Persistent body image disturbance following recovery from eating disorders

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Key words: Bodily self, body perception, eating disorders, recovered, interoception, rubber hand illusion.

Abstract

Background: It has been previously found that 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. Such heightened sensitivity to visual information about the body, and reduced somatosensory information processing about the body, indicate an increased malleability of the bodily self. The aim of the present study was to explore whether this is a state or persisting/trait phenomenon. **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 indicate that increased malleability of the bodily self persists following recovery and may be a trait phenomenon in people with eating disorders, such that 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.

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Embodiment refers to the sense of one's own body, involving a somatic form of knowledge that is associated with the sense of self (1). The rubber hand illusion (RHI) involves a perceptual illusion of feeling ownership of a fake hand (2). In this 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 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 proprioception (i.e., the sense of the position of one's body in space) (3, 4). Many studies have used the RHI paradigm to understand embodiment and the bodily self in healthy individuals (5-9), and current research is now also focusing in groups with altered body image and body representations (10-13).

In a previous study, we used the RHI to examine the bodily self in individuals acutely affected by an eating disorder (10). By manipulating visual and tactile sensory information to be incongruent with proprioception, individuals with an eating disorder experienced the RHI significantly more strongly than healthy controls in both proprioceptive drift and self-reported experience of the illusion. Additionally, both the subjective self-reported experience of the RHI and associated 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 be because affected individuals have dampened interoceptive perception, or cognitively inhibited 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 aetiological, 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 is the sense of the physiological state of the entire body, referring to 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). Whereas interoception refers to internal stimuli, exteroception is the sensation of external stimuli (21). The results of studies in this area are inconsistent, with some evidence for trait disturbances (15-17). For example, Aschenbrenner and colleagues (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.

Elevated pain threshold has consistently been found in those acutely ill with AN, BN, and binge eating disorder (17, 22, 23). Stein and colleagues (23) found evidence that individuals recovered from BN (recovery for at least 12 months) demonstrated an increased pain threshold compared with healthy controls. Whereas Krieg and colleagues (24) found no differences in pain threshold between a group recovered from AN, restrained eaters, and unrestrained eaters. Grunwald and colleagues (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 one 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 weight regain. Measures of EEG power during the haptic tasks and rest were also obtained, and demonstrated lower theta power 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 one's sense and experience of their body. Despite Bruch's (26) claims of interoceptive disturbance as key in eating disorders, interoception has not been typically examined in order to understand body image disturbance in EDs. Rather, the cognitive/affective component of body image disturbance has been widely studied in acute ED groups. Even so, surprisingly little research has examined body image disturbance in weight-recovered and fully recovered individuals. Bardone-Cone and colleagues (27) investigated individuals partially recovered from an ED, defined as full physical and behavioural 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 internalisation, despite being similar with the fully recovered and healthy control groups for other areas of psychopathology (e.g., psychosocial functioning). However, 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. Nevertheless, these findings suggest that compared with other factors that improve with weight regain and recovery, body image disturbance may be a more resistant factor to improve in eating disorders and highlights the need to further current understandings of body image in eating disorders and their course during weight regain and recovery.

In summary, the research to date investigating interoceptive and exteroceptive processing (smell, taste, pain, and haptic functioning) and body image in those recovered from an eating disorder provides some evidence for a trait disturbance. Yet more research on recovered groups is needed. In particular, comparative studies involving both recovered and acutely-affected individuals are lacking.

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. Three sets of findings are possible. First, if malleability of the bodily self is a trait phenomenon, there should be no difference on the RHI between individuals recovered from an eating disorder and individuals acutely ill with an eating disorder: 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 hypothesised that increased malleability of the bodily self is 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), such that the final sample for the present analyses 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 18-55 years of age, 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 not currently be on a diet to lose weight or have had a history of being underweight (BMI <17.5 kg/m^2), to not have any history of an ED, and to not have a 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 behaviour 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 18.5-25, 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) (29)

The SCID is a standardised interview for diagnostic assessment of DSM-IV disorders. 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) (30)

The EDI-3 is a 91-item self-report questionnaire of psychological traits clinically relevant in individuals with an eating disorder. 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 ranged between .68-.91 in the REC group, between .71-.91 in the ED group and between 39-.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 .67-.95 for these subscales.

