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ORIGINAL PAPER

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EEG-vigilance differences between patients with borderline personality disorder, patients with obsessive-compulsive disorder and healthy controls

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Abstract The regulation of brain activation, as assessed with the EEG, is a state modulated trait. A decline to lowered EEG-vigilance states has been found to be associated with emotional instability in older studies, but has not been systematically studied in patients with borderline personality disorder (BPD).Twenty unmedicated BPD patients were compared to 20 unmedicated patients with obsessive-compulsive disorder (OCD) as well as 20 healthy controls concerning their EEG-vigilance regulation over a 5-min period assessed with an algorithm classifying every artefact-free 2-s EEG segment into the EEG-vigilance state (A1–A3, B (=non-A)).If the alpha power was posterior more than 55% of the whole alpha power (anterior + posterior) in the artefact-free EEG-segments, that segment was marked as A1, if it was anterior more than 55% of the whole alpha power, as A3. For A2 the following rule was defined: Posterior or anterior alpha between 50 and 55% of the whole alpha power.BPD patients showed significantly lower rates of EEG-vigilance state A compared to OCD patients, indicating a lowered EEG-vigilance. All three groups showed a decrease in the rate of EEG-vigilance state A over the 5 min recording period in line with a lowering of vigilance. The study provides evidence for a less stable regulation of EEG-vigilance in BPD compared to OCD patients and is in line with concepts postulating that the behavioural pattern with sensation seeking and impulsivity in BPD has a compensatory and autoregulatory function to stabilize activation of the CNS.

Key words vigilance states · vigilance dynamics · qEEG · borderline personality disorder · obsessive-compulsive disorder

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Introduction

Arousal, activation, vigilance, alertness, sleep-wake dimension are overlapping notions and concepts which are broadly used in the literature without a commonly accepted definition (reviewed by Oken et al. [26]). Depending on the scientific context, these notions are used to describe unspecific activation observed in three different areas: behaviour (e.g. agitation), brain function (e.g. EEG parameters) and introspection (subjective aspects, e.g. sleepiness). Complexity arises from the fact that changes in these different areas of observation do often, but not always go in parallel and that tonic as well as phasic changes can be observed.

For assessing different levels of global brain activation, the EEG is the privileged method because it reflects the temporo-spatial pattern of synchronised cortical neuronal mass activity and is the only non-invasive method to measure directly and with a sufficient time resolution neuronal activity. The EEG patterns associated with different functional states of the brain are in the following termed EEG-vigilance states. Within sleep research, EEG-vigilance states are classified according to Rechtschaffen and Kales [29]: relaxed wakefulness, sleep states 1–4 and REM-sleep. This classification, however, is not intended for covering the EEG-vigilance states which can be observed already by visual inspection during the transition from active wakefulness to relaxed wakefulness and further on to reduced wakefulness (e.g. drowsiness)

until the onset of sleep [26]. These *wakefulness EEG-vigilance states* have been carefully described and subdivided in states with dominant alpha (EEG vigilance states A1–A3, see below) and states with low-voltage non-alpha-activity (EEG-vigilance states B1–B3) [1, 5, 23, 33, 36, 38, 39] (see Table 1).

The regulation of wakefulness EEG-vigilance states is a state-dependent trait. Although continuously modulated by factors such as novel or rewarding external and internal events, sleep deprivation, diurnal variations, nicotine, caffeine or other substances, stable inter-individual differences in the regulation of vigilance under resting conditions can be observed. When studying a subject under resting conditions with eyes closed, most subjects show increasingly transitions from vigilance state A–B within the first 15 min (physiological pattern). Others, however, stay continuously in the vigilance state A even for 15 min and longer (rigidity of vigilance regulation) or show a transition already after a few seconds (lability of vigilance regulation). These patterns of vigilance regulation have been shown to have trait character [1, 39, 46]. Subjects with the EEG phenotype of "low voltage alpha EEG" show only a few alpha waves after activating events (e.g. hyperventilation, closing eyes) and then drop immediately to lower vigilance levels. This extreme form of lability of vigilance regulation has even been found to be transmitted in an autosomal dominant fashion with high penetrance in twin and family studies [9, 45].

