

# Facial Reactions during Emotion Recognition in Borderline Personality Disorder: A Facial Electromyography Study

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## Key Words

Borderline personality disorder · Facial emotion recognition · Electromyography · Facial activity

## Abstract

**Background:** Previous studies have suggested increased sensitivity for emotional facial expressions and subtle impairments in emotion recognition from facial expressions in borderline personality disorder (BPD). It has been proposed that facial mimicry contributes to emotion recognition of and emotional response to facial expressions. This study investigated whether BPD patients differ in facial reactions, emotion recognition and their subjective emotional response to faces showing different emotional expressions. **Method:** Twenty-eight female BPD patients and 28 healthy controls underwent a facial recognition task with dynamic facial pictures while facial muscle activity (occipitofrontalis, corrugator supercilii, levator labii superioris, zygomaticus major and orbicularis oculi) was recorded. Furthermore, participants rated the emotional intensity of the presented faces and the intensity of their subjective feeling of this emotion. **Results:** Compared to controls, BPD patients showed enhanced responses of the corrugator supercilii muscle in response to angry, sad and disgusted facial expressions, and

attenuated responses of the levator labii superioris in response to happy and surprised faces. There were no overall group differences regarding emotion recognition performance or intensity ratings. **Conclusion:** These results do not support the view that facial recognition in BPD is impaired or that there is a general hypersensitivity to the emotional state of others. Instead, they suggest a negativity bias in BPD, expressed by reduced facial responding to positive social signals and increased facial responding to negative social signals. This is a pattern of facial reactions that might contribute to the difficulties in social interactions frequently reported by patients with this disorder.

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## Introduction

Patients with borderline personality disorder (BPD) show a persistent pattern of deficits in affect regulation and impulse control, and a pervasive instability in self-image and interpersonal relationships. Social cognitive impairments, such as a deficit in decoding and differentiating the mental (or emotional) state of others, have been proposed to contribute to the affective instability of BPD patients in the social context (e.g. [1, 2]). Recently,

it has been put forward that the social cognitive impairments in BPD, such as difficulties inferring mental states and emotions and a biased evaluation of social signals, interact with affective instability and thus might contribute to the social difficulties in BPD (for a review see [3]). This study investigated whether BPD patients show alterations in facial reactions to the dynamic emotional facial expressions of others. In particular, we used facial electromyography (EMG) to record subtle facial reactions from five relevant facial muscles in order to investigate if BPD patients show increased emotional responding to facial expressions, which could indicate increased emotional contagion in social interactions and account for emotional dysregulation in social situations.

A large line of research has focused on emotional dysregulation in BPD in terms of increased reactivity to emotional or aversive stimuli in general. A series of studies using self-reports of emotional responding has shown that BPD patients do not differ from healthy controls in their subjective emotional responses to emotional stimuli [4–7]. Other studies have demonstrated more intense emotional responses to negative stimuli in BPD [8–12]. Yet others have used peripheral physiological measures as an index of emotional reactions to emotional stimuli, with inconsistent findings. For example, some studies reported an increased skin conductance response in BPD patients in reaction to abuse-related stimuli [13], an increased skin conductance level in comparison to the healthy control group [14] or no difference at all [15–17]. In addition, BPD patients exhibited decreased parasympathetic activity to negative emotional stimuli manifested as respiratory sinus arrhythmia on ECG, which is considered to reflect greater emotional vulnerability [14, 18, 19]. However, no differences in heart rate were found when compared to a healthy control group [19]. The inconsistency of findings regarding the proposed general emotional hyperreactivity in BPD possibly points to the role of context variables, such as the social relevance of the presented stimuli.

More specifically, it has been assumed that BPD patients might be especially hyperreactive to emotional stimuli in specific social situations related to the personal experience of abandonment, rejection, neglect and punishment. Following this approach, some studies indeed reported exaggerated psychophysiological responses including skin conductance level and heart rate to these negative stimuli in the social context [13, 17, 20].

Few studies have recorded facial activity in BPD patients as a specific emotional response during the presentation of emotional stimuli. Some studies have shown de-

creased activity in the corrugator supercilii using recordings of facial EMG [6, 13]. Using video-based analysis of facial movements, another study showed a general reduction of facial activity in response to positive and negative movie-clips in BPD patients, which was comparable to the pattern displayed by depressed patients [7]. In a social-exclusion paradigm, compared to healthy controls, BPD patients showed more mixed and fewer positive emotions in facial expressions coded from videos recorded during the social interaction [21].