Self-Objectification Questionnaire (SOQ) (31)

The SOQ is a 10-item self-report assessment of self-objectification. It assesses the extent to which individuals view their bodies in observable, appearance-based, objectified terms versus non-observable, competence-based, non-objectified 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 (31, 32).

Depression Anxiety Stress Scales – 21 Item Version (DASS-21) (33)

The DASS-21 is a 21-item, three-scale, self-report measure of depression, anxiety, and stress. Each scale consists of 7 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 (34) reported reliability of .91 for the Depression scale, .84 for the Anxiety scale, and .90 for the Stress scale. Across the three groups in the present study, Cronbach's α ranged between .70-.93 for the Depression scale, .55-.85 for the Anxiety scale, and .78-.84 for the Stress scale across the three groups in this study.

Edinburgh Handedness Inventory (EHI) (35)

The EHI is a 10-item self-report measure that assesses handedness. It was used to ensure

participants were right handed. Cronbach's α was .82 in the REC group and .81 in the HC group. Cronbach's α was .39 in the ED group, which on closer examination increases to .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 where participants are asked to indicate the position of their unseen hand using a ruler placed on the worksurface prior to and following visuotactile stimulation. Bias in these proprioceptive judgements 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 ten items found to comprise an embodiment factor in Longo and colleagues' study (7). 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. For the RHI task, the participant

was seated at a table opposite the experimenter, with their left arm placed through the entrance hole of a specially constructed box (see Figure 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 and the index finger of the fake hand was 20cm.

- INSERT FIGURE 1 HERE –

Two visuotactile induction conditions, asynchronous and synchronous, were performed in random order. Prior to each trial, a finger location judgement 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 synchronised, whereas in the asynchronous condition the timing of the brush strokes was out of phase by 180 degrees, such that the stroking of the real and fake hand were approximately 500ms apart. Following this, the box cover was lowered and a post-induction finger location judgement was obtained in the same manner as prior to the induction. The RHI questionnaire was administered verbally after each trial, as is convention.

Analyses

Finger location judgement 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 judgement to the right of a participant's actual finger location (i.e., towards the fake hand) and a negative value indicates a judgement to the left of the actual finger location (i.e., away from the fake hand). Proprioceptive drift was calculated from subtracting the pre-induction finger location judgement from the

post-induction finger location judgement.

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) x 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. However, where paired tests were performed between the three groups, in post-hoc analyses, a Bonferroni correction was used in order to reduce Type I error. This was calculated by dividing the p-value by 3, as there are three pairs to compare (.05/3 = .017).

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 recovered from AN, six recovered from BN, and two recovered from EDNOS. There was no difference in duration of illness between the individuals in the REC group (MDN=6.0years, IQR = 8) and the acute ED group (MDN = 8.0years 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 was similar to the REC group on BMI and body dissatisfaction. The HC group had a significantly higher BMI and significantly lower body dissatisfaction than the ED group. 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 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.

- INSERT TABLE 1 HERE -

Rubber hand illusion task

Baseline finger location judgement

Baseline finger location judgements and one-sample t-tests revealed that each group had a significant bias towards the right (body midline) in their finger location judgement. The REC group showed a bias of 2.44cm (SD = 3.27), which was significant $t(26) = 3.88$, $p = .001$. The ED group demonstrated a bias of 2.51cm (SD = 3.52), which was also significant $t(76) = 6.25$, $p < .001$. Finally, the HC group also showed a bias of 1.77cm (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 judgement, it suggests that all groups had 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 3x2 repeated measures ANOVA demonstrated significant main effect of visuotactile stimulation condition was found, such that

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 found again, due to the reduced statistical power in the present analysis using the smaller REC group, though we did find a trend in the same direction $F(1,160) = 2.87$, $p = .092$.

- INSERT FIGURE 2 HERE -

Embodiment

The results for the embodiment score are illustrated in Figure 3. The 3x2 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 $F(1,160) = 6.16$, $p = .014$.

- INSERT FIGURE 3 HERE -

DISCUSSION

The aim of this study was to focus on individuals recovered 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 who have recovered. It was hypothesised 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), recovered individuals demonstrated increased malleability of the bodily self, similar to the acute ED group and reported a significantly greater experience of the RHI relative to the HC 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 and possibly also reduced somatosensory information processing due to the increased experience of the illusion found regardless of visuotactile stimulation condition.

