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Effects of personal space intrusion in affective contexts: an fMRI investigation with women suffering from borderline personality disorder

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The amygdala and the parietal cortex play a key role in the neural representation of personal space. Although the concept of personal space is clinically very relevant for borderline personality disorder (BPD), especially in affective contexts, it has not been investigated thus far with functional magnetic resonance imaging (fMRI). In this fMRI study, 25 female BPD patients and 25 healthy women were exposed to photos of angry, disgusted and neutral facial expressions. All stimuli were once shown as still photos, and once were zoomed-in in order to simulate intrusion into one's own personal space. Approaching faces generally provoked activation of the amygdala and the somatosensory cortex. BPD patients showed an increased activation within both regions, but only toward approaching disgusted faces. Their amygdala activation in this specific condition positively correlated with self-disgust scores. Moreover, the clinical group indicated an enhanced personal distance preference, which was associated with parietal activation. The present study revealed altered personal space processing of BPD patients, especially in situations that relate to social contexts involving disgust. Future studies should focus on the temporal stability of personal space processing during the natural course of BPD as well as during therapy.

Keywords: borderline personality disorder; disgust; anger; personal space; fMRI

INTRODUCTION

People often experience discomfort when other individuals infringe upon a self-established physical boundary during social interactions. This phenomenon is related to the concept of (peri)personal space (PPS) which is defined as the region immediately surrounding our bodies (Holmes and Spence, 2004). PPS can be conceptualized as a safety zone (Graziano and Cooke, 2006). Interestingly, this zone is variable, and for example depends on the affective context. It seems only logical that we allow a smaller distance when someone is approaching us with a friendly face than with a negative expression (Gessaroli *et al.*, 2013). Furthermore, certain personality traits (e.g. trait anxiety; Sambo and Iannetti, 2013), mental disorders (e.g. autism; Gessaroli *et al.*, 2013) and neurological conditions (e.g. amygdala atrophy; Kennedy *et al.*, 2009) affect personal space preferences and judgments. Kennedy *et al.* (2009) found that a patient with complete amygdala lesions lacked any sense of personal space, whereas healthy individuals responded with increased amygdala activation to close proximity of another person. This finding points to the pivotal role of the amygdala in personal space processing. In addition, a convergent series of studies in animals and humans showed that the central PPS representation is mediated by visuo-tactile neurons in the parietal cortex, the putamen and the premotor cortex (Graziano and Cooke, 2006; Brozzoli *et al.*, 2012).

It is widely accepted that patients suffering from borderline personality disorder (BPD) have difficulties in establishing and maintaining their own personal space. Family members, partners and also therapists are frequently experienced as either 'too close' or 'too far away'. The resulting interpersonal problems consist of frequent wavering between strong dependency and rejection sensitivity along with sometimes sudden withdrawal and even hostile behavior (Schmahl *et al.*, 2014).

Despite this clinical observation, neurobiological studies on personal space perception in BPD are lacking. In this study, we simulated intrusion into one's own personal space by means of pictures of facial expressions that were enlarged (zoomed-in) to make the person appear very close—almost touching. The expressions were angry, disgusted and neutral. The responses were contrasted to non-animated facial expressions and compared between BPD patients and healthy controls. Neuroimaging studies on the processing of facial expressions in BPD have mainly used still photos. It could be demonstrated that BPD patients show a higher degree of activation in (para)limbic structures (e.g. amygdala) in response to aversive (angry, disgusted) as well as ambiguous (neutral) facial expressions (for reviews see Domes *et al.*, 2009; Mitchell *et al.*, 2014).

The altered socioaffective processing in BPD has been linked to certain personality characteristics. It has been suggested that BPD can be understood as a maladaptive variant of traits described in the 5-factor model of personality involving elevated levels of neuroticism and lowered levels of conscientiousness and agreeableness (Hopwood *et al.*, 2009). When looking at specific emotional traits, a striking difference between BPD and other clinical as well as healthy groups concerns the high self-disgust scores reported by the afflicted patients (Schienle *et al.*, 2013; Ille *et al.*, 2014). Self-disgust is the tendency to devaluate one's own personal features and actions (Schienle *et al.*, 2013). Self-loathing in BPD might be a result of the continuing experience that other individuals find oneself disgusting. The feeling of rejection by others is internalized and then adopts the form of self-disgust (Ille *et al.*, 2014). Klonsky and Muehlenkamp (2007) proposed that non-suicidal self-injury (e.g. cutting, burning oneself), a common phenomenon of BPD, is mostly used to alleviate intense negative emotions, but may also serve to express self-directed disgust. An association between self-relevant disgust and self-harm in BPD was also revealed by Abdul-Hamid *et al.* (2014).

