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Cortical lateralization patterns related to self-estimation of emotional state

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The relationships between subjectively-reported emotional state and hemispheric laterality were investigated. Participants' emotional state was modified using emotional slides. Self-estimation of Energy Arousal and Hedonic Tone (positive valence) as well as Tense Arousal (negative valence) was derived from the Activation-Deactivation Adjective Checklist and the UWIST Mood Adjective Checklist. Energy arousal was found to be associated with right frontal dominance in the alpha2 (10–12 Hz) band, together with left frontal dominance in the beta2 (16–24 Hz) band. It was also related to left alpha2 dominance in the central and centro-parietal cortex. The effects for the Hedonic Tone scale were limited to a frontal beta2 effect. Surprisingly, no effects of state estimates from the tension scales were observed. It can be concluded that selected qualities of subjective emotional state measured by adjective lists can be related in specific ways to hemispheric laterality, as measured by EEG methods.

Key words: EEG power, emotional state, laterality, UMACL, ADACL, subjective estimation

INTRODUCTION

Emotional processing has received substantial attention in psychophysiology, but its experiential, subjective aspect is still not sufficiently explored. Mood and emotional state are important factors influencing many aspects of human behavior and cognition. In order to fully deal with subjective states, one has to focus to a greater extent on the subject's private report and integrate it into cognitive science (Varela and Shear 1999).

The concept of hemispheric differences in emotional processing is well established in the literature. It was initiated by observations of patients with lesions in the right hemisphere, which resulted in attenuated emotional expression (Babinski 1914). Since that time the data from many clinical observations and experiments provide the background for theories of hemispheric specialization in emotional processing, now widely discussed in the literature (for reviews, see Mandal et al. 1996, Demaree et al. 2005, Thibodeau et al. 2006). The historically-first right hemisphere model, claiming the superiority of the right hemisphere in all aspects of emotional processing (Ross 1985), was replaced by the valence model, which posits both hemispheres as nearly equally important in emotional processing, but differently specialized: the left related to positive emotions, and the right to negative emotions (e.g. Davidson 1992, 2004, Tomarken et al. 1992). Further observations, especially left-hemisphere activation in anger conditions, led to an update of this model toward approach/withdrawal theory. According to this, it is not a valence which directly underlies the specialization, but rather a motivational tendency to approach or withdraw associated with particular emotions (Harmon-Jones and Allen 1998, Harmon-Jones 2003).

A promising attempt to integrate these observations with cortical functioning can be found in the valence/arousal model (Heller 1993) which postulates two distinct cortical emotional systems. The first system, located in the frontal cortex, is claimed to account for the experience of emotional valence, with activity

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shifted to the left for positive and to the right for negative emotions. The second system, located in the right posterior area, is insensitive to valence, and reflects the magnitude of non-specific emotional arousal, which is also related to autonomic activation. This model has significant observational support.

However, a recent version also includes endogenously determined affects. Observations of various kinds of depression and anxiety states were incorporated, and the distinction between anxious apprehension and anxious arousal was introduced. Anxious arousal is a state accompanied by stress, panic reactions and physiological, somatic arousal, which is reflected in right frontal dominance and right posterior activation. On the other hand, anxious apprehension, which includes worry, verbal rumination and decreased overall level of arousal, together with anhedonia, is characterized by decreased activation of the posterior non-specific system. Additionally, anxious apprehension can be associated with left frontal dominance, which may be explained by approach behavior toward the subject's problems, or by verbal engagement (Heller and Nitschke 1998, Heller et al. 1998, Nitschke et al. 2001). Apprehension was also observed to be related to left predominance in the posterior region (Nitschke et al. 1999).

