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Body plasticity in borderline personality disorder: a link to dissociation

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Highlights

- ▶ Borderline personality disorder is accompanied by alterations in body perception.
- ▶ Body plasticity, as assessed by the rubber hand illusion paradigm, is enhanced.
- ▶ Body plasticity is positively correlated to trait and state dissociation.
- ▶ Remission of the disorder is associated with a stabilization of body perceptions.
- ▶ Dissociation and body plasticity might share common underlying mechanisms.

Abstract

Introduction: Patients with borderline personality disorder (BPD) often report an unstable sense of self, which is further enhanced in dissociative states. As one consequence, BPD patients show a labile body percept, which might result in a higher degree of body plasticity. However, experimental data on body plasticity in BPD are not yet available.

Material and methods: The rubber hand illusion (RHI) probes the plasticity of one's body by inducing the feeling of ownership for an artificial limb. We tested the proneness to perceive the RHI in female patients with current and remitted BPD compared to healthy controls, and related their perceptions to state and trait dissociation.

Results: Participants with current BPD, compared to healthy controls, reported higher proneness to perceive the RHI ($p < .05$, with an effect size [Cohen's d] of 0.68). Remission was associated with a stabilization of perceptions. RHI vividness was positively related to state and trait dissociation across the groups, and specifically in current BPD when controlling for symptom severity (all Pearson's $r \geq .30$, $p < .05$).

Discussion: These results indicate enhanced body plasticity related to dissociation in BPD, point to shared neurobiological mechanisms, and might help to elucidate the body-related perceptual disturbances associated with BPD.

Conclusion: The results provide initial empirical evidence for significant alterations in body ownership processing associated with a current BPD diagnosis, resulting in enhanced body plasticity. Dissociation significantly correlated with illusory limb ownership experiences, making body plasticity a marker for BPD.

Keywords: borderline personality disorder; rubber hand illusion; body perception; dissociation

1 Introduction

The perception of ownership for one's body, i.e., the sensation that the whole body or its parts belong to oneself^{1,2}, is an essential feature of self-experience. At any given time, a variety of sensory qualities have to be processed simultaneously and integrated into a corresponding percept. As a result of the integration of body-related sensory input, a coherent experience of the body is generated³, forming the base of one's own corporeal identity.

The rubber hand illusion (RHI) offers a tool to experimentally manipulate the experience of the body. In this paradigm, the sensation of ownership for an artificial limb is induced through visuotactile stimulation of the artificial limb in synchrony with the participant's real but hidden limb⁴. Thus, the RHI represents a multisensory phenomenon probing one's body plasticity, which describes how fluid people perceive the borders of their own body and how much they can incorporate objects from the peripersonal environment⁵.

Both body acceptance and body perception have been shown to be distorted in borderline personality disorder (BPD)^{6,7,8,9}, which is further characterized by emotional dysregulation, disturbed interpersonal relationships, and impaired self-awareness¹⁰. In addition, dissociation is common in BPD^{11,12}. Dissociation refers to a detachment from the immediate surroundings or emotional and physical experiences, including the feeling that one's body does not belong to oneself. These perceptual features suggest that dissociation might be related to a higher level of body plasticity. A relationship between body plasticity and dissociation is further suggested by the effects of subanesthetic doses of ketamine, which were found to induce dissociative experiences and to enhance indicators of body plasticity such as the RHI in healthy persons¹³. However, the relationship between body plasticity and dissociation has not yet been systematically investigated in BPD. An improved understanding of body representation in BPD might also shed light on the mechanisms underlying dissociation, which involves also detachment from one's body. It has been suggested that this might be a coping mechanisms related to overly strong emotions¹⁴.

In the present study, we investigated the sensation of illusory limb ownership during the RHI in patients with BPD. In order to differentiate between state and trait aspects of the disorder, we included patients with current and remitted BPD and compared their results to those obtained in healthy controls. Since current BPD is associated with states of dissociation and characterized by detachments from one's own body, we expected an enhanced proneness towards the RHI paradigm in these patients. Furthermore, we expected a positive association between dissociation and RHI experiences in current BPD.