We hypothesized that BPD patients would respond with increased activation in PPS-relevant brain areas (e.g. amygdala, parietal cortex) toward personal space intrusion especially in aversive affective contexts such as approaching disgust expressions.

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MATERIALS AND METHODS

Sample

We investigated 25 women with a BPD diagnosis according to DSM-5 (American Psychiatric Association, 2013) and 25 healthy women with comparable age, educational level and handedness (Table 1).

Except of two patients, all women showed non-suicidal self-injury behavior (especially cutting, burning); eight reported childhood sexual abuse; two further patients had experienced physical abuse. More than half of the patients (64%) were medicated. Of those, 60% took antidepressants, 40% neuroleptics, 16% a tranquilizer and 32% received a combination of antidepressants and neuroleptics.

Current symptoms of bipolar disorder, psychosis and major depression led to exclusion from the sample. Life time diagnoses of the patients included major depression (28%), eating disorders (20%), post-traumatic stress disorder (8%) and substance abuse, especially alcohol (40%). Current comorbidities are described in Table 1. Control group participants who suffered from any mental disorder were excluded.

All participants provided written informed consent after receiving full explanation of the test procedure. The study had been approved by the ethics committee of the University of Graz.

Procedure and materials

The study design included two sessions. The first diagnostic session was conducted by a board-certified clinical psychologist, who conducted a standardized clinical interview (Margraf, 1994) and a questionnaire assessment consisting of the following measures: (i) The short version of the Borderline Symptom List (Bohus *et al.*, 2009) is a self-rating instrument for BPD symptoms. The Cronbach's alpha is 0.95. (ii) The Questionnaire for the Assessment of Disgust Proneness (QADP) (Schienle *et al.*, 2002) describes 37 situations, which have to be judged on 5-point scales with regard to the intensity of experienced disgust (e.g. 'You smell urine'; Cronbach's alpha = 0.90), (iii) The Questionnaire for the Assessment of Self-Disgust (QASD) (Schienle *et al.*, 2014) has two subscales, 'personal disgust' (devaluation of one's own physical appearance; e.g. 'I find myself repulsive') and 'behavioral disgust' (devaluation of one's own behavior; e.g. 'I regret my behavior'). Measurement accuracy (Guttman's L4) is 0.86 (personal disgust) and 0.81 (behavioral disgust), (iv) The trait scale of the State-Trait Anger Expression Inventory (Schwenkmezger *et al.*, 1992) assesses the tendency of a person to experience anger (Cronbach's alpha = 0.87).

Table 1 Comparison of sociodemographic, clinical and self-report data between patients and controls

	BPD ($n = 25$) M (s.d.)	Controls ($n = 25$) M (s.d.)	$t(48)$	P
Mean age (years)	26.9 (7.8)	27.2 (7.6)	−0.11	0.912
Years of education	10.7 (4.5)	12.1 (3.5)	1.14	0.260
Handedness (right/left)	20/5	20/5		
Self-report				
BSL_sum	46.56 (17.26)	6.40 (6.81)	10.82	<0.001
QADP	2.13 (0.59)	2.21 (0.38)	−0.59	0.560
QASD person	2.09 (0.94)	0.27 (0.29)	9.22	<0.001
QASD behavior	2.24 (0.73)	0.48 (0.42)	10.44	<0.001
STAXI trait anger	26.38 (5.84)	17.00 (4.66)	5.99	<0.001
PPD	28.84 (14.22)	21.63 (8.8)	2.15	0.036
Comorbidity (current): number of patients				
Eating disorders	1	–		
Social phobia	1	–		
Generalized anxiety disorder	1	–		
Dysthymia	1	–		

BSL (Borderline Symptom List); QADP (Questionnaire for the Assessment of Disgust Proneness); QASD (Questionnaire for the Assessment of Self-Disgust); STAXI (State-Trait-Anger-Expression Inventory); PPD: preferred personal distance (bubble diameter in mm).

