Acta Psychiatr Scand 2009: 120: 62–70

DOI: 10.1111/j.1600-0447.2008.01335.x

ACTA PSYCHIATRICA SCANDINAVICA

A cross-sectional investigation of discontinuation of self-injury and normalizing pain perception in patients with borderline personality disorder

Ludäscher P, Greffrath W, Schmahl C, Kleindienst N, Kraus A, Baumgärtner U, Magerl W, Treede R-D, Bohus M. A cross-sectional investigation of discontinuation of self-injury and normalizing pain perception in patients with borderline personality disorder.

Objective: Several studies have shown reduced pain perception in patients with borderline personality disorder (BPD) and current self-injurious behavior (SIB). The aim of the present study was to test whether pain perception in patients with current SIB is different from that of patients who had stopped SIB, and whether pain perception of the latter group differs from healthy controls (HC).
Method: We investigated 24 borderline patients and 24 HC. Thirteen patients showed current SIB (BPD-SIB) and 11 patients did not exhibit SIB anymore (BPD-non-SIB). Pain thresholds were assessed using thermal stimuli and laser radiant heat pulses.
Results: We found significant linear trends for all pain measures. The BPD-SIB group was less sensitive than the BPD-non-SIB group and the latter were less sensitive than HC. The pain sensitivity negatively correlated with borderline symptom severity.
Conclusion: The results suggest an association between the termination of SIB, decline of psychopathology and normalization of pain perception in borderline patients.

P. Ludäscher[1]*, W. Greffrath[2]*, C. Schmahl[1]*, N. Kleindienst[1], A. Kraus[1], U. Baumgärtner[2], W. Magerl[2], R.-D. Treede[2], M. Bohus[1]

[1]Department of Psychosomatic Medicine, Central Institute of Mental Health, Mannheim and [2]Division of Neurophysiology, Center of Biomedicine and Medical Technology Mannheim (CBTM), Medical Faculty Mannheim, Ruprecht-Karls-University Heidelberg, Mannheim, Germany

Key words: borderline personality disorder; pain sensitivity; self-injurious behavior

Prof. Dr Martin Bohus, Department of Psychosomatic Medicine, Central Institute of Mental Health, J5, 68159 Mannheim, Germany.
E-mail: martin_bohus@web.de

*These authors contributed equally to this article.
Previous presentation: Parts of the results were presented in abstract form (SOBP 2004, 2005).

Accepted for publication November 19, 2008

Significant outcomes

- Patients with borderline personality disorder (BPD) who currently injure themselves show lower pain sensitivity than patients with BPD who have stopped to injure themselves and the latter were less sensitive than healthy controls.
- Pain sensitivity in patients with BPD negatively correlated with the severity of BPD.

Limitations

- Current major depression and psychopharmacological treatment as exclusion criteria increased internal validity but might have decreased external validity of our findings.
- Time of the last self-injurious behavior was assessed, but we did not assess frequency and method of self-injurious behavior.
- Due to the fact that this was a cross-sectional study the interpretation of our findings is limited and requires the investigation within a longitudinal design.

Introduction

Non-suicidal self-injurious behavior (SIB) is a dysfunctional behavioral pattern which is observed in about 60–90% of patients with borderline personality disorder (BPD) (1, 2). Most patients use SIB to terminate dysphoric states which they perceive as aversive inner tension (3, 4). Further

intentional aspects of SIB, as reported by patients with BPD, are to re-experience pain, to punish themselves, to stop dissociative states, to express anger or to get social attention (1–5). The successful reduction in inner tension or other aversive states by SIB can become a habitual and addictive way of dealing with psychological distress (5).

About 50–60% of patients with BPD report to feel no pain during SIB (1, 4), which may be associated with higher dissociation scores of patients with SIB when compared with those of patients without SIB (5, 6). Several studies have found reduced pain sensitivity under laboratory conditions in patients with BPD and current SIB when compared with that in healthy controls (7–10). For example, Schmahl et al. (9) have shown that when radiant heat stimuli are induced by an infrared laser, patients with BPD and current SIB have markedly lower pain sensitivity than healthy controls, although patients did not exhibit differences in sensory-discriminative pain processing in comparison with healthy controls. Therefore, the authors suggested that the modified pain perception in patients with BPD can be attributed to abnormalities in the affective-motivational and/or cognitive-evaluative pain components, which are responsible for the evaluation of pain stimuli and for the emotional reaction on pain perception (11, 12).

Several studies have demonstrated a remission of SIB in patients with BPD after psychotherapeutic treatment (13, 14). However, it is unknown whether pain perception in patients with BPD normalizes after they have stopped SIB.

Aims of the study

The aim of the present study was to examine whether pain perception in patients with BPD normalizes after they stop to injure themselves. We conducted a cross-sectional study and hypothesized that patients with BPD who stopped injuring themselves for at least 6 months may show a trend for normalized pain perception. We assumed that their pain thresholds would lie in between the pain thresholds of patients with BPD who still injure themselves and healthy controls.