2 Material and methods

2.1 Participants

While the HC sample was recruited via the local resident's registration office, current and remitted BPD patients were recruited via recruitment flyers, online and printed media announcements, and from the pool of in- and out-patients of the Department of General Psychiatry at the University of Heidelberg and of the Department of Psychosomatic Medicine and Psychotherapy at the Central Institute of Mental Health in Mannheim. Remitted BPD patients were recruited from the pool of patients formerly treated at the Central Institute of Mental Health. There is an overlap of the present sample and that one included in a previous study on pain perception in BPD¹⁵.

We included 34 participants with a current diagnosis of BPD (mean (*M*) age = 27.32 years, standard deviation (*SD*) = 6.71), 19 participants with BPD in remission (*M* age = 29.84 years, *SD* = 5.00), and 25 healthy controls (HC) (*M* age = 27.80 years, *SD* = 5.59). All participants were unmedicated for at least two weeks prior to participation, female, and the groups did not significantly differ in age, $F_{2,77} = 1.12$, $p = .33$. All participants were Caucasian and all but three participants were right-handed (two left-handed, one ambidextrous participant in the remitted BPD group).

The BPD diagnosis was based on the Diagnostic and Statistical Manual for Mental Disorder IV (DSM-IV¹⁶) and was assessed by the International Personality Disorder Examination (IPDE¹⁷). The German version of the Structured Clinical Interview for DSM-IV Axis I Disorders (SCID-I¹⁸) was used to record axis-I comorbidity. Inclusion criteria were current BPD (IPDE ≥ 5 criteria) for the past five years and age between 18 and 50 years.

Remitted BPD patients had to meet life-time DSM-IV criteria for BPD as an adult (five or more fulfilled BPD criteria of the IPDE for five years). In addition, they had to fulfill only three or less BPD criteria in the IPDE within the last two years prior to study participation, including absence of clinical admission for one year and self-harming behavior no more than twice within the last two years. These criteria for symptomatic remission are in line with the established literature (e.g. Zanarini et al.¹⁹). However, it is important to note that this definition of remission does not necessarily include attainment of social and vocational competence. Thus, remission of the symptoms is unequal to recovery of the disorder¹⁹.

Exclusion criteria were a lifetime diagnosis of schizophrenia or bipolar I disorder, current substance dependency disorder (in case of current substance abuse an abstinence of two months was required), current psychotropic medication, severe brain diseases, pregnancy, transsexuality, body mass index < 16.5 , and chronic pain. Prevalences of comorbidities of the samples are given in Table 1. Prior to the experiments, the participants underwent a urine drug test, and only participants with a negative result for drug intake were included.

All participants gave written informed consent before participating in this study. The study was approved by the ethics review board of the Medical Faculty Mannheim, Heidelberg University. The authors assert that all procedures contributing to this work comply with the ethical standards of the American Psychological Association, other relevant national and institutional committees on human experimentation, and with the Helsinki Declaration of 1975, as revised in 2008.

Insert Table 1 about here

2.2 Body plasticity

We used the RHI⁴ to assess the participants' body plasticity⁵. As a behavioral proxy, we further assessed the proprioceptive drift, i.e. the tendency to locate one's own limb as closer to the artificial limb after successful RHI induction²⁰.

2.2.1 Induction of the rubber hand illusion

The participant put her hands on a table with the palms down and the tips of the middle fingers on marked positions. In this position, the participant's left hand was hidden from view behind a screen and a life-like left rubber hand (i.e., a prosthetic glove, produced by Otto Bock GmbH, Duderstadt, Germany) was placed in the participants' field of view at a distance of 20 cm (as measured between the middle finger of the real hand and the middle finger of the rubber hand, Figure 1). The experimenter used cotton swabs for tactile stimulation of the participant's unseen left hand as well as the visible rubber hand on five locations for one minute each in the following order: back of the hand; first phalanges of second, third, and fourth digit; back of the hand. The stimulation was applied with short strokes (approximately 3 cm in length), following the acoustic signals given by a metronome (at a frequency of 40 beats per minute). Both stimulated hands had to be kept still during the experiment. The participant was instructed to observe the rubber hand while the experimenter stimulated it. We employed two conditions. In the congruent condition, the experimenter stroked the rubber hand in synchrony together with the participant's hidden hand keeping maximal similarity with respect to site, length, and direction of stroking, from proximal to distal. In the incongruent condition, all features were identical except for the fact that stroking was applied

