EMPIRICAL ARTICLE

Persistent Body Image Disturbance following Recovery from Eating Disorders

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ABSTRACT

Objective: Individuals with an eating disorder experience the rubber hand illusion (RHI) significantly more strongly than healthy controls on both perceptual (proprioceptive drift) and subjective (self-report embodiment questionnaire) measures. This heightened sensitivity to visual information about the body, and/or reduced somatosensory information processing about the body, suggest an increased malleability of the bodily self. The aim of the present study was to explore whether this is a state phenomenon or a persisting individual trait that outlasts the period of acute eating disorder.

Method: The RHI and self-report measures of eating disorder psychopathology (EDI-3 subscales of Drive for Thinness, Bulimia, Body Dissatisfaction, Interoceptive Deficits, and Emotional Dysregulation; DASS-21; and the Self-Objectification Questionnaire) were administered to 78 individuals with an eating disorder, 28 individuals recovered from an eating disorder, and 61 healthy controls.

Results: Proprioceptive drift in recovered individuals was intermediate between the acutely ill and HC groups. Subjective report of the strength of the illusion in recovered individuals was similar to acutely ill individuals.

Discussion: These results suggest that increased malleability of the bodily self persists, at least partially, following recovery and may be a trait phenomenon in people with eating disorders. Those with a lifetime history of an eating disorder may have heightened sensitivity to visual information about the body and reduced somatosensory information processing of the body.

Keywords: bodily self; body perception; eating disorders; recovered; interoception; rubber hand illusion

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Introduction

Embodiment refers to the sense of one's own body, involving a somatic form of knowledge that provides the basis of the sense of self.[1] The rubber hand illusion (RHI) involves a perceptual illusion of feeling ownership of a fake hand[2] and provides a useful quantitative measure of embodiment. In the RHI paradigm, the participant views a fake hand placed in front of them in a similar position to their own hand, which is hidden from view. When the fake hand is stroked in synchrony with the participant's own unseen hand, the participant feels the touch on the fake hand as if the fake hand belonged to them. The RHI paradigm thus involves a three-way interaction between the sensory modalities of touch, vision, and proprioceptive perception of body position in space.[3–5] Many studies have used the RHI paradigm to understand embodiment and the bodily self in healthy individuals.[6–9] Groups with altered body image and body representations have also been studied.[10–13]

In a previous study, we used the RHI to examine the bodily self in individuals acutely affected by an eating disorder.[10] When visual and tactile sensory information was incongruent with proprioception, individuals with an eating disorder experienced the RHI significantly more strongly than healthy controls, as measured by both proprioceptive drift of the participant's stimulated hand towards the rubber hand, and self-reported experience of the illusion. Additionally, both the subjective self-reported experience of the RHI and associated

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proprioceptive biases were correlated with eating disorder psychopathology. These results suggested those with an eating disorder have a heightened sensitivity to visual information which dominates and overrides proprioceptive information. This increased malleability of the sense of one's body may reflect dampened interoceptive perception and/or cognitive inhibition of interoceptive processing.

A key question arising from these findings is whether increased malleability of the bodily self in people with an eating disorder is a state phenomenon, appearing during the acute state of the eating disorder and possibly as a secondary consequence of the disorder (e.g., due to starvation and/or low weight), or whether it is a trait phenomenon that is present before the onset of the eating disorder (perhaps even contributing to its onset) and persists after recovery.

Distinguishing between state and trait factors in eating disorders is important for informing etiological, prevention, and treatment models. Only a few studies to date have considered the bodily self in people recovered from an eating disorder. These have generally focused on physiological functioning,[14] with less focus on interoceptive and exteroceptive processing.[15–17] Interoception refers to the sense of the physiological state of the entire body, involving autonomic nervous system information about the condition of the body and its organs (e.g., taste, smell, hunger, thirst, pain, muscular, and visceral sensation).[18–20] In contrast, exteroception is the sensation of external stimuli, in particular visual objects.[21] Crucially, the body is experienced both exteroceptively and interoceptively. The results of studies in this area are inconsistent, with some evidence for trait disturbances.[15–17] For example, Aschenbrenner et al.[15] studied olfactory (smell) functioning and gustatory (taste) functioning in patients with anorexia nervosa (AN) and bulimia nervosa (BN) throughout inpatient treatment. Their results suggested that gustatory deficits are a trait phenomenon which become exacerbated during the ill state in AN, while olfactory deficits are a state disturbance. However, the study duration was brief (83 days), and participants may have been weight-recovered but not psychologically recovered at discharge. Few studies have used longer follow-up periods, or participants that have achieved long-term recovery, and none have explicitly considered the interoceptive-exteroceptive balance following recovery.