A significant number of studies have searched for state-dependent EEG patterns, which are expected to co-vary with on-going affective states. Many reports confirming the asymmetry predictions have used EEG recording in non-clinical studies (Drevets et al. 1992, Sobotka et al. 1992, Bremner et al. 2000, Coan and Allen 2004, Davidson 2004, Fingelkurts et al. 2006, Mathersul et al. 2008), as well as PET or fMRI (George et al. 1995, Canli et al. 1998, Phan et al. 2002). Also, this effect was observed in depressed patients and subclinical groups (Pizzagalli et al. 2002, Shenal et al. 2003, Mathersul et al. 2008). Among these studies, few have used any kind of subjective measures. In the study of Wheeler and others (1993), resting frontal asymmetry (considered as a trait) was investigated. Subjects' affective state was manipulated by emotional films. In the case of subjects characterized by stable frontal asymmetry, self-estimation of more positive affect after the film was associated with a tendency to left, and more negative affect with a tendency to right frontal dominance. Biofeedback studies in which subjects had to control their frontal asymmetry have shown that changes in self-estimation of emotional mood after watching such films are modulated by changes of asymmetry (Allen et al. 2001). In contrast to the trait approach, Papousek and Schulter (2002) investigated state characteristics of frontal asymmetry. They found co-variation of prefrontal asymmetry with reported subjective state, and their spontaneous changes, however the direction of the effect (left dominance associated with negative affect and right dominance with positive affect) was opposite to the typical asymmetry pattern described in the literature. As can be seen, the issue of relationships between hemispheric asymmetry and emotional self-report is a still-unexplored area, especially when focusing on its state-dependent characteristics and areas others than frontal sites. Our study is thus intended to gather more information on this topic using modification of emotional state by affective stimuli.

To obtain quantitative and replicable subjective data, an appropriate measurement tool is needed. This requirement can be fulfilled by verbal self-description checklists, described as "controlled self-report" (Thayer 1970). These consist of a defined list of adjectives, which subjects use to rate their current mood/emotional state. Nevertheless, a doubt remains: are the "controlled self-reports" sufficient to display the true emotional state, or are they just a cognitive interpretation of the subject's current life circumstances in terms of selected adjectives? Empirical demonstration of correlation between a subject's own affective feeling (rating on a scale) and specific measures of brain activity may be a way to resolve this issue. Correlated EEG and subjective measures then could be thought of as two aspects (physiological and experiential) of the emotional state. In the case when no such correlation could be observed, the conclusion can be drawn that self report does not apply to the pure emotional state at the very moment of measurement, but is rather related to cognitive interpretation of current conditions. Such interpretation would be based on external factors as recognized by subject.

In the present experiment, two checklists were used for self-estimation of emotional state: the UWIST Mood Adjective Checklist – UMACL (Matthews et al. 1990), and the Activation-Deactivation Adjective Checklist – ADACL, short version (Thayer 1970). The former includes the valence subscale (Hedonic Tone), intended to measure emotional state by rating adjectives with positive as well as negative connotation or meaning. It also has two activational subscales

(Energetic Arousal and Tension Arousal). The ADACL has activational subscales only (Energy-Tiredness and Tension-Calmness), however these include relatively strong valence loads. According to Thayer (1989), The Energy-Tiredness subscale has some positive connotation, while Tension-Calmness has a stronger negative component. Their valence connotation is especially important, since that is related to the lateralization hypotheses. Usage of both scales allows their comparison, which is especially interesting for the corresponding scales. Both scales are intended to measure emotional state at the time of measurement, which is expressed in their instructions.

In the face of very scarce data concerning self-reports and EEG patterns, the aim of our study was to resolve how particular qualities of subjective emotional state, as reported by subjects, are related to hemispheric lateralization of brain activity. The question is whether it is in accordance with the well known effects of emotional stimulus processing widely discussed in the literature. It is especially interesting not to limit the data to prefrontal asymmetry, but also to determine the posterior relationships predicted by Heller's model.

Our previous studies (Kaiser and Wyczesany 2005, 2006, Wyczesany et al. 2008) succeeded in finding stable and specific relationships between EEG relative power of particular EEG bands and adjective checklist scores. For more pronounced qualities of emotions we attempted to increase the diversity of subjective states among subjects by presenting a series of positive, neutral or negative slides to different groups. We expected that the after-effect of these emotive events would modify both valence/activation of subjects' affective state as well as their pattern of EEG activity. The emotional state and EEG both before and after slide presentation were assessed.

