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Stuck in a negative me: fMRI study on the role of disturbed self-views in social feedback processing in borderline personality disorder

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Abstract

Background. Interpersonal difficulties in borderline personality disorder (BPD) could be related to the disturbed self-views of BPD patients. This study investigates affective and neural responses to positive and negative social feedback (SF) of BPD patients compared with healthy (HC) and low self-esteem (LSE) controls and how this relates to individual self-views.

Methods. BPD ($N = 26$), HC ($N = 32$), and LSE ($N = 22$) performed a SF task in a magnetic resonance imaging scanner. Participants received 15 negative, intermediate and positive evaluative feedback words putatively given by another participant and rated their mood and applicability of the words to the self.

Results. BPD had more negative self-views than HC and felt worse after negative feedback. Applicability of feedback was a less strong determinant of mood in BPD than HC. Increased precuneus activation was observed in HC to negative compared with positive feedback, whereas in BPD, this was similarly low for both valences. HC showed increased temporoparietal junction (TPJ) activation to positive *v.* negative feedback, while BPD showed more TPJ activation to negative feedback. The LSE group showed a different pattern of results suggesting that LSE cannot explain these findings in BPD.

Conclusions. The negative self-views that BPD have, may obstruct critically examining negative feedback, resulting in lower mood. Moreover, where HC focus on the positive feedback (based on TPJ activation), BPD seem to focus more on negative feedback, potentially maintaining negative self-views. Better balanced self-views may make BPD better equipped to deal with potential negative feedback and more open to positive interactions.

Introduction

Humans have an innate need to form relationships (Over, 2016). However, for patients with borderline personality disorder (BPD), this is a struggle as they encounter interpersonal problems on a daily basis (Lieb *et al.*, 2004; Lazarus *et al.*, 2014). Interpersonal difficulties are strongly interlinked with identity disturbance as the way we view ourselves shapes our interaction with others, just as our self-views are shaped by interaction with others (Jorgensen, 2010; Kerr *et al.*, 2015; van Schie *et al.*, 2018). Since BPD patients tend to have fragmented and conflicting self-views that are predominantly negative (Wilkinson-Ryan and Westen, 2000; Zeigler-Hill, 2006), this may make them more vulnerable for interpersonal difficulties. As of yet, the role of identity disturbances of BPD in the context of interpersonal difficulties has not been addressed (Kerr *et al.*, 2015). Therefore, the current study aims to investigate the role of negative self-views of BPD on the affective and neural responses to negative as well as positive social feedback (SF).

Core features of interpersonal difficulties in BPD are a heightened sensitivity to rejection and altered social cognition (Gunderson, 2007; Fertuck *et al.*, 2009; Ha *et al.*, 2013; Lis and Bohus, 2013; Sharp *et al.*, 2013). Studies have shown that patients with BPD perceive others' faces as more untrustworthy and tend to anticipate threat rather than acceptance in social interactions (Daros *et al.*, 2013; Fertuck *et al.*, 2013; Miano *et al.*, 2013; Nicol *et al.*, 2013; Deckers *et al.*, 2015). This lack of trust and expectation of rejection may relate to feeling less included during pleasant interactions (Staebler *et al.*, 2011; Renneberg *et al.*, 2012) and showing less cooperative behavior (King-Casas *et al.*, 2008; Saunders *et al.*, 2015). Altered responses in brain activation to negative emotional stimuli, i.e. increases in insula, posterior cingulate cortex (PCC) activation and decreases in dorsolateral prefrontal cortex, indicate increased sensitivity to and difficulty in dealing with negative stimuli (Ruocco *et al.*, 2013; Schulze *et al.*, 2016). The tendency to mistrust others has been conceptualized as not only obstructing the building of relationships but also social learning from others about the self (Fonagy and Allison, 2014; Fonagy *et al*., 2015; Bo *et al*., 2017).

Accordingly, interpersonal difficulties are tightly linked to a disturbed view of the self, or say, identity disturbance (Bender and Skodol, 2007). Self-views are organized knowledge about various aspects of the self, which is related to but separable from the evaluative attitude toward the self (i.e. self-esteem) (Higgins, 1987; Campbell *et al*., 2003; Swann and Brooks, 2012; Chiu *et al*., 2017). In interaction with others, individuals generally prefer feedback that is consistent with their self-views (Stinson *et al*., 2010; van Schie *et al*., 2018). For example, we previously found that negative feedback that is inconsistent with someone's self-view has more detrimental impact on mood than consistent negative feedback (van Schie *et al*., 2018). Moreover, there are individual differences with regard to the impact of (in)consistent feedback: individuals with lower self-esteem seem to have more difficulty in dealing with (inconsistent) negative feedback (vanDellen *et al*., 2011) as indicated by lower mood and precuneus activity (van Schie *et al*., 2018). Therefore, the way we respond to feedback during social interactions is impacted by both valence and consistency of feedback with self-views as well as a global self-evaluation (Markus and Wurf, 1987; Chen *et al*., 2006).