Elevated pain thresholds have often been reported in acute AN, BN, and binge eating disorder.[17,22,23] Stein et al.[23] found evidence that individuals recovered from BN demonstrated an increased pain threshold compared with healthy controls. In contrast, Krieg et al.[24] found no differences in pain threshold between a group recovered from AN, restrained eaters, and unrestrained eaters. However, it is important to note that different criteria for recovery are often used in research, complicating the generalization of findings across studies with recovered people. Indeed, in the study by Stein et al.,[23] individuals recovered from BN were required to have over the previous 12 months: stable normal weight, no bingeing, purging, or restrictive eating patterns, regular menstrual cycles, the absence of any DSM-IV Axis-I disorder and no psychoactive medications. Whereas the recovered participants in the study by Krieg et al.[24] were former inpatients with AN from the previous 10 year period who were included if they were deemed to have achieved a "good outcome" defined as weight above 75% of the ideal body weight, or even "intermediate outcome" if they continued to have low weight (negative deviation of more than 15% from the ideal body weight) and/or menstrual irregularities.

Grunwald et al.[25] longitudinally examined haptic functioning (i.e., sense of touch, involving tactile exploration) using a sunken-reliefs task in individuals with AN, from hospital admission to 1 month after discharge (on average 14.5 months after admission). They found that those with AN demonstrated difficulties with haptic functioning both at low weight and following subsequent weight regain. Measures of EEG power during the haptic tasks, and at rest, were also obtained. Theta power was reduced during haptic perception in those with AN compared to controls both at low weight and following weight regain.

Interoception and exteroception are regarded as the essential sources of information in comprising the sense and experience of the body. Despite Bruch's[26] claims of interoceptive disturbance as central to eating disorders, interoception has not typically been included in studies of body image disturbance in eating disorders. Rather, the cognitive-affective component of body image disturbance has been prioritized. Thus, surprisingly little research has examined body image disturbance as an interoceptive/exteroceptive balance, and none has done so in weight-recovered or fully recovered individuals. Bardone-Cone et al.[27] investigated individuals partially recovered from an ED, defined as full physical and behavioral recovery for the previous three months, but scoring above one standard deviation of the age-matched norm on at least one of the four EDE-Q subscales of Eating Concern, Dietary Restraint, Shape Concern, and Weight Concern. They also examined individuals

who they termed as fully recovered, defined as those with a BMI of at least 18.5, no current eating disorder (in the previous three months), and scoring within one standard deviation of age-matched community norms on all EDE-Q subscales. The partially recovered individuals were similar to individuals acutely ill with an eating disorder in body-related areas of appearance schemas, body shame, and thin-ideal internalization, despite being similar with the fully recovered and healthy control groups for other areas of psychopathology (e.g., psychosocial functioning). The finding of ongoing body image disturbance in the partially recovered group is perhaps not surprising given the fact that this group was defined by increased weight, shape, dietary, and/or eating concern. These findings suggest that, compared with other factors that improve with weight regain and recovery, body image disturbance may be a persistent trait-like factor in eating disorders. Thus, further research is needed regarding state and trait factors relating body image to eating disorders, particularly during recovery.

In summary, the research to date on body image in those recovered from an eating disorder provides some evidence for a trait disturbance. More research on recovered groups is needed. In particular, comparative studies involving both recovered and acutely affected individuals are lacking. No previous research of this kind has clearly focused on the balance of interoceptive and exteroceptive processing related to the body.

Aims and Hypotheses

The aim of the present study was to extend our previous finding of increased malleability of the bodily self in the RHI in individuals with an eating disorder[10] and examine whether this is a state or a trait phenomenon, by investigating recovered individuals. We envisaged three possible results, with very different implications. First, if malleability of the bodily self is a purely *trait* phenomenon, there should be no difference in RHI scores between individuals recovered from an eating disorder and individuals acutely ill with an eating disorder, while both groups should differ significantly from healthy controls. Second, if increased malleability of the bodily self is a *state* phenomenon, then recovered individuals should be similar to healthy controls, while both groups should differ significantly from individuals with an eating disorder. Third, if disturbance of the bodily self is both a state and trait phenomenon, then recovered individuals should demonstrate an intermediate level of disturbance between the acutely ill eating disorder and healthy control groups. Considering that the limited research to date in recovered individuals has suggested enduring effects of body image and other interoceptive and exteroceptive disturbances, we hypothesized that increased malleability of the bodily self is largely a trait phenomenon.

Method

Participants

Twenty-eight individuals recovered from an eating disorder were recruited for this study and comprised the recovered group (REC). They were compared with the ED and HC participants reported in our previous study.[10] The final sample therefore consisted of a total of 167 participants: 28 REC, 78 ED, and 61 HC.