Material and methods

Participants

Twenty-four unmedicated patients with BPD and 24 healthy controls (all women) participated in the study. Patients fulfilled DSM-IV criteria for BPD as assessed by the International Personality Disorder Examination (IPDE, 15). All of them had a history of SIB, and the most frequent SIB method was cutting. Thirteen patients showed current SIB (BPD-SIB) and 11 patients did not exhibit SIB for at least the last 6 months (BPD-non-SIB). Mean time interval since the last SIB episode was 20 months for BPD-non-SIB (range 6–60 months) and 21 days for BPD-SIB (range 1–90 days). Subjective pain intensity during the last SIB was rated retrospectively on a Visual Analogue Scale from 0 to 100 (VAS; 0 = no pain at all and 100 = most intense pain imaginable). A statistical trend for higher pain intensity ratings during their last SIB event was found for BPD-non-SIB (36 ± 23) when compared with that for BPD-SIB (20 ± 16, $P = 0.10$). The mean age of patients with ongoing SIB was 28 ± 8 years, whereas for patients who had stopped SIB it was 30 ± 7 years, and for age-matched healthy controls it was 25 ± 4 years ($P = 0.83$).

Co-occurring axis I diagnoses were assessed with the Structured Clinical Interview for DSM-IV axis I (SCID-I; 16). Exclusion criteria were current major depression, bipolar I disorder, schizophrenia and alcohol or drug addiction or abuse within the last 6 months as well as psychotropic medication within 2 weeks prior to investigation. All diagnostic interviews where administered by trained and experienced psychologists (inter-rater reliability IPDE: $\kappa = 0.77$, SCID: $\kappa = 0.70$). Patients were recruited at the Central Institute of Mental Health in Mannheim, Germany, and at the Department of Psychiatry and Psychotherapeutic Medicine, University of Freiburg, Germany. Seventeen patients were out-patients (eight with current SIB and nine who had stopped SIB) and seven patients were in-patients (five with current SIB and two who had stopped SIB).

The control group was recruited at the Institute of Physiology and Pathophysiology at the University of Mainz, Germany. Most of them were students. Exclusion criteria for the control group were any diagnosis of DSM-IV axis I and II as assessed by the German version of the Mini-International Neuropsychiatric Interview (MINI) for axis I (17) and the IPDE for axis II (15). None of the participants had a history of neurological diseases. The study was approved by the local ethics committee and written as well as verbal informed consent was given by all participants. All attendees received reimbursement for their participation. All measurements were performed in a light- and noise-reduced, electromagnetically shielded chamber.

Detection and pain thresholds

Thermal contact stimulation. Thermal stimuli were applied using a contact thermode on the back of both left and right hands (30 × 30 mm, NeuroSensory Analyzer, TSA II; Medoc Advanced Medical Systems Ltd, Ramat Yishai, Israel). Baseline temperature of the thermode stimulator was 32°C. For determination of both detection and pain thresholds, the thermode temperature was increased or decreased by 1°C/s (cut-off temperatures 50 and 0°C), and subjects had to press a button when detecting warming or cooling (detection thresholds) or when they perceived the temperature as painful (pain thresholds). Detection and pain thresholds were defined by means of three repetitions per stimulated area.

Laser radiant heat stimulation. Radiant heat pulses were applied using an energy-controlled infra-red thulium-YAG laser [2.01-μm wavelength, 5-mm beam diameter indicated by a pilot laser, 3-ms stimulus duration (18)]. The laser beam was transmitted via a glass fiber to a hand-piece inside the chamber. Both participants and experimenters wore protective goggles. The output energy was adjustable between 60 and 600 mJ.

Detection and pain thresholds for radiant heat pulses were determined applying three ascending and descending series of laser stimuli to the dorsum of each hand (method of limits). To prevent subjects or patients from using the term 'pain' and its affective connotation, participants were asked to rate their perceived quality of the laser pulse using a verbal descriptor scale (nothing, touch, warm, pricking, stinging, burning and miscellaneous). Detection threshold was defined as the geometric mean of six intensities ranging from detected to not detected, while pain threshold was defined as the geometric mean of the six supra- and infra-threshold intensities leading to painful qualities (18, 19).

Suprathreshold laser stimulation during focused attention and distraction

As in the study of Schmahl *et al*. (9), four runs of laser stimulation at constant intensity (540 mJ) were applied during an easy spatial discrimination task and a difficult spatial discrimination task as well as during mental distraction by an arithmetic task, respectively, tested in balanced order. For the discrimination task, the line distances in radial–ulnar direction to which the stimuli were applied were 6 mm (narrow = difficult discrimination) and 12 mm (wide = easy discrimination), which has previously led to 70% and 80% correct localizations in healthy volunteers and patients with BPD respectively (9, 20). Twenty stimuli were applied in randomized order: 10 stimuli on each line within one run and each stimulus was signaled by an auditory cue given 1 s before the laser pulse. The first two stimuli of a run were applied to demonstrate the location of the lines. For the remaining 18 stimuli, participants had to indicate to which of the two lines the stimulus was applied by elevating the thumb or the fifth finger for the more radial or ulnar line. After each run, subjects rated how painful they perceived the laser stimulus to be and how confident they felt in the local indication of the applied laser stimulus on 100-mm Visual Analogue Scales respectively (pain intensity ratings: from 0 = not painful to 100 = most intense pain imaginable, confidence ratings: 0 = unsure, just guessed to 100 = absolute confidently distinguished). During the distraction task, participants had to subtract a given one-digit number (7 or 9) consecutively from three-digit starting numbers while stimulated with 20 laser stimuli per run applied to the narrow and wide spaced lines respectively. At the end of each run, subjects were asked to give the mathematical answer, which was evaluated for the effort, i.e. the number of subtractions performed, and for the correctness of the answer. Because in previous studies (9) patients with BPD seemed to calculate at a slower rate but more correctly than healthy controls; the arithmetic efficiency was calculated by the mean number of calculated steps times the fraction of correct trials within the four runs per subject.