Based on recent progress in our understanding of narcolepsy, an extreme form of vigilance dysregulation with abrupt transitions into sleep states, the regulation of vigilance and its relevance for psychopathology have become an interesting research area [25]. It has to be assumed that inter-individual differences in such a basic and possibly inherited aspect of brain function as the regulation of EEG-vigilance has profound consequences for many other psychological and psychopathological aspects (e.g. drop of integral values of main alpha frequency). Only few studies have addressed this issue so far:

- Rémond and Lesèvre [30] divided healthy persons into a group with continuous and a group with discontinuous alpha-activity (rigid versus labile vigilance regulation) and an intermediary group (physiological vigilance regulation) and compared these groups using simple auditive and verbal stimulus paradigms, projective tests (e.g. Thematic Apperception Test, Rorschach test) and personality questionnaires (e.g. F-factor from the 16-PF by Raymond B. Cattell, Heuyer-Courthial personality questionnaire). Persons with physiological vigilance regulation obtained the best results, those with rigid vigilance regulation had a slower psychic tempo, less reactivity and higher passivity, whereas those with labile vigilance regulation were found to be more reactive, emotionally unstable, more impulsive and "neurotic".
- Bente [1] examined patients with the disability of holding their EEG-vigilance at a high level (EEG-vigilance state A according to Loomis et al. [23]). They found the EEG vigilance to be a very stable parameter as most of the patients showed the same patterns of EEG-vigilance regulation even after years (Bente and colleagues repeated the EEG measurements a number of times over several years). They did not correlate the EEG-vigilance states with psychiatric symptoms, but found that patients with a lability of their EEG-vigilance regulation (e.g., drop of integral values of main alpha frequency) showed "neurasthenic symptoms" like disturbed wake-sleep cycles with fatigue, affective symptoms with depression and anxious-hypochondriac characteristics when compared to a control group with normal EEG-vigilance regulation [1] (the authors had included neuropsychiatric patients suffering from neurasthenic syndromes with the above-mentioned symptoms).
- The EEG phenotype of "low voltage alpha EEG", corresponding to a labile vigilance regulation, was found to be highly associated with alcoholism and anxiety [9].
- In patients with attention-deficit hyperactivity syndrome (ADHS) concepts and EEG data supporting a lability of their vigilance regulation have been published (for review: [8]). Similar observations with EEG

Table 1 Transition from wakefulness to sleep and corresponding EEG-vigilance states

EEG-vigilance states			
Transition from wakefulness to sleep	Rechtschaffen and Kales [29]	Loomis et al. [23]	EEG-characteristics
Alertness Relaxed wakefulness	Awake	A	Dominant α-activity (subdivided by Bente [1]): A1: α-activity, posterior accentuation A2: equally distributed α-waves A3: frontal maximum α-rhythm
Drowsiness	I	B	Dissolving α-activity, dominance of flat θ activity, subdivided by Roth [33] B1: fast low voltage β-activity, partly spindles B2: additional lower δ waves B3: additional higher δ waves
Sleep	II, III, IV	C	Slow wave activity, sleep spindles, vertex waves and K-complexes

sleep spindles occurring already after few seconds of recording (microsleeps) have been published for manic patients [3, 34, 35, 40]. The opposite was found in depressed patients [2, 39, 42].

In the present exploratory study, we analysed retrospectively the EEG-vigilance regulation in patients with borderline personality disorder (BPD) and obsessive-compulsive disorder (OCD), compared to healthy controls. Some EEG studies in BPD and OCD patients have been published (for BPD: [4]; for OCD: [48]), but none focussed on the regulation of the wakefulness EEG vigilance states. Sleep EEG studies suggest that OCD patients are characterized by significantly lower sleep efficiency with more awakenings [18, 21, 44], as compared to healthy controls and a negative association between severity of OCD symptoms and total sleep time, sleep efficiency as well as duration of stage 1 + 2 sleep [32]. These findings point to increased arousal in patients with OCD.