Many studies dedicated to emotional processing have shown the importance of narrow-band EEG analysis, due to functional heterogeneity observed within traditional bands (Lorig and Schwartz 1989, Marosi et al. 2002). Our data (Wyczesany et al. 2008) pointed to lower beta as the band especially related to emotional processes, supporting other observations (Lehman et al. 1995, Isotani et al. 2001). Our hypotheses relating emotional states to EEG are as follows: An association between valence estimation (Hedonic Tone scores) and left hemispheric predominance in the frontal area will be observed. It will result in greater power of alpha at the right (reversed relationships with activation) and beta at the left hemisphere.

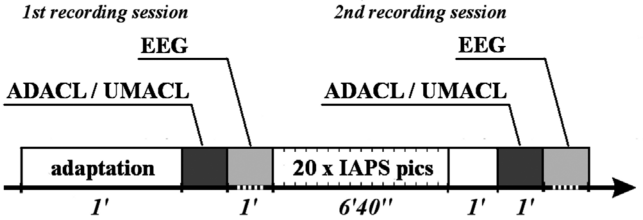

Fig. 1. Experimental procedure

The energetic arousal subscales, which have positive valence load, will be related to relative left hemisphere dominance in frontal electrodes, while the tension subscales, with negative connotation, will be associated with the inverse pattern.

Increase of both energetic and tension arousal will be additionally related to increased right hemisphere dominance, pronounced in right central and posterior regions and observed as an increase of low-frequency beta activity.

METHODS

Subjects

Fifty-six volunteers (34 women), aged 18–37 (mean 24.2 years), participated in the study. They were healthy and medication-free, and none were ever diagnosed with any neurological or psychiatric illness. All of them gave written informed consent to participate in the study.

Subjective estimation tools

Assessment of emotional state was made by means of two checklists: the UWIST Mood Adjective Checklist – UMACL (Matthews et al. 1990) in the Polish adaptation of Goryńska (2001), and the Activation-Deactivation Adjective Checklist – ADACL, short version (Thayer 1970) in the Polish adaptation of Grzegołowska-Klarkowska (1982).

Procedure

The experiment took place in a sound-proofed air-conditioned chamber, illuminated with dimmed light.

The procedural instructions were presented on a 20'' LCD screen. Before the experiment, subjects were briefly informed about the aim of the study, which was "recording of brain activity during presentation of some information and pictures". All the electrodes were then attached and connected, and subjects were asked to keep theirs eyes open, avoid rapid body movements during the procedure, and to pay attention to the computer screen, where further directives were going to be shown.

The procedure was based on that used previously in our experiments (Kaiser and Wyczesany 2005, 2006, Wyczesany et al. 2008). It began with an initial period of 4 minutes rest, intended for adaptation to the experimental conditions. During the next 1-minute period the tonic EEG was recorded, immediately followed by a computer version of both check-lists. Their order was randomly changed to counterbalance any effects of the first check-list on the following one. Subjects were randomly divided into 3 groups: neutral, negative and positive. Depending on the group, separate sets of 20 emotional pictures selected from the International Affective Picture System (IAPS) (Lang et al. 1997) were presented, preceded by the instruction to pay attention to the screen during their presentation. Selection of pictures was based on the standardized "pleasure" values. The following rules were used: for the neutral group, the "pleasure" value for both sexes was between 4 and 5; for the negative group it was lower than 2.5. For the positive group, due to the discrepancy of pleasure ratings between sexes, separate sets were composed with "pleasure" ratings not lower than 7.5 points. Presentation time was 20 s for each picture, which required 6 min 40 s for the whole set. The pictures were followed by a 1-minute rest period. Then the post-presentation recording session started. The detailed procedure is presented schematically in Fig. 1. This resulted in 2 sets of emotional state rating and EEG data from each of the 56 participants, generating 112 conjunctions of subjective and objective variable sets.

The separate estimation of subjective (rating scales) and objective (EEG) measurement was necessary to avoid possible EEG artifacts caused by cognitive and/or motor activity while filling in the checklists. This method of quasi-simultaneous measurement was used in our previous studies, and by other research (e.g. Thayer 1989, Lehmann et al. 1995, Gamma et al. 2000, Papousek and Schulter 2002, Fairclough and Venables 2006).