Psychopathology

To assess psychopathology, participants filled in the three questionnaires: i) Borderline Symptom List (BSL) (21, 22). The BSL is a self-rating instrument which measures the severity of borderline-typical pathology. This questionnaire was only administered to patients with BPD and not to healthy controls. ii) Fragebogen zu Dissoziativen Symptomen (FDS) (23): the dissociation questionnaire is the German adaptation of the Dissociation Experience Scale (DES) (24), a self-rating instrument to assess dissociative symptoms as a trait. iii) The Dissociation Stress Scale (DSS) (25) which assesses the current aversive inner tension as well as current dissociative symptoms (state dissociation).

Data analysis

For all analyses of group differences, we used one-way ANOVAs for all pain measurements as well as for

all psychometric data. Data included in analyses of variance were in line with the assumption of normality and with the assumption of equality of variances. Assumption of normality was formally tested using the Shapiro–Wilks test and double checked from visual inspection of the data.

When there was a significant effect by group, we calculated *post hoc* analyses by linear trend contrasts in order to test our hypotheses that laser detection, all pain thresholds, pain intensity and the degree of psychopathology are the highest in patients with BPD with current SIB and the lowest in healthy controls. Because thermal detection thresholds were not normally distributed, we used Kruskal–Wallis tests for data analysis. Spatial discrimination tasks assessed by the laser were calculated by a two-way repeated measurement ANOVA (group × task difficulty). We performed discrimination analysis yielding hit rate and confidence ratings by means of *post hoc* Sheffé analyses. We used bivariate correlation analyses for independent variables (Pearson's coefficient) to calculate correlations of symptom severity and pain measurements. To collapse all different pain parameters measured in a single subject independent of their physical dimensions, all five pain measures obtained in this study (contact cold pain threshold, contact heat pain threshold, radiant heat detection threshold, radiant heat pain threshold and subjective radiant heat pain intensity) were transferred into *Z*-scores (19).

These (up to) five different *Z*-scores obtained in an individual subject were then averaged to obtain one individual value per subject. These *Z*-scores indicate how far and in what direction the overall pain sensitivity in a subject deviates from the distribution of the mean of values obtained in healthy controls, expressed in units of standard deviation of a normal distribution. An overall loss of pain sensitivity in comparison with controls is indicated by negative and a gain of pain sensitivity by positive *Z*-scores (19). For group comparison of borderline symptom severity (BSL), we analyzed two-tailed *t*-tests for independent variables. We used SPSS for Windows version 11.5 (SPSS Inc., Chicago, IL, USA) for all analyses. Data are presented as mean ± standard deviation (SD). Probabilities of $P < 0.05$ were considered as being statistically significant.

Missing values

Because of technical failures of the laser in three controls and two patients with BPD (one with and one who had stopped SIB), we acquired radiant heat pain thresholds from 21 controls and 22 patients (10 without and 12 with current SIB). Interestingly, three patients who had stopped SIB quit participation during or after the assessment of radiant heat pain thresholds because they perceived the stimuli as being too painful to continue the experiments. Seven patients without current SIB were left for the assessments of subjective pain ratings during constant laser pain, following the determination of pain thresholds.

Results

Sample

Table 1 lists co-occurring axis I diagnoses of both patient groups. Healthy controls did not fulfill any axis I diagnosis.

Pain sensitivity

Thermal contact stimulation. We found no group differences for non-painful thermal detection thresholds but significant group effects for all pain measurements (cold pain: $F = 18.8$, d.f. = 2, 45, $P < 0.001$; heat pain: $F = 21.5$, d.f. = 2, 45, $P < 0.001$). For all pain measures, patients with BPD with ongoing SIB displayed the highest thresholds, healthy controls the lowest thresholds and patients who had stopped SIB were in between (*post hoc* linear trend analyses: cold pain: $F = 37.67$, d.f. = 1, 45, $P < 0.001$; heat pain: $F = 40.69$, d.f. = 1, 45, $P < 0.001$; Fig. 1a, Table 2). Correlation analyses revealed that extreme values for cold and heat pain were both found in the same subjects ($r = 0.79$, $P < 0.001$, Fig. 1b). Analyses without the three patients who had quit participation during or after the assess-

Table 1. Co-occurring axis I disorders of patients with borderline personality disorder (BPD) with current self-injurious behavior and patients with BPD who had stopped self-injurious behavior for at least 6 months

	BPD-SIB (n = 13)	BPD-non-SIB (n = 11)
Lifetime diagnoses (remitted)		
Major depressive disorder	9	7
Obsessive–compulsive disorder	0	2
Bulimia nervosa	0	3
Anorexia nervosa	2	0
Substance abuse	4	2
Current diagnoses		
Social phobia	3	0
Panic disorder	4	5
PTSD	5	4

BPD-SIB, patients with BPD with current self-injurious behavior; BPD-non-SIB, patients with BPD who had stopped to injure themselves for at least 6 months.