Disturbed self-views in BPD could be highly relevant in SF processing (Wilkinson-Ryan and Westen, 2000; Zeigler-Hill, 2006). On the one hand, literature on the preference for consistent information explains the ease with which BPD patients process negative information compared with positive information (Stinson *et al*., 2010; Winter *et al*., 2015; Auerbach *et al*., 2016; Korn *et al*., 2016). On the other hand, one might expect that negative feedback may yield relatively mild emotional responses in BPD, since it is consistent with their self-views, whereas positive information may not elicit much positive responses because of its inconsistency with their self-views (Higgins, 1987; Winter *et al*., 2015; Auerbach *et al*., 2016; Korn *et al*., 2016). However, literature on rejection sensitivity suggests that BPD may be particularly prone to negative feedback regardless of its consistency with the self-view (Berenson *et al*., 2011; Miano *et al*., 2013).

The current study investigates how self-views of BPD influence the affective and neural responses to negative as well as positive SF. First, we aim to ascertain that self-views of BPD patients are more negative than healthy control (HC) participants. Next, we investigate how valence of the feedback and consistency with the self-views moderate the responses to SF. Importantly, as self-esteem influences responses to SF and BPD patients are characterized by low self-esteem (LSE) (Zeigler-Hill, 2006; Brown, 2010), we compare BPD patients not only with HC but also with a group of participants matched by the level of self-esteem. This LSE group allows for specifying the effect of disturbed self-views in BPD that goes beyond BPDs LSE.

Methods and materials

Participants

Participants ($N = 80$, all female, age $M = 29.9$, S.D. = 9.4, range = 18–54 years) consisted of patients with the BPD group ($N = 26$), HC group ($N = 32$), and LSE control group ($N = 22$). Participants included in the LSE group had a score lower than 18 on the Rosenberg Self-Esteem Scale [RSES, clinical cut-off for LSE (Schmitt and Allik, 2005; Korrelboom, 2011)]. As expected, BPD patients ($M = 11.28$, S.D. = 6.1) had lower levels of self-esteem compared with HC ($M = 23.75$, S.D. = 3.2). The LSE ($M = 12.73$, S.D. = 2.9) were matched with BPD patients on the level of trait self-esteem. HC and LSE were included to resemble BPD in gender, age, education, and handedness to BPD, see Table 1. We distinguished three levels of education: high school level only, continued education on vocational level, and continued education on higher level. HC (but not LSE) reported higher education levels compared with BPD, see Table 1.

Exclusion criteria for all participants were incompatibility with a magnetic resonance imaging (MRI) scanner, and usage of benzodiazepines (equivalent of >20 mg of oxazepam) or antipsychotics. Exclusion criteria for HC: any current Axis I or Axis II disorder. Exclusion criteria for LSE: current Axis I and II disorders were allowed, except for a diagnosis of BPD. HC and LSE participants were recruited from the general population where LSE were specifically targeted with adverts seeking insecure individuals. BPD patients were recruited from a mental health institution (GGZ Rivierduinen). Medication use, both for physical ailments and psychotropic medication, was taken into account with HC ($N = 3$, 9%), LSE ($N = 4$, 18%) and BPD ($N = 11$, 42%) reporting medication use (for specifications see online Supplementary Table S1). Two HC and one BPD participant were excluded from analyses because of scanner artifacts. One BPD participant was excluded because of neural abnormalities resulting in a final set of 80 participants.

Participants signed informed consent. The study was approved by the medical ethics committee of the Leiden University Medical Center (P12.249) and performed in accordance with the Helsinki Declaration of 1975, as revised in 2008 and the Dutch Medical Research Involving Human Subjects Act (WMO). Part of the HC and LSE data has been reported in van Schie *et al.* (2018).

Social feedback task

Before performing the SF task in an MRI scanner, participants were introduced to another female participant who in reality was a confederate to the study. Together they were instructed that the participant would receive feedback of the confederate based on a personal interview. The interview, consisting of nine personal questions and three moral dilemmas, was held without the confederate, outside the scanner. The voice recorded interview was supposedly handed over to the confederate to provide feedback choosing from the provided list of trait words. The chosen trait words were presented on screen to the participant while in an MRI scanner. In reality, the SF was the same for each participant and consisted of 15 negative (e.g. arrogant), 15 intermediate (e.g. reserved) and 15 positive (e.g. happy) evaluative words, presented one by one (2500 ms) in random order (with no consecutive trials of the same valence). After each word, the participant was asked how she was feeling at that moment on a scale from really bad (1) to really good (4) using button boxes attached to the participants' legs. We used an event-related design with a jittered interstimulus interval ($M =$ 2004 ms, S.D. = 370) and self-paced responses to each trial. Outside the scanner, before debriefing, participants were asked to rate the feedback words on valence from very negative (−4) to very positive (4) with 0 indicating intermediate and on applicability to self from not at all applicable (1) to very much applicable (4). Finally, a manipulation check interview was held with indirect and direct questions to assess whether participants believed the cover story, see online Supplementary material. Most participants believed that the feedback was given by the confederate (HC: 91%, LSE: 95%, BPD: 96%) and groups did not differ in this respect, $\chi^2(4) = 1.20$, $p = 0.879$.