Besides the investigation of psychological and physiological reactivity to emotional stimuli, another line of research focused on facial emotion recognition as a cognitive facet of empathy in BPD patients. Some of these studies reported decreased facial emotion recognition [8, 22, 23], while others found a hypersensitivity to negative facial expressions [1, 24, 25]. However, the majority of studies so far have not found fundamental deficits in facial emotion recognition [4, 5, 26–29]. In addition, there is inconsistent empirical evidence regarding differences in the error pattern made during the recognition of facial expressions: BPD patients have been reported to show a negativity bias for neutral faces [30], a bias towards reporting anger [26] surprise and disgust [23] as well as lower error rates for anxiety [1, 31] or increased error rates across all valences [31]. Domes et al. [26] found that the recognition performance of BPD patients increased over the course of the experiment when compared to the controls, whereas Merkl et al. [31] did not. Other studies found BPD patients to have difficulties in differentiating the perception of their own emotional states [9, 32, 33]. In sum, the studies on facial emotion recognition so far suggest that BPD is associated with subtle differences in facial emotion recognition, maybe best described as being biased towards a high sensitivity for social signals of threat and rejection, e.g. anger and fear [1, 3, 34].

However, as summarized above, studies examining the psychophysiological correlates of emotional responses to the facial expressions of others have provided inconsistent findings, which might be due to the unspecific measures used. EMG recordings of facial muscle activity have been used to assess facial reactions as specific indicators of the underlying emotional response [35]. In previous facial EMG studies, the corrugator supercilii muscle showed an increased activity in the context of anger [36], sadness [37], fear [38] and disgust [39] and a decreased activity in the context of happiness [40]. The zygomaticus major muscle is associated with an increased activity in the context of happiness, and shows decreased activity in anger [36] and fear [35, 38]. Increased activity of the leva-

tor labii superioris is observed in anger and disgust [40]. The orbicularis oculi show an increased activity in the contexts of disgust and happiness [40, 41]. For the occipitofrontalis muscle, increased activity in sadness [37], fear [42] and surprise [43] has been reported. Finally, dynamic facial stimuli appear to be more potent than static pictures of emotional expressions in triggering facial reaction in the observer [44].

Another concept relevant to the perception of facial expressions is facial mimicry, i.e. the tendency to involuntarily imitate the facial expression of another person [45, 46]. Facial mimicry has been associated with empathy [47]. Empathy might be divided in a cognitive part (perspective-taking and emotion recognition) and an emotional part (vicarious feelings) [48, 49]. In addition, empathy implies the ability to discriminate between oneself and others [50], and is influenced by motivational processes [51]. Some researchers have suggested that empathy might be triggered by facial mimicry while observing someone's facial expressions [46, 52]. This consideration is linked to the 'facial feedback hypothesis' [53, 54], which presumes a bidirectional or circular relationship between the afferent and efferent effects of facial expressions. Emotions such as happiness or anger are potent triggers for specific efferent motor patterns of facial activity and, in turn, might evoke or promote the associated emotional state by increased facial muscle activity in terms of afferent sensory feedback. This feedback loop might be extended to the social context: the facial expressions of others might evoke facial mimicry and might thus trigger the vicarious experience of the observed emotion by afferent sensory feedback in the observer [47].

Multi-site EMG recordings of subtle facial reactions in response to the facial expressions of others might help to differentiate between empathy-related facial mimicry and negativity-biased emotional reactions in BPD: the former would result in an emotion-specific pattern of activation of relevant facial muscles regardless of emotional valence whereas the latter would result in increased facial reactions to negative, but attenuated facial-muscle reactions to positive facial expressions.

This study focused on facial reactions during facial emotion recognition as well as on intensity ratings in BPD patients compared to healthy controls. Following the negativity bias hypothesis introduced above, we expected that BPD patients – compared to the control group – would show better performance in emotion recognition of negative facial expressions. In addition, we hypothesized that BPD patients would rate positive facial expressions as being of lower intensity and negative expressions (in par-

ticular fear, anger and sadness) as being of higher intensity. Regarding their facial reactions, we postulated that BPD patients would show increased facial reactivity to negative emotions and lower reactivity to positive facial expressions when compared to healthy controls.

## Methods

### *Participants*

Twenty-eight women with BPD were recruited from the inpatient and outpatient wards at the Department of Psychiatry, Rostock University Hospital, Germany. BPD patients fulfilled at least five criteria for BPD according to the DSM-IV-TR, including emotional instability and impulsivity. Exclusion criteria were: a history of brain damage, a lifetime diagnosis of any psychotic or bipolar disorders, a current diagnosis of major depression, any anxiety disorders, any substance dependence (except nicotine dependence/consumption), an IQ < 75 based on the Wechsler Abbreviated Scale of Intelligence (WAIS) or insufficient German-language skills. All patients were free of psychotropic medication for at least 2 weeks prior to the study. BPD patients showed the following comorbid disorders: 8 (28.57%) had posttraumatic stress disorder, 3 (10.72%) had an eating disorder and 10 (35.71%) had other comorbid personality disorders at the time of examination.

