.22$, $p=.03$). Melancholic temperament types have showed significantly longer P2-latencies than sanguine. Also, the significant differences were found between melancholic and phlegmatic in N2-latencies on O1-electrode ($t_{(25)}=2.16$, $p=.04$) and on O2-electrode ($t_{(25)}=2.20$, $p=.04$). The phlegmatic temperament types showed significantly longer N2-latencies than melancholic (Figure 3). Finally, the significant differences in Sw-latency on O1-electrode ($t_{(27)}=2.56$, $p=.02$) and on O2-electrode ($t_{(27)}=2.36$, $p=.03$), have been found

between melancholic and choleric. According to that, melancholic showed significantly longer Sw-latencies than choleric (Figure 3).

Figure 3. Latencies (msec) of P2, N2 and Sw components for the four temperamental types (phlegmatic, choleric, sanguine and melancholic) on occipital (O1 & O2) and parietal (P3 & P4) electrodes



Altogether, significant differences have been determined between melancholic and sanguine in P2-latencies on both parietal electrodes, and between melancholic and choleric in Sw-latencies on both occipital electrodes. In both cases, melancholic showed significantly longer EP-latencies. This finding is rather logic, since melancholic had higher levels of neuroticism and introversion, which were the most prone to psychological dysfunction. Therefore, it is logic to found the longest P2-Sw-latencies in this temperament group, e.i. the

slowest encoding of physical stimuli and controlled information processing. It is interesting that the first difference in P2-latencies is only between melancholic and sanguine that had a high level of extraversion and emotional stability. In addition, the difference in Sw-latency is only significant between melancholic and choleric who were similar in the neuroticism dimension, but had a higher level of extraversion.

On the other side, phlegmatic showed significantly longer N2-latencies in difference to melancholic. N2-latency presents the speed of the subject's extraction, determination of physical characteristics of stimuli and choosing the final answer. In this phase of information processing, it seems that the emotional stability presented the significant factor or the reason for the determined difference, since the introversion level is the same in melancholic and phlegmatic. Even though there were a small number of similar studies, and limitations of this study due to apparatus used and sample characteristics, these findings are very interesting and present a solid ground to be further investigated. Nevertheless, the significance of the determined P2-Sw-latencies, which were significantly longer in melancholic, confirming their suggested greater vulnerability toward psychological dysfunction (N+E-) and their characteristic of slow emotional change must be emphasized (Polich, 1998; Polich, & Kok, 1995).

The relationship between four temperament types and EP-amplitudes

As it could be seen in Table 3, which showed means, standard deviations and t-test results for the four temperament types and EP-amplitudes in the first and the second trial on the four electrodes (O1, O2, P3 and P4), the most dominant were the changes in N2-amplitude.

Table 3. Means (M), Standard deviations (SD) and t-test results for Eysenck's temperament typology groups and amplitudes of EPs: N1, P2, N2, P3 and Sw (amplitudes from the 1st (A1) and the 2nd (A2) trial) on the four electrodes (O1, O2, P3 and P4)