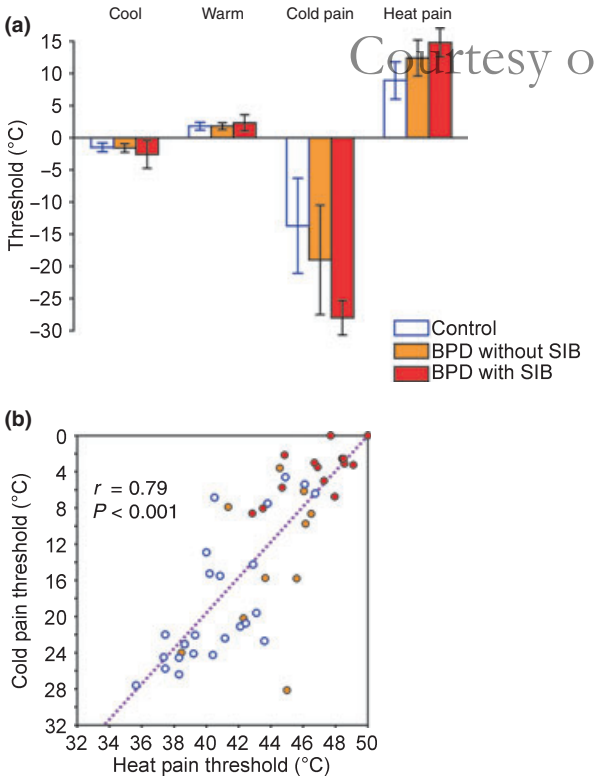

Fig. 1. Pain induced by contact thermal stimuli differs among groups in ranked order. (a) Mean values (±SD) of contact thermal detection and pain thresholds. Linear trend analyses revealed congruent group differences in contact thermal cold and heat pain. No differences were found for contact thermal detection thresholds. (b) Correlation between contact thermal cold and heat pain thresholds. Extreme values of cold and heat pain were shown by the same subjects. BPD, borderline personality disorder; SIB, self-injurious behavior.

ment of laser radiant heat pain thresholds also revealed significant main effects and the same pattern of linear trends.

Laser radiant heat stimulation. Similarly, we found significant main effects of group for laser detection thresholds ($F = 5.5$, d.f. = 2, 40, $P < 0.01$), laser pain thresholds ($F = 7.4$, d.f. = 2, 40, $P < 0.01$) and laser pain intensity ratings ($F = 5.1$, d.f. = 2, 37, $P < 0.05$). For all these pain measures, *post hoc* linear trend contrasts were significant (laser detection thresholds: $F = 10.46$, d.f. = 1, 40, $P < 0.01$; laser heat pain thresholds: $F = 14.24$, d.f. = 1, 40, $P < 0.001$; laser heat pain ratings: $F = 9.7$, d.f. = 1, 37, $P < 0.01$; Table 2, Fig. 2a). Again, patients with BPD with ongoing SIB showed the lowest, healthy controls the highest pain sensitivity and patients with BPD who had stopped SIB were in between. Here too, analyses without the three patients without current SIB who quit participation during or after the assessment of radiant laser heat pain thresholds revealed the same pattern of linear trend analyses.

Yet, the ability to spatially discriminate noxious radiant heat stimuli did not differ between the three groups (main effect group: $F = 1.7$, d.f. = 2, 37, $P = 0.20$). This was true for both the easy and difficult discrimination tasks, that – as expected – resulted in thoroughly differing hit rates in all groups (main effect task difficulty: $F = 41.8$, d.f. = 1, 37, $P < 0.001$; interaction term: $F = 0.2$, d.f. = 2, 37, $P = 0.82$). Moreover, the subjective confidence ratings reflected the task difficulty and also did not display any differences between groups (main effect group: $F = 1.4$, d.f. = 2, 37, $P = 0.27$, main effect task difficulty: $F = 25.3$, d.f. = 1, 37, $P < 0.001$, interaction term: $F = 0.4$, d.f. = 2, 37, $P = 0.71$).

Although patients with BPD calculated slower in the distraction task ($F = 3.4$, d.f. = 2, 38, $P < 0.05$), the arithmetic efficiency that combines effort and correctness of mental arithmetic, did not differ between groups ($F = 0.8$, d.f. = 2, 39, $P = 0.92$, Table 2).

An overall view on altered pain sensitivity in patients with BPD. By collapsing all five different pain parameters measured in a single subject into one individual *Z*-score, we were able to compare those global pain scores between groups to obtain an overall view on altered pain sensitivity in patients with BPD with and without ongoing SIB, independent of a specific pain modality. Again, patients with BPD continuing SIB displayed marked loss of an overall pain sensitivity when compared with controls (−1.63 ± 0.65 SDs below normal), whereas patients with BPD who had stopped SIB were exactly located midway in between those groups (−0.69 ± 1.08 SDs below normal) and significantly differed from either group ($F = 9.7$, d.f. = 2, 45, $P < 0.001$; Fig. 2b). Again, analyses after omitting the three patients who quit participation also revealed significant main effects. However, the difference of the *Z*-scores seen in healthy controls and the seven patients with BPD who completed all laser stimulation tasks even lost significance (−0.97 ± 0.91 SDs below normal; $n = 7$, $P = 0.16$ vs. control, $P < 0.01$ vs. patients with BPD with ongoing SIB).

