Associations Between Self-Report of Emotional State and the EEG Patterns in Affective Disorders Patients

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Abstract. The study determines the associations between self-report of ongoing emotional state and EEG patterns. A group of 31 hospitalized patients were enrolled with three types of diagnosis: major depressive disorder, manic episode of bipolar affective disorder, and nonaffective patients. The Thayer ADACL checklist, which yields two subjective dimensions, was used for the assessment of affective state: Energy Tiredness (ET) and Tension Calmness (TC). Quantitative analysis of EEG was based on EEG spectral power and laterality coefficient (LC). Only the ET scale showed relationships with the laterality coefficient. The high-energy group showed right shift of activity in frontocentral and posterior areas visible in alpha and beta range, respectively. No effect of ET estimation on prefrontal asymmetry was observed. For the TC scale, a high estimation of tension was related to right prefrontal dominance and right posterior activation in beta1 band. Also, decrease of alpha2 power together with increase of beta2 power was observed over the entire scalp.

Keywords: EEG, laterality, emotional state, self-report, affective disorders

Introduction

This study addresses the issue of the relationships between self-report of ongoing emotional state and corresponding parameters of EEG activity. Since brain emotional systems (including cortical structures) are a substrate for emotion-related processes, EEG data can reveal important information on their functioning. The issue of associations between EEG activity and emotions has received much attention in the literature. Most often, however, affective state is not directly measured by self-report; rather, inference about its valence and magnitude is made on the basis of the procedure (e.g., type of emotional slides or emotional content presented to participants, recalling particular memories asked by the researcher, etc.).

One of the most promising theoretical attempts at describing how cortical structures contribute to emotional processing is the valence/arousal model postulated by Heller and coworkers (Heller, 1993; Heller & Nitschke, 1998; Heller, Nitschke, & Miller, 1998). This model takes into account experiential aspect of emotions, which makes it especially interesting for our investigations. It distinguishes two emotion-related cortical systems: The first one, located in frontal area, is related to experiential aspect of emotional valence. Its activity accounts for the phenomena of prefrontal asymmetry, where left hemisphere predominance is associated with positive and right predominance with negative emotional conditions. This asymmetry concept was integrated into Heller’s model on the basis of numerous clinical and laboratory observations, as well as from the withdrawal/approach theory, widely discussed in the literature (Davidson, 1995; Davidson & Tomarken, 1989; for a review, see Demaree, Everhart, Youngstrom, & Harrison, 2005). The second cortical system postulated by Heller is located in the right posterior area; it is related to nonspecific emotional arousal and is claimed to be active in conditions of both positive and negative activation. The majority of data underlying these theoretical models stem from research on processing of emotional stimuli as well as from clinical observations. The question is whether cortical EEG patterns postulated by the valence/arousal model shows similar relationships with verbally self-reported emotional state.

Our previous studies succeeded in determining some state-dependent associations between self-report of emotional state (Thayer, 1970) and EEG activity in selected cortex areas. Estimation of positive energetic state was related to frontal asymmetry with left hemisphere dominance (expressed in alpha2 and beta frequencies), while estimation of tension was associated with global decrease of beta1 power, mostly over right posterior area (Wyczesany, Kaiser, & Coenen, 2008). In the present study, af-
fective disorder patients (diagnosed with major depressive disorder and manic phase of bipolar affective disorder) were chosen. Their subjective ratings of spontaneous emotional state together with EEG patterns were analyzed. Participation of affective disorder patients provides the opportunity for increasing between-subject variability of measured affective states between subjects (especially for depressive and manic patients). At this point it is important to emphasize that the primary objective of the study was to determine associations between affective state estimation and EEG patterns. Therefore, the experimental approach presented here disregards the diagnosis, but uses self-report as a main variable in the subsequent analysis. The participants were differentiated on the basis of their subjective scores rather than on their diagnosis. Unfortunately, only a small part of the literature on EEG and emotions shares our interest toward subjective assessment. Two studies reported on state-dependent changes between CES-D depression scores (Center for Epidemiological Studies Depression Scale; Radloff, 1977) and frontal EEG asymmetry. Depression scores were found to be positively correlated with left frontal alpha power (Diego, Field, & Hernandez-Reif, 2001). The BDI scores (Beck Depression Inventory) scale was also found to be related to greater alpha power at the left hemisphere (i.e., right dominance) (Schaffer, Davidson, & Saron, 1983). The single-case study of Earnest (1999) confirmed the positive association between BDI scores and right frontal hemisphere dominance, as measured by a decrease of alpha power. The study of Papousek and Schulter (2002), carried out in healthy subjects, was also dedicated to the frontal asymmetry issue. They found that EEG recorded on frontopolar electrodes can be considered state-dependent, and the pattern of their activity changes along participants’ estimation of their current emotional state. There is an apparent lack of studies taking other areas of the cortex and their associations with current emotional state into account.

