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Emotion avoidance and fear bradycardia in patients with borderline personality disorder and healthy controls

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ABSTRACT

Background and objectives: Exaggerated emotional reactivity is supposed to be essential in the etiology of borderline personality disorder (BPD). More specifically, models of defensive behavior would predict reduced freezing behavior −indicated by fear bradycardia-in response to threat. This study examined automatic fear bradycardia responses in BPD versus healthy controls and the role of emotion dysregulation, more specifically tendencies to avoid emotions.
Methods: Patients with BPD ($n = 23$) and healthy controls ($n = 18$) completed questionnaires and then watched neutral, pleasant and unpleasant pictures while heart rate was assessed.
Results: Emotion avoidance interacted with group: it was associated with distinct autonomic responses in healthy controls but not in BPD patients. Controls with lower emotion avoidance tendencies showed bradycardia in response to unpleasant pictures, while controls with higher emotion avoidance tendencies did not. BPD patients showed no bradycardia, irrespective of their emotion avoidance tendencies.
Limitations: This study is limited by a small sample size. Comorbidity or medication intake were not controlled for.
Conclusions: The results may suggest impaired automatic defense responses in BPD. Further understanding of the regulation of distress and defense responses might improve BPD treatment.

1. Introduction

Borderline personality disorder (BPD) is characterized by a pervasive pattern of instability in interpersonal relationships, self-image, and affects, and marked impulsivity (American Psychiatric Association, 2013). Inadequate regulation of emotions is proposed to be a key deficit in BPD (Linehan, 1993; Selby & Joiner, 2009). Dysregulated emotional responses and affective instability are thought to be affected by two factors: emotional reactivity (hyperreactivity to emotional stimuli) and emotion regulation strategies (attempts to affect the emotion) (Carpenter & Trull, 2013; Gross & Jazaieri, 2014). With regard to emotional reactivity, empirical findings are contradictory. Increased emotional reactivity is usually operationalized by enhanced subjective and/or physiological responses to stress-inducing stimuli compared to positive and neutral stimuli. With respect to subjective responses, some studies indeed found enhanced self-reported emotional reactivity in BPD patients (Glaser, Van Os, Mengelers, & Myin-Germeys, 2008) but others did not (e.g., Arntz, Klokman, & Sieswerda, 2005; Herpertz, Kunert, Schwenger, & Sass, 1999; Herpertz et al., 2001) or only in reaction to stimuli with a specific BPD-relevant content such as social interaction or abandonment (Gratz, Rosenthal, Tull, Lejuez, & Gunderson, 2010; Sauer, Arens, Stopsack, Spitzer, & Barnow, 2014). Findings on physiological reactivity are contradictory too. Some authors found increased autonomic reactivity in BPD patients on some, but not on other parameters (Baschnagel, Coffey, Hawk, Schumacher, & Holloman, 2013; Ebner-Priemer et al., 2005;

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Herpertz et al., 2001), or no increased reactivity at all (Kuo & Linehan, 2009; Schmahl et al., 2004; Vitale & Newman, 2012). Interestingly, none of the studies found the expected increase in heart rate in BPD patients compared to normal controls (e.g. Baschnagel et al., 2013; Ebner-Priemer et al., 2005; Herpertz et al., 2001; Kuo, Fitzpatrick, Metcalfe, & McMain, 2016).

Lack of a comprehensive theoretical framework of affective dysregulation has been proposed to complicate the interpretation of these contradictory findings, and to cause problems in designing the right experimental methods (Ebner-Priemer et al., 2015). In the present study, we examined whether the automatic defense cascade model (Lang, Bradley, & Cuthbert, 1997) would be an adequate framework for increased emotional reactivity in BPD. This model - describing freezing, fight and flight responses to threat - is based on animal threat responses and may therefore adequately represent the emotional reactivity factor of emotion regulation. Importantly, the defense model proposes that threat-related behavior is flexible and changes depending on threat imminence and magnitude (Blanchard & Blanchard, 1988; Bracha, 2004; Fanselow & Lester, 1988; Lang, Simons, & Balaban, 1997; Ratner, 1967; Rivers, 1920). Such distance-related threat responses have been found in humans too (e.g., Mobbs et al., 2007; Richter et al., 2012). Physiological correlates differ, depending on (perceived) threat proximity. Importantly, for optimal survival chances an organism should be able to shift between fight/flight (with predominant sympathetic activation) and freezing (with sympathetic and parasympathetic co-activation), following environmental changes (Eilam, 2005). Following this model, maladaptive regulation might present itself as inadequate regulation of freezing and fight/flight, rather than exaggerated fight/flight, which has been used as an indicator of reactivity-deficits in many studies. Thus, the defense model may help in interpreting findings in terms of whether the response is appropriate for the specific defense stage.