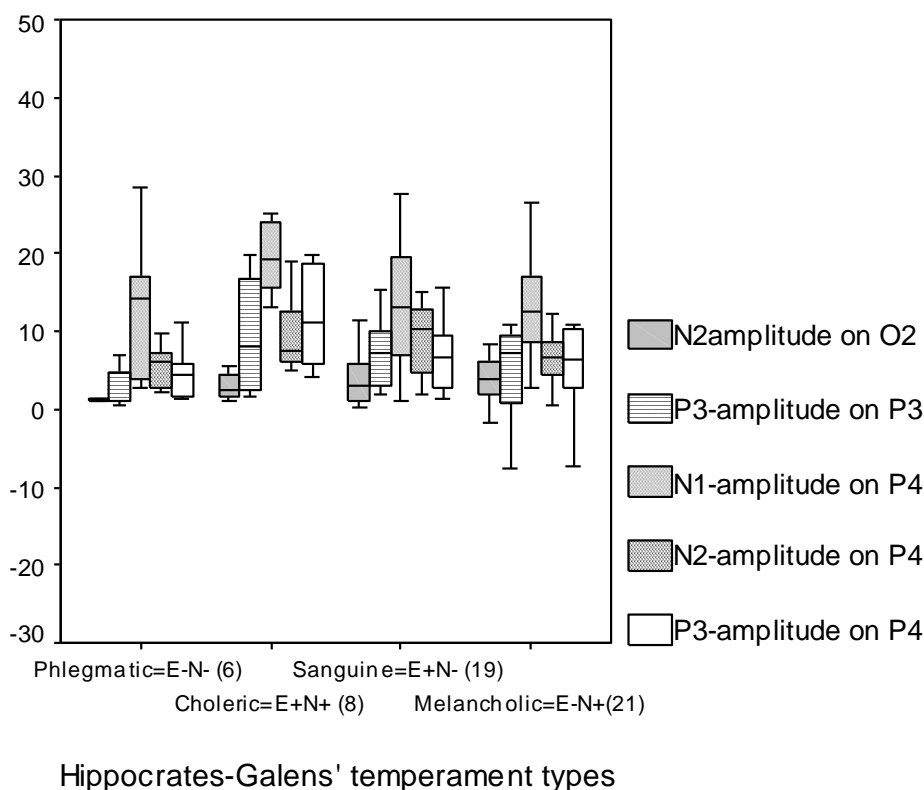
| EP-latencies | | N1 | | P2 | | N2 | | P3 | |
|----------------|-----|-----------------|------------------|------------------|------------------|-----------------|----------------------------|---------------------------|-----------------|
| | | A1 | A2 | A1 | A2 | A1 | A2 | A1 | A2 |
| Types | | M(SD) | | | | | | | |
| 1. Melancholic | O1 | 10.08 (4.66) | 10.86 (4.61) | 8.53 (5.03) | 8.61 (4.52) | 4.96 (4.47) | 5.38 (4.81) | 5.00 (3.60) | 3.4 (3.42) |
| | O2 | 13.07 (7.46) | 13.23 (7.35) | 9.53 (6.39) | 9.8 (5.32) | 6.37 (6.13) | 6.51 (5.66) | 5.23 (3.81) | 3.54 (2.68) |
| | P3 | 12.92 (7.42) | 13.22 (7.58) | 12.76 (8.16) | 10.43 (7.65) | 7.55 (4.22) | 6.7 (4.38) | 10.83 (8.44) | 8.88 (6.99) |
| | P4 | 14.83 (8.95) | 13.78 (7.4) | 13.81 (8.95) | 11.09 (7.2) | 6.56 (3.96) | 6.02 (4.85) | 10.56 (9.55) | 8.83 (7.53) |
| 2. Choleric | O1 | 12.13 (5.64) | 11.55 (5.91) | 9.32 (6.27) | 8.78 (4.13) | 3.13 (2.63) | 1.52 (1.32) | 4.30 (1.99) | 2.68 (2.27) |
| | O2 | 14.05 (4.03) | 13.18 (5.35) | 12.19 (5.68) | 10.94 (4.33) | 2.91 (1.72) | 1.82 (.9) | 3.55 (1.79) | 3 (1.65) |
| | P3 | 13.04 (6.41) | 15.16 (6.29) | 10.74 (7.79) | 11.8 (6.38) | 12.95 (9.08) | 9.98 (8.8) | 12.2 (8.15) | 8.67 (3.28) |
| | P4 | 21.38 (8.79) | 20.82 (8.16) | 12.85 (10.44) | 14.02 (9.5) | 9.52 (5.01) | 9.01 (7.62) | 13.72 (6.08) | 9.57 (4.41) |
| 3. Phlegmatic | O1 | 7.61 (2.46) | 9.57 (2.4) | 10.11 (3.86) | 10.82 (4.5) | 2.69 (1.67) | 4.78 (3.91) | 3.59 (2.87) | 2.7 (2.87) |
| | O2 | 12.7 (5.59) | 12.94 (6.54) | 9.92 (3.02) | 10.18 (5.6) | 1.46 (.57) | 2.93 (1.81) | 4.03 (2.58) | 2.83 (2.63) |
| | P3 | 12.53 (5.63) | 10.84 (7.34) | 14.72 (9.4) | 10.55 (9.46) | 6.05 (6.08) | 10.8 (7.78) | 3.73 (2.54) | 8.81 (6.04) |
| | P4 | 13.37 (9.44) | 14.29 (11.72) | 17.13 (10) | 13.03 (10.96) | 5.65 (2.81) | 8.89 (7.55) | 4.72 (3.54) | 10.86 (6.92) |
| 4. Sanguine | O1 | 10.21 (6.49) | 9.74 (6.85) | 9.59 (5.22) | 8.57 (4.99) | 5.25 (4.98) | 4.84 (5.67) | 4.34 (2.47) | 4.26 (3.38) |
| | O2 | 10.83 (6.23) | 10.18 (5.25) | 11.81 (6.79) | 10.78 (6.76) | 5.26 (5.62) | 5.09 (5.2) | 4.42 (3.16) | 4.19 (3.33) |
| | P3 | 14.45 (8.83) | 12.85 (7.54) | 15.51 (7.43) | 13.46 (9.46) | 9.58 (5.99) | 9.12 (6.6) | 7.99 (3.98) | 9.08 (8.2) |
| | P4 | 14.3 (7.2) | 13.4 (5.98) | 15.74 (8.97) | 14.64 (8.44) | 10.06 (6.43) | 8.69 (4.97) | 7.35 (3.9) | 8.5 (7.64) |
| T-test, p | 1-2 | | P4* | | | | O1** O2** | | |
| | 1-3 | | | | | O2** | O2* | P3** | |
| | 1-4 | | | | | P4* | | | |
| | 2-3 | | | | | O2* | | P3* P4** | |
| | 2-4 | P4* | P4** | | | | | P4* | |
| | 3-4 | | | | | O2** | | P3* | |