As in our previous work (Kaiser & Wyczesany, 2005, 2006, 2008; Wyczesany et al., 2008), we applied Thayer’s Activation-Deactivation Adjective CheckList (Thayer, 1970) to measure subjective state. This tool can quantify the internal state on two main bidirectional dimensions: (1) energetic arousal, estimated on continuum between high energy and tiredness, characterized by positive valence related to increase of energy; and (2) tension arousal, located between a calm, relaxed state and tension or stress response, related to negative valence while tension estimation increases. These dimensions are closely related to the nonunitary arousal concept, which seems to especially valuable for verifying a valence/arousal model.

The present experiment presumes that estimation of subjective state will co-vary with ongoing EEG parameters, and that these relationships will be as follows:

- An increase of Energy scores will be related to relative left frontal dominance.
- An increase of Tension scores will be related to relative right frontal dominance.

- An increase of both Energy and Tension scores will be nonspecifically associated with increase of posterior activity, mostly pronounced in the right hemisphere.

Materials and Methods

Subjects

A group of 31 hospitalized, neuropsychiatric patients under medication (13 women and 18 men) participated in the study. Mean age was 46.2 years (range 26–58). All of them gave informed consent. The study was carried out under approval and supervision of the hospital authorities. In order to create as heterogeneous group as possible, the following subjects were included according to their diagnosis at the time of admission to the hospital (based on the ICD-10 system):

- depression (13 persons with major depressive disorder of no psychotic type with low anxiety),
- mania (5 persons with bipolar affective disorder during manic episode, with no psychotic features)
- without mood disorders (13 nonaffective patients suffering from peripheral neurological complaints but with no pain at the time of experiment).

Mood Assessment

For the assessment of mood, we used the paper version of the Activation Deactivation Adjective CheckList (ADACL) in a Polish adaptation by Grzegotowska-Klarkowska (1982). The scale consists of 20 adjectives rated on a 4-level scale to indicate the extent to which they describe participants’ current mood and activation state. Two dimensions can be distinguished: Energy-Tiredness (ET), operating on the continuum between positive energetic state and drowsiness and tiredness; and Tension-Calmness (TC), which measures negative tension arousal of a defensive character as opposite to relaxed state.

EEG Recording and Quantification

EEG data were recorded with a 32-channel Biosemi ActiveTwo device [manufacturer and place??], equipped with active electrodes integrated with amplifiers and 24-bit A/D converters. The electrodes were placed using a cap with extended 10–20 system. Linked mastoid reference was used. For offline ocular artifact removal, additional electrodes were used, which recorded the signals from eye muscles. Electrode impedances were kept in the recommended range during the whole recording.

The frequencies between 3 and 46 Hz were extracted using digital bandpass filter with 24 dB/octave slope. Ocular artifacts were removed using the Gratton-Coles-Donchin
Data Analysis

The relationships between EEG power and mood self-report were calculated by a series of Pearson-r linear correlation analyses separately for each frequency band (5) and electrodes (32). The effect of subjective estimation on the laterality coefficient was investigated using 15 separate ANOVA analysis for each frequency band (alpha1, 2, beta1, 2, 3) and localization (PF, FC, PS). For this purpose, in the case of both ADACL subscales (ET, TC), participants were divided into three groups according to their scores (low, medium, high). The statistical tests were followed by additional verification of significance level using false discovery rate procedure (FDR, Shaffer, 1995) in order to control for type I error level probability, which was increased because of multiple statistical tests. This procedure was applied independently within each considered frequency band.

Results

Subjective Scales

As expected, the subjective scores ratings were widely dispersed, due likely to our including subjects with both depressive as well as manic affective disorders. Descriptive statistics of both subjective scales (Energy-Tiredness and Tension-Calmness) are provided in Table 1. A positive value on the ET scale suggests a state related to high energy, while a negative value points to low energy and drowsiness. Similarly, positive scores on the TC scale means a state of high tension, while negative scores are associated with a relaxed state. Relatively high values of standard deviations suggest that emotional states were widely dispersed between the subjects, in accordance with our expectations.