in an incongruent manner, i.e. the visible rubber hand was stroked from proximal to distal, whereas the real hand was stroked from distal to proximal. Incongruent visuotactile stimulation has been shown to diminish behavioral correlates of the RHI²¹ and thus served as a manipulation check for the RHI condition. The order of conditions was counterbalanced. After each condition, the participant was asked to complete a questionnaire (a modified German version of that used by Botvinick and Cohen⁴) and to rate the intensity of illusory body perceptions using two target items. Five additional distractor items aiming at sensations not expected or not related to an incorporation of the rubber hand (Table 2) were employed. The items were randomized and answered in terms of their intensity using a numerical rating scale ranging from 0 (not at all) to 10 (most intense). The target and distractor ratings were averaged so that significantly higher target ratings compared to distractor ratings would indicate a more vivid sensation of illusory limb ownership.

Further, participants were asked to indicate the perceived congruence between the seen and felt tactile stimulation applied to the rubber hand and their own hidden hand, by using a numerical rating scale ranging from 0 (no congruence) to 10 (maximum congruence). This was a further explicit measurement of sensory integration and experience, and the data served also as a manipulation check for the conditions.

Insert Figure 1 about here

Insert Table 2 about here

2.2 Measurement of proprioceptive drift

As a behavioral proxy of the RHI, we further assessed proprioceptive drift, i.e. the tendency to locate one's own limb as closer to the artificial limb after successful RHI induction²⁰. Prior to and after the congruent and incongruent condition, the participant had to indicate the perceived position of the hidden left hand by putting the right hand under the table and to specify the location under the table that was perceived to be exactly below the left hand. The target point was the tip of the left middle finger. During this procedure, the participants were blindfolded. This proprioceptive pointing measurement served as a behavioral proxy of the RHI, since the proprioceptive drift, i.e., a shift in perceived location of the stimulated hidden hand towards the rubber hand, has been shown to be stronger after congruent compared to incongruent stimulation²¹ and to positively correlate with RHI intensity²⁰. The proprioceptive drift was calculated separately for both conditions by subtracting the post-illusion from the pre-illusion measurement. Positive scores indicate a stronger shift.

2.3 Assessment of symptom severity and dissociation

The short version of the *Borderline Symptom List* (BSL23²²) is an efficient and convenient self-rating instrument to assess BPD symptoms in accordance with DSM IV. The BSL23 assesses self-ratings on the subscales *self-perception*, *affect regulation*, *self-destruction*, *dysphoria*, *loneliness* and *intrusions*. Whereas the IPDE was used to diagnose BPD, the BSL23 assesses BPD symptom severity on a dimensional continuum. Two current and one remitted BPD patients did not complete the BSL23.

The *Fragebogen zu Dissoziativen Symptomen* (FDS²³) is the German adaptation of the *Dissociative Experiences Scale* by Bernstein-Carlson and Putnam²⁴. This self-assessment questionnaire is a screening tool for detecting various dissociative phenomena. Its use is recommended in the context of dimensional diagnosis of dissociative traits in several mental

disorders including BPD. We used the pooled sum score of the FDS. Three current and three remitted BPD patients as well as one HC did not complete the FDS.

Finally, the DSS-4 (Stiglmayr et al.²⁵; short version of the *Dissociation-Tension-Scale acute*²⁶), reliably assesses state dissociation, even when used repeatedly during the course of an experiment.

We expected both state and trait dissociation to be positively correlated with body plasticity in current BPD patients. We assessed both markers of dissociation to evaluate the short- and long-term relationship between dissociation and body plasticity. Since dissociation is closely related to BPD symptom severity in general, we controlled for this feature in the subsequent analyses (see below).