Psychopathology

An analysis of differences in BPD symptom severity between the two patient groups revealed a high effect size ($d = 0.83$), but did not reach significance (BPD-SIB: mean 2.23, SD 0.64; BPD-non-SIB: mean 1.66, SD 0.8, $T = 1.6$, $P = 0.13$). A

Table 2. Group comparisons of psychopathology and pain sensitivity

	Healthy controls (n = 24)	BPD-non-SIB (n = 11)	BPD-SIB (n = 13)	P (ANOVA)	P (linear trend)
Age (years)	24 ± 4	30 ± 7	28 ± 8		
Dissociation trait (FDS)	3.3 ± 2.7 (19)	12.0 ± 7.5 (8)	24.5 ± 18.9 (12)	†††	***
Dissociation state (DSS)	0.04 ± 0.1 (17)	0.6 ± 0.7	0.9 ± 1.1 (12)	††	**
Aversive inner tension	0.8 ± 1.1 (19)	3.1 ± 2.8	2.5 ± 2.2(12)	††	*
Borderline Symptom List (BSL)		1.7 ± 0.8 (5)	2.2 ± 0.6	n.s. (t-test)	
Contact warm detection threshold (°C)	33.8 ± 0.6	33.8 ± 0.5	34.3 ± 1.3	n.s.‡	
Contact cold detection threshold (°C)	30.5 ± 0.7	30.4 ± 0.7	29.4 ± 2.2	n.s.‡	*
Contact heat pain threshold (°C)	40.9 ± 2.9	44.4 ± 2.8	46.8 ± 2.2	†††	***
Contact cold pain threshold (°C)	18.3 ± 7.4	13.0 ± 8.5	3.9 ± 2.7	†††	***
Laser detection threshold (mJ)	257 ± 78.9 (21)	313 ± 90.1 (10)	355 ± 85.0(12)	††	**
Laser pain threshold (mJ)	304 ± 61.5 (21)	359 ± 78.2 (10)	403 ± 85.0(12)	††	***
Laser-evoked pain (mm on VAS)	40.7 ± 18.9 (21)	27.0 ± 22 (7)	19.6 ± 16.6(12)	†	**
Laser discrimination tasks					
Hit rate for 12 mm (%)	82.4 ± 7.4	79.2 ± 10.2	83.2 ± 4.2	n.s.	
Hit rate for 6 mm (%)	72.9 ± 7.6	67.9 ± 6.6	71.6 ± 6.2	n.s.	
Confidence rating (12 mm; %)	50.7 ± 16.5	40.9 ± 9.3	40.4 ± 18.0	n.s.	
Confidence rating (6 mm; %)	41.9 ± 14.4	35.1 ± 22.4	32.9 ± 19.2	n.s.	
Mental arithmetic task performance					
Effort (seconds/step)	4.4 ± 1.6 (21)	6.0 ± 1.3 (7)	5.5 ± 1.6 (11)	†	
Correctness (%)	33.3 ± 28 (21)	39.3 ± 24 (7)	35.4 ± 33 (11)	n.s.	
Arithmetic efficiency	10.5 ± 8.7 (21)	10.0 ± 9.3 (7)	9.2 ± 8.0 (11)	n.s.	

Values are represented as mean ± SD. †$P < 0.05$, ††$P < 0.01$, †††$P < 0.001$ (one-way ANOVA). *$P < 0.05$, **$P < 0.01$, ***$P < 0.001$ (linear trend analysis). Numbers in brackets indicate the number of subjects tested, if differing from the values given in the header. BPD-non-SIB, patients with BPD who had stopped to injure themselves for at least 6 months; BPD-SIB, patients with BPD with current self-injurious behavior; FDS, Fragebogen zu Dissoziativen Symptomen (dissociation as trait); DSS, Dissociation Stress Scale (dissociation as state); BSL, Borderline Symptom List; VAS, Visual Analogue Scale.
‡Kruskal–Wallis test.

one-way ANOVA showed significant differences for state dissociation ($F = 5.7$, d.f. = 2, 41, $P < 0.01$), for trait dissociation ($F = 13.4$, d.f. = 2, 38, $P < 0.001$), as well as for state aversive inner tension ($F = 5.67$, d.f. = 2, 41, $P < 0.01$; Table 2). *Post hoc* linear trend analyses were significant for state dissociation ($P < 0.01$), for trait dissociation ($P < 0.001$), as well as for state aversive inner tension ($P < 0.05$). For state and trait dissociation, patients with ongoing SIB showed higher intensity levels than healthy controls and, as predicted, patients who had stopped to injure themselves were in between these two groups (see Fig. 3). For state aversive inner tension, the highest mean was shown by patients who had stopped to injure themselves and the lowest by healthy controls (Table 2).