EEG Recording and analysis

EEG data were recorded with a 32-channel Biosemi ActiveTwo device, equipped with active electrodes

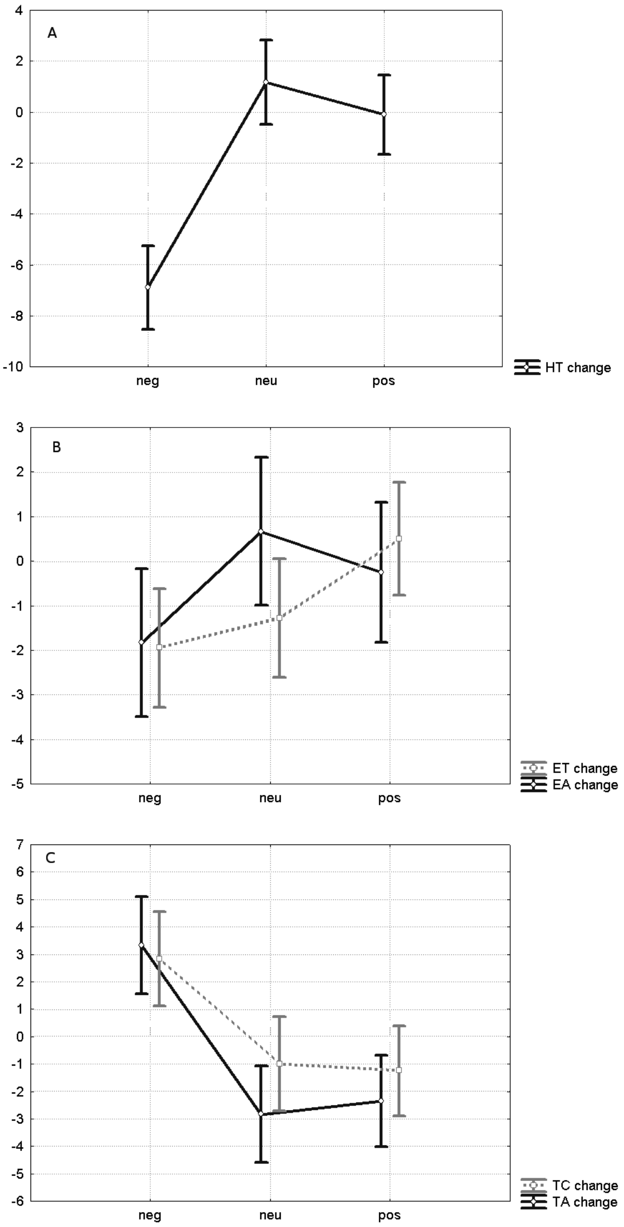

Fig. 2. Changes of the emotional state estimation between recording sessions as an effect of stimulus valence. (neg) Negative; (neu) neutral; (pos) positive slides set; (HT) Hedonic Tone; (ET) Energy Tiredness; (EA) Energy Arousal; (TC) Tension Calmness; (TA) Tension Arousal.

Table I

Correlations between subjective subscales

	Energy-Tiredness (ET)	Tension-Calmness (TC)	Energetic Arousal (EA)	Tense Arousal (TA)	Hedonic Tone (HT)
Energy-Tiredness (ET)	–	−0.17	0.51*	−0.18	0.41*
Tension-Calmness (TC)	−0.17	–	−0.14	0.77*	−0.58*
Energetic Arousal (EA)	0.51*	−0.14	–	−0.19	0.48*
Tense Arousal (TA)	−0.18	0.77*	−0.19	–	−0.61*
Hedonic Tone (HT)	0.41*	−0.58*	0.48*	–0.61*	–