In contrast, BPD patients were found to have higher levels of delta power in the sleep EEG in non-REM sleep as healthy subjects [27], suggesting lowered EEG-vigilance. It will be interesting to know whether there are not only significant differences between OCD patients and BPD patients in EEG sleep parameters as suggested by the above-mentioned references, but also significant differences between these groups in the regulation of the wakefulness EEG vigilance states (e.g., higher frequency of vigilance state A in OCD compared to BPD).

Material and methods

Subjects

The present retrospective study was performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki. All subjects gave their informed consent prior to their inclusion in the study. Patients have been diagnosed according to ICD-10 criteria (compare [7]).

EEGs were recorded in the Department of Psychiatry and outpatient clinic of the Ludwig-Maximilians-Universität Munich (Munich, Germany). The following groups were studied:

- Twenty patients with BPD (F 60.31; ICD-10 [7]); 17–51 years (means ± SD: 27.0 ± 8.4 years; female 14; male 6);
- Twenty patients with OCD (F 42.0; F 42.1; F 42.2; ICD-10 [7]); 20–47 years (means ± SD: 30.8 ± 7.2 years; female 14; male 6);
- Twenty healthy controls. 19–57 years (means ± SD: 30.5 ± 10.5 years; female 14; male 6).

The three groups were comparable regarding age and gender distribution. All patients were free of medication. Healthy subjects were randomly selected from the general population of Munich via the local agencies and contacted by mail. In order to exclude subjects suffering from neuropsychiatric disorders or persons with first-degree relatives fulfilling the correspondent diagnostic criteria, further screenings were undertaken before the subjects were enrolled in the present study. First, responding subjects were screened by phone. Assessment of detailed medical and psychiatric histories was performed for both the responding subjects and their first-degree relatives using systematic forms. In a next step, the subjects were invited to participate in a comprehensive interview including the Structured Clinical Interview for DSM-IV (SCID I and SCID II) [10, 47] for evaluation of their lifetime Axis I and II disorders. Psychiatric diagnoses in their first-degree relatives were assessed using the Family History Assessment Module [31]. Subjects were excluded if they suffered from relevant somatic diseases or hearing problems (measured with standardized 1,000 Hz-tone audiometry) or if they had a history of any Axis I or II psychiatric disorders. Subjects were also excluded if they had first-degree relatives with a history of a mental disorder.

Exclusion criteria for the subgroup of patients with BPD were as follows: schizophrenia; schizoaffective disorder; bipolar affective disorder; current history of eating disorder that required hospitalisation; schizotypal personality disorder, neurological or severe somatic disorders; exclusion criteria for the subgroup of OCD patients were: alcohol or opiate dependency; other severe psychiatric diseases (like schizophrenia or bipolar affective disorders); neurological diseases; severe somatic disorders; pregnancy; a history of treatment with selective serotonin reuptake inhibitors as monotherapy or part of a combination therapy; low motivation.

Regarding the OCD patients, they participated in a neurophysiological study (for details: [11]) focusing on effects of sertraline and behaviour therapy on auditory evoked potentials in OCD. They were clinically diagnosed by experienced psychiatrists according to DSM-IV as well as ICD-10 criteria [7] at the Psychosomatic Hospital at Windach and characterized by a mean total score of 25.26 (SD: 7.22; N = 19; for one patient clinical data were not available) in the Yale-Brown Obsessive-Compulsive Scale (Y-BOCS) [12, 13] (mean ± SD score for obsessions: 13.95 ± 3.47; for compulsions: 11.32 ± 4.49), reflecting middle to severe intensity of OCD symptoms. Mean duration of OCD was 12.40 years (SD: 9.66 years), the average age at onset of OCD 18.54 years (SD: 6.45 years). The OCD patients were markedly ill (mean Clinical Global Impressions (CGI) [14] severity score: 5.68; SD: 0.67) and had mild to moderate depression (mean total score in the Hamilton Depression Rating Scale (HAMD; 17-item version [15]): 15.72; SD: 6.42).

Registration

The EEGs were recorded under resting condition with eyes closed with the Vision Analyzer software™ (version 1.5) and stored in digitalized form as 32 channel EEGs. The electrodes were fixed according to the international 10/20 system. Sampling rate was 250 Hz. The impedance between electrodes and skin was in most cases below 5 kΩ. A low pass filter of 50 Hz and a Notch filter of 50 Hz were preset. The Notch filter had a band width of 5 Hz which lay symmetrically around the Notch frequency (50 ± 2.5 Hz). Two-second segments with artefacts (muscle artefacts; alternating current, sweat, ocular movements) were marked and excluded from the analysis after visual inspection.