Correlation analyses of pain assessments and symptom severity

For symptom severity in patients with BPD, we found a significant negative correlation with pain intensity ratings ($r = -0.67$, $P < 0.01$) and a medium correlation of $r = 0.39$ with laser pain thresholds which barely failed to reach significance ($P = 0.07$). Correlations between symptom severity and thermal pain thresholds were not significant (cold pain: $r = -0.12$, $P = 0.33$; heat pain: $r = 0.24$, $P = 0.17$).

Discussion

To our knowledge, this is the first study investigating pain sensitivity in patients with BPD who have stopped to injuring themselves in comparison with patients with ongoing SIB and healthy controls. Regarding the patients with ongoing SIB, we could replicate earlier findings of Schmahl *et al*. (9), demonstrating that those display lower pain sensitivity when compared with healthy controls. Patients with BPD who had stopped SIB consistently scored in between patients with BPD with ongoing SIB and healthy controls: this was found for all five pain measures obtained in this study. It is notable that pain sensitivity in patients with BPD who stopped SIB seems to be underestimated rather than over-rated, despite the fact that one-fourth of the patients without current SIB stopped the laser experiment due to painfulness of the initial laser stimuli applied. The dropping out of these three patients due to painfulness of the laser stimuli before finishing the complete protocol did not bias the essence of our results. All group differences described between past and active cutters persisted when analysis was performed without the data sets for the patients who dropped out, which means that those three patients did not cause the group differences between patients with BPD with/without current SIB. In accordance

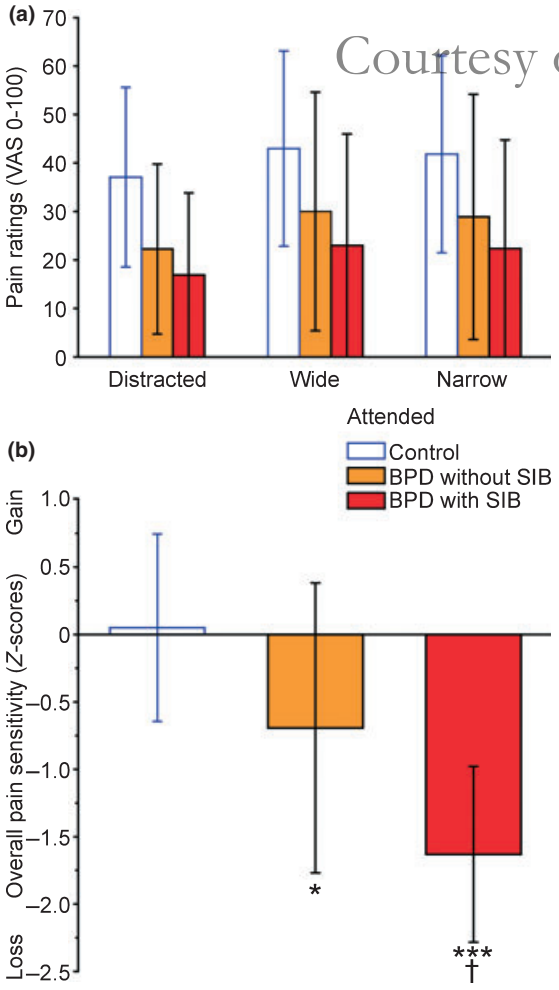

Fig. 2. Pain induced by laser radiant heat stimuli differs among groups in the same ranked order. (a) Mean values (±SD) of subjective laser heat pain ratings. Linear trend analyses revealed congruent group differences in subjective laser heat pain ratings in the different tasks (wide, narrow and distracted). (b) Mean values (±SD) of subjective *Z*-scores aggregating all five pain measures obtained into one overall pain sensitivity score (SD of controls). $*P < 0.05$, $***P < 0.001$ vs. control, $\dagger P < 0.05$ vs. borderline patients without self-injurious behavior, ANOVA with Scheffé *post hoc* test. BPD, borderline personality disorder; SIB, self-injurious behavior; VAS, Visual Analogue Scale.

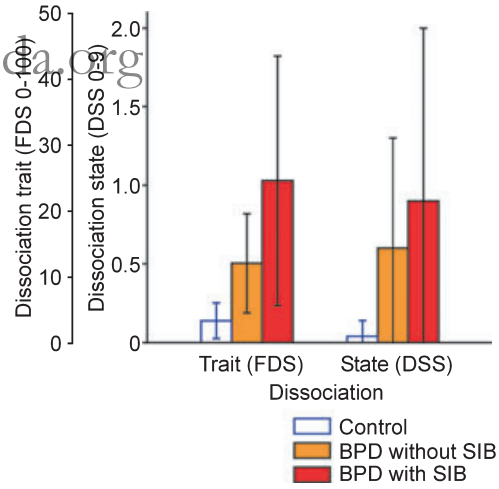

Fig. 3. Trait and state dissociation differs among groups in the same ranked order. Mean values (±SD) of trait dissociation, state dissociation and aversive inner tension. Linear trend analyses were significant for all three psychometric assessments, although patients with BPD without self-injurious behavior showed the highest mean values in aversive inner tension. BPD, borderline personality disorder; SIB, self-injurious behavior; FDS, Fragebogen zu Dissoziativen Symptomen (dissociation as trait); DSS, Dissociation Stress Scale (dissociation as state).

with Schmahl *et al.* (9), there was no group effect for laser discrimination tasks, confirming the intactness of the sensory discriminative pain component in patients with BPD, independent of SIB.