Participants were eligible to take part if they were female, between 18 and 55 years, right-handed, and were proficient in English. In addition to these criteria, participants in the HC group were also required to have a BMI between 18.5 and 25 kg/m^2, to currently not be on a diet to lose weight or have had a history of being underweight (BMI $<$17.5 kg/m^2), to have no history of ED, and to have no current or prior history of psychiatric illness (as defined in the DSM-IV-TR).[28] Individuals in the ED group were also required to meet DSM-IV-TR diagnostic criteria for an eating disorder.[28] The Individuals in the REC group were also required to have a prior history of an eating disorder, but no behavior consistent with an eating disorder for the previous 12 months (e.g., bingeing, purging, or restricting). They were also required to have a BMI between 18.5 and 25 and to not be experiencing (or on medication for) depression or anxiety over the previous 3 months.

Participants were recruited from students and staff at a UK tertiary institution, an eating disorder research volunteer database at this institution, and posters in public settings. Ethical approval was obtained from the Psychiatry, Nursing and Midwifery Research Ethics Sub-Committee (PNM/09/10-19), King's College London. All participants provided informed consent and were offered financial reimbursement for their time and travel.

Measures

Structural Clinical Interview for Diagnosis, Research Version (SCID-I). The SCID is a standardized interview for diagnostic assessment of DSM-IV disorders.[29] A tailored version of the SCID-I using only the overview, screening, and eating disorders modules were administered to assess participants to ensure they met inclusion criteria and to allocate them to the appropriate group.

For recovered participants, the SCID-I depressive and anxiety disorder modules were also administered.

Eating Disorder Inventory—3 (EDI-3). The EDI-3 is a 91-item self-report questionnaire of psychological traits clinically relevant in individuals with an eating disorder.[30] Participants respond on a 6-point Likert scale ("Always" through to "Never"). This study reports the EDI-3 subscales of drive for thinness, bulimia, body dissatisfaction, interoceptive deficits, and emotional dysregulation. Cronbach's α for drive for thinness was 0.83 in the REC group, 0.73 in the ED group, and 0.57 in the HC group. Cronbach's α for the Bulimia subscale was 0.85 in REC, 0.93 in ED, and 0.39 in HC. Cronbach's α for the body dissatisfaction was 0.91 in REC, 0.83 in ED, and 0.82 in HC. Cronbach's α for the interoceptive deficits subscale was 0.90 in REC, 0.86 in ED, and 0.70 in HC. Finally, Cronbach's α for the emotional dysregulation subscale was 0.68 in REC, 0.71 in ED, and 0.65 in HC. Thus, Cronbach's α ranged between 0.68 and 0.91 in the REC group, between 0.71 and 0.93 in the ED group, and between 0.39 and 0.82 in the HC group for these subscales across the three groups of the present sample. Particularly, in the REC and ED group, this is similar to those reported by Garner[30] of 0.67–0.95 for these subscales. For the HC group, however, the drive for thinness and bulimia subscales in particular are lower than those reported by Clausen et al.[31]

Self-Objectification Questionnaire (SOQ). The SOQ is a 10-item self-report assessment of self-objectification.[32] It assesses the extent to which individuals view their bodies in observable, appearance-based, objectified terms versus nonobservable, competence-based, nonobjectified terms. The five appearance-based attributes are physical attractiveness, weight, sex appeal, body measurements, and muscle tone. The five competence-based attributes are muscular strength, physical coordination, health, physical fitness, and physical energy level. Participants rank a list of 10 body attributes in order of how important each is to their physical self-concept. Validity of the SOQ has been demonstrated through significant correlations with measures of appearance anxiety, neuroticism, body dissatisfaction, body shame, and negative affect.[32,33]

Depression Anxiety Stress Scales—21 Item Version (DASS-21). The DASS-21 is a 21-item, three-scale, self-report measure of depression, anxiety, and stress.[34] Each scale consists of seven items and participants respond on a 3-point Likert scale ("Did not apply to me over the past week," through to "Applied to me very much or most of the time over the past week"). The DASS-21 provides a total score, which is the sum of all items. Lovibond and Lovibond[35] reported reliability of 0.91 for the depression scale, 0.84 for the anxiety scale, and 0.90 for the stress scale. In the present study, Cronbach's α for the depression scale was 0.93 in REC, 0.92 in ED, and 0.70 in HC. For the anxiety scale, Cronbach's α was 0.79 in REC, 0.85 in ED, and 0.55 in HC. Cronbach's α for the stress scale was 0.83 in REC, 0.84 in ED, and 0.78 in HC.

Edinburgh Handedness Inventory (EHI). The EHI is a 10-item self-report measure that assesses handedness.[36] It was used to ensure participants were right handed. Cronbach's α was 0.82 in the REC group and 0.81 in the HC group. Cronbach's α was 0.39 in the ED group, which on closer examination increases to 0.73 with the deletion of item 3 (throwing).