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<th>Mean</th>
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<td>-13</td>
<td>12</td>
<td>6.94</td>
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<td>Tension-Calmness</td>
<td>-6.21</td>
<td>-15</td>
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Integration of the EEG and Self-Report Data

Energy-Tiredness

Of the two EEG measures employed, only the laterality coefficient turned out to be sensitive to Energy estimation. In alpha frequencies there was a significant difference between the low- and high-energy group observed at the frontocentral area. The latter showed more alpha activity at the right hemisphere, while the former showed more alpha activity at the left hemisphere (alpha1: F(2, 28) = 3.99; p = .03; alpha2: F(2, 28) = 4.53, p = .02). In the beta band the differences were found...
Table 2. Correlation values between the Tension-Calmness and EEG spectral power with p levels for two-tailed tests. Significant items that passed the FDR procedure are marked with asterisks.

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Significant correlations between the Energy-Tiredness estimation and Laterality Coefficient in alpha (frontocentral) and beta (posterior) bands. Positive LC values are related to greater power at left while positive, at right hemisphere. The miniature scalps show location of the effect with direction of asymmetry observed along with increase of Energy marked with asterisks.

Figure 1. Significant correlations between the Energy-Tiredness estimation and Laterality Coefficient in alpha (frontocentral) and beta (posterior) bands. Positive LC values are related to greater power at left while positive, at right hemisphere.
at posterior sites: The high-energy group showed greater activity of right hemisphere than the other groups (beta2: \( F(2, 28) = 11.03, p < .001; \) beta3: \( F(2, 28) = 5.23, p = .01; \) Figure 1). No significant effects of energetic arousal estimation on EEG absolute power measures were found.

### Tension-Calmness

In contrast to the energy subscale, significant relationships were found among Tension scores only for absolute power measures. In the alpha2 range, negative correlation with tension self-report was observed with the effect mostly pronounced in the left temporal and parietal area; it was, however, also visible over the entire range except for the prefrontal cortex. For the beta range, positive associations with tension estimation varied depending on the frequency range. For beta1, the effect was visible mostly in the right prefrontal and frontal as well as in the right centroparietal and parietal area. For beta2, positive correlation was found across the whole scalp, although the effect was the strongest in the left posterior cortex (Figure 2, Table 2).

### Discussion

In accordance with our expectations, self-report scores of Energy and Tension were widely dispersed within the group. This is not surprising, since the affective state reported by patients – beside behavioral, motivational, and physical aspects – is one of the important symptoms accounting for such diagnose. High variance of self-report scales supports the assumption that the sample of patients with affective disorders gives the opportunity to obtain the wide range of emotional states. It should be noted that mood disorder as a factor, includes not only the disease process but also the influence of psychotherapy and pharmacotherapy. But, since our experimental approach focuses on the subjective estimation of emotional state, it does not require homogeneity according to disorder subtype, medication or the length of therapy.

The only significant effect in the frontal cortex was heightened beta1 activation at the right hemisphere together with increase of reported Tension (Figure 2b). Only right hemisphere changes contributed to this effect, which did not show a typical asymmetry pattern, i.e., simultaneous decrease of left hemisphere activity. Right frontal predominance observed in state of Tension characterized by negative emotional valence is in accordance with our expectations and theoretical predictions. This finding confirms our assumption that prefrontal asymmetry has state-dependent properties, which was a subject of discussion in the literature (see Coan & Allen, 2002). On the other hand, no associations between the Energy scale and frontal asymmetry was detected, nor was any absolute power laterality coefficient found.

Positive correlation between estimation of energy and magnitude of left frontal cortex predominance was expected. Since the Energy dimension is characterized by positive valence, our expectation concerning frontal asymmetry was based on the concept of hemispheric specialization in emotional processing. In order to interpret the findings, a closer look should be taken at this issue, which, despite much attention paid, is still not entirely clear. Apart from many reports confirming left hemisphere predominance in positive and right hemisphere in negative emotional state (e.g., Coan & Allen, 2002; Demaree et al., 2005), there is also a significant number of observations that do not confirm this effect – or even consider it contrary to the theoretical expectations (Carson et al. 2000[not in refs]; Drevets et al., 1992; Nitschke, Heller, Etienne, & Miller, 1995; Papousek & Schulter, 2002; Stabell et al., 2004). To explain these inconsistencies, possible mediating factors affecting frontal asymmetry were considered: differences in experimental conditions, affective disorders and its subtypes, accompanying anxiety, comorbidity, as well as personality traits (Coan & Allen, 2002: Davidson, 1998; Heller & Nitschke, 1998; Reid, Duke, & Allen, 1998). It is also known that frontal asymmetry does not directly reflect valence of emotions (positive/negative), but rather the motivational direction (approach/withdrawal). This important distinction was included in the theoretical models to incorporate observations of left frontal dominance in state of anger (Harmon-Jones & Allen, 1998; Harmon-Jones & Sigel-
man, 2001) – or in case of some depression subtypes, where patients were focused on recollecting their problems (Heller & Nitschke, 1998). Lack of an effect for Energy scale could be caused by the fact that the Energy scale is not directly related to the approach/withdrawal dimension. There is some positive valence load in this scale, but its relationship to motivational direction remains ambiguous. In the case of the Tension scores, which show the effect of right frontal predominance, motivational direction can be more easily attributed to avoidance. Another possible explanation suggests medication as a factor that could disrupt frontal asymmetry patterns observed in patients. There are many reports describing changes in EEG activity caused by pharmaceuticals, including their influence on frontal cortex (Banoczi, 2005; Cook et al. 2002; Hunter, Leuchter, Morgan, & Cook, 2006; Knott, Howson, Perugini, Ravindran, & Young, 1999; Knott & Lapierre, 1987; Saletu, Andrerer, & Saletu-Zyhlarz, 2006).