The pain assessment hierarchy was also found for trait and state dissociation, meaning that patients with ongoing SIB showed the highest scores for trait and state dissociation, patients who had stopped SIB showed lower scores and healthy controls the lowest. A linear trend analysis of state aversive inner tension was also significant in the expected order, although patients with BPD without SIB showed the highest mean scores. This result is probably due to the high standard deviation in the BPD-non-SIB group. To exclude the possible influence of different aversive inner tension levels between the two patient groups on pain perception (10), we tested *post hoc* group differences in aversive inner tension between the two patient groups, which were not significant (*t*-test: $P = 0.57$). Thus, inner tension does not account for differing pain sensitivity observed among borderline patients.

Considering statistical power, the conceptual rationale to split patients with BPD into subgroups of SIB ($n = 13$) and non-SIB ($n = 11$) seemed to be justified from the large effect size ($d = 2.16$) we had found in our previous study comparing patients with BPD with healthy controls in terms of laser pain sensitivity (9). Formal power calculation indicates that for such a high effect size the sample sizes in the subgroups were clearly sufficient to achieve adequate statistical power. To avoid spurious results, we took care during the sampling process to strictly avoid the violation of the most critical assumption in both one-way ANOVA and Kruskal–Wallis tests – i.e. the assumption of independence of the subjects included. We checked whether the data were in line with normality (using both formal testing by the Shapiro–Wilks test and visual inspection of the data) and chose the statistical test accordingly. If the assumption of normality was questionable, Kruskal–Wallis tests

were used instead of ANOVAs. As the critical values of both the Kruskal–Wallis test and of the *F*-test used in ANOVAs are exact (i.e. they do not require approximation or asymptotic calculations), significant results are also accurate for small samples as long as the assumptions are met.

Due to the fact that this is a cross-sectional study, differences in pain perception between patients with BPD with and without SIB can be explained in three ways: i) *Differences in pain sensitivity may be due to distinct pre-existing subgroups of patients with BPD who tend towards or eschew SIB*. This would imply that pain sensitivity levels predict continuation or discontinuation of SIB. Such pre-existing differences in pain sensitivity could be explained by genetic or early developmental factors. The fact that the two patient groups retrospectively estimated pain ratings differently during the last SIB event supports this explanation, although recall bias has to be considered. ii) *Termination of SIB leads to normalization of pain perception*. This explanation implies that continuous SIB attenuates pain sensitivity of borderline patients, e.g. by repetitive stimulation of the endogenous opioid system. iii) *Normalization of pain perception is an epiphenomenon of improved overall borderline symptomatology*. There was a significant correlation between symptom severity and pain intensity ratings and a statistical trend for the correlation between symptom severity and laser pain thresholds. We also found a high effect size for differences in symptom severity between the two BPD groups; the failed statistical significance for the difference between these two groups may be due to a power problem. Each of these three possible explanations impacts our understanding of the pathophysiology of borderline personality disorder in different ways. Thus, investigation of BPD subjects who have never injured themselves as well as longitudinal studies investigating pain sensitivity (e.g. during the course of treatment) are necessary to shed more light on the relation between behavioral alterations and neurobiological measures in these patients.

As shown in Table 1, patients with BPD showed different current comorbid anxiety disorders. Previous studies have shown altered pain sensitivity in patients with anxiety disorders (26). In our study, both subgroups of patients showed a similar high percentage of comorbid anxiety disorders (BPD SIB: 92.3% and BPD-non-SIB: 82%). Other psychiatric disorders which can alter pain perception, such as schizophrenia or current major depression, were excluded. Thus, we assume that differences in pain sensitivity between groups are unlikely to be caused by the potential influence of comorbidities. As a limitation of our study it should be mentioned that we did not assess pain tolerance thresholds. Assessment of tolerance thresholds is another frequently used method to assess pain sensitivity in addition to detection and pain thresholds.

In summary, this study suggests an association between termination of self-injurious behavior and normalization of pain perception in patients with BPD. Prospective longitudinal studies are necessary to strengthen causal attribution.

Acknowledgements

The authors highly appreciate the help of Gertrud Schatt in the psychophysical experiments. This study was supported by a grant of the Borderline Personality Disorder Research Foundation (BPDRF) NY, the Bundesministerium für Bildung und Forschung (BMBF) Grant 01-EM-0506 (German Research Network on Neuropathic Pain, DFNS) and by the Deutsche Forschungsgemeinschaft (Tr236/11-3 and 13-3).

Declaration of interest

The authors declare no conflicts of interest related to the content of this article.