The SF task has been validated before in healthy participants and shown to affect mood, with a better mood after positive

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Table 1. Demographic data ($N = 80$)

Variable	HC ($N = 32$) Mean (s.d.)/count (%)	LSE ($N = 22$) Mean (s.d.)/count (%)	BPD ($N = 26$) Mean (s.d.)/count (%)	Comparison
Age (years)	28.12 (9.8)	31.91 (8.9)	30.46 (9.2)	$F_{(2,77)} = 1.13$, $p = 0.330$
Education level[a]				$\chi^2(2) = 9.77$, $p = 0.006$ HC > BPD, LSE = HC and BPD
High School	1 (3.1%)	4 (18.2%)	8 (30.8%)	
Vocational training (MBO)	19 (59.4%)	7 (31.8%)	14 (53.8%)	
Higher education (HBO and University)	12 (37.5%)	11 (50.0%)	4 (15.4%)	
Handedness	8.09 (5.0)	8.33 (4.7)	7.38 (6.2)	$F_{(2,76)} = 0.21$, $p = 0.811$
Right handed (8+)	28 (87.5%)	19 (90.4%)	22 (84.6%)	
Left handed (−8+)	1 (3.1%)	1 (4.8%)	3 (11.5%)	
Ambidextrous (−7–7)	3 (9.4%)	1 (4.8%)	1 (3.9%)	
Trait self-esteem (RSES)	23.75 (3.2)	12.73 (2.9)	11.28 (6.1)	$F_{(2,76)} = 74.47$, $p < 0.001$ HC > LSE = BPD
Axis I disorder (DSM-IV) [Current/lifetime (incl. current)]				
Mood disorders	0/3	5/11	7/18	
MDD	0/3	4/10	6/15	
Dysthymia	0/0	1/1	1/3	
Anxiety disorders	0/2	5/6	6/9	
Panic disorder	0/1	0/0	2/6	
Agoraphobia	0/1	0/0	1/1	
Social phobia	0/0	3/3	1/1	
Specific phobia	0/0	0/0	1/1	
OCD	0/0	0/1	0/0	
GAD	0/0	2/2	2/2	
PTSD	0/1	0/0	2/2	
ADHD	0 /0	2/2	5/5	
Substance abuse and addiction	0/0	0/0	6/9	
Alcohol	0/0	0/0	2/4	
Drugs	0/0	0/0	4/5	
Other disorders	0/0	4/7	1/1	
Borderline symptoms				
VKP-BPD	1.34 (1.6)	7.48 (3.9)	–	
BPD-SI	–	–	31.05 (10.2)	
Axis II disorders (DSM-IV)				
Borderline	–	–	26	
Antisocial	–	–	2	
Paranoid	–	–	1	

MBO: middelbaar beroepsonderwijs (in Dutch); MDD: major depressive disorder.
[a]Group differences in the education level were assessed using a Kruskal–Wallis test followed by three Wilcoxon rank sum tests (Bonferroni corrected).

feedback and a worse mood after negative feedback especially when feedback is inapplicable. Moreover, a broad neural network is involved in the processing of SF including anterior cingulate cortex (ACC), insula, precuneus, PCC, and temporoparietal junction (TPJ) areas, with differential activation for negative, positive and more or less applicable feedback. For more details, see van Schie *et al.* (2018).

Clinical measures

Axis I disorders

The MINI, a semi structured interview, was used to assess lifetime and current Axis-I disorders based on DSM-IV (First *et al.*, 1997). BPD patients were assessed by a trained psychologist as part of their intake and diagnosis at the mental health institute. HC and LSE participants were assessed by a trained psychologist (C.v.S).

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Axis II disorders

Axis II disorders in BPD patients were assessed using IPDE-IV (Loranger, 1999). Borderline symptom severity was assessed using the Borderline Personality Disorder-Severity Interview (BPD-SI) (Giesen-Bloo *et al.*, 2010). HC and LSE were screened for personality disorders using the self-report standardized assessment of personality – abbreviated scale (SAPAS-SR) (Germans *et al.*, 2008). A score of four or greater indicates the likelihood of a personality disorder and led to exclusion in the case of HC. In the case of LSE, it led to a follow-up to exclude BPD using the SCID-II, a semi structured interview used to diagnose personality disorders (First *et al.*, 2000). Furthermore, the presence of borderline symptoms was assessed in both HC and LSE using the BPD items of the 'Questionnaire for Personality traits' [Vragenlijst voor Kenmerken van de Persoonlijkheid (VKP) (Duijsens *et al.*, 1996)].

Trait self-esteem

The RSES measures the level of trait self-esteem using 10 items with a four point scale (Rosenberg, 1965). The Dutch translation has been well validated (Schmitt and Allik, 2005; Frank *et al.*, 2008). The reliability of the RSES was good ($\alpha = 0.92$).

Procedure

Participants were screened over phone and with online questionnaires to assess compatibility with the MRI scanner (e.g. no metal objects in their body), Axis I disorders (First *et al.*, 1997), Axis II disorders (First *et al.*, 2000; Germans *et al.*, 2008), BPD symptoms (Duijsens *et al.*, 1996), handedness (van Strien, 1992) and medication use. After screening and inclusion two appointments were made. During the first appointment participants signed informed consent, filled in a demographic form and the RSES and were prepared for the MRI scan session. During the second appointment, they performed the SF task in the MRI scanner. After the experiment participants were debriefed of the set-up of the experiment and received a monetary reward of €30.

Data acquisition, preprocessing and analysis

The SF task was programmed in E-prime 2.0. Responses to the SF task were prepared for analysis using Excel 2010 and IBM SPSS statistics version 23. Preprocessing of fMRI data was performed in Feat v6.00 in FSL 5.0.7. Details on data acquisition and preprocessing can be found in the online Supplementary materials. For both affective and neural responses, the moderation of valence and applicability on group effect was tested by trial level modeling using multilevel analyses and parametric modulation. The reference category (i.e. intercept) of valence was set to 'intermediate feedback' enabling the contrasting of negative and positive feedback with intermediate feedback. Applicability ratings were recoded from values 1, 2, 3, 4 to values −3, −1, 1, 3, contrasting inapplicable to applicable feedback. Our main interest was to compare BPD with HC. To investigate the specificity of the results, BPD were also compared with LSE, making BPD the reference group.