Classification of EEG-vigilance states and their dynamics

All 60 recorded EEGs (reference electrode Cz) were transformed to a bipolar derivation against ipsilateral ear reference (A1 or A2), in order to be comparable to earlier publications. The vigilance classification was based on 150 two-second-segments (=first 5 min of registration). Because of the dominance of the alpha rhythm over occipital (state A1) and frontal (state A3) sites, following four EEG-channels were evaluated [41]: O1-A1/O2-A2/F3-A1/F4-A2.

The vigilance classification was performed with a computer algorithm ("vigilance macro") that has been developed with the assistance of Dr. Gutberlet, BlindSight Consulting™. The classification is based upon the relative alpha power, i.e. the proportion of the alpha waves within the whole spectrum. For each of the 4 channels the power of the alpha band (7.5–12.5Hz) and the total power (0.5–30Hz) were calculated per 2-s segment (see [41]). If at least one EEG channel showed a relative alpha power >50% compared to the total power of the respective channel, this segment was classified as a vigilance state A. If none of the four recorded EEG channels showed a clear alpha rhythm the segment was classified as vigilance state B.

Vigilance state A can be further divided in vigilance states A1–A3 [1]. In case the alpha power was *posterior* more than 55% of the whole alpha power (anterior + posterior) in the artefact-free EEG-segments, that segment was marked as vigilance state A1. When the alpha power was *anterior* more than 55% of the whole alpha power in the artefact-free EEG-segments, that segment was marked as A3. For A2 the following rule was defined: Posterior alpha between 50 and 55% of the whole alpha power or anterior alpha between 50 and 55% of the whole alpha power.

As a further secondary parameter reflecting the pattern of vigilance regulation the rate of switches between EEG-vigilance state A and B was calculated.

A switch was defined when there was an instantaneous transition from one artefact-free EEG segment classified as EEG-vigilance state A to another one classified as state B or vice versa.

Analysis und statistical evaluation

The results of the computer-aided EEG analysis were evaluated using the statistics software SPSS™ (Statistical package for the Social Sciences, SPSS Inc, Chicago, Illinois, version 13.0.1). Using univariate analysis of covariance (ANCOVA) with the number of EEG-segments with artefacts being the covariate, group differences concerning the frequency of vigilance states (A1, A2, A3, B) in the first 5 recorded minutes of the EEG were analysed. Different time courses of EEG-vigilance states between the three groups were analysed with a multivariate analysis of covariance (MANCOVA) (covariate: number of EEG-segments with artefacts). A p value <0.05 in the Greenhouse Geisser test for the interaction of the factors "group" and "time" indicated a significantly different time course profile between the three groups. In this case a multivariate analysis of covariance (MANCOVA) with five measuring times (every minute) was performed for each two groups. In case of a significant MANCOVA main effect for the factor "group" (Greenhouse Geisser test: $p < 0.05$), each minute of the registration was checked for significant differences between two groups (ANCOVA). Thus the question could be answered whether statistically significant differences were present for the whole recorded period or only for single minutes.

Results

Rate of EEG-vigilance states A

The groups differed significantly regarding vigilance states A ($p = 0.03$; compare Fig. 1).

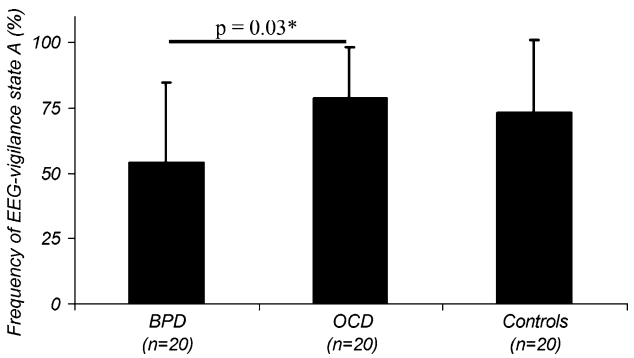

Fig. 1 Frequency (%) of vigilance states A (computer-aided evaluation of 60 EEGs; first 5 min. of EEG derivation; divided in 150 segments per 2 s). The vigilance state A was significantly more frequent in OCD patients, as compared to BPD patients. BPD: Borderline personality disorder; OCD: Obsessive-compulsive disorder. * $p < 0,05$ (two-sided test)