References

1. Shearer SL. Phenomenology of self-injury among inpatient women with borderline personality disorder. J Nerv Ment Dis 1994;**182**:424–526.
2. Gunderson JG, Ridolfi ME. Borderline personality disorder: suicidality and self-mutilation. Ann NY Acad Sci 2001; **932**:61–73.
3. Herpertz S. Self-injurious behaviour. Psychopathological and nosological characteristics in subtypes of self-injurers. Acta Psychiatr Scand 1995;**91**:57–68.
4. Kleindienst N, Bohus M, Ludaescher P, Limberger MF, Kuenkele K, Ebner-Priemer UW, Chapman AL, Reicherzer M, Stieglitz RD, Schmahl C. Motives for non-suicidal self-injury among women with Borderline Personality Disorder. J Nerv Ment Dis 2008;**196**:230–236.
5. Paris J. Understanding self-mutilation in borderline personality disorder. Harv Rev Psychiatry 2005;**13**:179–185.
6. Zweig-Frank H, Paris J, Guzder J. Psychological risk factors for dissociation and self-mutilation in female patients with personality disorders. Can J Psychiatry 1994;**39**:259–265.
7. Russ MJ, Roth SD, Lerman A, Kakuma T, Harrison K, Shindledecker RD, Hull J, Mattis S. Pain Perception in self-injurious patients with borderline personality disorder. Biol Psychiatry 1992;**32**:501–511.
8. Bohus M, Limberger M, Ebner U, Glocker FX, Schwarz B, Wernz M, Lieb K. Pain perception during self-reported distress and calmness in patients with borderline personality disorder and self-mutilating behavior. Psychiatr Res 2000;**95**:251–260.
9. Schmahl C, Greffrath W, Baumgartner U, Schlereth T, Magerl W, Philipsen A, Lieb K, Bohus M, Treede RD. Differential nociceptive deficits in patients with borderline personality disorder and self-injurious behavior: laser-evoked potentials, spatial discrimination of noxious stimuli, and pain ratings. Pain 2004;**110**:470–479.

10. Ludaescher P, Bohus M, Lieb K, Phillipsen A, Jochims A, Schmahl CG. Elevated pain thresholds correlate with dissociation and aversive arousal in patients with borderline personality disorder. Psychiatr Res 2007;**149**:291–296.
11. Melzack R, Casey KL. Sensory, motivational, and central control determinants of pain A new conceptional model. In: Kenshalo DR, ed. The skin senses. Springfield, IL: Thomas, 1968:423–439.
12. Treede RD, Kenshalo DR, Gracely RH, Jones AK. The cortical representation of pain. Pain 1999;**79**:105–111.
13. Lieb K, Linehan M, Schmahl C, Zanarini M, Bohus M. Borderline personality disorder. Lancet 2004;**364**:453–461.
14. Zanarini MC, Frankenburg FR, Hennen J, Bradford Reich D, Silk KR. Prediction of the 10-year course of borderline personality disorder. Am J Psychiatry 2006;**163**:827–832.
15. Loranger AW. IPDE: International Personality Disorder Examination; DSM-IV Module. Ed. Weltgesundheitsorganisation WHO. Deutschsprachige Ausgabe von Mombour W, Zaudig M, Berger P, Gutierrez K, Berner K, v. Cranach M, Giglhuber O, v. Bose M. Bern: Huber, 1996.
16. Wittchen HU, Wunderlich U, Gruschwitz S, Zaudig M. SKID-I. Strukturiertes Klinisches Interview für DSM-VI, Achse-I. Göttingen: Hogrefe, 1997.
17. Sheehan DV, Lecrubier Y, Harnett Sheehan L, Amorim P, Weiller E, Hergueta T, Baker R, Dunbar G. The Mini International Neuropsychiatric Interview (M.I.N.I.): The development and validation of a structured diagnostic psychiatric interview for DSM-VI and ICD-10. J Clin Psychol 1998;**59**:22–57.
18. Spiegel J, Hansen C, Treede RD. Clinical Evaluation criteria for the assessment of impaired pain sensitivity by thulium-laser evoked potentials. Clin Neurophysiol 2000;**111**:725–735.
19. Rolke R, Magerl W, Campbell KA, Schalber C, Caspari S, Birklein F, Treede RD. Quantitative sensory testing: a comprehensive protocol for clinical trials. Eur J Pain 2006; **10**:77–88.
20. Schlereth T, Magerl W, Treede R. Spatial discrimination thresholds for pain and touch in human hairy skin. Pain 2001;**92**:187–194.
21. Bohus M, Limberger MF, Frank U, Sender I, Gratwohl T, Stieglitz RD. Development of the Borderline Symptom List. Psychother Psychosom Med Psychol 2001;**51**:201–211.
22. Bohus M, Limberger MF, Frank U, Chapman A, Kühler TH, Stieglitz RD. Psychometric properties of the Borderline Symptom List (BSL). Psychopathology 2007;**40**:126–132.
23. Freyberger HJ, Spitzer C, Stieglitz RD. Fragebogen zu dissoziativen Symptomen (FDS). German Adaption of the Dissociative Experience Scale (DES); Bernstein U & Putnam FW. Bern: Huber, 1986.
24. Bernstein EM, Putnam FW. Development, reliability, and validity of a dissociation scale. J Nerv Ment Dis 1986; **174**:727–735.
25. Stiglmayr CE, Shapiro DA, Stieglitz RD, Limberger MF, Bohus M. Experience of aversive tension and dissociation in female patients with borderline personality disorder – a controlled study. J Psychiatr Res 2001;**35**:111–118.
26. Lautenbacher S, Krieg C. Pain perception in psychiatric disorders: a review of the literature. J Psychiatr Res 1994; **28**:109–122.