The control group of 28 healthy women was recruited from different local vocational schools to match the patients with regard to education level and age. Participants of the control group did not meet any lifetime Axis I or Axis II diagnosis according to the DSM-IV-TR (except nicotine dependence/consumption).

The study was approved by the local institutional ethical review board at the University of Rostock, and all participants gave written informed consent before participating.

### *Clinical Assessment and Questionnaires*

All participants were investigated with the Structured Clinical Interview for DSM-IV Axis I Disorders [55] and the International Personality Disorder Examination [56, 57]. General intelligence (IQ) was estimated with the WAIS [58]. Empathy was measured using the psychometric Empathy Quotient (EQ) [48, 59] and the Interpersonal Reactivity Index (IRI) [60–62]. In addition, we assessed depressive symptoms with the Beck Depression Inventory (BDI) [63], trait anxiety with the trait version of the State-Trait Anxiety Inventory (STAI) [64], trait anger with the State-Trait Anger Expression Inventory (STAXI) [65] and the severity of borderline symptoms with the Borderline Symptom List 23 (BSL-23) [66] and the Zanarini Rating Scale for Borderline Personality Disorder (ZAN-BPD) [67]. All psychometric measurements were performed on the same day as the experiments.

### *Experimental Procedures*

Five female faces and 5 male faces depicting six basic emotions (happiness, fear, anger, sadness, disgust and surprise) were selected from the NimStim Face Stimulus Set database [68]. The images were converted to grayscale, and an elliptical vignette was applied to hide everything but the face itself. In order to generate dynamic facial expressions from this standardized set of stimuli, each of the 60 facial images was morphed with WinMorph 3.01 from neutral

**Table 1.** Demographic characteristics

	Control group (n = 28)		BPD group (n = 28)		t test	
	Mean	SD	Mean	SD	t	p
Age	24.43	5.40	24.93	5.81	0.33	0.740
School years	11.93	1.46	10.25	1.37	-4.41 <sup>a</sup>	<0.001*
Total IQ	113.43	12.20	107.7	12.56	-1.70	0.094
Verbal IQ	109.68	14.19	104.11	15.09	-1.42	0.160
Performance IQ	112.04	14.33	107.93	15.76	-1.02	0.312

<sup>a</sup> Variances are different; \* p < 0.05.

to one of the six emotions in 1% increments, generating a series of 101 images. In a single trial, a series of 101 images was presented over a period of 10 s (each picture was thus presented for approx. 100 ms), which resulted in dynamic faces, developing a specific basic emotion to the full-blown expression. At the end of a trial, participants were asked to choose the appropriate emotional label. Thereafter, they were asked to rate the intensity of the emotion displayed and in a second step, to rate the intensity of their subjective feeling while watching this emotion. The experiment started with 4 practice trials to familiarize participants with the procedure. All trials (10 trials in 6 conditions) were presented in a random order. Participants watched the stimuli (1,024 × 768 px) projected on a screen (135 × 90 cm), which was placed at a distance of 3.4 m.

EMG activity was recorded from five facial muscles: the occipitofrontalis, corrugator supercilii, levator labii superioris, zygomaticus major and orbicularis oculi. Pairs of Ag/AgCl surface electrodes (E220X Mesmed, Munich, Germany) with a diameter of 4 mm and filled with a conductive paste (Lectron II, Mesmed) were attached [69]. The ground electrode was placed on the forehead. The EMG data recordings were made with a unipolar amplifier (BrainAmp, BrainProducts, Munich, Germany). The raw EMG was amplified and recorded with a low cut-off frequency of 5 Hz and high cut-off of 1 kHz, and digitized with a sampling rate of 5 kHz. EMG data was analyzed with inhouse scripts written in Matlab (Mathworks, Natick, Mass., USA). The raw signal was rectified and integrated for intervals of 1 s within a time window of -1 to 10 s with reference to the onset of the stimulus.