Analysis of affect

Behavioral and self-report data were analyzed using R version 3.3.3 (R Core Team, 2013), packages: lme4 (linear mixed-effect modeling) and ggplot2 (for creating figures) (Wickham, 2009; Bates *et al.*, 2015). To test the significance of main and interaction effects, models increasing in complexity were compared using the χ^2 test.

To ascertain whether self-views of BPD patients are more negative, applicability ratings for each feedback word for each participant were used as outcome, predefined valence categories were used on the first level and group membership on the second level. To investigate the impact of the SF on affect, mood ratings for each feedback word for each participant were used as outcome, while the predefined valence categories and individual applicability ratings were specified on the first level. The second level consisted of group membership. The two-way interaction effects of group by valence and group by applicability and the three-way interaction of group by valence by applicability were tested.

Analysis of fMRI

Analysis of fMRI data was performed in Feat v6.00 in FSL 5.0.7. On the individual level, an event related design was used for modeling both valence and applicability. For valence, the onset and duration of each feedback word per valence was specified, resulting in three regressors (Neg, Int and Pos valence). The parametric modulation analysis for applicability contained three regressors (one per valence) in which trials were weighted by the applicability ratings. The onset and duration of the mood question was modeled as a regressor but not of interest to the hypotheses. Six motion parameters indicating rotation and translation, and mean time series of white matter and cerebrospinal fluid were added as confound regressors (Birn *et al.*, 2006; Mier *et al.*, 2013; Cheng and Puce, 2014). The bold response was convolved with the double-gamma HRF function. Six *t*-contrasts were formulated to contrast negative feedback to intermediate (Neg *v.* Int) and positive feedback (Neg *v.* Pos) and positive to intermediate feedback (Pos *v.* Int) in both directions. The general relation between applicability and neural activation was tested (Applicability), as well as the specific relation for applicability of negative, intermediate and positive feedback (interaction effects: Applicability × Neg, Applicability × Int and Applicability × Pos).

For group level inference, a mixed effects model with the FLAME1 method was used. The three groups with separate variance estimation were specified in the model. *T*-contrasts were formulated to compare BPD with HC and BPD with LSE in both directions on all lower level contrasts. This resulted in the test of two two-way interaction effects, i.e. group by valence and group by applicability and one three way-interaction effect, i.e. group by applicability by valence. Data were cluster corrected supported by the findings of Eklund *et al.* (2016) indicating that the FLAME1 method and cluster correction of $Z > 2.3$ and cluster $p < 0.05$ keep the amount of false positives within allowable limits.

For labeling peak voxels the following atlases were used: Harvard-Oxford structural atlas for cortical and subcortical regions (Frazier *et al.*, 2005; Desikan *et al.*, 2006; Makris *et al.*, 2006; Goldstein *et al.*, 2007), Mars connectivity-based parcellation for TPJ and inferior parietal lobe (IPL) areas (Mars *et al.*, 2011, 2012), the cerebellar atlas for cerebellum coordinates (Diedrichsen *et al.*, 2009), and the Talairach Deamon labels for Brodmann areas (Lancaster *et al.*, 2000).

Results

Applicability of feedback to self-views

Applicability ratings were affected by a valence by group interaction [$\chi^2(4) = 106.19$, $p < 0.001$], see online Supplementary Tables S4 and S5 for model comparisons and parameters. Consistent with our hypothesis, BPD patients rated the

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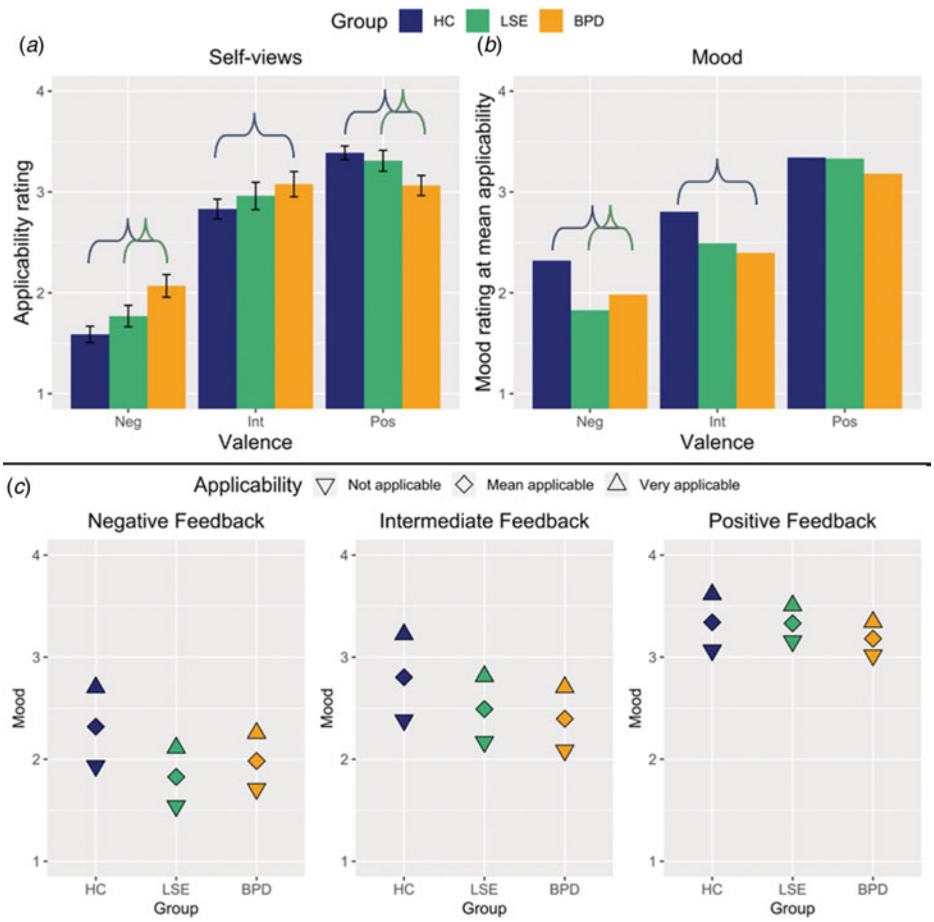