*$P<0.05$

and 24-bit A/D converters. The electrodes were placed using a cap with the extended 10–20 system. The linked mastoid reference was used during the recording. For ocular artifact correction, four additional electrodes were used for recording the signals from eye muscles. Electrode impedances were kept in a recommended range during the whole recording. The EEG signal was filtered with a digital bandpass filter with low and high cut-off frequencies of 1 and 46 Hz respectively, and slope of 24 dB/octave. Ocular artifact correction was based on the Gratton-Coles-Donchin method (Gratton et al. 1983). One-minute EEG segments were divided into 2-second overlapped epochs, and manually inspected for artifacts. For each segment averaged spectral power density ($\mu V^2/Hz$) was calculated as the average of spectral power for all 2-second artifact-free epochs contributing to this band (FFT method with 0.5 Hz resolution and 10% Hanning window). Finally, the spectral power density values were aggregated into the following bands: alpha1 (8–10 Hz), alpha2 (10–12 Hz), beta1 (13–15 Hz), beta2 (16–24 Hz), and beta3 (25–30 Hz). As a measure of hemispheric imbalance, a Lateralization Coefficient (LC) was calculated for 12 homologous electrode pairs (Fp1–Fp2, AF3–AF4, F7–F8. F3–F4, FC1–FC2, FC5–FC6, T7–T8, C3–C4, CP1–CP2, CP5–CP6, P7–P8, P3–P4). The coefficient is expressed by the following formula: $LC=(L-R)*100/(L+R)$, where L and R are spectral power values in the selected frequency window for the left and right hemisphere, respectively (Porac and Coren 1981). Its positive value indicates left-, while a negative value indicates right-hemispheric dominance. The advantage of the LC over the simple difference between the hemispheric spectral power values, or its logarithms, is its insensitivity to the general level of EEG activity. The large amount of LC data (12 electrode pairs × 5 frequency bands) was reduced using Principal Component Analysis (PCA) to group data channels separately for each of the bands. This method is typically used to reduce multidimensional data sets to lower dimensions by identifying their main "components", which are linear combinations of the original data. The two components within each band with the largest eigenvalues were used for further analysis.

RESULTS

Effect of the procedure

Effect of the randomization

The chi-Square statistic showed that the gender distribution across the three experimental groups did not differ: $\chi^2(2)=0.211$; $P=0.26$.

Subjective measures of emotional state

Subjective scores were obtained using the original instructions for both checklists, yielding five dimensions: three of them from the UMACL (Hedonic

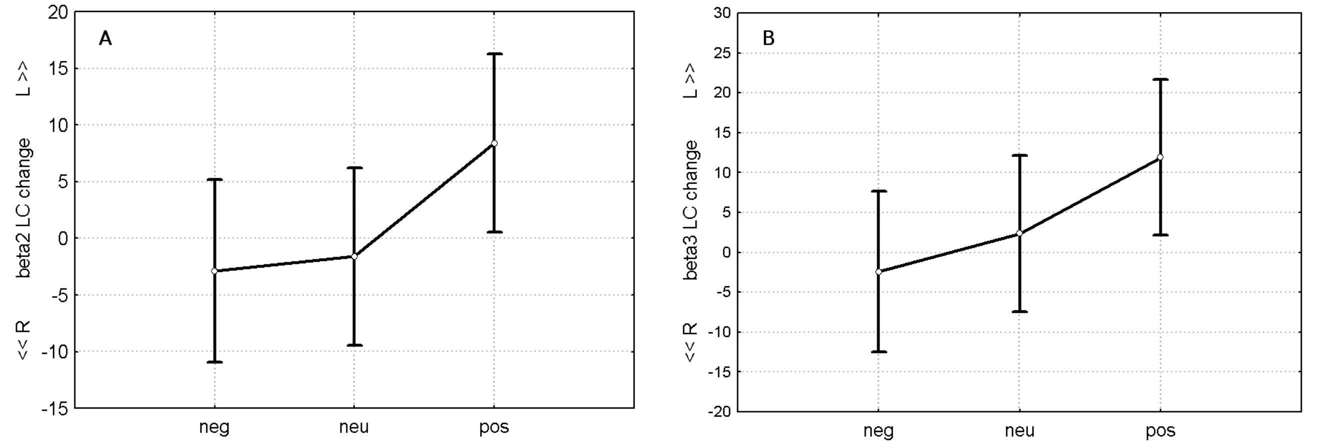

Fig. 3. Changes of the frontal Laterality Coefficient (LC) as the effect of the slides' valence. (neg) Negative; (neu) neutral; (pos) positive slides set.