The relevance of fight/flight responses (e.g., avoidance) for the etiology of threat-related disorders has been recognized (Brewin & Holmes, 2003; Porges, 2001). From a cognitive perspective, emotional hyperreactivity is proposed to be the result of increased threat perception and/or intolerance for distress (Leyro, Zvolensky, & Bernstein, 2010). Increased threat perception (or stimulus evaluation) has in turn been associated with (automatic fight/flight) action (Cacioppo & Gardner, 1999; Chen & Bargh, 1999; Neumann, Förster, & Strack, 2003; Rinck & Becker, 2007). Some recent studies suggested that distorted freezing behavior might be a relevant factor in the maintenance of threat-related psychiatric disorders as well (Blanchard, Griebel, Pobbe, & Blanchard, 2011; Fragkaki, Stins, Roelofs, Jongedijk, & Hagenaars, 2016; Hagenaars, Oitzl, & Roelofs, 2014).

Freezing, in animal studies defined as having a motionless posture (Fanselow, 1994), is a reaction to threat that serves survival (Hagenaars, Oitzl et al., 2014; Lang et al., 1997). It occurs after threat detection, can be prolonged in the absence of escape options, and has been associated with moderate threat. It is considered to serve orienting, enhance attentional processing, reduce detection by predators and prepare for action (Hagenaars, Oitzl et al., 2014). In freezing, parasympathetic and sympathetic systems are both active, resulting in its key characteristic: fear bradycardia (Hagenaars, Oitzl et al., 2014; Kozlowska, Walker, McLean, & Carrive, 2015; Walker & Carrive, 2003). Moreover, freezing is associated with risk assessment and the selection of appropriate action (Blanchard et al., 2011). Being associated with risk assessment, freezing should be especially present when using an emotion regulation strategy targeting the problem (thus taxing the situation), whereas *exaggerated* use of avoidance or suppression strategies should be associated with automatic flight behavior, i.e., decreased freezing (see also page 9 for further explanation).

Note that freezing should not be confused with orienting, a brief and immediate attentional response to novel stimuli. Freezing should also be distinguished from tonic immobility ("playing dead"), a threat response that occurs in case of physical contact with a predator, which includes immobility but also additional symptoms such as analgesia and possibly dissociation (Abrams, Carleton, & Asmundson, 2012; Kozlowska et al., 2015). Finally, learned helplessness can also be expressed by immobility. However, freezing is an active response with increased muscle tonus as a feature (parasympathetic and sympathetic co-activation), whereas learned helplessness is shown by muscle weakness.

Freezing responses have recently been elicited successfully in humans using a passive viewing paradigm with bradycardia as an important indicator of freezing (Azevedo et al., 2005; Hagenaars, Stins, & Roelofs, 2012; Roelofs, Hagenaars, & Stins, 2010). In such a paradigm, participants typically watch pictures with different valences without action-instruction so that spontaneous responses to unpleasant pictures can be compared to responses to neutral and pleasant pictures. This setup also proved adequate to detect individual differences in freezing responses (Hagenaars et al., 2012; Roelofs et al., 2010). It is also sensitive to threat expectancy, induced by for example preceding mental imagery interventions (Hagenaars, Mesbah, & Cremers, 2015). Importantly, pictures in the passive viewing paradigm are usually presented in blocks (usually 1 min in total), as freezing is considered a sustained response (Hagenaars, Roelofs, & Stins, 2014). Picture presentation times are usually shorter in experiments that investigate emotional reactivity. Using the passive viewing paradigm, healthy participants typically show fear bradycardia in response to unpleasant relative to neutral and pleasant pictures. The next step would be to test freezing behavior in threat-related psychiatric disorders such as BPD and posttraumatic stress disorder (PTSD). Adenauer, Catani, Keil, Aichinger, and Neuner (2010) used a passive viewing paradigm with traumatized participants with and without PTSD and healthy controls. They found bradycardia in response to aversive pictures in healthy controls, but not in traumatized participants with PTSD. Traumatized participants without PTSD showed bradycardia in response to all picture categories, suggesting that immediate bradycardia may be associated with resilience. The authors suggested that the patients reacted with rapid fight/flight responses without prior exploration of the stimulus. Note that Adenauer et al., (2010) used brief picture presentations, probably eliciting orienting rather than freezing responses. However, given that risk-assessment is highly associated with freezing, the same conclusion might apply. Moreover, these findings would be in line with the findings of Hagenaars et al. (2012) who found enhanced freezing-like responses (reduced body sway and bradycardia) in traumatized but healthy participants. It also matches the results of another study, in which healthy participants showed greater heart rate decreases during unpleasant pictures after a mental imagery intervention with a negative outcome that was related to these pictures, relative to mental imagery interventions with a positive outcome (related and unrelated to the pictures; Hagenaars et al., 2015). Speculatively, bradycardia after negative related imagery might indicate further exploration of the stimulus or adequate vigilance whereas immediate action and associated sympathetic activity is shown in case of unexpected threat. One other study including psychiatric patients (panic disorder; Lopes et al., 2009) found reduced body sway (interpreted as freezing-like behavior) throughout the experiment for patients with panic disorder relative to healthy controls. However, this effect was independent of picture category (neutral, unpleasant, and panic disorder-related content), and heart rate was not assessed.