Fig. 1. (*a*) Mean applicability ratings by group after negative, intermediate and positive feedback (error bars indicate 95% confidence intervals). (*b*) Illustration of mood ratings by group after negative, intermediate and positive feedback at the mean level of applicability of feedback. (*c*) Illustration of mean mood ratings by group after negative, intermediate and positive feedback for not to very applicable feedback. Applicability has a greater impact on mood during negative and intermediate feedback than positive feedback. Applicability has a greater impact on the mood of HC compared with BPD. Mood rating is rescaled to scores 1–4 for display purposes.

intermediate ($b = -0.40$, s.e. = 0.16, $t = -2.50$) and especially negative feedback ($b = -0.53$, s.e. = 0.16, $t = -3.36$) as more applicable compared with HC, see Fig. 1*a*. Positive feedback was rated as less applicable by BPD compared with HC ($b = 1.07$, s.e. = 0.16, $t = 6.74$). Compared with LSE, BPD also rated negative feedback as more applicable ($b = -0.43$, s.e. = 0.17, $t = -2.43$) and positive feedback as less applicable ($b = 0.63$, s.e. = 0.18, $t = 3.61$) but did not differ in applicability of intermediate feedback ($b = -0.15$, s.e. = 0.18, $t = -0.83$). Moreover, using the valence ratings (i.e. degree of negativity or positivity), we found that all three groups rated the valence of the words in a similar way [$\chi^2(2) = 2.4$, $p = 0.307$], with negative and positive words being more emotional than intermediate words, see online Supplementary Tables S2 and S3. However, there was a trend for an interaction effect between valence and group [$\chi^2(4) = 8.42$, $p = 0.077$], which could indicate that negative feedback was rated slightly less negative by BPD than HC ($b = -0.43$, s.e. = 0.16, $t = -2.69$), see also online Supplementary Table S3 for model parameters.

Affective responses

Mood was affected by group [$\chi^2(2) = 11.4$, $p = 0.003$] with BPD reporting a worse mood than HC overall ($b = 0.81$, s.e. = 0.19, $t = 4.28$), see Table 2 and online Supplementary Table S6. Valence moderated the group effect [$\chi^2(4) = 39.89$, $p < 0.001$]. BPD reported a worse mood after negative ($b = -0.14$, s.e. = 0.15, $t = -0.95$) and intermediate feedback ($b = -0.81$, s.e. = 0.19, $t = 4.28$) and similar mood after positive feedback ($b = -0.49$, s.e. = 0.13, $t = -3.70$) compared with HC, see Fig. 1*b*. Compared with LSE, BPD reported equal mood after intermediate ($b = 0.19$, s.e. = 0.21, $t = 0.91$) and positive feedback ($b = 0.11$, s.e. = 0.15, $t = 0.75$) but a better mood after negative feedback ($b = -0.50$, s.e. = 0.16, $t = -3.10$).

Applicability moderated the group effect as well [$\chi^2(4) = 14.8$, $p = 0.005$]. BPD mood ratings were less affected by applicability compared with HC ($b = 0.07$, s.e. = 0.03, $t = 2.27$), but did not differ in this respect from LSE ($b = 0.01$, s.e. = 0.03, $t = 0.23$), see Fig. 1*c*. There was no three-way interaction of valence by applicability by group [$\chi^2(4) = 8.0$, $p = 0.090$].

Neural responses

Groups differed in neural correlates of feedback valence, see Table 3 for clusters and peak voxels[†1]. In response to negative feedback compared with positive feedback, HC showed stronger left precuneus activation, whereas BPD showed relatively low and equal precuneus activation for negative and positive feedback, see Fig. 2. In this precuneus cluster, LSE showed relatively high and equal activation for negative and positive feedback, albeit not significantly different from BPD, see Fig. 2. In response to positive compared with negative feedback, HC showed stronger right anterior TPJ activation, whereas BPD showed the reverse pattern, with stronger TPJ activation for negative feedback

[†]The notes appear after the main text.