Tone HT, Energetic Arousal EA, Tense Arousal TA) and two from the ADACL (Energy-Tiredness ET and Tension-Calmness TC). Correlations between subjective subscales were calculated using the Pearson correlation coefficient. The energetic subscales are correlated at the moderate level of 0.51, and tense arousal at the quite high level of 0.77. It is also apparent that all the subscales covary with HT scores; the energy estimation comprises positive, while tension comprises negative connotation. Table I shows correlations between all subjective subscales.

The pre-stimuli level of emotional estimation was checked using an ANOVA test, which ensured that the experimental groups did not differ significantly before the experimental manipulation. A MANOVA analysis, run for both checklists together, showed that the presentation of emotional slides strongly affected emotional state as reported by subjects. The differences between state before and after the slide presentation were analyzed. Positive values mean that the estimation on the scale was higher after the stimulus presentation than before. Valence of state reported using the HT scale was significantly lower in negative compared to both neutral and positive conditions (Fig. 2A). There was a strong effect of slide valence ($F_{10,98}$=6.69; P<0.001). Detailed HSD *post-hoc* tests show differences for particular subscales. The ADACL estimation of energy (ET) was significantly higher in positive compared to both neutral and negative conditions. For the EA scale, the relationships had the same direction, but negative conditions differed significantly from the others (Fig. 2B). Estimation of arousal related to tension was significantly higher in negative conditions for both ET and EA scales (Fig. 2C).

EEG data

The results from the PCA based on the LC data are shown in Table II. For the two main components (c1, c2) for each frequency band, component loadings greater than 0.65 are shown. As can be seen, these components largely reflect activity from either a consistent region (based on neighboring electrodes), or the one pair of electrodes.

There are two general localizations of lateralized EEG activity: one in the central area (usually including central, fronto-central and centro-parietal electrodes), and a second in the frontal area. The exception is for low alpha, where the second component is dominant in parietal cortex. Thus this analysis suggests two main EEG activity areas which can be distinguished on the base of laterality patterns.

Frontal laterality and the valence of the slides

In order to determine the impact of the slides' valence on the frontal laterality, a repeated measures ANOVA with a planned contrast (negative vs. positive slides) was carried out on the frontal component data (alpha2 to beta3 frequencies). The influence of the emotional content was found to be significant for beta2 (Fig. 3A; $F_{1,53}$=4.04, P=0.049; LC_{neg}=−2.8, LC_{neu}=−1.7, LC_{pos}=6.4) and beta3 (Fig. 3B; $F_{1,53}$=4.19, P=0.045; LC_{neg}=−2.1, LC_{neu}=2.2, LC_{pos}=11.8) frequencies; positive slides caused a shift of EEG activity to the left while negative slides caused a shift to the right.

Table II

Factor coordinates of the two main components (c1, c2) based on the PCA analysis

	alpha1		alpha2		beta1		beta2		beta3	
	c1	c2	c1	c2	c1	c2	c1	c2	c1	c2
Fp1–Fp2								−0.764		−0.706
AF3–AF4				−0.670		−0.753		−0.819		−0.717
F7–F8										
F3–F4						−0.680				
FC1–FC2					−0.698		−0.717		−0.842	
FC5–FC6	−0.814		−0.756						−0.758	
T7–T8										
C3–C4	−0.799		−0.796		−0.783		−0.850		−0.851	
CP1–CP2	−0.738		−0.691		−0.682		−0.684			
CP5–CP6	−0.764		−0.697		−0.753					
P7–P8		0.680								
P3–P4										

Integration of the EEG and subjective data

For the analysis of associations between subjective scores and the LC, all the subjects were taken together. The three experimental groups were not distinguished, because they were used only for varying the subjective states within the whole group. A series of 25 multiple regression analyses (5 subjective subscales × 5 frequency bands) was run with the subjective score as dependent variable. The LC values of the two principal components related to electrode location (c1 and c2) were taken as predictors, together with gender (used as a dichotomized factor). This series of analysis did not show any significant effect of gender, so the regression procedure was repeated without gender as a predictor. Due to multiple statistical testing, additional verification of results was necessary to avoid increasing type I errors. Assuming a required α level of 0.05, the False Discovery Rate procedure (FDR) (Shaffer 1995) was applied independently on each frequency band.