In the second session (~1 week later), the participants passively viewed pictures of facial expressions during functional magnetic resonance imaging (fMRI). They were presented with pictures from the Karolinska Directed Emotional Faces (Lundqvist *et al.*, 1998) that showed angry, disgusted and neutral facial expressions. Each of the emotional categories consisted of 32 images; half of the posers were men, the other half women. Each picture was presented for 3000 ms once 'still' and once 'approaching'. In the latter condition the original picture was enlarged (factor: 2.75) up to point that only the region involving the mouth and the eyes could be seen. This gave the impression that the approaching person almost touched oneself (example see: https://www.youtube.com/watch?v=sy1FaEhEO5o). There were a total of 192 picture presentations (in random order). The inter-stimulus interval varied between 2500 and 3000 ms. The total experiment lasted ~30 min.

Subsequent to the MRI experiment the participants rated valence and arousal (1 = calm, positive; 9 = aroused, negative) for a random selection of the presented images (half male, half female) outside of the scanner. They rated eight pictures of each condition.

Finally, the participants were presented with a black silhouette of a female person (height: 50 mm; width: 13 mm) from the side. They were asked to draw a bubble around the silhouette (representing herself) to indicate the distance she would like to maintain between herself and others. The bubble diameter was taken as an indicator of preferred personal distance (PPD).

fMRI recording

The fMRI session was conducted with a 3T scanner (Skyra, Siemens, Erlangen, Germany). For functional runs a total of 515 volumes were acquired using an echo-planar imaging protocol (number of slices: 35, descending, tilted -25° from the AC-PC line; flip angle = 90°, slice thickness: 3 mm; slice spacing: 3.99 mm; matrix: 64×64; TE = 30 ms; TR = 2290 ms; FoV: 192; in-plane resolution = $3 \times 3 \times 3$ mm). All analyses were conducted using SPM8 (Wellcome Department of Cognitive Neurology, London). Three volumes from the beginning of the time series were discarded to account for saturation effects.

First, the functional data were motion-corrected via realignment and acquisition timing was accounted in the slice timing step. Individuals $T1$ images were coregistered to their functional data. Afterwards coregistered $T1$ images got 'new segmented' into gray matter (GM), white matter (WM) and cerebrospinal fluid. To create a study-specific template and to increase inter-subject alignment GM and WM images were used in a 'Fast Diffeomorphic Registration Algorithm' (DARTEL). Resulting images were then normalized to MNI-space (3 mm isotropic voxel) and smoothed with an 8 mm isotropic Gaussian kernel. We compiled vectors for each event of interest (picture onset) and entered them into the design matrix to model event-related responses by the canonical hemodynamic response function in the first level stage. Data were high pass filtered (128 s). Temporal sphericity was controlled by an AR(1) process with consecutive pre-whitening of the data.

Statistical analyses

The rating data were analyzed with repeated measures ANOVAs (SPSS; version 22) with the within-subject factors 'Emotion' (Anger, Disgust, Neutral) and 'Motion' (Still, Approaching) and the between-subject factor 'Group' (BPD, Control). Significant effects were followed up with post-hoc t-tests and effect sizes η^2_P were computed. Questionnaire scores and the measure for PPD were compared between the two groups via t-tests.

For the fMRI data, we computed an analysis of variance with the factors 'Emotion' (Anger, Disgust, Neutral), 'Motion' (Still, Approaching) and 'Group' (BPD, Control). Statistically significant main effects and interaction effects were followed up (post-hoc) by one-dimensional *t*-contrasts.