#### Statistical Analysis

Statistical analysis was conducted with the Statistical Package for the Social Sciences (SPSS 17). Demographic, psychopathological and psychometric data were analyzed with the Student t test for independent samples. For the analysis of group differences in emotion recognition, error pattern and intensity ratings, separate multivariate ANOVAs were calculated. In addition to the overall multivariate effect, we also explored the univariate effects. Facial muscle reactions during stimulus presentation were analyzed with repeated-measures 2-way ANOVAs (group × time) for each facial emotion individually. The threshold for statistical significance was set to p < 0.05. In the case of unequal variances, the Greenhouse-Geisser correction was applied. Effect sizes are reported as explained variance using partial squared eta ( $\eta_{\text{par}}^2$ ).

## Results

### Demographic, Psychometric and Psychopathological Characteristics

There were no significant differences in age or intelligence between groups (table 1). However, participants in the BPD group had completed fewer years of school compared to the control group, and the groups showed differences in professional qualifications.

Not surprisingly, the BPD group showed significantly greater borderline symptom severity than the control group in the BSL (table 2). Comparing the scores of the ZAN-BPD with those of the validation study by Zanarini et al. [67] revealed significantly higher scores in our study, except for the affect subscale (table 2). In addition, BPD patients showed significantly higher values in the psychopathological characteristics of depression, anxiety, anger and impulsivity when compared to the control group (table 2). No significant group differences were found in cognitive or emotional empathy according to the EQ, or in perspective-taking, fantasy or emotional concern subscales according to the IRI. However, significant group differences were found in the total score and the social skills subscale according to the EQ, with the BPD patients scoring lower than the controls. According to the IRI, BPD patients scored higher on the personal distress subscale (table 2).

### Facial Emotion Recognition and Intensity Ratings

In the emotion recognition test, the BPD group showed no significant differences from the controls, neither for any specific emotion (all p > 0.05; fig. 1) nor across all emotions, indicated by the MANOVA on recognition performance ( $F_{1, 54} = 0.28$ , p = 0.599,  $\eta_{\text{par}}^2 = 0.005$ ). For happy faces only, the BPD group tended to have a poorer

**Table 2.** Psychopathological characteristics

	Controls			BPD			t value	p value
	n	mean	SD	n	mean	SD		
BSL	28	0.93	0.16	28	2.19	1.06	10.26	<0.001
ZAN-BPD <sup>a</sup> , total score	139 <sup>a</sup>	14.3	6.8	28	18.25	6.37	3.279	0.003*
Affect	139 <sup>a</sup>	5.9	2.9	28	6.25	2.53	0.731	0.471
Cognition	139 <sup>a</sup>	3.5	2.4	28	4.68	2.09	2.982	0.006*
Impulsivity	139 <sup>a</sup>	1.7	1.4	28	2.71	1.96	2.738	0.011*
Interpersonal	139 <sup>a</sup>	3.2	2.0	28	4.64	2.12	3.585	0.001*
BDI, total score	28	3.43	5.56	27	29.93	12.84	9.86	<0.001*
STAXI Trait, total score	28	14.78	3.75	28	26.14	6.55	7.95 <sup>b</sup>	<0.001*
Angry temperament	26	7.30	2.27	28	13.03	3.92	6.62 <sup>b</sup>	<0.001*
Angry reaction	27	7.66	1.88	28	13.10	3.57	7.10 <sup>b</sup>	<0.001*
Anger in		12.81	3.51	28	21.96	5.10	7.76 <sup>b</sup>	<0.001*
Anger out	27	10.81	2.74	28	16.17	5.40	4.66 <sup>b</sup>	<0.001*
Anger control	27	23.81	4.37	28	19.96	4.66	-3.15	0.003*
STAI Trait, total score	28	33.82	8.19	28	58.78	8.29	11.32	<0.001*
IRI, total score	28	68.82	11.03	28	70.71	14.14	0.55	0.579
Perspective taking	28	19.07	4.00	28	17.35	4.36	-1.53	0.132
Fantasy	28	17.17	4.27	28	16.75	6.52	-0.29	0.773 <sup>b</sup>
Empathic concern	28	20.03	3.56	28	19.46	3.97	-0.56	0.574
Personal distress	28	12.53	2.54	28	17.14	4.41	4.78	<0.001 <sup>b, *</sup>
EQ, total score	28	43.32	7.58	28	37.78	10.96	-2.19	0.033 <sup>b, *</sup>
Cognitive empathy	28	10.89	3.26	28	10.57	4.64	-0.29	0.766
Emotional reactivity	28	9.28	2.08	28	8.39	2.96	-1.30	0.198
Social skills	28	8.00	1.80	28	4.57	2.08	-6.58	<0.001*

\*  $p < 0.05$ .<sup>a</sup> One-sample t test comparison with the validation study [67].<sup>b</sup> Variances are different.

recognition performance than the controls [correct responses (mean  $\pm$  SD) BPD:  $9.64 \pm 0.62$  and controls:  $9.89 \pm 0.31$ ,  $t_{54} = 1.899$ ,  $p = 0.063$ ].