For the Hedonic Tone scale (UMACL HT), we observed a predominance of left prefrontal activity in beta2 (c2: R=0.22, $F_{2,109}$=2.79, P<0.06; t_{109}=−2.33, P=0.010, one-tailed test; Fig. 4).

The associations of both energetic subscales (EA and ET) with beta2 power had the same localizations (Fig. 5B and 6B). Moreover, they were similar to those observed for the valence scale (EA beta2 c2: R=0.22, $F_{2,109}$=2.82, P<0.03; t_{109}=−2.18, P=0.015; ET beta2 c2: R=0.26, $F_{2,109}$=4.15, P<0.09; t_{109}=−2.70, P=0.008; one-tailed tests). Additional effects in the alpha2 range were visible: an increase of right frontal dominance (EA alpha2 c2: R=0.32, $F_{2,109}$=6.41, P<0.001; t_{109}=3.42, P<0.001; ET alpha2 c2: R=0.35, $F_{2,109}$=7.82, P<0.001; t_{109}=2.99, P=0.002,

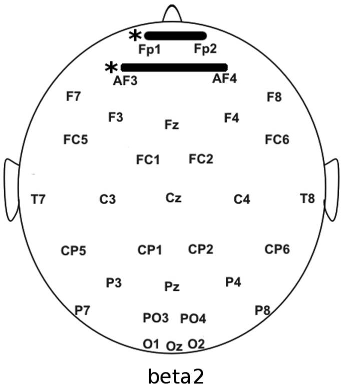

Fig. 4. Significant correlations between Hedonic Tone (HT) scores and the Lateralization Coefficient, marked with heavy lines. The asterisks mark the dominant hemisphere related to high scores on the subscale.

one-tailed test), as well as a massive left predominance in the central area for the ADACL subscale (ET alpha2 c1: $t_{109}=-2.20$, $P=0.014$, one-tailed test) in conditions of positive reported emotional state (Fig. 5A and 6A).

Surprisingly, no effects for the tension related scales were observed in any of the considered bands.

DISCUSSION

Effect of emotional stimuli on the subjective scores and the EEG

In accordance with expectations, emotional stimuli significantly affected subjective state. The direction of the changes caused by the emotional slides are in line with Thayer's claim concerning affective value comprised in the ADACL subscales – positive connotation is related to the ET scale, and negative to the TC. This is the case also for the UMACL which has dimensions corresponding to those in the ADACL. This effect is in line with our prediction and can also be observed in the checklist scores' correlation matrix (Table I) which shows the relatively strong association between the direct valence measure (HT) and the remaining subscales.

The two main EEG-defined areas yielded by PCA analysis can be considered, to some extent, as the two functional systems for emotional processing postulated in Heller's model: prefrontal and centro-parietal. The influence on the frontal system lateralization was in accordance with the theoretical expectations, however this was apparent only in beta and not in alpha frequencies.

That is, the slides presentation is a factor that affects both subjective estimation and EEG laterality. It indicates that we observe corresponding temporal, state-dependent after-effects in both these dependent variables.

Integration of the EEG and subjective data

Similar effects visible for both ET and EA subscales suggest their common physiological background, and that these subscales measure similar phenomena. Both energetic dimensions share common frontal beta effects. Moreover, an alpha2 effect appeared at AF3–AF4 electrodes, which may be interpreted as a marker of left hemisphere relative dominance. The increase of relative dominance of right central and posterior regions, observed in conditions of high energy arousal estimation (ET), can be considered as similar to the theoretical predictions by