2.4 Data analysis

Illusory limb ownership ratings were analyzed by testing for significant differences between the averaged values of targets and distractors within and between the congruent and incongruent condition in each group. This was done by using paired *t*-tests (the results of these analyses are given in the supplementary material). For each test we also calculated the effect size (Cohen's *d*), based on mean values and standard deviations. One-way ANOVAs were used to detect significant group differences (current BPD, remitted BPD, and HC), with subsequent post hoc tests. The same procedure was used for the data on proprioceptive drift and perceived congruence between seen and felt touch (applied to the own or the rubber hand) as well as for the data reflecting state and trait dissociation.

We further applied Pearson correlations to examine the relationship between illusory limb ownership and proprioceptive drift as well as between state and trait dissociation and illusory ownership across all participants in general and in current BPD in particular. For this group, we also report partial correlation coefficients, controlling for symptom severity (as assessed by the BSL23). Although two of the 23 BSL items (*'I was absent-minded and unable to*

remember what I was actually doing’ and *‘I felt as if I was far away from myself’*, forming the subscale *self-perception*) assess experiences which are characteristic for dissociation, the score mainly reflects general symptom severity. We used the scale to test if body plasticity and dissociation were related independent of symptom severity. Unless stated otherwise, one-tailed testing was applied, and we used Bonferroni corrections whenever multiple testing was performed.

3 Results

3.1 Illusory limb ownership

In all three groups, the RHI was successfully induced in the congruent stimulation condition as indicated by higher illusory limb ownership sensations than distractor sensations as well as higher ratings in the congruent condition compared to the incongruent condition. Further, all three groups discriminated the congruent and incongruent tactile stimulation, as indicated by higher ratings of perceived congruence between seen and felt touch in the congruent compared to the incongruent condition (see supplementary material).

3.1.1 Rating data

There was a significant group difference in perceived illusory limb ownership, $F_{2,77} = 3.35$, $p = .040$. Post hoc tests revealed that the current BPD patients had higher values than the HC group ($p = .018$, $d = 0.68$), but there was no significant difference between the remitted BPD and HC group ($p = .42$, $d = 0.33$) or the current BPD and remitted BPD group ($p = .34$, $d = 0.35$; see Figure 2 and Table 3). To exclude the possibility that the differences between the HC and the current BPD group were driven by unequal sample sizes, we subsequently performed a comparison of illusory limb ownership data between the HC and the same number of age-matched current BPD members; this analysis confirmed the previous result of

higher illusory limb ownership ratings in the current BPD group, $t_{48} = 2.74$, $p = .004$, $d = 0.78$ (uncorrected).

 Insert Figure 2 about here

3.1.2 Behavioral data

There was no significant group difference related to the proprioceptive drift data, $F_{2,77} = 1.97$, $p = .15$. However, the current BPD group descriptively showed stronger shifts towards the artificial limb after illusion induction than the other groups (Figure 2), but also larger variance in this measure (Table 3). Although we found a positive correlation between subjective and behavioral data in the RHI experiment across all three groups (Pearson's $r_{76} = .30$, $p = .004$), this correlation was mainly driven by the current BPD group ($r_{32} = .45$, $p = .011$). The respective relationships in the other two groups were not significant.

 Insert Table 3 about here

3.2 Dissociation

There was a significant group difference in state $F_{2,77} = 12.83$, $p < .001$, as well as trait dissociation, $F_{2,71} = 28.17$, $p < .001$. Post hoc tests for state dissociation revealed that current BPD patients had significantly higher values than the HC ($p < .001$, $d = 1.37$) and the remitted BPD group ($p = .005$, $d = 0.77$). HC and remitted BPD did not significantly differ in this measure ($p = .26$, $d = 0.73$). Post hoc tests for trait dissociation showed a similar pattern.

Current BPD reported significantly higher trait dissociation compared to HC ($p < .001$, $d = 2.03$) and remitted BPD ($p < .001$, $d = 1.03$). However, remitted BPD also showed significantly higher values than the HC ($p = .012$, $d = 1.49$). Figure 3a and 3c illustrate these data.