In conclusion, although emotional hyperreactivity is considered to be a key factor in the etiology of BPD, empirical findings are contradictory. The automatic defense cascade model could be a useful theoretical framework for studying psychopathology, especially BPD, where stress reactivity (and thus diminished freezing) plays a major role. The current study therefore aims to investigate fear bradycardia as an indicator of freezing in reaction to affective pictures in BPD patients. BPD patients are expected to show attenuated bradycardia in response to unpleasant pictures relative to healthy controls.

As stated at the beginning of this article, dysregulated emotion responses in BPD are proposed to be affected by two factors: emotional reactivity and regulation strategies (Carpenter & Trull, 2013; Gross & Jazaieri, 2014). Our second aim therefore was to investigate how emotion avoidance (an emotion regulation strategy that is associated with BPD symptomatology; Chapman, Dixon-Gordon, & Walters, 2011; Iverson, Follette, Pistorello, & Fruzzetti, 2012) is associated with emotional reactivity. Emotion avoidance as a strategy to regulate distress is described as a tendency to avoid or immediately attenuate emotions. As such, it is a component of distress intolerance (Simons & Gaher, 2005). We hypothesized that such an emotion avoidance tendency would be associated with the absence of fear bradycardia. That is, freezing is associated with enhanced risk assessment, which is proposed to be linked with defensive approach behavior (McNaughton & Corr, 2004). In contrast, avoidance strategies are supposed to interfere with elaborate processing of threat stimuli (Mogg, Bradley, Miles, & Dixon, 2004). Thus, immediate action away from the threat, associated with intolerance for the threat-related distress, is likely to be linked to reduced risk assessment and less freezing. Note that this would be the case in healthy individuals. In patients with chronic threat-related disorders, baseline vigilance and arousal are high, suggesting chronically increased sympathetic activity (Kuo et al., 2016). Such chronically elevated arousal levels are self-perpetuating and difficult to down-regulate (Selby & Joiner, 2009). In other words, healthy individuals are proposed to adjust their stress-responses in accordance to threat imminence. In contrast, patients with threat-related psychiatric disorders are proposed to be characterized by inflexibility, i.e., defense behavior that is not adjusted to the circumstances (LeDoux, Moscarello, Sears, & Campese, 2016). Thus, in this case, patients would show an automatic fight/flight response during mild threat, which normally elicits freezing, regardless of their coping strategy. This would be in line with the finding that patients with another threat-related disorder -PTSD-showed inflexible autonomic coping, i.e., proposedly decreased parasympathetical activity (lower heart rate variability) throughout different affective conditions (Hauschildt, Peters, Moritz, & Jelinek, 2011).

In sum, we expected attenuated bradycardia in response to unpleasant pictures in BPD patients. Also, in healthy individuals, lower emotion avoidance is expected to be associated with bradycardia (as an indicator of freezing) in response to threatening stimuli. Moreover, we expected an interaction between experimental group and emotion avoidance: Lower emotion avoidance should be associated with bradtcardia responses in healthy controls, but not in BPD patients. Thus, we expected diminished bradycardia in response to unpleasant pictures for healthy individuals —but not BPD patients-who make stronger efforts to avoid or alleviate negative emotions (*high emotion avoidance*), relative to those with *low emotion avoidance*.

2. Material and methods

2.1. Participants

Based on power analyses (set at 0.80) and previous studies using the passive viewing task, we aimed at 20 participants per group. Female patients with BPD (N = 23) were recruited at the Jelgersma Clinic for Personality Disorders. Eighteen healthy female controls —matched on age and educational level-were recruited by flyers and social media (Facebook). The groups indeed did not differ on age ($t(39) = 0.48$, $p = 0.64$) or educational level (χ^2 (N = 41) = 2.20, $p = 0.33$; see Table 1). The study was approved by the local ethics committee and all participants gave written informed consent. They received a monetary imbursement after completing the experiment.

2.2. Apparatus and material

Heart rate. Heart rate was recorded continuously using the BIOPAC system (MP150:BIOPAC systems, Inc, USA) with three matching Ag-AgCl (silver-silverchloride) electrodes. The signal was processed offline using AcqKnowledge software (BIOPAC systems, Inc, USA) and mean heart rate was calculated from the resulting interbeat interval (IBI).