Outcome Measures of the Rubber Hand Illusion (RHI). The RHI paradigm performed in this research was based on the original version[2] and is outlined in detail in the *Procedure* section. The two outcome measures of the RHI used were (i) proprioceptive drift and (ii) subjective report of the strength of the illusion, using a self-report questionnaire ("embodiment score"). Proprioceptive drift is a quantitative perceptual measure of the illusion. Participants are asked to indicate the position of their unseen hand using a ruler placed on the work surface prior to and following visuotactile stimulation. Bias in these proprioceptive judgments towards the fake hand due to visuotactile stimulation is taken as a measure of the visual dominance of the fake hand over proprioception of one's own hand.

The self-report embodiment questionnaire is a subjective measure of the illusion about the experience that the rubber hand becomes part of one's own body as a result of the multisensory stimulation provided in the illusion condition. The questionnaire consists of the 10 items found to comprise an embodiment factor in a previous large-scale study by Longo et al.[37] Participants responded on a 7-point Likert scale, ranging from -3 = "strongly disagree" through to $+3$ = "strongly agree" and an embodiment score was calculated from the mean of the 10 item scores. Items included "It seemed like the touch I felt was caused by the paintbrush touching the rubber hand," "It seemed like I was looking directly at my own hand, rather than at a rubber hand," and "It seemed like the rubber hand belonged to me."

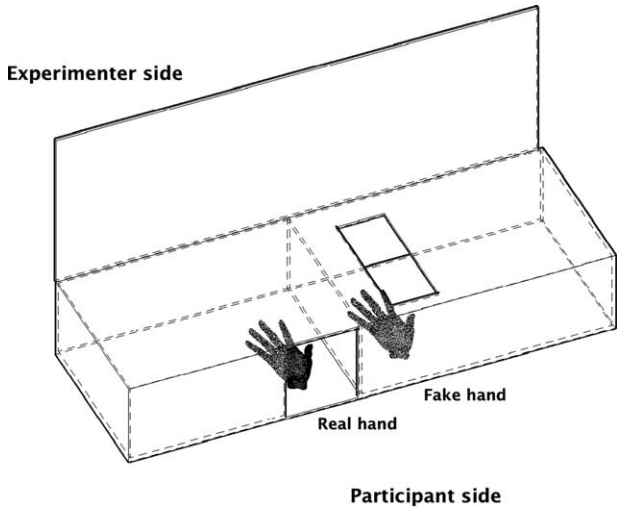
Height and Weight

Height and weight were measured by the experimenter.

Procedure

Each participant was tested individually in a single session by an experimenter (EE) who was not blind to participant group status. For the RHI task, the participant was seated at a table opposite the experimenter, with their left arm placed through

FIGURE 1. Rubber hand illusion apparatus. In this view, the box lid is lifted up, so the participant can view the fake hand and the experimenter is out of sight.



the entrance hole of a specially constructed box (Fig. 1). A life-sized model of a left hand and forearm was placed in the box, directly in front of the participant at the body midline. The participant could see this fake hand through a hole on the top of the box. The box had a hinged cover to expose the fake hand and hide the experimenter from view (and vice versa). Participants wore a cloth smock, which was attached to the front of the box and hid the participant's real arm from view. The distance between the participant's index finger on their hidden left hand and the index finger of the fake hand was 20 cm.

Two visuotactile induction conditions, asynchronous and synchronous, were performed in random order. Prior to each trial, a finger location judgment was obtained by placing a ruler across the top of the box and asking the participant to indicate where they felt the tip of their left index finger was located. After this, the cover of the box was raised and the participant was instructed to focus on the rubber hand while two paintbrushes stroked the fake hand and the participant's real hidden hand for 60 seconds at approximately one stroke per second. In the synchronous condition, the timing of the brush strokes was synchronized, whereas in the asynchronous condition the timing of the brush strokes was out of phase by 180°, such that the stroking of the real and fake hand were ∼500 ms apart. Following this, the box cover was lowered and a postinduction finger location judgment was obtained in the same manner as prior to the induction. The RHI questionnaire was administered verbally after each trial, as is convention.[1]

Analyses

Finger location judgment was calculated as the difference between the position reported by the participant and the actual position of the participant's finger. A positive value indicates a judgment to the right of a participant's actual finger location (i.e., toward the fake hand) and a negative value indicates a judgment to the left of the actual finger location (i.e., away from the fake hand). Proprioceptive drift was calculated from subtracting the preinduction finger location judgment from the postinduction finger location judgment.

The statistical software used was SPSS (version 17). Analyses were performed to examine differences between the REC group from the HC and ED groups. Two separate 3 (group: HC vs. REC vs. ED) $\times$ 2 (visuotactile stimulation condition: synchronous vs. asynchronous) repeated measures ANOVAs were performed, with the first to examine the outcome measure of proprioceptive drift, and the second to examine the subjective measure of the strength of the illusion (embodiment score). Contrasts were used to further explore main effects of group. The significance level for analyses was set at $p < .05$ and results reported are two-tailed.