3.3 Relationship between illusory limb ownership, proprioceptive drift, and dissociation

Across the total sample, we found significant relationships for both state ($r_{76} = .30$, $p = .003$) and trait dissociation ($r_{70} = .33$, $p = .002$) and illusory limb ownership (see Figure 3a and 3c). In the current BPD group state dissociation and illusory ownership were significantly positively correlated ($r_{32} = .29$, $p = .048$), but only a trend in the same direction emerged for trait dissociation ($r_{29} = .24$, $p = .094$). However, when symptom severity was partialled out, the relationships became significant for both state ($r_{26} = .30$, $p = .049$) and trait dissociation ($r_{26} = .32$, $p = .043$; Figure 3b and 3d). For the current BPD group, there was no significant relationship between proprioceptive drift and state ($r_{32} = .06$, $p = .38$) or trait dissociation ($r_{29} = .07$, $p = .36$). This was also true for the respective partial correlations controlling for symptom severity, both for state ($r_{26} = .12$, $p = .26$) and trait dissociation ($r_{26} = .12$, $p = .27$).

 Insert Figure 3 about here

4 Discussion

In the present study, we examined body plasticity in patients with current and remitted BPD compared to healthy controls. We assessed the participants' proneness to perceive illusory ownership for an artificial limb induced by the RHI paradigm. We found that subjects with

current BPD compared to HC were significantly more prone to perceive ownership for an artificial limb. This alteration was specific for patients with current BPD, indicating that a remission is accompanied by a normalization of body plasticity. Further, when we controlled for symptom severity, we found a significant positive relationship between both state and trait dissociation and illusory limb ownership sensations, which was non-significant in the case of trait dissociation when symptom severity was not considered. We conclude that dissociation as clinical feature is positively associated with body plasticity in BPD.

There is extensive evidence that BPD is accompanied by reduced pain perception^{27,28,29,30}.

However, this sensory alteration appears to be specific for the pain domain, as patients with BPD show no alterations in tactile and proprioceptive perception compared to healthy controls^{31,32}. This is of special importance in the light of the present results, since the sensation of body ownership relies on the capability to relate seen and felt touch and posture³ and thus multisensory integration, which is different from perception in one modality.

Successful RHI induction in each group was confirmed by significantly stronger affirmation to target than distractor items and stronger illusory ownership ratings in the experimental condition when congruent stimulation was applied. Nevertheless, the current BPD group responded more strongly than both control groups on a subjective level. The non-significant differences in perceiving congruence between seen and felt touch indicate that basic multisensory integration capabilities are intact, suggesting that top-down rather than bottom-up processing is altered in BPD.

Most importantly, the results presented here not only indicate enhanced body plasticity in current BPD, but its relationship to dissociation. State dissociation correlated with illusory limb ownership irrespective of general symptom severity. Trait dissociation became significant when general symptom severity was partialled out, which might relate to the fact that both measures are trait variables. These results clearly suggest that naturally occurring dissociation is related to higher degrees of body plasticity, probably complicating the

differentiation between oneself and the environment. This perceptual alteration might explain certain symptoms in BPD patients such as uncertainties related to one's own identity and experiences of depersonalization.

Our findings may also be related to neurochemical alterations in BPD. Morgan et al.¹³ showed that healthy participants reported stronger sensations of illusory limb ownership in the RHI paradigm after a dose of ketamine compared to a placebo. Ketamine is an *N*-methyl-*D*-aspartate (NMDA) receptor antagonist inducing dissociation^{33,34}, suggesting that dysfunctions related to the NMDA neurotransmission might at least partly contribute to the enhanced body plasticity in BPD described in the present study. An important role of the NMDA neurotransmission in BPD, probably related to early-life stress³⁵, has previously been proposed^{15,36}, but supporting evidence is still lacking. However, since ketamine mimics the sensory alterations experienced in dissociation³⁷, Morgan et al.¹³ suggested that its effect on the RHI could not be explained by a simple enhancement of bottom-up integration of sensory input, but rather by central changes allowing the integration of an artificial body part into one's body representation. Our results indicate that naturally occurring dissociation, which actually represents a central phenomenon³⁸, may be based on similar neurobiological and psychological mechanisms.