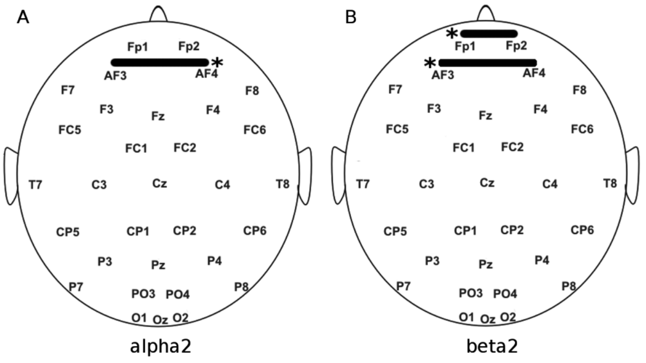

Fig. 5. Significant correlations between Energetic Arousal (EA) scores and the Lateralization Coefficient were observed in similar localizations. The asterisks mark the dominant hemisphere related to high scores on the subscale.

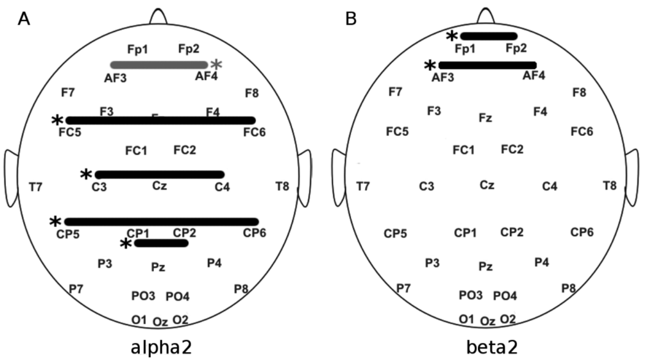

Fig. 6. Significant correlations between Energy-Tiredness (ET) scores and the Lateralization Coefficient. The asterisks mark the dominant hemisphere related to high scores on the subscale.

the valence/arousal model. However, the valence/arousal model locates this effect more posteriorly that our observations.

The associations between the HT subscale and the LC scores were in accordance with our expectations. As predicted, an effect is visible at the frontal cortex (Fp1–Fp2 and AF3–AF4 electrodes), with positive state associated with left hemisphere dominance. In other words, in people who estimated their state as more positive, left hemisphere dominance was observed. On the other hand, no co-variations were observed with the Tension-Calmness or Tension Arousal dimensions. This means that, in our experiment, lateralization patterns based on the LC did not correlate with scores on the tension subscales. This is surprising, since the Tension subscales supposedly comprise the negatively-valenced aspects of emotional state. According to our assumptions that Tension dimensions measure phenomena closely related to "anxious arousal" as described by Heller's model, we would expect effects in both emotional systems (a right shift of cortical arousal observed in the prefrontal region, together with an increase of arousal in the right posterior area). However, detailed analysis of the adjectives used in the Tension subscales suggests that they could be related not only to "anxious arousal", but also to "anxious apprehension" states. Since those states are characterized by different patterns of frontal and posterior EEG, their contributions to the effect could partly cancel each other, which may explain the overall lack of effect. In order to clarify this issue, a subjective estimation method which can distinguish between "anxious arousal" and "apprehension" should be used in future research. In addition, the lack of a lateralization effect for tension estimation could also be explained by the experimental conditions, which were characterized by relatively low uncertainty and an absence of any kind of physical or social risk. Such conditions should not provoke a significant increase of tension, however subjects rated this subscale quite high, possibly describing some interpretation of their current conditions rather than their actual state. It is also possible that the lack of correlation between tension estimation and the LC is related to the fact that both measurements could not be done simultaneously, due to the reasons described in the Procedure section.

Some aspects of emotional processing are supposed to differ between females and males (Schneider et al. 2000, Kemp et al. 2004). However, according to the measures used in this study, no gender differences were apparent.

CONCLUSIONS

We may conclude that between-subjective ratings and laterality differences partly fit with the theoretical predictions provided by Heller's model. This model, however, was based mainly on measures different from the subjective estimation used in our study, and this could possibly explain the observed differences. It is also possible that the process of adjective rating used in the present study is not a simple automatic response, but can be affected by cognitive self-evaluation, i.e. interpretation of the subject's current situation. In such a case, the relationships between adjective rating and the LC scores may not appear. Thus, to obtain self-report matching the actual subject's internal state may require conditions of non-reflective (impulsive) adjective rating.

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