Pictorial Stimuli. Three sets of stimuli were selected from the International Affective Picture System (IAPS; Center for the Study of Emotion and Attention, 1999).[1] The first set comprised 20 pictures of neutral objects such as utensils. The second set comprised 20 pleasant pictures such as sports. The third set consisted of 20 unpleasant pictures depicting mutilated bodies and corpses. The exact same pictures were used in previous studies using the passive viewing paradigm (Azevedo et al., 2005; Hagenaars, Roelofs et al., 2014) in order to improve comparisons across studies and facilitate interpretation of the results in terms of freezing. Stimuli were presented full screen at eye-height on a 17-inch height adjustable computer screen, approximately 1 m in front of the participant with a visual angle (height x width in degrees) of 15.5° × 10.8°. Each set of pictures was presented as a block with 3 s presentation time for each picture (randomized), resulting in three 60 s blocks. Blocks were counterbalanced and separated by 7 s intertrial intervals (5 s black screen and 2 s fixation cross).

2.3. Measures

Emotion avoidance. Emotion avoidance was assessed with the Regulation subscale of the Distress Tolerance Scale (DTS-R, Simons & Gaher, 2005), comprising 3 items (e.g., “When I feel distressed or upset, I must do something about it immediately”). This subscale is specifically relevant as it measures the ability to regulate the strength of action tendencies to either avoid or immediately attenuate an unpleasant emotional reaction. That is, low scores on this scale indicate high efforts to avoid negative emotions and rapid attempts to alleviate negative emotions. Such regulation strategy is typical for individuals with low distress tolerance (Simons & Gaher, 2005). We refer to this subscale as “emotion avoidance” instead of the broader term “regulation” to prevent confusion with other conceptualizations of emotion regulation. Moreover, the items do not measure actual distress, so we do not refer to “distress (in) tolerance” either, in order to stay close to the item content. All items are reversely scored (1 = strongly agree, 5 = strongly disagree) thus lower total scores on this scale indicate higher efforts to avoid negative emotions and rapid attempts to alleviate negative emotions (Simons & Gaher, 2005). Internal consistency of this subscale

[1] IAPS catalog numbers for pictures used in this study are: Neutral: 7000, 7002, 7004, 7006, 7009, 7010, 7020, 7025, 7030, 7031, 7035, 7040, 7050, 7052, 7060, 7080, 7090, 7150, 7175, 7211; Pleasant: 8021, 8032, 8034, 8040, 8041, 8090, 8161, 8186, 8190, 8192, 8200, 8210, 8300, 8370, 8400, 8460, 8465, 8467, 8470, 8620; Unpleasant: 3000, 3010, 3030, 3051, 3053, 3060, 3061, 3062, 3063, 3064, 3069, 3080, 3100, 3102, 3110, 3130 3140, 3150, 3261, 3400.

Table 1
Descriptives (means, SDs) for patients with borderline personality disorder and healthy controls (N = 41).

Variable	BPD ($n = 23$)		Controls ($n = 18$)	
	M (*SD*)	95% CI	*M* (*SD*)	95% CI
Age	28.9	[25.35, 32.48]	30.4	[24.30, 36.59]
Educational level				
Low (*n*)	2 (11%)		7 (30%)	
Middle (*n*)	7 (33%)		6 (26%)	
High (*n*)	10 (56%)		10 (44%)	
STAI-state*	53.22 (12.00)	[48.03, 58.41]	32.00 (11.20)	[26.06, 37.97]
STAI-trait*	61.30 (12.11)	[56.07, 66.54]	35.75 (9.18)	[30.86, 40.64]
STAXI-state**	13.00 (4.82)	[10.91, 15.09]	10.31 (0.60)	[9.99, 10.63]
STAXI-trait*	22.17 (5.75)	[19.69, 24.66]	15.25 (4.28)	[12.97, 17.53]
DES*	629.57 (411.94)	[451.43, 807.70]	277.50 (152.95)	[196.00, 265.00]
BIS*	71.74 (8.44)	[68.09, 75.39]	62.00 (9.49)	[56.94, 67.06]
Emotion Avoidance*				
High (*n*)	8 (35%)		12 (67%)	
Low (*n*)	15 (65%)		6 (33%)	
Mean	6.59 (3.07)	[5.23, 7.95]	9.16 (3.02)	[7.70, 10.62]

Note. STAI = State-Trait Anxiety Inventory; STAXI = State-Trait Anger Expression Inventory; DES = Dissociative Experiences Scale; BIS = Barratt Impulsiveness Scale. Emotion Avoidance was assessed with the Distress Tolerance Scale-Regulation subscale (DTS-R).
*$p < 0.01$, **$p < 0.05$.

is acceptable (Cronbach's $\alpha = 0.77$; Leyro, Bernstein, Vujanovic, McLeish, & Zvolensky, 2011).