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Table 2. Effect parameters of model predicting mood ratings by valence category (intermediate = reference), group (BPD = reference), and applicability of feedback and two-way interactions

Effect	Estimate	Std. error	*t*-value
Intermediate valence (Intercept)	−0.21	0.14	−1.45
Negative valence	−0.83	0.11	−7.64***
Positive valence	1.57	0.10	15.03***
HC	0.81	0.19	4.28**
LSE	0.19	0.21	0.91
Applicability	0.21	0.03	7.19***
Negative valence × HC	−0.14	0.15	−0.95
Positive valence × HC	−0.49	0.13	−3.70***
Negative valence × LSE	−0.50	0.16	−3.10***
Positive valence × LSE	0.11	0.15	0.75
Negative valence × Applicability	−0.02	0.03	−0.78
Positive valence × Applicability	−0.10	0.04	−2.78**
Applicability × HC	0.07	0.03	2.27**
Applicability × LSE	0.01	0.03	0.23

Significance level (***<0.001, **<0.01, *<0.05, ^<0.10) based on χ^2 test of model comparisons, see online Supplementary Table S6.

compared with positive feedback. Compared with LSE, BPD showed stronger left precuneus activation during negative compared with positive feedback, see Table 3 and Fig. 2. However, this cluster in the left precuneus did not overlap with the cluster found in comparison to HC. Groups did not differ in neural correlates of applicability. The three-way interaction of applicability by negative valence of BPD compared with HC in the motor cortex, superior parietal lobule and inferior parietal lobule is probably attributable to button press movements (Mars *et al*., 2011).

Exploratory findings

For exploratory purposes, we checked whether LSE differed in self-views from HC by rerunning the model with applicability ratings as an outcome but with HC set as a reference group instead of BPD. We found that despite lower self-esteem, LSE did not report that negative feedback was more applicable to them ($b = 0.11$, s.e. = 0.17, $t = 0.65$), neither was intermediate feedback ($b = 0.26$, s.e. = 0.17, $t = 1.52$). However, they did report that positive feedback is less applicable to them ($b = -0.44$, s.e. = 0.17, $t = -2.64$).

Confounds

To control for potential effects of whether the participant believed the SF paradigm (yes/no), medication status (on/off) and current depression comorbidity, we took this into account in additional affective and neural analyses. These confounds had no effects on the affective results.

Handedness was also taken into account in neural analyses. The stronger precuneus activation in HC compared with BPD found after negative feedback compared with positive feedback did not survive significance threshold after current depression or handedness was taken into account.

Discussion

The current study investigated how disturbed self-views related to interpersonal difficulties in patients with BPD by examining affective and neural responses to negative and positive SF which varied in applicability to the self-view. BPD patients reported more negative self-views compared with both the HC and LSE groups, confirming previous findings of a negative self-referential bias (Winter *et al*., 2015; Korn *et al*., 2016) and extending them by showing that distorted self-views in BPD cannot be attributed to LSE alone.

The consistency of self-views with SF was an important determinant of affective and neural responses. In general, more applicable feedback is related to a better mood especially during negative and intermediate feedback (van Schie *et al*., 2018). In BPD, however, the applicability of negative feedback did not reduce its negative impact resulting in a lower mood after negative feedback than HC. Thus, BPD responded similarly to all negative feedback regardless of consistency to the self. Responses in HC, on the other hand, vary with the consistency of the feedback with the self-view. Another study also found that BPD have trouble ignoring negative stimuli even when these are irrelevant (Domes *et al*., 2006). BPD can perhaps not rely on their self-knowledge to judge the accuracy of the feedback and respond to negative feedback in a more rigid way (Fonagy *et al*., 2015).

Analyses of the neural responses seemed to corroborate these affective findings. In general, applicability of feedback relates to increased precuneus activation, especially during negative feedback (van Schie *et al*., 2018). The precuneus is implicated in putting self-relevant stimuli in autobiographical context (Northoff *et al*., 2006). Relating feedback to existing self-knowledge could be a way of critically evaluating negative feedback, reducing its impact on state affect when a specific trait is already incorporated in the self-view (vanDellen *et al*., 2011). Interestingly, BPD differed from HC in precuneus activation during negative *v.* positive feedback: BPD showed low recruitment and lack of differentiation in precuneus activity. HC in contrast, showed greater precuneus recruitment in response to negative compared with positive feedback. Where healthy individuals may benefit from using their (positive) self-views to evaluate the relevance of the negative feedback, BPD patients may have more difficulties in relying on their self-knowledge to critically evaluate the negative feedback (Fonagy and Allison, 2014).

Individuals with low levels of self-esteem were more adversely affected by negative feedback than BPD. However, their self-views were less negative and more positive than BPD and only differed from HC in having less positive self-views (not more negative). It is therefore surprising that when negative feedback is equally applicable to HC and LSE, LSE responded with worse mood. Other research has suggested that when faced with threats to the self, e.g. through negative feedback, individuals with LSE have difficulties in recovering their state affect and give in to the threat, resulting in lower mood (vanDellen *et al*., 2011). When looking at the precuneus activation for LSE in this study, it seemed heightened for both negative and positive feedback, though this was not significantly different from BPD or HC. One possible explanation could be that LSE considered the relevance of negative (and positive) feedback to the self, given the precuneus activity, but were less able to disregard the negative

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Table 3. Selected neural correlates for group comparisons on contrasts of valence and applicability of feedback[a], cluster corrected $Z = 2.3$, cluster $p < 0.05$