Results

Demographics

The demographic and clinical details of these participants are reported in **Table 1**. The participants comprising the HC and ED groups presented in this study are the same participants whose data we reported in our previous study.[10] The ED group ($n = 78$) was comprised of 36 individuals with a diagnosis of AN, 22 with a diagnosis of BN, and 20 with a diagnosis of eating disorder not otherwise specified (EDNOS). The REC sample is new and consisted of 20 individuals with a previous history of AN, six with BN, and two with EDNOS. There was no difference in duration of illness between the individuals in the REC group (MDN = 6.0 years, IQR = 8) and the acute ED group (MDN = 8.0 years and IQR = 9), as demonstrated by Mann-Whitney $U = 805.5$, $z = -1.75$, $p = .082$.

There was no significant difference between groups on age, years of education, or handedness. As reported in **Table 1**, the HC group had a significantly higher BMI and significantly lower body dissatisfaction than the ED and REC groups. The ED and REC groups were significantly more depressed, stressed, and anxious than the HC group, and the ED group was significantly more depressed, stressed, and anxious than the REC group. The REC

TABLE 1. Median scores (IQR) of demographic and clinical measures across the three diagnostic groups

	HC (n = 61)	REC (n = 28)	ED (n = 78)	Comparison Test	Post Hoc Test
Age	24.0 (7)	25.5 (8)	23.5 (14)	H(2) = 2.96, p = .227	NA
Education (years)	17.0 (3)	17.0 (9)	16.0 (4)	H(2) = 5.12, p = .077	NA
BMI	21.5 (2.80)	20.7 (2.7)	18.5 (4.0)	H(2) = 37.04, p < .001	HC > REC: U = 620.0, z = −2.07, p = .038 HC > ED: U = 982.0, z = −5.71, p < .001 REC > ED: U = 570.0, z = −3.56, p < .001
Duration of illness (years)	0	6.0 (8)	8.00 (9)	H(2) = 122.17, p < .001	HC < REC: U = .00, z = −9.13, p < .001 HC < ED: U = .00, z = −10.54, p < .001 ED same as REC: U = 805.5, z = −1.74, p = .082
Total DASS score	12.0 (11)	24.0 (30)	53.00 (43)	H(2) = 92.85, p < .001	HC < REC: U = 341.5, z = −4.54, p < .001 HC < ED: U = 214.5, z = −9.19, p < .001 REC < ED: U = 478.5, z = −4.40, p < .001
DASS-depression	2.0 (4)	6.0 (12)	20.00 (24)	H(2) = 80.23, p < .001	HC < REC: U = 520.0, z = −3.03, p = .002 HC < ED: U = 347.5, z = −8.67, p < .001 REC < ED: U = 454.0, z = −4.51, p < .001
DASS-anxiety	2.0 (2)	5.0 (10)	12.00 (14)	H(2) = 60.01, p < .001	HC < REC: U = 486.5, z = −3.38, p = .001 HC < ED: U = 622.0, z = −7.55, p < .001 REC < ED: U = 636.0, z= −3.28, p = .001
DASS-stress	6.0 (6)	14.0 (14)	22.00 (16)	H(2) = 70.89, p < .001	HC < REC: U = 362.5, z = −4.37, p < .001 HC < ED: U = 477.0, z = −8.09, p < .001 REC < ED: U = 639.0, z = −3.25, p = .001
Drive for thinness	2.0 (4)	7.5 (10)	22.50 (8)	H(2) = 122.60, p < .001	HC < REC: U = 301.5, z = −4.94, p < .001 HC < ED: U = 12.0, z = −10.07, p <.001 REC < ED: U = 151.0, z = −6.75, p < .001
Bulimia	1.0 (2)	3.0 (5)	12.00 (18)	H(2) = 58.14, p < .001	HC < REC: U = 499.5, z = −3.20, p = .001 HC < ED: U = 675.5, z = −7.29, p < .001 REC < ED: U = 570.0, z = −3.75, p < .001
Body dissatisfaction	10.0 (12)	12.5 (15)	29.00 (11)	H(2) = 102.19, p < .001	HC < REC: U = 598.0, z = −2.27, p = .023 HC < ED: U = 143.5, z = −9.49, p < .001 REC < ED: U = 223.5, z = −6.23, p < .001
Interoceptive deficits	1.0 (2)	8.5 (12)	17.00 (12)	H(2) = 99.84, p < .001	HC < REC: U = 298.5, z = −5.03, p < .001 HC < ED: U = 151.0, z = −9.51, p < .001 REC < ED: U = 468.0, z = −4.48, p < .001
Emotional dysregulation	1.0 (3)	3.0 (3)	8.50 (7)	H(2) = 84.79, p < .001	HC < REC: U = 390.5, z = −4.20, p < .001 HC < ED: U = 352.0, z = −8.66, p < .001 REC < ED: U = 427.5, z = −4.77, p < .001
Self-objectification	−3.0 (21)	7.0 (23)	8.00 (18)	H(2) = 19.77, p < .001	HC same as REC: U = 637.0, z = −1.92, p = .055 HC < ED: U = 1292.0, z = −4.45, p < .001 REC same as ED: U = 867.5, z = −1.44, p = .151
Laterality quotient	87.5 (22.9)	83.3 (39.9)	89.47 (30.2)	H(2) = 1.22, p = .543	NA