*p<.05 **p<.01

As for the first EP-component, it could be seen that the significant difference has been determined between choleric and sanguine in N1-amplitude from the first trial on the P4-

electrode ($t_{(25)}=2.74$, $p=.02$). According to that, choleric showed the significantly higher N1-amplitudes than sanguine (Figure 4).

Figure 4. Amplitudes (μV) of N1, N2 and P3 components measured in the first trial for the four temperamental types (phlegmatic, choleric, sanguine and melancholic) on occipital (O2) and parietal (P3 & P4) electrodes



In the second trial, the significant differences in N1-amplitude have been determined on P4-electrode between choleric and melancholic ($t_{(38)}=2.23$, $p=.04$), and choleric and sanguine ($t_{(25)}=2.64$, $p=.01$). Choleric temperament types showed significantly higher N1-amplitude on one parietal electrode in the second trial than melancholic and sanguine (Figure 5).

Besides, analysing the N2-amplitude measured in the first trial on P4-electrode, the determined significant difference between melancholic and sanguine could be seen ($t_{(38)}=2.1$, $p=.04$). Sanguine showed significantly higher N2-amplitude than melancholic types (Figure

4). Within analyses of the same EP-component but on the O2-electrode it is evident that

several differences were determined as a significant (Table 3, Figure 4). Phlegmatic temperament types have showed significantly the most lower N2-amplitudes on that occipital electrode in the first trial according to all other temperament types: melancholic ($t_{(25)}=3.16$, $p=.01$), choleric ($t_{(12)}=2.22$, $p=.05$), and according to sanguine ($t_{(23)}=2.89$, $p=.01$). Concerning the analyses of the same EP-component but in the second trial, the significant differences between melancholic and choleric have been determined on O1-electrode ($t_{(27)}=3.37$, $p=.01$) and on O2-electrode ($t_{(27)}=3.68$, $p=.01$). Melancholic showed the significantly higher N2-amplitudes in the second trial in difference to choleric types. The significant difference has been determined between melancholic and phlegmatic, where melancholic had a significantly higher N2-amplitudes in the second trial on O2-electrode ($t_{(25)}=2.49$, $p=.02$). The differences between four temperament types in N2-amplitude on occipital electrodes in the second trial could be seen at the Figure 5.

Finally, choleric showed significantly higher P3-amplitudes in the first trial on both parietal electrodes (Table 3, Figure 4) than phlegmatic: on P3-electrode ($t_{(12)}=2.76$, $p=.02$), and on P4-electrode ($t_{(12)}=3.48$, $p=.01$). Besides, it was determined that choleric had significantly higher P3-amplitudes in the first trial on P4-electrode than sanguine too ($t_{(25)}=2.74$, $p=.02$). Also, the significant was the difference in P3-amplitude between phlegmatic and sanguine ($t_{(23)}=2.44$, $p=.02$), where sanguine showed higher P3-amplitudes in the first trial on P3-electrode. Similarly, melancholic showed significantly higher P3-amplitudes than melancholic ($t_{(25)}=3.36$, $p=.00$) in the first trial on P3-electrode too (Figure 4).

In comparison of the determined significant differences in EPs between four temperament types, it could be clearly seen that most differences were placed within the relationship between temperament types and EP-amplitudes. In prior studies personality research it has been concluded if there was psychometrically independence between extraversion and neuroticism, the significant correlation between neuroticism and EEG-

indexes of cortical arousal could not be expected. Since it has been determined a rather high negative correlation between extraversion and neuroticism in this study ($r=-.45$, $p<.01$), the expectation of certain significant relationship between measured EPs and neuroticism within four temperament types has been justified (Stelmack, 1981). Also, according to Pavlov's excitation-inhibition hypothesis, it was assumed that melancholic (IN) would have the biggest so called "natural frequency" or predomination of excitation, and vice versa sanguine (ES) would have the lowest "natural frequency" or the predomination of inhibition (Robinson, 1982).