Table 2 Results of analysis of variance for group comparisons regarding frequency of the EEG-vigilance states A, A1, A2 and A3

Variables	F^a	df	p^b
ANCOVA[b]	–	–	–
EEG-vigilance state A	3.95	2,56	0.03
EEG-vigilance state A1	1.96	2,56	0.15
EEG-vigilance state A2	2.57	2,56	0.09
EEG-vigilance state A3	0.89	2,56	0.42
MANCOVA[b] with repeated measurements (only EEG-vigilance state A)			
All groups (BPD, OCD, HC)	–	–	–
main effect "group"	3.89	2,56	0.03
main effect "time"	4.06	3.3,183.9	0.006
interaction "group" × "time"	2.69	6.6,183.9	0.01
BPD versus OCD	–	–	–
main effect "group"	8.18	1,37	0.007
main effect "time"	3.00	3.4,127.4	0.03
interaction "group" × "time"	3.61	3.4,127.4	0.01
BPD versus HC	–	–	–
main effect "group"	3.65	1,37	0.06
main effect "time"	4.57	3.1,113.3	0.004
interaction "group" × "time"	4.02	3.1,113.3	0.009
OCD versus HC	–	–	–
main effect "group"	0.23	1,37	0.63
main effect "time"	1.53	2.9,108.6	0.21
interaction "group" × "time"	0.63	2.9,108.6	0.59

Notes: ANCOVA, (univariate) analysis of covariance; BPD, borderline personality disorder; df, degrees of freedom; HC, healthy controls; MANCOVA, multivariate analysis of covariance (with repeated measurements for the first five minutes of EEG recording); OCD, obsessive-compulsive disorder.
[a]Exact values for the Greenhouse-Geisser tests in case of MANCOVA.
[b]The effects of the number of EEG-segments with artefacts have been controlled for.

Post hoc comparisons show a significant difference for vigilance states A between the group of BPD patients and the group of patients with OCD (BPD < OCD; ANCOVA: $F = 8.21$; df = 1/37; $p = 0.01$) only. Over the whole time period the EEGs of the BPD patients showed the lowest proportion of EEG-vigilance state A, the EEGs of the patients with OCD the highest one. The corresponding frequency of the healthy controls lay between that of the BPD patients and that of the patients with OCD.

No significant differences existed between the three groups concerning EEG-vigilance sub-states A1, A2 and A3 (compare Table 2).

In Fig. 2 the bivariate distribution of the rate of EEG-vigilance state A and the rate of switches between A and B is given. The inverted U shape of the distribution reflects the obvious fact that patients with very high or very low rate of state A also have low switches, but also the less obvious fact that the pattern with few transitions between stable phases of EEG-vigilance states of A and B is rare. It can be seen that BPD patients are over-represented at the left side of the distribution with lower rate of states A.

Time course of vigilance state A

In the patient groups as well as in the control group the rate of EEG-vigilance state A decreased over the whole time period (see Fig. 3). There were significant