Due to non-normal distributions, statistics reported are medians followed by the interquartile range in brackets and comparison tests were non-parametric: Kruskal–Wallis H test statistic and post hoc tests Mann–Whitney test (U test).
IQR, interquartile range; HC, healthy control group; ED, eating disorder group; REC, recovered from an eating disorder group.

and ED groups also reported greater drive for thinness, bulimia, interoceptive deficits, and emotional dysregulation than the HC group, again with the ED group also reporting significantly higher scores on these measures than the REC group. For self-objectification, the REC group was not significantly different from the HC or ED groups, however, the HC group had a significantly lower mean score than the ED group.

Given the significantly higher drive for thinness and bulimia scores in the sample recruited to comprise the "recovered" group, it appears this group rather consists of individuals that have achieved behavioral recovery (see inclusion criteria) rather than full psychological recovery. Thus, from here onwards the REC group is considered to be a "recovering" group and relabeled as such. However, we have maintained the REC abbreviation for this group for readability.

Rubber Hand Illusion Task

Baseline Finger Location Judgment. Baseline finger location judgments and one-sample t-tests revealed that each group had a significant bias toward the right (body midline) in their finger location judgment. The REC group showed a bias of 2.44 cm (SD = 3.27), which was significant $t(26)$ = 3.88, p = .001. The ED group showed a bias of 2.51 cm (SD = 3.52), which was also significant $t(76)$ = 6.25, p < .001. Finally, the HC group also showed a bias of 1.77 cm (SD = 2.31), which was significant $t(60)$ = 5.98, p < .001. A one-way ANOVA was performed to test for any differences between groups on these values. As Levene's statistic of homogeneity of variance was significant, Welch's F was used, revealing no significant differences between groups $F(2, 68.61)$ = 1.27, p = .288. As there was no significant difference between groups on baseline finger location judgment, it suggests that all groups had

FIGURE 2. Mean and standard error of proprioceptive drift in each group for each RHI condition. Error bars represent ± one standard error of the mean.

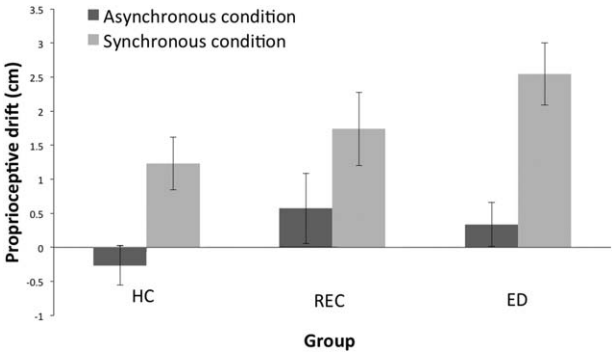
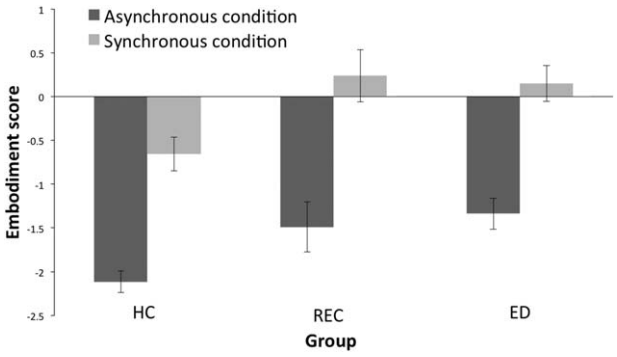


FIGURE 3. Mean and standard error of embodiment score in each group for each RHI condition. Error bars represent ± one standard error of the mean.



similar proprioceptive ability prior to visuotactile induction, and that this factor does not play a role in the results obtained for the dependent variables.