Although we did not find a significantly enhanced proprioceptive drift in the current BPD group, there was a characteristic enhancement in this measure. Further, the proprioceptive drift was significantly correlated with induced illusory limb ownership in the current BPD subgroup, but it was not associated with dissociation, indicating a dissociation-specific enhancement of subjective body plasticity. This difference in sensory and sensorimotor processing should be further investigated.

A widely distributed frontoparietal network^{4,39}, is involved in higher-order body perception. Reduced own body ownership experiences have been shown to be related to dysfunctions in this network involved in the integration of somatosensory, vestibular, and visual input, such

as the premotor cortex, posterior parietal cortex, and cerebellum^{40,41}. Furthermore, the temporoparietal junction is involved in maintaining a coherent body perception. Disruption of this area using transcranial magnetic stimulation made the distinction between what may or may not be part of one's body on the basis of multisensory evidence more ambiguous⁴². Dysfunction of the TPJ is related to dissociative body experiences^{43,44}. Our findings suggest alterations in this or other integrative areas in BPD. Dysfunctions might result in a very labile body percept, which probably blurs the line between the self and the environment. The accompanying neural correlates of this perceptual feature in BPD should be investigated in prospective studies.

The finding that body plasticity as assessed by the RHI is enhanced in BPD patients might have important implications for the understanding of this disorder. First, our results add BPD to an array of clinical conditions that are characterized by disturbed body processing such as schizophrenia^{45,46} and eating disorders⁴⁷, highlighting that body plasticity is an important factor in a variety of mental disorders. In both schizophrenia and eating disorders, the proneness to perceive the RHI is enhanced compared to healthy controls, indicating likewise altered body plasticity as in BPD. In both disorders, there were significant positive correlations with core symptoms such as hallucinations in schizophrenia⁴⁵ and body dissatisfaction in eating disorders⁴⁷. Since both hallucinations in psychotic patients and abnormal eating behavior in the general population are associated with trait dissociation^{48,49}, our results suggest that dissociative experiences could at least partly represent the common thread between the disorders characterized by enhanced body plasticity. Interestingly, there is preliminary evidence that recovery from eating disorder does not normalize body plasticity⁵⁰, demanding for future research on the underlying mechanisms.

Since there is evidence that normal psychological functioning requires certainty about the spatial characteristics one's own body⁵¹, the disturbed processing in BPD might explain other dissociation-related experiences, such as impairments in hearing and seeing and other higher-

order cognitive functions. Together with the results provided in our study, we suggest that the clear delineation of one's own bodily borders might be a prerequisite for normal psychological functioning. Dissociation might be associated with a rather labile body percept related to exaggerated sensory integration processes causing the diverse perceptual impairments in BPD. As a consequence of enhanced body plasticity, BPD patients might be unable to stabilize self-awareness and related concepts, such as sexual identity and the self-image. To what extent this enhanced body plasticity is a maladaptive attempt to cope with high emotional reactivity related to traumatic experience needs to be investigated

There are some limitations for the present study. Its correlational design allows for alternative interpretations of the findings. Although we observed a significant association between dissociative symptoms and RHI experiences, the amount of explained variance is small, suggesting that additional factors must be considered. Candidate factors might be traits such as empathy and schizotypy which have been shown to positively co-vary with body plasticity⁵² and have been associated with BPD symptomatology^{53,54}. There might be other important factors to identify and to discriminate in prospective studies. Further, the results on the RHI presented here are significant only on a subjective level. Prospective studies should take advantage on previous studies showing peripheral and central physiological responses accompanied by the induction of bodily illusions^{39,55,56,57}, since our results might at least partly reflect a response bias.