Group contrast	Valence contrast	Cluster size	Cluster *p* value	Label peak voxels	Voxel test value	MNI coordinates		
					Z	*X*	*Y*	*Z*
HC > BPD	Negative > positive	365	0.028	L Lateral occipital cortex	4.00	−10	−68	62
				L Superior parietal lobule, BA7	3.20	−26	−54	56
				L Superior parietal lobule, BA7	3.08	−32	−56	52
				L Lateral occipital cortex, BA7	3.01	−32	−66	56
				L Superior parietal lobule	2.98	−30	−56	48
				L Lateral occipital cortex	2.91	−18	−74	58
	Positive > negative	378	0.023	R Postcentral gyrus, IPLA, BA3	3.33	62	−12	30
				R Parietal operculum cortex, IPLA, BA40	3.28	56	−24	16
				R Supramarginal gyrus, IPLA	3.24	54	−20	30
				R Supramarginal gyrus, TPJa	3.17	56	−42	16
				R Parietal operculum cortex, IPLA, BA40	2.98	60	−26	20
				R Superior temporal gyrus	2.93	70	−36	4
BPD > HC	Negative × Applicability	383	0.022	R Postcentral gyrus, SPLA, IPLB	3.33	36	−30	56
				R Postcentral gyrus, SPLA, BA5	3.13	36	−36	64
				R Postcentral gyrus, IPLB	3.12	40	−28	52
				R Postcentral gyrus, SPLA, BA40	3.10	36	−34	60
				R Precentral gyrus, BA4	2.88	42	−18	58
				R Postcentral gyrus, IPLB, BA40	2.75	48	−32	60
BPD > LSE	Negative > positive	331	0.046	L Precuneus	3.33	−16	−62	24
				L Cuneus	3.30	−12	−82	26
				L Lateral occipital cortex	3.18	−24	−78	32
				L Precuneus, BA31	3.06	−4	−74	34
				L Cuneus	2.96	−20	−68	28
				L Precuneus, BA7	2.94	−8	−72	36
	Intermediate × Applicability	793	<0.001	L Paracingulate gyrus	3.54	−10	42	26
				L Frontal pole, BA9	3.33	−2	58	22
				L Superior frontal gyrus	3.32	−8	54	30
				L Superior frontal gyrus, BA9	3.26	−4	52	28
				R Frontal pole	3.19	4	60	26
				R Paracingulate gyrus	3.17	10	54	14

(*Continued*)

Table 3. (*Continued.*)

Group contrast	Valence contrast	Cluster size	Cluster *p* value	Label peak voxels	Voxel test value	MNI coordinates		
					Z	*X*	*Y*	*Z*
LSE > BPD	Positive > intermediate	458	0.007	L Lateral occipital cortex	3.24	−38	−66	34
				L Lateral occipital cortex	3.22	−46	−72	18
				L Lateral occipital cortex	3.22	−38	−78	24
				L Lateral occipital cortex	3.20	−32	−74	24
				L Lateral occipital cortex, BA39	3.09	−46	−70	14
				L Lateral occipital cortex	3.00	−42	−64	14

[a]Contrasts without any above threshold clusters are not reported in this table.

feedback, resulting in even worse mood (vanDellen *et al.*, 2011). This intriguing hypothesis should be addressed in future studies.

Against our expectation, positive feedback related to similar positive moods in BPD and HC. Therefore despite less positive self-views, BPD patients were able to benefit in mood from positive feedback. One other study found that BPD patients can positively update their self-view after positive feedback (Korn *et al.*, 2016).

However, it is interesting that in terms of neural responses, BPD showed more right TPJ activation during negative compared with positive feedback, whereas the reverse pattern was observed in HC. The TPJ has been implicated in processes of reorienting attention as well as social cognition and self-other processing (Donaldson *et al.*, 2015; Schurz *et al.*, 2017). A stronger TPJ activation after negative compared with positive feedback could indicate that BPD have a stronger reorientation of attention toward negative compared with positive feedback than HC (Schurz *et al.*, 2017). This would be in line with a more negative interpersonal evaluation bias previously found in BPD (Barnow *et al.*, 2009). In addition, two interesting integrative perspectives on TPJ functionality relevant to this study are that the TPJ subserves the creation of a social context for understanding another person and that the TPJ plays a role in the differentiation between or blending of self- and other-representation. A possible explanation of the current TPJ finding could be that HC use the positive feedback to create a shared representation of self and other knowledge. Given the heightened TPJ activation in response to negative feedback patients with BPD may create this self-other representation after negative rather than positive feedback. This is in line with previous research indicating that BPD showed less emotional contagion for positive social signals (Matzke *et al.*, 2014).

Though clinically self-other differentiation is very relevant to BPD pathology, future research is needed to clarify whether and how exactly TPJ activation relates to social interactions and maladaptive self-other differentiation in BPD. Of interest here, is that the characteristic interpersonal difficulties observed in BPD may be rooted in maladaptive self-other knowledge (Fertuck *et al.*, 2013; Miano *et al.*, 2013; Nicol *et al.*, 2013; Fonagy and Allison, 2014; Deckers *et al.*, 2015; Bo *et al.*, 2017). Speculatively, SF processing observed in BPD not only supports negative interpersonal bias but also interferes with learning (positive aspects) about the self, maintaining disturbed self-views.