We conducted exploratory whole-brain voxel intensity tests as well as region of interest (ROI) analyses for the amygdala, the insula, the premotor cortex, the putamen and parietal regions [intraparietal sulcus, inferior parietal region, primary/secondary somatosensory cortex (SI, SII)]. These regions had been selected based on previous findings on personal space processing (e.g. Graziano and Cooke, 2006; Kennedy *et al.*, 2009). Because fMRI investigations on affective face processing (Roelofs *et al.*, 2009; Volman *et al.*, 2011) had identified the (lateral) orbitofrontal cortex (OFC) and the ventrolateral prefrontal cortex (VLPFC) as important areas for the control of approach-avoidance behavior (a concept closely related to personal space regulation), we additionally included these ROIs in the analysis.

In addition to the analyses of variance, we conducted multiple regressions separately for each group to correlate questionnaire scores with activation in the specific ROIs. The used ROI masks were taken from the Harvard-Oxford Cortical and Subcortical Structural Atlas (Center for Morphometric Analysis, MGH-East, Boston/MA) and from the Juelich histological atlas (Eickhoff *et al.*, 2005). For the ROI analyses, we applied a height threshold of $P < 0.05$ (uncorrected) and an extent threshold of five voxels. Whole-brain analyses used a threshold of $P < 0.001$ (uncorrected) and an extent threshold of 10 voxels. Results reported are based on family wise error (FWE) correction for voxel intensity tests ($p_{FWE} < 0.05$).

RESULTS

Questionnaire data

BPD patients obtained higher scores on all self-report measures with the exception of the QADP (disgust proneness; Table 1).

Affective ratings

The analysis of variance for arousal ratings revealed significant main effects for Emotion [$F(2,96) = 36.2$, $P < 0.001$, $\eta_P^2 = 0.430$], Motion [$F(1,48) = 11.8$, $P = 0.001$, $\eta_P^2 = 0.198$] and Group [$F(1,48) = 9.75$, $P = 0.003$, $\eta_P^2 = 0.171$]. All other effects were statistically non-significant [Emotion × Group: $F(2,96) = 0.75$, $P = 0.478$, $\eta_P^2 = 0.015$; Motion × Group: $F(1,48) = 0.29$, $P = 0.596$, $\eta_P^2 = 0.006$; Emotion × Motion: $F(2,96) = 0.94$, $P = 0.395$, $\eta_P^2 = 0.019$; Emotion × Motion × Group: $F\ (2,96) = 0.76$, $P = 0.469$, $\eta_P^2 = 0.016$]. The conducted post-hoc *t*-tests showed that the patients generally gave higher arousal ratings than controls, and that approaching faces were perceived as generally more arousing than still ones (all P's < 0.05). Disgusted and angry faces received higher arousal ratings than neutral images (P's < 0.001).

For the valence ratings effects of Emotion [$F(2,96) = 72.7$, $P < 0.001$, $\eta_P^2 = 0.602$] and Motion [$F(1,48) = 6.65$, $P = 0.013$, $\eta_P^2 = 0.122$] reached statistical significance. All other effects were statistically non-significant [Emotion × Group: $F(2,96) = 0.11$, $P = 0.895$, $\eta_P^2 = 0.002$; Motion × Group: $F(1,48) = 0.07$, $P = 0.798$, $\eta_P^2 = 0.001$; Emotion × Motion: $F(2,96) = 0.46$, $P = 0.634$, $\eta_P^2 = 0.009$; Emotion × Motion × Group: $F\ (2,96) = 1.04$, $P = 0.359$, $\eta_P^2 = 0.021$; Group: $F(1,48) = 0.58$, $P = 452$, $\eta_P^2 = 0.012$]. Post-hoc *t*-tests indicated stronger negative valence for approaching relative to still faces ($P = 0.01$). Disgusted and angry faces were perceived as more negative than neutral ones (P's < 0.001). The ratings are displayed in Supplementary Table S1 (Supplementary Material).

fMRI data

The conducted analysis of variance revealed significant main effects for the factors Emotion and Motion. Disgust and Anger images induced greater amygdala activation than Neutral pictures. Disgusted facial expressions additionally elicited insula activation (ROI effects Table 2, Figure 1). Results of the whole-brain analysis are depicted in the Supplementary Table S2.

Approaching relative to still photos provoked increased activation in the right amygdala, and several parietal regions (primary somatosensory cortex, inferior parietal region, intraparietal sulcus).