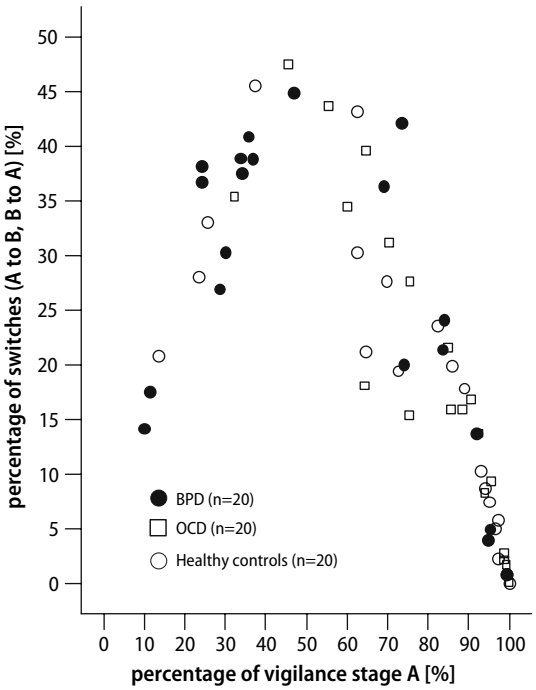

Fig. 2 Percentage (%) of vigilance states A and percentage of switches from the vigilance states A to B and vice versa (%) regarding artefact-free EEG-segments is given in the studied groups. OCD patients and healthy controls have a similar distribution. BPD patients show a relative overrepresentation on the left side, with a lower rate of state A. Uncommon is the combination of low switch rate with an equal distribution between state A and B

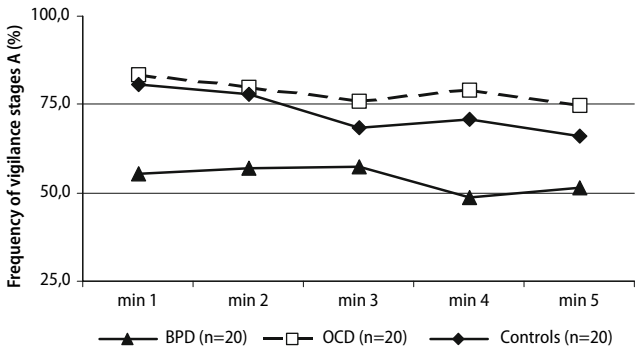

Fig. 3 Time course of the frequency (%) of vigilance states A (minutes 1–5). All groups showed a decrease in the rate of EEG-vigilance state A over time. BPD, Borderline personality disorder; OCD, Obsessive-compulsive disorder

differences for the vigilance states A concerning the interaction between the factors "group" (BPD patients, patients with OCD; healthy controls) and "time" (minute 1; minute 2, minute 3, minute 4, minute 5) ($p = 0.01$; Table 2). In the detailed analysis, there were significant differences in the time course profile between the BPD patients and the controls (BPD < healthy controls) ($p = 0.009$; Table 2). The difference between these groups was not significant for the whole derivation period, but only in the first, second and fourth minute (first minute: $F = 7.95$; df = 1/37; $p = 0.01$; second minute: $F = 4.69$; df = 1/37; $p = 0.04$; fourth minute: $F = 4.65$; df = 1/37; $p = 0.04$) (BPD < healthy controls). Similarly, BPD patients had significantly lower frequency of vigilance state A than OCD patients (MANCOVA: $p = 0.01$ (Table 2)). The difference between these groups was significant for the first, second, fourth and fifth minute (first minute: $F = 11.72$; df = 1/37; $p = 0.002$; second minute: $F = 6.72$; df = 1/37; $p = 0.01$; fourth minute: $F = 12.46$; df = 1/37; $p = 0.001$; fifth minute: $F = 4.72$; df = 1/37; $p = 0.04$) (BPD < OCD).

Analysis of artefact-free segments per group

The EEGs of the patients with BPD had the highest mean number of 2-s segments which were excluded because of artefacts (21.6 (SD: 22.1) out of 150 two-second segments). The EEGs of OCD patients showed the lowest mean value (7.3 ± 7.6). The healthy controls lay in between (11.7 ± 7.3). This difference was statistically significant (ANOVA: $F = 5.35$; df = 2/57; $p = 0.01$). In the post hoc analysis a significant difference was found between the BPD patients and the patients with OCD (BPD > OCD; Tamhane test: $p = 0.04$).

Discussion

In this study unmedicated patients with BPD and OCD were compared to healthy controls regarding vigilance regulation. The main finding was that patients with BPD stayed less time in the EEG-vigilance level A and dropped more often to level B than OCD patients. The EEG-vigilance regulation of healthy controls was positioned in between these two groups. This decreased rate of states A in BPD indicates a less stable EEG-vigilance pattern with a permanent tendency to drop to lower vigilance states. This pattern was apparent during the whole recording period of 5 min.