Subjective valence and arousal. Subjective valence and arousal was rated using the 9-point Likert scale from the IAPS rating system (range 1–9), with higher scores indicating negative valence and low arousal.

Symptoms. In order to confirm whether BPD patients indeed scored higher on BPD-related symptoms, we assessed state and trait anxiety (State–Trait Anxiety Inventory, STAI; Spielberger, Gorsch, Lushene, Vagg & Jacobs, 1983), state and trait anger (State–Trait Anger Expression Inventory, STAXI; Spielberger, 1988), dissociative tendencies (Dissociative Experiences Scale, DES; Bernstein & Putnam, 1986), and impulsivity (Barratt Impulsiveness Scale, BIS-11; Patton, Stanford, & Barratt, 1995).

Borderline personality disorder symptoms. BPD symptoms were assessed with the Clinical Interview for DSM-IV Axis II Personality Disorders (SCID-II; First, Gibbon, Spitzer, Williams, & Benjamin, 1997). Internal consistency of the BPD scale is good (Armor's $\theta = 0.86$; Maffei et al., 1997).

2.4. Procedure

Diagnoses of the BPD patients were confirmed (using the SCID-II) after they indicated they wanted to participate. All participants completed the DTS-R at arrival in the lab. Then, the heart rate device was connected after which the Passive Viewing task was started. The heart rate device was decoupled after the task. One week later, participants came back to the lab to rate the pictures on valence and arousal. This was done in order to minimize the burden for the patients, and also because the experimental session had to fit into the limited time-off from treatment for BPD patients. Finally, they received the monetary imbursement.

2.5. Statistical analyses

A 3 × 2 repeated measures ANOVA (rmANOVA) was used to analyze heart rate with Picture Valence (neutral, pleasant, unpleasant) as within factor, Group (BPD, Controls) as between factor, and Emotion Avoidance as covariate. A MANOVA was performed to test differences between the groups on the neutral-unpleasant and pleasant-unpleasant contrasts (mean heart rate for unpleasant minus mean heart rate for neutral and pleasant respectively). All tests were two-tailed with the significance level set at 0.05.

3. Results

3.1. Descriptives and experimental checks

BPD patients scored higher on anxiety, anger, dissociation, and impulsiveness than Controls (all *ts* > 2.37, all *ps* < 0.03; see Table 1 for descriptives). BPD patients also scored higher on Emotion Avoidance than Controls ($t(39) = 2.69$, $p = 0.01$).

3.2. Group differences in picture ratings

Five BPD patients did not return for the ratings, so means are compared for 18 BPD patients and 18 Controls. BPD patients that did not return for the ratings did not differ from those who did return on any of the questionnaires (including Emotion Avoidance; all *ts* < 0.97, all *ps* > 0.34), but note the unequal sample sizes, which reduce power. The main effect of Valence was significant ($F(2,68) = 140.46$, $p < 0.001$, $\eta^2_p = 0.85$). All picture categories differed from each other with the unpleasant pictures rated as unpleasant ($M = 7.83$, $SD = 1.39$), the pleasant pictures as pleasant ($M = 3.49$, $SD = 1.24$) and the neutral pictures in between ($M = 4.98$, $SD = 1.14$; all *ps* < 0.001). The Valence × Group interaction was not significant ($F(2, 68) = 0.77$, $p = 0.47$, $\eta^2_p = 0.02$), nor was the main effect of Group ($F(1, 34) = 1.12$, $p = 0.30$, $\eta^2_p = 0.03$) indicating that Valence ratings did not differ for BPD patients and Controls. The main effect of Arousal was also significant ($F(2, 68) = 75.39$, $p < 0.001$, $\eta^2_p = 0.69$). Across groups, participants rated the unpleasant pictures as most arousing ($M = 4.19$, $SD = 2.04$), the neutral pictures as the least arousing ($M = 8.14$, SD = 1.21), and the pleasant pictures in between ($M = 5.86$, $SD = 1.71$; all *ps* < 0.001). The Valence × Group interaction was not significant for Arousal ($F(2, 68) = 2.01$, $p = 0.14$, $\eta^2_p = 0.06$), nor was the main effect of Group ($F(1, 34) = 0.37$, $p = 0.55$, $\eta^2_p = 0.01$), indicating that Arousal ratings did not differ between groups.