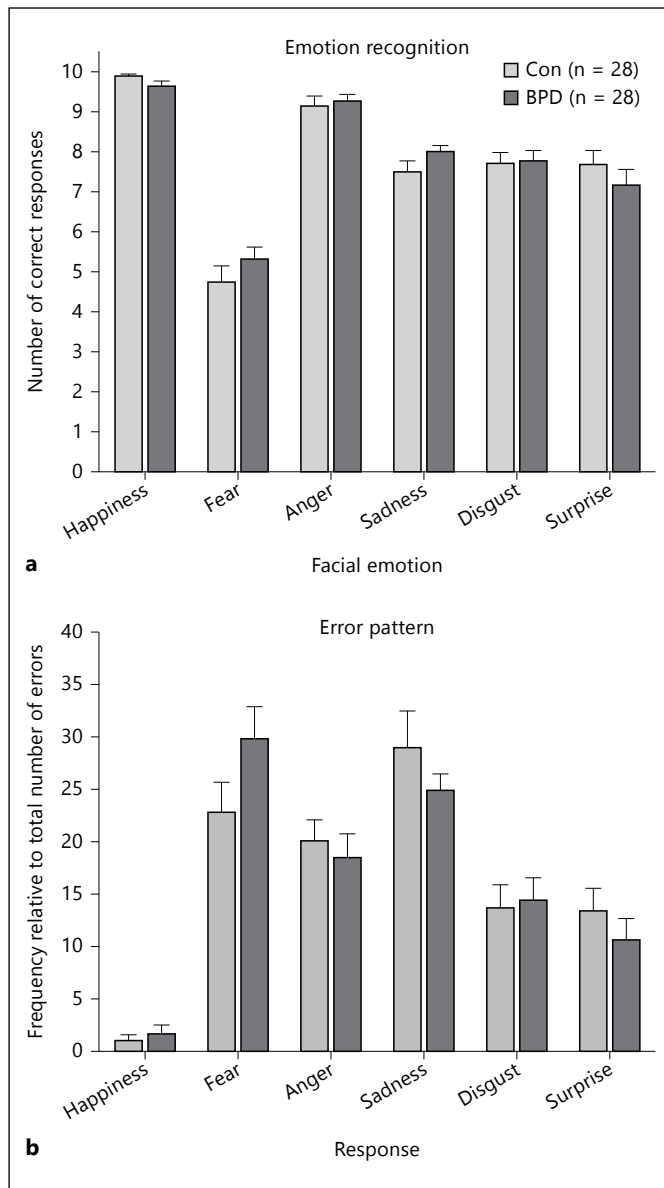
Regarding the distribution of errors (fig. 2), there was no overall difference between the groups, as for the specific emotional labels, except for fear: compared to the controls, the BPD group tended to misattribute facial expressions in the direction of fear more frequently [(mean  $\pm$  SD) BPD:  $29.8 \pm 15.9$  and controls:  $22.8 \pm 14.9$ ,  $t_{54} = 1.698$ ,  $p = 0.095$ ].

The MANOVA on the intensity ratings of the presented facial expressions revealed no overall group effect ( $F_{1, 54} = 1.477$ ,  $p = 0.229$ ,  $\eta_{\text{par}}^2 = 0.027$ ). Furthermore, no group differences were found for specific emotions, as indicated by a nonsignificant emotion  $\times$  group interaction ( $F_{4.03, 218.12} = 0.741$ ,  $p = 0.567$ ,  $\eta_{\text{par}}^2 = 0.014$ ). However, testing for univariate differences revealed that the BPD group tended to rate fearful expressions with a lower intensity ( $F_{1, 54} = 3.120$ ,  $p = 0.083$ ,  $\eta_{\text{par}}^2 = 0.055$ ).

With regard to the intensity of the subjective emotional response, reported by participants while processing facial stimuli, no overall group effect was found. ( $F_{1, 54} = 0.004$ ,  $p = 0.948$ ,  $\eta_{\text{par}}^2 < 0.001$ ). However, when inspecting univariate differences, the BPD group tended to report lower levels of happiness while processing happy facial expressions compared to the control group ( $F_{1, 54} = 3.926$ ,  $p = 0.053$ ,  $\eta_{\text{par}}^2 = 0.068$ ).