A 3-fold interaction effect (Emotion × Motion × Group) resulted from stronger activation of the amygdala, as well as the primary and secondary somatosensory cortex (SI, SII) in the BPD group when approaching Disgust faces were shown (Figure 2). The control participants showed stronger amygdala activation to approaching Anger relative to Disgust faces (Table 2). No other effect reached statistical significance.

In order to follow up on this finding, we investigated correlations between ROI activation in the Approaching Disgust condition and self-report measures. In the BPD group, self-disgust (QASD-person) was positively correlated with amygdala activation [MNI coordinates *x*, *y*, *z*: 21, −6, −12; $t = 3.35$, p(FWE) = 0.026]. Moreover, the PPD to another person (in mm) positively correlated with activation of the inferior parietal region [−45, −36, 27; $t = 4.02$, p(FWE) = 0.005], the primary somatosensory cortex [−36, −45, 63, $t = 4.25$, p(FWE) = 0.014] and the intraparietal sulcus [−45, −36, 33, $t = 3.25$, p(FWE) = 0.049]. The control group showed positive correlations between PPD and activation of the primary somatosensory cortex [−42, −24, 60; $t = 4.02$, p(FWE) = 0.030], and the putamen [−30, −6, 3; $t = 3.88$, p(FWE) = 0.031] in the approaching disgust condition. Trait anger was not correlated with ROI activation in the disgust or anger conditions, neither in the clinical nor control group.

Table 2 Results of the analysis of variance for ROIs

	H	*x*	*y*	*z*	F	Post-hoc *t*-tests	p(FWE)	Cluster size
Main effect emotion								
Anger > neutral								
Amygdala	R	24	−3	−15	9.34	4.23	<0.0001	78
Amygdala	L	−18	−9	−12	11.74	4.73	<0.001	61
Disgust > neutral								
Amygdala	R	24	−3	−15	9.34	3.18	0.014	28
Amygdala	L	−21	−6	−15	10.79	3.64	0.005	27
Insula	L	−33	12	−12	7.25	3.77	0.006	76
Main effect motion								
Approaching > still								
Amygdala	R	27	−3	−21	10.73	3.28	0.014	34
Premotor cortex	R	36	−3	48	64.78	8.05	<0.001	341
Premotor cortex	L	−39	−3	51	45.67	6.76	<0.001	312
SI	R	30	−45	54	30.82	5.55	<0.001	55
SI	L	−24	−48	51	73.72	8.59	<0.001	69
Intraparietal sulcus	R	24	−57	51	88.43	9.04	<0.001	72
Intraparietal sulcus	L	−24	−57	54	110.4	10.51	<0.001	61
Inferior parietal region	R	60	−39	21	22.74	4.77	<0.001	45
Inferior parietal region	L	−45	−36	27	10.01	3.16	0.012	30
Interaction effect emotion × motion × group								
BPD > controls: approaching: disgust > neutral								
Amygdala	L	−15	−6	−9	8.62	2.97	0.028	42
SI	L	−51	−9	27	7.20	3.88	<0.001	112
SII	L	−54	−12	24	7.12	3.74	0.006	96
Controls > BPD: approaching: anger > disgust								
Amygdala	L	−15	−6	−9	8.62	4.57	<0.001	23

H: hemisphere, *x*, *y*, *z*: MNI coordinates, *F*-values of analyses of variance, post-hoc *t*-tests with *p* (corrected for FWE); cluster size: number of voxels in associated cluster; SI: primary somatosensory cortex; SII: secondary somatosensory cortex, BPD = borderline personality disorder.

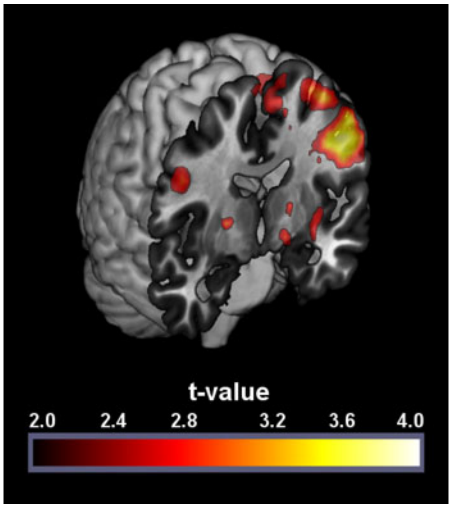

Fig. 1 Brain activation associated with the emotional content and presentation type of the images.