However, data in this study have been something different from the Robinson's results (2001). First, it was determined that choleric had higher N1-amplitudes than sanguine in the first and the second trial, and than melancholic in the second trial. Choleric are characterized by higher levels of neuroticism and extraversion. So, if the higher N1-amplitude, which appears during early and automatic information processing and reflects the selective attention, (Näätänen, 1992) is defined as an index of cortical arousal, it could be connected to a higher level of neuroticism according to this study and theoretical background. However, if the significant differences could be closely observed, choleric types were significantly differed from melancholic and sanguine too – the two temperament types which not differed significantly in N1-amplitude. It seems that extreme combinations of extraversion and neuroticism did not differ in N1-amplitude, because the combination of high neuroticism and extraversion that could be found in choleric presented the solid ground for significant changes in N1-amplitude. On the other side, the type of given visual task in this study must be mentioned within the context of earlier mentioned different habituation rate and reaction on different task difficulty in introverts and extraverts (Stenberg, 1994). Therefore, it would be very interesting and useful to conduct research that would use a greater number of subjects of different occupations with a possibility of experimental design and variation of the task

difficulty and modality for evoking the cortical potentials. The use of greater number of electrodes and much more modern technical device for EP-measurement would be also recommended since it would give much better analyses results about specific differences that would emerge between those four temperament types.

The greatest number of significant differences have been determined concerning the N2-amplitude. It reflects the determination of physical characteristics of stimuli and the final answer (reaction) following the given parameters from the subject. Concerning this EP-component, melancholic showed significantly higher amplitudes than phlegmatic and choleric. This finding has confirmed earlier hypothesis. On the other side, melancholic showed significantly lower N2-amplitudes than sanguine, what was not expected within the frame of the same hypothesis. To resume, the highest N2-amplitudes have been determined to be found in sanguine, then in melancholic, choleric and finally the lowest in phlegmatic. Analysing the results from the second trial, which are under bigger influence of task difficulty and habituation rate, it could be seen that the highest N2-amplitude showed melancholic than phlegmatic and choleric. It is very important to separately observe the first and the second trial. In the first trial, N2-amplitude as a strength of N2-wave has been determined to be the highest at sanguine, who theoretically have the biggest strength of the nervous system indeed. Therefore, within the first trial it could be said that we could analyse the baseline of evoked potentials in the four temperament types. In the second trial, the situation has been changed. All the following measurement trials have been under great influence of the level of the subject's engagement in the task, what resulted with the determined highest N2-amplitudes in melancholic, as it was supposed. This explanation is meaningful within the theoretical frame, but definitely must go through the empirical validation taken into account before mentioned factors: more participants of different occupations and sex, better EP-

measurement equipment, more electrodes, different modality tasks with the different difficulty levels and more trials.

At the end, concerning the analyses of the P3-amplitude differences, the highest amplitude showed choleric (same as in N1-component), then melancholic, sanguine and finally phlegmatic. Those results, same as the one related to differences in N1-amplitude, are in agreement with the Robinson's findings (2001), who determined the supposed significant predomination of excitation in choleric, and the highest balance between excitatory and inhibitory effect in sanguine and phlegmatic. However, there is no agreement between the results in this study concerning the determined EP-differences in melancholic and the Robinson's hypothesis about their characteristic of predomination of inhibition. The possible explanation could be related to the effects of different habituation rates in introverts and extraverts and their different ways in attention allocation (Sternberg, 1994; Tatalović Vorkapić, 2005; Tatalović Vorkapić, 2010; Tatalović Vorkapić et al., 2010), since the tendency for habituation effect has been determined here: the significantly higher P3-amplitude in the first than the second trial ($t_{(54)}=2.32, p>.05$).

CONCLUSION

Analysing the EP-changes in the four Eysenck's temperament types, the greater number of differences have been determined in the EP-amplitudes than in the EP-latencies. Generally, melancholic showed the longest EP-latencies, choleric the highest N1 and P3 amplitudes and sanguine the highest N2-amplitudes in the first trial. In the second trial, melancholic showed the highest N2-amplitude, what has confirmed the hypothesis. Taken altogether, the findings partially confirmed described theoretical background and Robinson's hypothesis. The significantly longer P2-Sw-latencies have determined in melancholic, confirming their suggested greater vulnerability toward psychological dysfunction (N+E-) and

their characteristic of slow emotional change. As it was mentioned, the hypothesis of greater EP-amplitudes in melancholic was partially confirmed. Considering the first trial, greater N1-P3-amplitudes were found in choleric and greater N2-amplitude in the sanguine group. However, in the second trial the N2-amplitudes were found to be significantly higher in melancholic – confirming a higher cortical arousal during their engagement in the visual task. Future studies should try to avoid the described limitation of this study, and using bigger comparison groups, samples consisting of students from various study groups, easy/difficult task, more measuring trials and electrodes should improve the methodological quality of the research, and consequently the result interpretation.

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