#### Facial Reactions – EMG Data

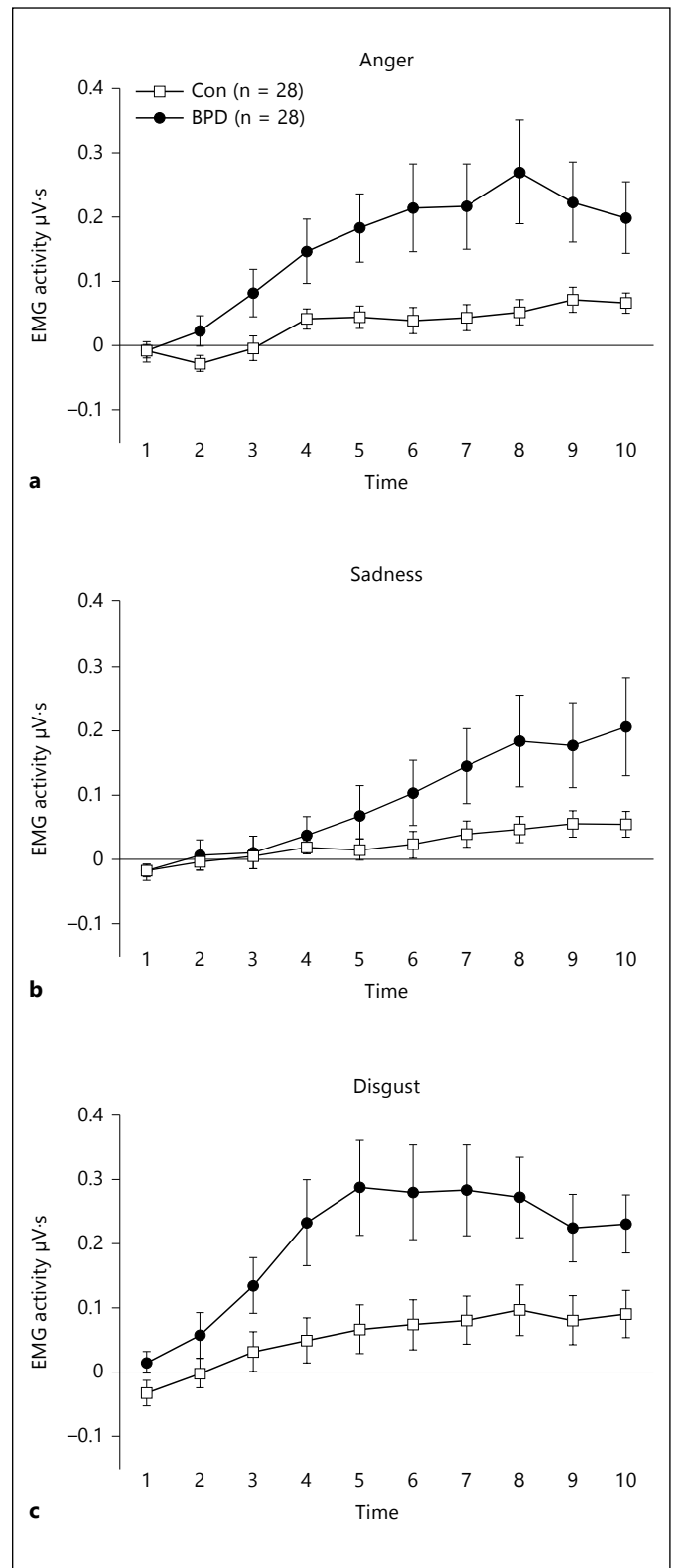
The separate ANOVAs of the EMG data for each muscle and facial emotion revealed significant main group effects of the corrugator supercilii in response to facial expressions of anger ( $F_{1, 54} = 6.942$ ,  $p = 0.011$ ,  $\eta_{\text{par}}^2 = 0.114$ ) and disgust ( $F_{1, 54} = 6.628$ ,  $p = 0.013$ ,  $\eta_{\text{par}}^2 = 0.109$ ). The time  $\times$  group interaction was also significant for anger ( $F_{9, 486} = 3.300$ ,  $p = 0.035$ ,  $\eta_{\text{par}}^2 = 0.058$ ), disgust ( $F_{9, 486} = 3.030$ ,  $p = 0.041$ ,  $\eta_{\text{par}}^2 = 0.053$ ) and sadness ( $F_{9, 486} = 3.319$ ,  $p = 0.041$ ,  $\eta_{\text{par}}^2 = 0.058$ ) indicating in-