In the proprioceptive outcome of the RHI task (proprioceptive drift), the recovered 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, namely, a pre-existing vulnerability that is exacerbated during the period of acute illness. The findings suggest that a heightened sensitivity to visual information could be this proposed pre-existing vulnerability, such that visual information overriding information from other bodily senses is a trait feature of 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 aetiology 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., hunger cues). Similarly, in terms of the maintenance of an eating disorder, the primacy given to visual processing of the body may result in persistent maladaptive cognitions and behaviour (e.g., prioritising visual feedback regarding one's shape, over mounting hunger cues).

Our result has clear implications for treatments of eating disorders. Several computational and psychophysical studies suggest that the representation of external objects (36), and of one's own body (37) 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, since kinesthetic training was found to produce dramatic improvements in proprioceptive representation in children (22, 38). 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 should be reduced and accuracy of somatosensory information processing 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 this imbalance in body representation may in fact 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 three key limitations in the present study. Firstly, the individuals comprising the recovered 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, comprised 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 ED versus HC group in our first acute study

(10), we included all participants with an eating disorder in a single group again in the present analyses. We also extended this approach to individuals recovered from different eating disorder diagnoses. Particularly as there is little research to date in the field examining the bodily self in eating disorders, and because of the overlap across eating disorder diagnoses with respect to symptoms and associated behaviours (39) we regarded this to be a valid approach for the present study. Nevertheless, future research examining more homogeneous groups is required. In particular, a comparison between individuals acutely ill and recovered from AN and BN separately would be informative.

The 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., tertiary education sites) or acute eating disorder individuals (e.g., eating disorder and health/medical services).

The third limitation is the recovery status of the recovered individuals in the present study. Although participants were required to have an absence of behaviours 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 recovered 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 and colleagues (27) defined fully recovered as within one standard deviation of age-matched community norms on all EDE-Q subscales. In order to reduce the possibility of individuals in remission being included with recovered individuals in the REC group, which may be the case in the current REC sample given some of the higher EDI scores than HCs, future research would benefit from including

these physical (i.e., weight stability) and psychological (i.e., scoring within community norms) criteria for recovery, in addition with the behavioural criteria presently used.

Further research is needed to understand the experience of the bodily self in eating disorders, and whether any differences in the acutely ill state are also present in the recovered state as trait factors. With the exception of the research on cognitive/attitudinal body image, taste, smell, and pain, this area has been relatively neglected. Our distinction between internal and external representations of the body, and between the interoceptive/proprioceptive and exteroceptive/visual processes 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 in eating disorders. Therefore, research specifically examining visual capture and somatosensory information processing in eating disorders is required. In particular, multisensory training might, in principle, restore the imbalance between external and internal representations of the body that characterises individuals with ED.

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 and is suggestive of a trait factor. The perceptual outcome measure demonstrated the presence of both state and trait disturbance as the recovered group were intermediate to the healthy control and acute group. While the outcome measure of the subjective experience of the illusion demonstrated more clearly a trait disturbance, as the recovered group was similar to the acute group, but dissimilar to the healthy control group. That is, the subjective disturbance remains after weight regain and recovery, 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, 39). 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.