Proprioceptive Drift. The results for proprioceptive drift are illustrated in **Figure 2**. The 3 × 2 repeated measures ANOVA demonstrated a significant main effect of visuotactile stimulation condition. Specifically, there was significantly greater proprioceptive drift in the synchronous versus asynchronous condition $F(1, 160) = 21.68$, $p < .001$. The main effect for group just failed to reach statistical significance $F(1, 160) = 26.04$, $p = .059$. The interaction between visuotactile stimulation condition and group was not significant $F(2, 160) = .85$, $p = .431$. Pairwise contrasts demonstrated no significant differences between the HC and REC group $F(1, 160) = 1.42$, $p = .235$, or the REC and ED group $F(1,160) = 0.25$, $p = 0.618$. The significant difference found in our original study between HC and ED was not replicated, perhaps reflecting reduced statistical power in the present analysis linked to the smaller REC group, though we did find a trend in the same direction $F(1, 160) = 2.87$, $p = .092$.

Embodiment. The results for the embodiment score are illustrated in **Figure 3**. The 3 × 2 repeated measures ANOVA demonstrated a significant main effect of visuotactile stimulation condition, such that the reported experience of the illusion was significantly greater in the synchronous versus asynchronous condition $F(1, 161) = 138.29$, $p < .001$. There was also a significant main effect for group $F(1, 161) = 6.56$, $p = .002$. The interaction between visuotactile stimulation condition and group was not significant $F(2, 161) = .158$, $p = .854$. Pairwise contrasts demonstrated a significant difference between the HC and REC group $F(1, 160) = 5.67$, $p = .018$, but not between the REC and ED group $F(1,160) = 0.01$, $p = .921$. There was a significant difference between the HC and ED groups $F(1,160) = 6.16$, $p = .014$.

Discussion

This study focused on individuals recovering from an eating disorder, in order to examine whether increased malleability of the bodily self as found in individuals with an eating disorder[10] is also present in those in recovery. It was hypothesized that increased malleability of the bodily self is a trait phenomenon, such that individuals recovered from an eating disorder would show comparable levels of the RHI to those with an eating disorder, while demonstrating a significantly larger RHI than the healthy controls.

In the subjective outcome on the RHI task (embodiment score), recovering individuals demonstrated increased malleability of the bodily self. The recovering group reported a significantly greater experience of the RHI relative to the HC group, but not relative to the acute ED group. This suggests that eating disorders involve a trait vulnerability associated with a heightened sensitivity to visual information (i.e., visual capture) about the body. Reduced somatosensory information processing could also explain the result. In particular, the illusion was increased regardless of visuotactile stimulation condition, making these two alternatives difficult to distinguish.

For the proprioceptive drift measure of RHI, the recovering individuals were not significantly different from either the acute ED group or the HC group. The intermediate position of the REC group in proprioceptive drift suggests that the RHI may involve both a trait and state factor. For example, a pre-existing vulnerability may be exacerbated during the period of acute illness. The findings suggest

that a heightened sensitivity to visual information could constitute this proposed preexisting vulnerability. Dominance of visual information over information from other bodily senses could be a trait feature of individuals with eating disorders that becomes further exacerbated during the acute stages of illness.

Clinical Implications

These findings may provide valuable information for developing an understanding of the role of the bodily self in the etiology and maintenance of eating disorders. For example, it may be that prior to illness onset there is a heightened sensitivity to external visual information (e.g., the degree to which the individual perceives her shape to deviate from the thin ideal) that overrides other internal information about or from the body (e.g., somatosensory information, or systemic interoceptive information such as hunger cues). Similarly, maintenance of an eating disorder may be favored by the primacy given to visual processing of the body, leading to maladaptive cognitions and behavior.

Our result has clear implications for treatments of eating disorders. Several computational and psychophysical studies suggest that the representation of external objects,[38] and of one's own body[39] involves an optimal weighted average of external visual and internal somatosensory information. Our results suggest that, in eating disorders, the representation of the body is dominated more by external visual, and less by internal somatosensory information, than in healthy controls. This observation suggests that sensory training to increase the contribution of internal somatosensory information might restore an undistorted body representation. The feasibility of such sensory training is supported by findings that kinesthetic training produced dramatic improvements in proprioceptive representation in children.[22,40] In particular, sensory training could reduce or ameliorate the disturbance in the experience of the bodily self by helping to restore the balance between internal and external/visual information about the body. Increasing interoceptive and/or proprioceptive awareness should produce a less malleable and more accurate body perception. Disproportionate sensitivity to visual information about the body might then be reduced, and reliance on somatosensory and/or interoceptive information should be increased. Our results further suggest that an imbalance between internal and external representations of the body is a trait feature of eating disorders, rather than just a feature of the acute state. This raises the intriguing possibility that imbalance of multisensory sources in body representation might also contribute to the development of an eating disorder. Thus, multisensory therapies might also be preventatively useful in those at risk of developing an eating disorder.