Due to our cross-sectional study design, no causal implications can be derived from the results. Dissociation might cause altered body perception, but reversely, altered body perception due to other clinically relevant features in BPD, such as self-injurious behavior, might trigger the occurrence of dissociation. Longitudinal studies are necessary to understand the temporal sequence of these experiences. Further, it might be that current BPD patients show additional and specific cognitive alterations associated with the impaired sense of self. Patients suffering from depersonalization disorder display a specific pattern of alterations

related to the attentional and perceptual systems, resulting in lower performances in tasks requiring attention, short-term visual and verbal memory, and spatial reasoning within the context of comparable intellectual abilities⁵⁸. There might be a similar mechanism in BPD patients.

5 Conclusions

Our results provide initial empirical evidence for significant alterations in body ownership processing associated with a current BPD diagnosis, resulting in enhanced body plasticity. It is likely that this finding rely on changes in multisensory integration related to brain areas involved in higher-order body perceptions. Dissociation significantly correlated with illusory limb ownership experiences, making body plasticity a marker for BPD and pointing to underlying neural dysfunctions as well as neurochemical alterations. Prospective studies should focus on the biological mechanisms related to altered body ownership experiences, body plasticity, and BPD symptomatology.

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Figure legends (for all printed versions of figures, black-and-white printing is required)

Figure 1: Setup for the rubber hand illusion (RH = rubber hand).

Figure 2: Subjective and behavioral data in the rubber hand illusion experiment. Illusory limb ownership data and proprioceptive drift data obtained in the rubber hand illusion experiment (congruent stimulation condition). * $p < .05$. Error bars indicate the standard error of the mean.

Figure 3: Rubber hand illusion experiences and its association to dissociation in current and remitted borderline personality disorder (BPD) patients and healthy controls (HC). The plots on the left side visualize the relationship between state (a) and trait (d) dissociation across all participants. Given is the mean for healthy controls (HC), remitted BPD (BPDr) and current BPD patients (BPDc). The gray space around the means indicates the standard error of the mean. Regression line represents the trend across all groups. On the right side, the scatter plots for the relationship between illusory limb ownership and state (b) and trait (d) dissociation in the current BPD group are shown. In both correlational analyses on the right side, we controlled for symptom severity (partial correlations). * $p < .05$, ** $p < .01$.

Tables

Table 1: Comorbidities of the samples.

	current BPD	remitted BPD	HC
	<i>n</i> (%)	<i>n</i> (%)	<i>n</i> (%)
Comorbid major depression	11 (32)	6 (32)	0 (0)
Major depression (remitted)	6 (18)	2 (11)	0 (0)
Comorbid post-traumatic stress disorder	6 (18)	0 (0)	0 (0)
Other acute comorbid disorder	16 (47)	5 (26)	0 (0)
More than one acute comorbid disorder	11 (32)	2 (11)	0 (0)

BPD = borderline personality disorder; HC = healthy controls; *n* = number

Table 2: Description of the items used to assess the rubber hand illusion. Bold font indicates target items.

Item #	Wording
1	I felt as if the rubber hand were my hand.
2	The touching of the rubber hand felt just like an actual touch.
3	It felt as if my own hand had moved involuntarily.
4	It visually appeared as if the rubber hand had moved.
5	It seemed as if the touch I was feeling came from somewhere between my own hand and the rubber hand.
6	It seemed as if I might have more than two hands.
7	My own hand felt rubbery.

Table 3: Means and standard deviations (in brackets) of the rubber hand illusion (illusory ownership, synchronous condition) for the three groups included in the study

Measures	current BPD	remitted BPD	HC
	<i>M (SD)</i>	<i>M (SD)</i>	<i>M (SD)</i>
Target items (0 – 10)	5.54 (3.43)	4.31 (3.58)	3.14 (3.64)
ppc drift (in cm)	2.77 (7.18)	0.95 (3.55)	0.20 (3.25)
Distractor items (0 – 10)	1.98 (1.97)	1.48 (1.75)	1.02 (1.37)
Perceived congruence of seen and felt touch (0 – 10)	7.50 (2.38)	8.58 (1.81)	7.44 (3.33)

BPD = borderline personality disorder; HC = healthy controls; *M* = mean; ppc drift = proprioceptive drift; *SD* = standard deviation

Fig. 1

Fig. 2

Fig. 3