3.3. Group differences in heart rate

A rmANOVA yielded a significant Valence x Group x Emotion

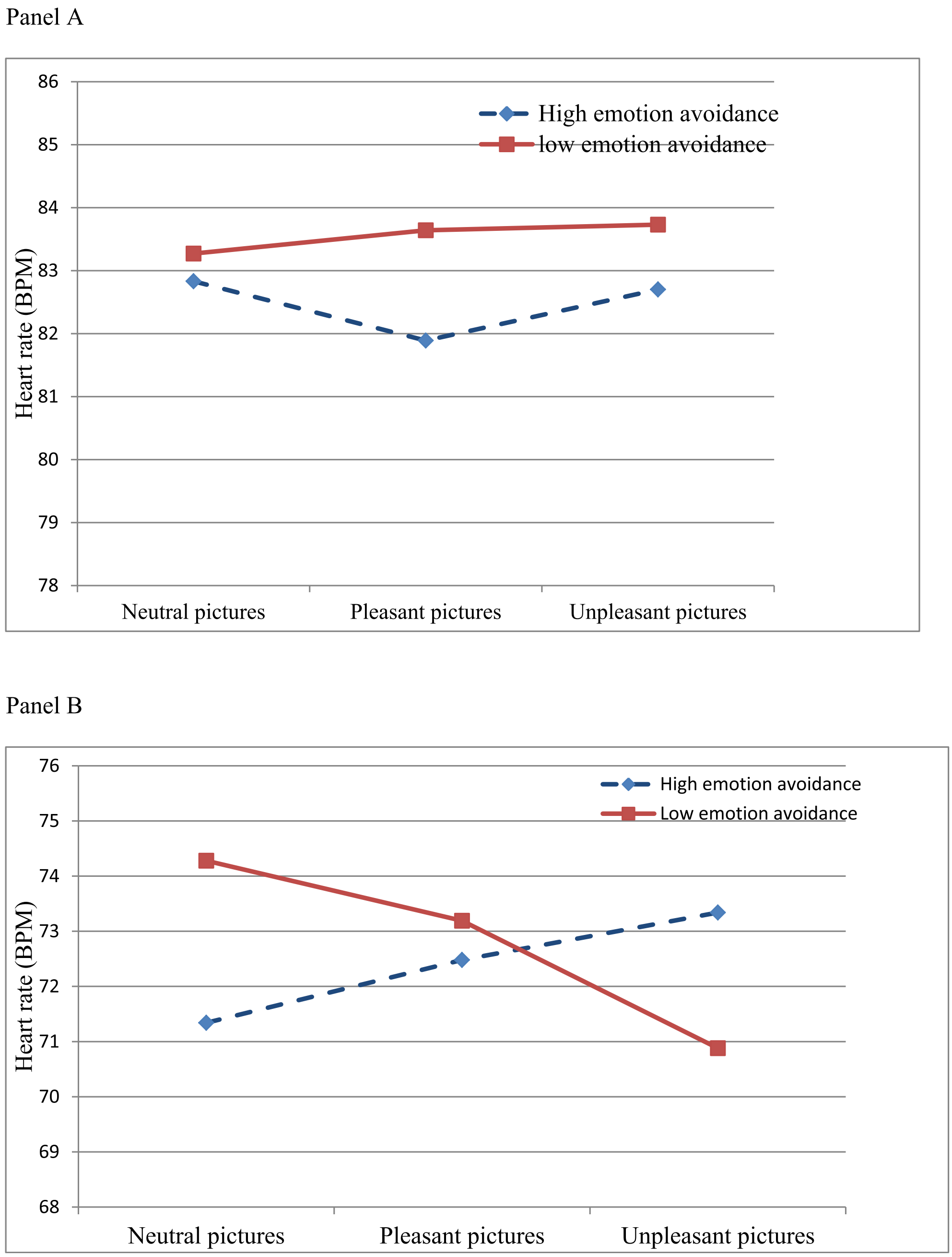

Fig. 1. Changes in heart rate in response to neutral, pleasant and unpleasant pictures in BPD patients (Panel A) and controls (Panel B) with high and low emotion avoidance skills (median-split).

Avoidance interaction ($F(2, 74) = 3.22$, $p = 0.046$, $\eta^2_p = 0.08$; see Fig. 1).[2] There were no Valence x Group and Valence x Emotion Avoidance interactions (both $Fs < 1.90$ and both $ps > 0.15$). The main effects of Valence and Emotion Avoidance were not significant. The main effect of Group was significant, with BPD patients having higher heart rates than Controls ($F(1, 37) = 4.84$, $p = 0.03$, $\eta^2_p = 0.12$).