We like to mention a few strengths and limitations of the study that should be taken into account. In terms of strengths, first, the inclusion of the LSE group allowed us to decouple BPD pathology from LSE. Second, the SF paradigm designed for this study has high ecological validity, as it is credible and personally relevant. Third, using multilevel and parametric modulation analyses enabled us to model the idiosyncratic applicability ratings and investigate the effect of each feedback word on an individual. Herewith, we could take into account specific (disturbed) self-knowledge when receiving SF. Finally, by using both self-report ratings and fMRI activity, we integrated affective and neural responses (Eisenberger, 2015).

With respect to limitations, like many studies in this field, we only investigated female BPD patients and results may therefore not be generalizable to men. Second, the applicability ratings of the feedback words were measured after the SF task. The applicability ratings therefore may be influenced by having been evaluated by these words, though participants were instructed explicitly to rate the applicability regardless of the feedback of the confederate. Arousal of the feedback words was not directly assessed.

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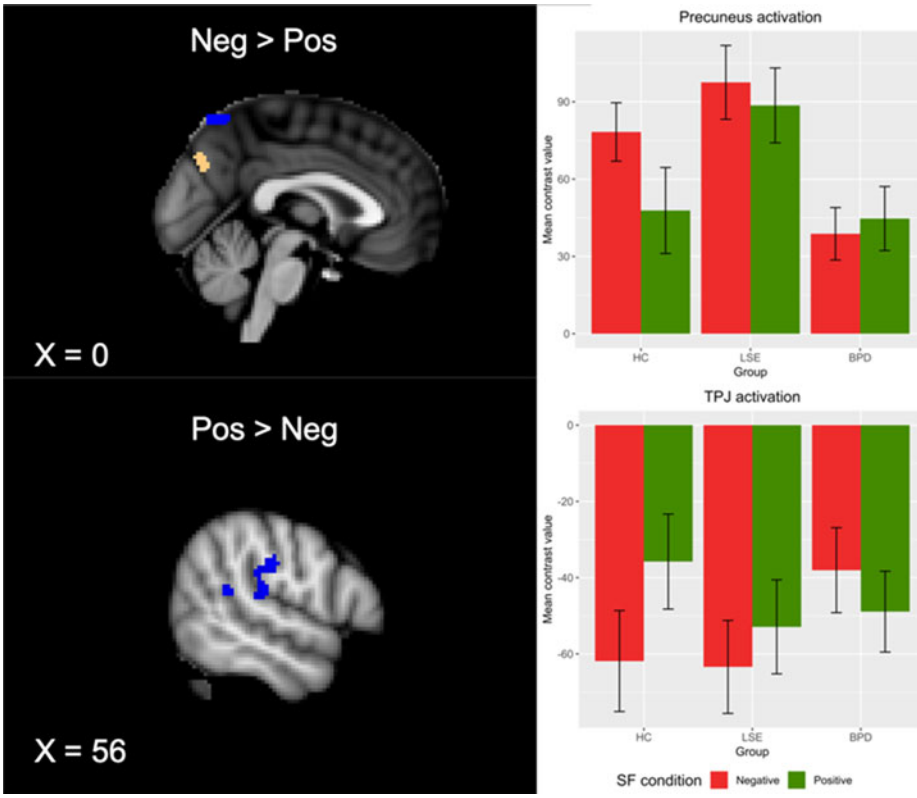

Fig. 2. Left: Clusters of neural activation indicating HC > BPD (blue) and BPD > LSE (orange). Right: Mean contrast values for the HC > BPD clusters (blue clusters) by group and contrast.

Though responses seem specific to valence, as groups differed in their responses to positive and negative feedback, we cannot rule out the possibility that e.g. the BPD group perceived positive/negative feedback as more arousing than HC. Third, by comparing the BPD to a LSE control group we have taken an important confound into consideration. However, these groups may differ in other respects. Finally, it must be noted that the precuneus finding is affected by current depression and handedness and hence this finding should be interpreted with caution. Comorbidities are common in BPD, especially depression (Lieb *et al.*, 2004) which in this sample was also quite prevalent (26%). Depression has been associated with a negative interpersonal style related to seeking verification of self-views which are often negative and at the same time relying on others for reassurance (Hames *et al.*, 2013). Noteworthily, the LSE group showed a similar rate of depression comorbidity (23%). Nevertheless, the LSE group showed different responses to the SF than BPD. The pattern of results that we found in BPD is therefore unlikely explained by MDD only. Still, a replication of these results with a depression group and larger sample size is recommended.

In conclusion, consistency of SF with self-views is a crucial determinant of the emotional and neural reactions to social interactions. Where healthy individuals may benefit from using their self-views to critically examine negative feedback, BPD patients seem to be adversely impacted by negative feedback regardless of the consistency with the self-view. Moreover, the increased TPJ activation after negative but not positive feedback may point to altered self-other differentiating processes in BPD, potentially obstructing learning positive information from others about themselves. Importantly, disturbed self-views in BPD patients go beyond low self-evaluation. The current findings suggest that clinically, one should pay special attention to how positive feedback (e.g. compliments) is received and how information based on interactions with others is processed. A lack of other representation during positive interactions may obstruct learning about the self from others, maintaining disturbed self-views and relations.

Notes

[1] Complete overview of clusters and peak voxels of all contrasts can be found in online Supplementary Table S7.

Supplementary material. The supplementary material for this article can be found at https://doi.org/10.1017/S0033291719000448.

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