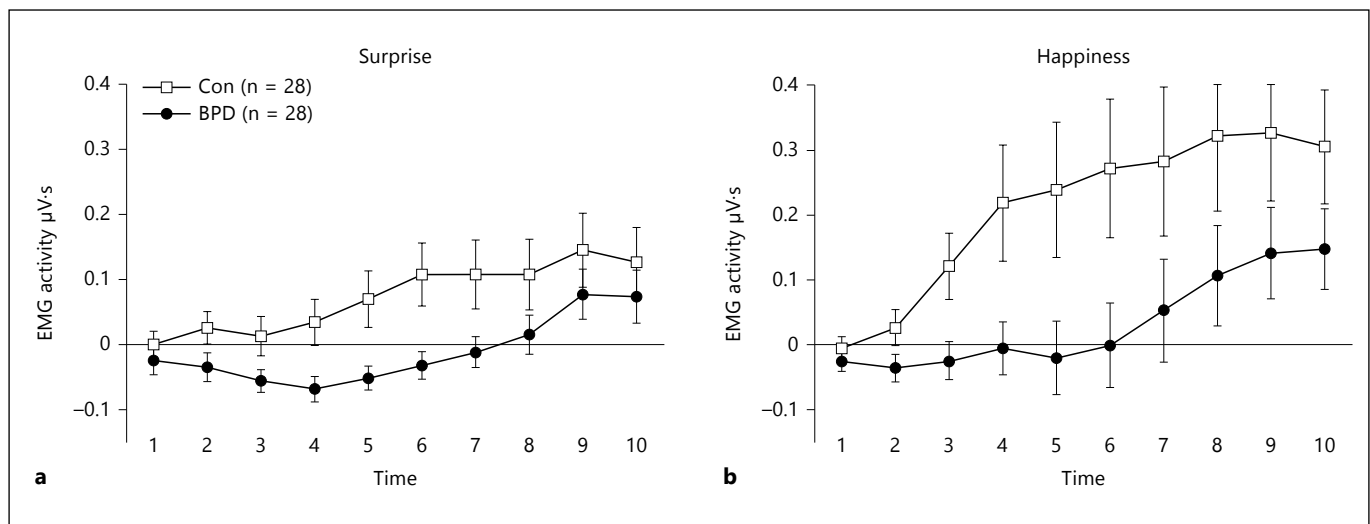
**Fig. 1.** Emotion recognition performance (a) and distribution of errors (b) in percent across all erroneous trials. Con = Controls.

creased responses of the corrugator supercilii to these facial expressions in BPD patients (fig. 2). No significant group or time  $\times$  group interaction effects were found in response to happy, fearful or surprised faces in corrugator supercilii activity.

In addition, the BPD group showed lower levator labii superioris activity than healthy controls in response to surprised faces ( $F_{1,54} = 4.51$ ,  $p = 0.038$ ,  $\eta_{\text{par}}^2 = 0.077$ ) and marginally significant lower levator labii superioris activity in response to happy faces ( $F_{1,54} = 3.998$ ,  $p = 0.051$ ,



**Fig. 2.** Group differences in the activity of the corrugator supercilii in response to faces showing anger (a), sadness (b) and disgust (c).



**Fig. 3.** Group differences in the activity of the levator labii superioris in response to faces showing surprise (a) and happy faces (b).

$\eta_{\text{par}}^2 = 0.069$ ) (fig. 3). No other group effect was significant in response to faces of anxiety, anger, sadness or disgust, as were the time  $\times$  group interactions.

For the other three facial muscles (occipitofrontalis, zygomaticus major and orbicularis oculi) we did not find any group differences in response to the facial emotions presented. In addition, no significant correlations (all  $r < 0.30$ ) between EMG responses or subjective emotional responses to the different facial emotions and psychometric measurements of emotional state or trait variables (BDI, STAI and STAXI), calculated separately for both groups, could be detected.

## Discussion

In this study, we assessed facial reactions, in the form of facial muscle activity, of patients with BPD and of healthy controls while performing a dynamic facial-emotion recognition task. Compared to controls, BPD patients showed increased EMG activity in the corrugator supercilii when processing faces showing anger, sadness and disgust and decreased EMG activity in the levator labii superioris while processing faces showing happiness and surprise. As the corrugator supercilii and the levator labii superioris are involved in frowning and smiling, respectively, their activation corresponds with the associated emotions of anger, sadness or disgust on the one hand and happiness on the other. As pointed out in the introduction, the pattern of increased corrugator and de-

creased levator labii superioris activations in BPD patients while they process the corresponding facial expressions is in line with the hypothesis that BPD patients perceive their social environment with a negativity bias, rather than being more sensitive to social signals or being more empathic in general. From the latter assumption, we would have predicted an increase in facial responses to positive and negative facial expressions such as happiness and sadness. In addition, the pattern of facial EMG responses cannot be explained by the depressive state or single emotional trait variables such as being prone to anger or anxiety.