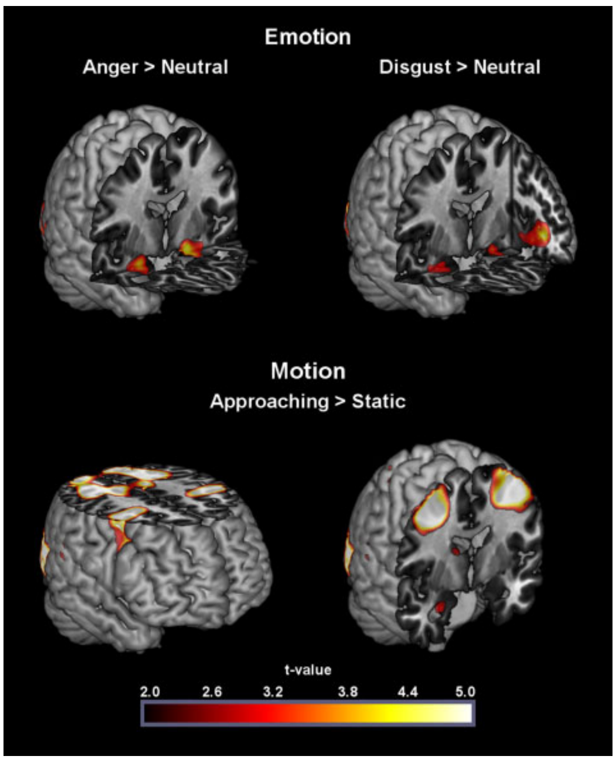

Fig. 2 Enhanced activation of the amygdala and the somatosensory cortex in BPD patients during the viewing of approaching Disgust faces.

We also conducted exploratory analysis of variance for the clinical group in order to compare brain activation between patients with ($n = 10$) and without traumatization ($n = 15$), and with ($n = 16$) and without psychotropic medication ($n = 9$). The comparisons revealed no suprathreshold activation. In addition, we investigated a possible effect of poser sex as the pictures had depicted men as well women. Both groups showed no significant difference in activation in response to female and male posers.

DISCUSSION

We found that intrusion into one's own personal space (simulated by zooming in pictures of facial expressions) activated fronto-parietal areas as well as the amygdala. The parietal regions included the primary as well as the secondary somatosensory cortex (SI, SII) and the intraparietal sulcus. The SI in the postcentral gyrus is the main sensory receptive area for the sense of touch, while the SII is associated with higher-order somatosensory functions. This multimodal integration cortex may embody an abstract notion of touch. The intraparietal sulcus contains neurons with tactile receptive fields that represent space in a head-centered reference frame (Gazzola and Keysers, 2008; Ebisch *et al.*, 2011; Schaefer *et al.*, 2012). Several fMRI investigations demonstrated that not only actual but also observed touch and the observation of a stimulus which enters one's own PPS recruits the mentioned regions (e.g. Gazzola and Keysers, 2008; Cardini *et al.*, 2010; Ebisch *et al.*, 2011; Schaefer *et al.*, 2012). Moreover, seeing someone being touched (e.g. viewing one's own face being touched) is able to activate the frontal premotor cortex, which can be conceptualized as part of a mirror system for action observation (Cardini *et al.*, 2010). In this study, the zooming-in procedure gave the impression that the other face would come closer to one's own face almost touching it. Consequently, not only the sight of touch, but also imagined or predicted physical contact with another person is able to recruit fronto-parietal regions involved in PPS processing.