A decreasing rate of EEG-vigilance states A was also observed over the time period of the recording. This is what has to be expected when a subject is lying quietly with eyes closed.

This finding that BPD and OCD patients differ clearly concerning their vigilance regulation and lie on opposite sides of the healthy controls concerning this issue is in accordance with models relating BPD to lowered cortical activity (hypoarousal) [17] and OCD to an increased cortical activity [6, 11, 24, 37]. In a psychophysiological study with 24 female BPD patients and a control group, Herpertz et al. [17] found that the patient group did not differ concerning startle reflex and heart frequency from the control group while looking at "joyless" pictures: However, BPD patients showed a lowered electrodermal reaction, which was interpreted by the authors as indicating central nervous hypoarousal of the BPD patients. The finding was integrated in the concept that the typical

behaviour of BPD patients characterized by impulsiveness, sensation seeking or extraversion could reflect an autoregulatory mechanism intending to raise the CNS activation with external or emotional stimuli and to compensate for the tendency to lowered CNS activation.

Concerning OCD, our research group has found increased amplitude of the auditory evoked P3b [11, 24], a finding which is in line with a hyperactive cortical state in these patients. Since dipole source analysis of the P300 components revealed the maximum dipole of the P3b at temporo-basal regions [16], this finding may reflect disturbances of temporo-parietal and hippocampal regions in these patients, as suggested by neuroimaging studies [19, 22, 28]. Similar electrophysiological findings have been reported by others [6, 37].

In our study, OCD patients were characterized by a numerically, but not statistically higher percentage of EEG-vigilance states A, as compared to healthy controls.

The rate of switches between EEG-vigilance states A and B is another aspect of EEG-vigilance dynamics. This parameter takes into account that the rate of states A can be low because there are many, but short switches to B or because there are only one or few switches from A to a stable state B. The latter pattern turned out to be rare. No differences between the three groups were found concerning this aspect of EEG-vigilance regulation.

In the present study the EEGs of BPD patients had more artefacts than those of patients with OCD and healthy controls. A significant difference was found between the BPD patients and the patients with OCD. This result might reflect the increased impulsiveness of patients with BPD, whereas OCD patients typically make every endeavour to finish the EEG registration correctly. Marked influences of these differences on our main findings are rather unlikely since only artefact-free EEG-segments were analysed with respect to the relative proportion of vigilance states.

A strength of the study is the inclusion of completely unmedicated patients, limitations are the relatively short recording time of 5 min, the fact that the day time of EEG registration was not kept stable across all subjects and the lack of systematic assessment of possible vigilance modulating factors such as smoking, caffeine consumption or sleeping behaviour in the preceding night in this retrospective study. Because of the retrospective character of our study, the BPD and OCD diagnoses were assessed purely clinically, whereas a standardized diagnostic procedure was applied for the healthy subjects in order to exclude mental disorders. For future (prospective) studies, it would be advisable to base BPD and OCD diagnoses on standardized diagnostic procedures, to keep day time of EEG registration stable in view of the known differences of vigilance between morning and midday and to characterize the BPD patients with more detail (application of impulsivity or sensation seeking scales; separation of BPD patients with comorbid attention-deficit hyperactivity disorder (ADHD) and BPD patients with comorbid post-traumatic stress disorders (PTSD) in view of possible relevance of these comorbid conditions for the neurophysiological data (hyperarousal in PTSD [43]; vigilance system deficits in ADHD [20])).

In summary, the present study provides evidence for a less stable regulation of EEG vigilance in patients with BPD compared to those with OCD and is in line with concepts postulating that the behavioural pattern with sensation seeking and impulsivity in BPD has the compensatory and autoregulatory function to stabilize brain activation [17]. We cannot completely exclude that BPD patients were more "active" during the EEG recording, maybe showed more beta activity and therefore had more artefacts. However, the differences between BPD patients and the other two groups in the frequency of vigilance state A were significant after controlling for the number of EEG-segments with artefacts. Therefore, our findings cannot primarily be explained by the fact that BPD patients were characterized by more EEG artefacts than OCD patients and healthy controls. In order to address this question more precisely, video-controlled EEG investigations could be a fruitful approach.

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