Limitations of the Present Study and Suggestions for Future Research

There are some key limitations in the present study that must be taken into account in interpreting the results and their implications. First, the individuals comprising the recovering sample were heterogeneous, with participants having recovered from a range of eating disorder diagnoses, namely AN, BN, and EDNOS. As such, any specific diagnostic trait differences could not be ascertained in such a sample. The ED group was also a mixed group, composed of AN, BN, and EDNOS. However, as the main findings comparing the eating disorder diagnostic subgroups with the HC group were consistent with the main results of comparing an ED with an HC group in our first acute study,[10] we again included all participants with an eating disorder in a single group in the present analyses. We also extended this approach to individuals recovering from different eating disorder diagnoses. As there is little research to date in the field examining the bodily self in eating disorders, and as there is overlap across eating disorder diagnoses with respect to symptoms and associated behaviors,[41] we regarded this to be an appropriate approach for the present study. Nevertheless, future research examining more homogeneous groups is required. In particular, the ability to compare acutely ill and recovered individuals with an AN diagnosis only, or with a BN diagnosis only, would be informative.

A second limitation of the present study is the smaller number of participants in the REC group, especially as compared with the HC and ED group. However, recruiting recovered participants, particularly those who meet the strict criteria for recovery, is complex. This is partly because recovered individuals cannot be targeted easily in recruitment procedures in the same manner as healthy controls (e.g., through educational institutions) or acute eating disorder individuals (e.g., eating disorder and health/medical services). Another limitation is the recovery status of the recovered individuals in the present study. Although participants were required to have an absence of behaviors consistent with an eating disorder for the previous 12 months and to have a BMI within the healthy range of 18.5–25, weight stability and regular menses for the previous

12-months were not included in the criteria. Additionally, this recovering group reported higher drive for thinness and bulimia scores on the EDI-3, in comparison with controls. Although this was significantly lower than the acute ED group, it was not required that participants score below a certain cut-off in order to meet criteria for our recovered group. Bardone-Cone et al.[27] defined fully recovered as within one standard deviation of age-matched community norms on all EDE-Q subscales. Future research would benefit from including physical (i.e., weight stability) and psychological (i.e., scoring within community norms) criteria for recovery, in addition with the behavioral criteria presently used in order to reduce the possibility of individuals in remission being included with recovered individuals.

It may be that the differences found on the RHI between the acutely ill and recovering group, compared with the controls, may be in some part due to general suggestibility or cognitive augmentation function. However, this may be present in various psychological disorders and not specific to eating disorders.[42] The present study did not examine this aspect of the RHI but it could be examined in future research by including comparison groups of people with other psychological illnesses. Future research could also address the limitation in the present study that the experimenter was not blind to the participant's group status.

Finally, the lower reliability in the HC group on the EDI-3 subscales drive for thinness and bulimia as well as the DASS anxiety subscale should be noted.

Further research is needed to understand the experience of the bodily self in eating disorders. The interaction between state factors, trait factors, and recovery remains particularly under-researched, although there has been some interest in cognitive/attitudinal body image, and in taste, smell, and pain. Our distinction between internal and external representations of the body, and between the interoceptive/proprioceptive and exteroceptive/visual inputs that support them, offers a new framework for studying the bodily self in eating disorders. Our findings from the current and previous study indicate that visual dominance and reduced somatosensory information processing may be a trait of individuals with eating disorders. Therefore, research specifically examining visual and somatosensory information processing in eating disorders is required. For the moment, our research raises the intriguing possibility that multisensory training might restore the imbalance between external and internal representations of the body that characterizes individuals with eating disorders.

Conclusion

The findings from the present study suggest that the disturbance in the experience of the bodily self in people with an eating disorder[10] remains to a large degree following weight regain. Our perceptual outcome measure suggested presence of both state and trait disturbance: the recovering group was intermediate to the healthy control and acute group. Questionnaires regarding the subjective experience of the illusion more clearly demonstrated a trait disturbance: the recovering group was similar to the acute group, but dissimilar to the healthy control group. That is, the subjective disturbance remains after weight regain, while the proprioceptive disturbance shows limited improvement. These findings provide general, although not complete, support for the study hypothesis of increased malleability of the bodily self as a trait disturbance in eating disorders.

The current study adds to the limited research to date that has examined the bodily self in eating disorders, particularly with regard to investigating its trajectory over time. The findings are consistent with previous reports that body image disturbance is a pervasive characteristic of eating disorders and may be an underlying factor in their development.[27,41] Indeed, the results provide preliminary evidence for an underlying trait neuropsychological disturbance in body perception in eating disorders, adding to the limited research to date on interoceptive and exteroceptive processing. With further research, these findings may contribute to our understanding of the experience of the bodily self over different phases of an eating disorder and thus aid in improving current prevention and treatment approaches.

Finally, the degree of recovery in the recovering group must be taken into account in interpreting the findings of the present study and its implications, as this may have influenced the results. It is important for future research to use more comprehensive criteria for recovery in order to more precisely address the state/trait issue of body image disturbance in eating disorders.

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