We additionally observed that simulated proximity of another person provoked amygdala activation. This finding replicates previous reports (Kennedy *et al.*, 2009). In both groups (patients and controls), the amygdala was sensitive to changes in interpersonal distance. The amygdala is central for the control of defensive responses to threat (LeDoux, 2014). The intrusion of another individual into one's own personal space implies potential danger, and therefore recruited this region. Very interestingly, this defensive reaction to personal space reduction differed between groups and affective contexts. The only group effect we found concerned the condition with approaching disgusted faces. Here, BPD patients displayed enhanced activation in those areas crucial for personal space representation (amygdala, SI, SII). On the contrary, controls responded more strongly to angry faces and showed increased amygdala activity. This response seems logical from a bioevolutionary standpoint because when personal space acts as an interface for defensive responses, then in case of an aggressive attack it is especially important to trigger this mechanism as quickly as possible (LeDoux, 2014).

BPD patients showed increased sensitivity to personal space reductions in contexts involving devaluation and repugnance expressed by another person. On the subjective level the patients had described an elevated level of self-disgust, which has been conceptualized as perceived revulsion by others, which has been imbedded into the self-concept (Ille *et al.*, 2014). This interpretation is supported by the observation that the degree of self-loathing (as indexed by the QASD scores) was able to predict amygdala activation in the Approaching Disgust condition. According to Linehan's biosocial theory BPD symptoms evolve in invalidating developmental contexts. The social environment of the patients does either not tolerate their personal emotional experiences or is even characterized by emotional abuse (Crowell *et al.*, 2009). These types of stressors during childhood, which are rather common in BPD patients, constitute a risk factor for self-disgust (Schienle *et al.*, 2014). In this sample, the majority of patients had reported affective (or even sexual) abuse. Therefore, the development of increased self-referenced disgust sensitivity in social contexts seems understandable.

In addition, the PPD of the patients positively correlated with activation of the primary sensory cortex, and the intraparietal sulcus in the Approaching Disgust condition. Similar correlations were present in the control group underlining the importance of specific parietal areas for the explanation of interindividual variability in personal space preference.

Besides increased self-disgust and increased preferred personal space in the clinical group, the patients were characterized by a noticeable greater variance in their PPD ratings. Therefore, the question arises how temporally stable this measure is over time. Past studies pointed to the striking feature of personality trait instability in BPD (Hopwood *et al.*, 2009). Longitudinal studies are needed in order to relate possible changes in personal distance preference with the symptom course in BPD and the underlying neuronal correlates.

We have to mention the following limitations of our study. We recruited only women because they represent the majority of individuals diagnosed with BPD. However, this limits the generalizability of our results to men. Further critical aspects refer to the medication status and experienced trauma of the clinical sample. Although we were not able to detect differences in brain activation between patients with and without psychotropic medication and with and without traumatization this might be due to the small sample sizes of the sub groups and the resulting low statistical power.

Further, the BPD patients were afflicted by additional mental disorders. Although the observed comorbidity pattern is typical for this disorder, this raises questions with regard to the specificity of our findings. Therefore, future studies should include at least one other clinical group.

Finally, in future experiments additional emotion conditions should be integrated into the design. In a study by Kobeleva *et al.* (2014), BPD patients were presented with pictures of different affective facial expressions (fear, anger, happiness, sadness, neutral) and were asked to indicate how many steps they would make toward or away the depicted person. The patients showed stronger avoidance of happy and fearful faces than healthy controls. Thus, the authors did not find a general negative evaluative style, but emotion-specific effects as in the present investigation. The mentioned paradigm required the execution of approach-avoidance behavior and by that the active regulation of personal space. This approach has also been used in fMRI investigations with healthy participants (e.g. Roelofs *et al.*, 2009; Volman *et al.*, 2011) and pointed to the relevance of a specific neural network (OFC, VLPFC) for voluntary control of approach-avoidance behavior. The contrasting of brain responses to active as well as passive changes of interpersonal space would be of special interest for the understanding of BPD symptomatology.

In conclusion, this fMRI study on BPD is the first one to investigate neuronal correlates of personal space intrusion. The emotion specificity of the observed effect, the increased responding of the patients to social contexts involving disgust, could even be used to improve treatment approaches. Psychotherapy manuals might integrate specific modules on personal space processing (introduction into the concept of personal space, individual preferences and regulation of interpersonal distance in affective situations).

SUPPLEMENTARY DATA

Supplementary data are available at *SCAN* online.

Conflict of Interest

None declared.

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