The expectations concerning nonspecific cortical activation with its center in the right posterior area received some support in the data. In narrow beta bands, a heightened activation of right posterior region associated with increase of both Energy as well as Tension scores was observed. Such an effect was predicted by our hypothesis as well as observed in our previous findings (Kaiser & Wyczesany, 2008; Wyczesany et al. 2008). However, a more detailed look at these data shows significant differences between Energy and Tension scales concerning their associations with posterior EEG. In the case of the ET scale, self-report of high energy was associated with beta2 and beta3 predominance in the right posterior region compared to low and medium energy groups, which showed more beta power at the left, especially in the beta3 band. This result was significant only by means of the laterality coefficient measure, which means that both hemispheres contributed to this effect in opposite directions (Figure 1cd). For the TC scale, the pattern of covariation between EEG and subjective scores was different; in the beta1 band there was focused increase of right posterior activation with no effect of left hemisphere attenuation (Figure 2b). Similar patterns of association between the Tension scale and beta1 activity was found (Wyczesany, unpublished results). Observed wide-power measures. The first one was a negative correlation with alpha2 activity visible on the scalp area except for the prefrontal and right temporal area, and most pronounced on the left posterior derivations. Another one was a positive correlation with beta2 frequencies, mostly similar according to localization to alpha2 effect. The similarity of these two observations according to localization may suggest that these two effects could be complementary (decrease of alpha2 along with an increase of beta2). This hypothesis needs further investigation, however, since some suggestions for a complementarity of these bands can be found (Wyczesany, unpublished results). Observed wide-localized correlations of beta power with Tension scores can be preliminarily explained by the importance of beta rhythm in emotional processes. Some interpretations can be made on the basis of literature reports, where a reduction of emotional tension resulted in a decrease of beta power, mostly in the anterior region (Jacobs, Benson, & Friedman, 2006). A recollection of “angry” memories was also accompanied by an increase of wide beta range at the frontal and temporal electrodes (Foster & Harrison, 2002). Similarly, alpha rhythm is known to be related to the calm, relaxed state (Andreassi, 2000), and these observations are in accordance with our data. As can be seen, the associations of alpha2 and beta2 power turned out not to be focused and specific for any particular localization, but rather were observed throughout the entire cortex. Our data support the importance of narrow band spectral analysis of EEG signals due to their specific functional significance (Lorig & Schwartz, 1989; Marosi et al., 2002).
Conclusions

In summary, associations between emotional self-report and EEG measures were observed. The data show that particular EEG measures have some predictive power on the experiential aspect of the affective state. The relationship between prefrontal asymmetry and tension estimation was visible in the expected direction, but no such effect was found for energetic arousal. The right posterior region, presumed to be the system related to experience of nonspecific emotional arousal, showed an increase of activation for both the energetic and tension scales. However, two patterns of activation related to energetic and tension arousal differed from each other according to frequency and the accompanying changes in the left hemisphere. Our data suggest that energetic and tension arousal affects the posterior cortex in a specific way contradictory to Heller’s claim. Therefore, we conclude that the predictions of Heller’s model were confirmed only partially. One possible reason for this observed discrepancy was the difference between our approach with a focus on self-report data and the experimental paradigms on which Heller’s model had been based. Verbal estimation of current emotional state could then be considered a different process than the normally investigated aspects of emotions. Nevertheless, some consistivity between the presented findings and the valence/arousal model was described, which suggests a common factor linking self-report and other emotional processes. This factor could be considered in terms of the experiential aspect of affective state. It supports the idea that verbal estimation can reflect a real functional state of the brain related to emotions.

Acknowledgments

This work was supported by the Ministry of Science and Higher Education funds reserved for scientific research (2009).

References


Accepted for publication: October 8, 2009

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