Further analyses using a MANOVA with neutral-unpleasant and pleasant-unpleasant contrasts yielded significant Group x Emotion Avoidance interactions for both contrasts ($F(1, 37) = 5.22$, $p = 0.03$, $\eta^2_p = 0.12$ and $F(1, 37) = 4.43$, $p = 0.04$, $\eta^2_p = 0.11$ for neutral-unpleasant and pleasant-unpleasant respectively). The main effect of Group was at trend-level for the neutral-unpleasant contrast ($F(1, 37) = 3.08$, $p = 0.09$, $\eta^2_p = 0.08$) and non-significant for the neutral-unpleasant contrast ($F(1, 37) = 2.05$, $p = 0.16$, $\eta^2_p = 0.05$). The main effect of emotion avoidance was non-significant (both $Fs < 1.5$, $ps > 0.23$).

In order to interpret the direction of the 3-way interaction, subsequent t-tests were done using high/low Emotion Avoidance groups (created by median-split, see footnote 2). Controls with low

[2] Emotion Avoidance was dichotomized by a median-split in order to visualize the 3-way interaction and facilitate its interpretation. The median-split was done on the total sample to ensure that low Emotion Avoidance Controls had similar scores as low Emotion Avoidance BPD patients. See Table 1 for cell sizes. Using Emotion Avoidance as a dichotomized variable yielded similar results, including the significant 3 (Valence) x 2 (Group) x 2 (Emotion Avoidance) interaction, $F(2, 74) = 4.81$, $p = 0.01$, $\eta^2_p = 0.12$.

Emotion Avoidance differed from Controls with high Emotion Avoidance in heart rate responses to unpleasant versus neutral or pleasant pictures ($t(16) = -2.47$, $p = 0.03$ and $t(16) = -2.26$, $p = 0.04$ respectively). Paired t-tests confirmed that Controls with low Emotion Avoidance showed a heart rate reduction from neutral or pleasant to unpleasant picture viewing (both $ps \leq 0.02$), whereas Controls with high Emotion Avoidance did not (both $ps > 0.15$). There was no difference in heart rate responses between BPD patients with high versus low Emotion Avoidance (neutral-unpleasant: $t(21) = 0.98$, $p = 0.34$; pleasant-unpleasant: $t(21) = -0.33$, $p = 0.75$). Paired t-tests showed that both low and high emotion avoiding BPD patients did not show heart rate reductions in response to unpleasant pictures (both ps > 0.32).

The association between Emotion Avoidance and bradycardia could be explained by the fact that those with high Emotion Avoidance were simply more aroused by the unpleasant pictures. We tested this by correlating Emotion Avoidance with increases in Valence and Arousal ratings from neutral/pleasant to unpleasant ($N = 36$). Emotion Avoidance was not related to relative increases in unpleasantness or arousal in response to the unpleasant pictures (both $rs < 0.13$, both $ps > 0.42$).

4. Discussion

This study investigated automatic fear bradycardia (indicative for freezing) and emotion avoidance in BPD patients and healthy controls. As expected, BPD patients did not display bradycardia in response to unpleasant pictures compared to neutral or pleasant pictures, regardless of emotion avoidance tendencies. Healthy controls with low emotion avoidance (i.e., no strong efforts to avoid or rapidly alleviate emotions) showed bradycardia in response to unpleasant pictures, while controls with high emotion avoidance did not.

The absence of a freezing response in BPD patients is in line with the idea that heightened emotional reactivity is an essential characteristic of BPD (Carpenter & Trull, 2013). This is the first study to use the defense cascade model as a theoretical framework for emotional reactivity in BPD patients. The model may be highly relevant as it recognizes different stages in threat processing, from perception to action and recovery, as well as the relevant involvement of sympathetic and parasympathetic activity at those different stages. Using this model, our findings may indicate that reactivity in BPD may be characterized by inflexibility, i.e., predominant fight/flight behavior when freezing would be more adaptive. Speculatively, our findings may suggest that emotional reactivity in BPD is characterized by the absence of threat-related parasympathetic activity (thus no co-activation of the sympathetic and parasympathetic system) rather than by just increased sympathetic activity. This would be in line with some previous studies on emotional reactivity in BPD patients (e.g. Weinberg, Klonsky, & Hajcak, 2009). Future research should examine the distinct contribution of these two systems. As freezing occurs in case of distant or moderate threat (i.e., picture viewing), our findings may suggest that BPD patients are not able to select an adequate defense strategy, but instead always respond with fight/flight behavior, which matches the idea that response-inflexibility is characteristic for maladaptive freezing (Hagenaars, Oitzl et al., 2014), i.e., non-responsive freezing, or freezing that is not adjusted by circumstances. Diminished freezing is also in line with the notion that BPD patients "act before thinking" in response to stress (Rentrop et al., 2008). In addition, speculatively, our findings may indicate distorted stress perception in BPD patients, which has been suggested previously (Bertsch et al., 2013). That is, if freezing is associated with moderate or anticipated stress, the absence of freezing in BPD patients may indicate (the perception of) severe and acute stress (Graeff & Del-Ben, 2008). The alternative explanation that the BPD patients perceived more threat was not confirmed by the subjective ratings, though: BPD patients and controls did not differ in how negative and arousing they found the unpleasant pictures. This might confirm the existence of two threat response circuits; One behavioral system including associated physiological responses, and one subjective system (LeDoux & Pine, 2016). In sum, the defense cascade model seems to be a useful framework for the investigation of emotional reactivity.