An alternative interpretation refers to the fact that increased emotional responding to other types of negative stimuli, such as aversive scenes, has been demonstrated in a number of previous studies [11, 13, 14, 17, 20]. Thus, increased responding to negative facial expressions in this study might reflect increased emotional responding to negative stimuli in general (regardless of their social relevance). In addition, it should be noted that BPD patients generally tend to report more negative emotions and less positive emotions (e.g. [70]) which might have influenced facial expressions in response to the presented faces in the study.

Regarding emotion recognition, our findings do not support the assumption of a general impairment in facial emotion recognition in BPD patients. No significant intergroup differences were found with regard to emotion recognition, which is consistent with a number of previous studies on facial emotion recognition in BPD



[1, 16, 26–30]. Other studies, however, reported impaired facial emotion recognition and increased error rates in BPD [8, 22, 23, 31]. The differences in the findings might be due to differences in the experimental paradigms used, e.g. presentation times. For instance, Guittart-Masip et al. [22] used a discrimination paradigm with faces presented for 700 ms and Merkl et al. [31] presented facial expressions for 300 ms – both studies reported impaired facial emotion recognition and increased error rates in BPD. Regarding the dual process model of social cognition (see [71]) very brief presentations of social stimuli are supposed to primarily activate the reflexive system (amygdala, basal ganglia and lateral temporal cortex) in contrast to the reflective system (lateral prefrontal cortex and medial prefrontal cortex), which is more involved in conscious perceptions. Impairment in facial emotion recognition, found in studies which used very short presentation times [22, 31], is in line with the assumption of a dysfunctional implicit processing of social stimuli, a hypothesis that could be the focus of future studies.

In addition to a normal emotion recognition performance, there were no indications for altered error patterns in BPD, despite a tendency to mistakenly report fear when making errors in emotion recognition. This is consistent with the previously reported heightened sensitivity towards the recognition of fear in BPD [1].

Decreased facial responding to happy facial expressions was accompanied by a tendency to report lower levels of happiness while processing happy faces in BPD. Thus, it seems that positive social stimuli were less potent in triggering ‘facial mimicry’ [45] and probably less potent in inducing positive emotions in terms of ‘emotional contagion’. On the contrary, higher intensities of negative emotions during the presentation of negative facial expressions suggest that negative social stimuli might be particularly potent in inducing negative emotions. Afferent facial feedback (see [53, 72]) could be a promising concept for understanding the relationship between biased facial activity to social cues, subjective emotional feelings and interpersonal problems in BPD. In concrete terms: reduced afferent facial feedback associated with reduced smiling-associated muscle activity while viewing happy facial expressions would explain the reduced experience of happiness in BPD. However, contrary to our predictions, there were no group differences regarding the intensity ratings of negative facial expressions and subjective emotions.

It should be noted that we are not able to conclude that there was a reduced afferent facial feedback to positive

facial displays from the present data in a strict sense, as facial reactions and intensity ratings were assessed as the dependent variables in response to faces showing varying emotions. In future research, it would be interesting to manipulate the facial reactions in BPD as the independent variable and assess emotional reactions; this would be a direct approach to the facial feedback hypothesis (see [73]).

This study has some limitations. First of all, we only included female patients, thus the results might not generalize to male BPD patients. In addition, the study lacked a clinical control group, which leaves the question of specificity of the findings unanswered. For example, depression has also been associated with impaired facial reactivity specifically to happy facial expressions (e.g. [74]). Future studies are needed to address the question of whether the emotional state interferes with social perception and facial contagion in BPD, in order to further elucidate the contribution of the emotional state. Finally, this study focused on basic emotions and did not investigate other more complex emotions such as shame, guilt or mixed emotions, which could be the focus of future studies using facial EMG to assess complex yet subtle facial expressions.

In sum, our results do not support the notion of generally impaired facial emotion recognition in BPD or the generally increased sensitivity to the emotional state of others inferred from their facial display. The pattern of increased facial reactions to negative facial stimuli and decreased facial responding to positive faces is rather in line with the hypothesis that BPD patients tend to perceive their social world with a negativity bias. First evidence suggests that the subtle facial reactions of BPD patients found in this study may be associated with a reduced subjective experience of positive emotions but a heightened experience of negative emotions while they are watching the corresponding facial expressions.

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## Disclosure Statement

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