Our second hypothesis, that healthy subjects with higher emotion avoidance tendencies show an attenuated freezing response, was supported for both the pleasant-unpleasant contrast and the neutral-unpleasant contrast. This is in line with the idea that emotion regulation affects emotional reactivity (and vice versa; Gross & Thompson, 2007). In this case, attempts to immediately alleviate the emotion may hinder approaching the "problem", risk-assessment and subsequent decision making. This finding also supports the assumption that freezing is important in risk assessment and action selection (Blanchard et al., 2011). Higher emotion avoidance was not simply associated with higher arousal in response to the pictures, nor was it related to increased unpleasantness ratings.

As expected, controls with low emotion avoidance tendencies showed more freezing than those with high emotion avoidance tendencies, while the tendency to avoid emotions was not associated with autonomic responding in BPD patients. Possibly, a non-avoiding or approach attitude towards emotions (enabling risk assessment) is a strategy that is effective for low or moderately arousing emotions, whereas high arousing emotions (supposedly experienced by BPD patients; Kuo & Linehan, 2009) cannot be regulated adequately with such non-avoidance strategies, even when increased regulation attempts are made (Rive et al., 2015). Possibly, these chronically increased stress levels in BPD patients may interfere with the development of adaptive regulatory strategies. The overall higher heart rate in BPD patients supports this interpretation. It would also be in line with the findings of Kuo et al. (2016), who found elevated baseline heart rate in BPD patients relative to controls rather than increased emotional reactivity. Alternatively, the finding that BPD patients had higher emotion avoidance scores may suggest a lack of adaptive regulating skills, which would be in line with the decreased inhibition typical for BPD (Rentrop et al., 2008). This combination of increased overall arousal and decreased freezing may contribute to the emotional dysfunction in BPD. Note that the absence of a Valence x Emotion Avoidance interaction effect suggests that the results cannot solely be explained by Emotion Avoidance alone. Future research should further investigate the exact mechanisms.

This study has some limitations. Although the passive viewing paradigm usually evokes strong effects and small samples are not uncommon (Hagenaars et al., 2015; Herpertz et al., 1999; Reitz et al., 2012) future studies should include larger samples to overcome type II errors. Larger samples would also allow testing covariates. Second, not excluding patients with psychiatric comorbidity limits the possibility to draw conclusions about BPD-specific patterns. However, comorbidity rates in BPD are extremely high (see Skodol et al., 2002 for a review) and comorbidity may be inherent to the disorder. Samples without comorbidity may therefore be rare and not representative. Comparing BPD patients to other clinical groups could partly solve this problem in future studies and would be a next step in examining the specificity of our findings for BPD. Possibly, some findings may be present in other threat-related disorders as well (e.g., the absence of freezing in PTSD), whereas other findings may be specific for BPD (e.g., the interaction with emotion avoidance). For now, we aimed to show the relevance of the defense model as a first exploration.

Third, the direct BPD–controls comparison in our study was complicated by medication intake of the BPD patients, which affects autonomic responses (Ebner-Priemer et al., 2007). Future studies should control for medication intake, although this is practically challenging. Fourth, adding body sway measures, additional cardiac measures and respiratory data would further enlighten the freezing response including its distinct sympathetic and parasympathetic components. We chose to use mean heart rate as a well-accepted and frequently used indicator of freezing instead of less-established indices such as heart rate variability that may respond to arousal rather than valence (Brouwer, van Wouwe, Muhl, van Erp & Toet, 2013). Finally, future studies should also use additional measures of (or manipulate) emotion avoidance and regulation in order to examine the interaction between specific regulatory strategies and automatic defense responses. The validity of the 3-item DTS-subscale used in our study may be limited. Also, the scale measures avoidance tendencies and we do not know whether the participants actually performed this behavior while watching the pictures.

In sum, the automatic defense cascade model might be a good framework for studying emotional reactivity in BPD. Using this framework, we found no fear bradycardia in response to unpleasant pictures in BPD patients, regardless of emotion avoidance tendencies. Healthy controls with low emotion avoidance tendencies did show fear bradycardia, stressing the relevance of this risk-assessment-related response. The findings are a first step towards unravelling the role of diminished freezing in the maintenance of BPD and other threat-related disorders. With distress tolerance and emotion regulation being a primary component of treatment of BPD, further understanding of distress responses such as freezing might further improve treatment for BPD.

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