References

1. Longo MR, Schuur F, Kammers MPM, Tsakiris M, Haggard P. What is embodiment? A psychometric approach. Cognition. 2008;107(3):978-98.
2. Botvinick M, Cohen J. Rubber hands 'feel' touch that eyes see. Nature. 1998;391(6669):756.
3. Botvinick M. Probing the neural basis of body ownership. Science. 2004;305(5685):782-3.
4. Pavani F, Spence C, Driver J. Visual capture of touch: Out-of-the-body experiences with rubber gloves. Psychological Science. 2000;11(5):353-9.
5. Ehrsson HH, Spence C, Passingham RE. That's my hand! Activity in premotor cortex reflects feeling of ownership of a limb. Science. 2004;305(5685):875-7.
6. Longo MR, Schuur F, Kammers MPM, Tsakiris M, Haggard P. Self awareness and the body image. Acta Psychol (Amst). 2009;132(2):166-72.
7. Longo MR, Schüür F, Kammers MPM, Tsakiris M, Haggard P. What is embodiment? A psychometric approach. Cognition. 2008;107(3):978-98.
8. Tsakiris M, Haggard P. The rubber hand illusion revisited: Visuotactile integration and self-attribution. Journal of Experimental Psychology-Human Perception and Performance. 2005;31(1):80-91.
9. Tsakiris M, Hesse MD, Boy C, Haggard P, Fink GR. Neural signatures of body ownership: A sensory network for bodily self-consciousness. Cereb Cortex. 2007;17(10):2235-44.
10. Eshkevari E, Rieger E, Longo MR, Haggard P, Treasure J. Increased plasticity of the bodily self in eating disorders. Psychological medicine. 2012;42(4):819-28.
11. Peled A, Pressman A, Geva AB, Modai I. Somatosensory evoked potentials during a rubber-hand illusion in schizophrenia. Schizophr Res. 2003;64(2-3):157-63.
12. Peled A, Ritsner M, Hirshman S, Geva AB, Modai I. A rubber-hand touch feel illusion in schizophrenic patients. Neurosci Lett. 1999:S33-S.
13. Thakkar KN, Nichols HS, McIntosh LG, Park S. Disturbances in Body Ownership in Schizophrenia: Evidence from the Rubber Hand Illusion and Case Study of a Spontaneous Out-of-Body Experience. PLoS One. 2011;6(10):e27089.
14. Herzog W, Deter HC, Fiehn W, Petzold E. Medical findings and predictors of long-term physical outcome in anorexia nervosa: a prospective, 12-year follow-up study. Psychological medicine. 1997;27(2):269-79.
15. Aschenbrenner K, Scholze N, Joraschky P, Hummel T. Gustatory and olfactory sensitivity in patients with anorexia and bulimia in the course of treatment. J Psychiatr Res. 2008;43(2):129-37.
16. Grunwald M, Ettrich C, Krause W, Assmann B, Dahne A, Weiss T, et al. Haptic perception in anorexia nervosa before and after weight gain. Journal of Clinical and Experimental Neuropsychology. 2001;23(4):520-9.
17. Papezova H, Yamamotova A, Uher R. Elevated pain threshold in eating disorders: physiological and psychological factors. J Psychiatr Res. 2005;39(4):431-8.
18. Craig AD. How do you feel? Interoception: the sense of the physiological condition of the body. Nat Rev Neurosci. 2002;3(8):655-66.
19. Craig AD. Interoception: the sense of the physiological condition of the body. Curr Opin Neurobiol. 2003;13(4):500-5.
20. Kaye W. Neurobiology of anorexia and bulimia nervosa. Physiol Behav. 2008;94(1):121-35.

21. Damasio AR. The feeling of what happens: Body and emotion in the making of consciousness. New York: Harcourt Brace; 1999.
22. Sims K, Henderson SE, Hulme C, Morton J. The remediation of clumsiness. I: An evaluation of Laszlo's kinaesthetic approach. Dev Med Child Neurol. 1996;38(11):976-87.
23. Stein D, Kaye WH, Matsunaga H, Myers D, Orbach I, Har-Even D, et al. Pain perception in recovered bulimia nervosa patients. The International journal of eating disorders. 2003;34(3):331-6.
24. Krieg JC, Roscher S, Strian F, Pirke KM, Lautenbacher S. Pain sensitivity in recovered anorexics, restrained and unrestrained eaters. J Psychosom Res. 1993;37(6):595-601.
25. Grunwald M, Ettrich C, Assmann B, Dahne A, Krause W, Busse F, et al. Deficits in haptic perception and right parietal theta power changes in patients with anorexia nervosa before and after weight gain. Int J Eating Disord. 2001;29(4):417-28.
26. Bruch H. Perceptual and Conceptual Disturbances in Anorexia Nervosa. Psychosom Med. 1962;24(2):187-94.
27. Bardone-Cone AM, Harney MB, Maldonado CR, Lawson MA, Robinson DP, Smith R, et al. Defining recovery from an eating disorder: Conceptualization, validation, and examination of psychosocial functioning and psychiatric comorbidity. Behav Res Ther. 2010;48(3):194-202.
28. American Psychiatric Association. Diagnostic and statistical manual of mental disorders. 4th ed. Text revision (DSM-IV-TR). Washington, DC: American Psychiatric Association; 2000.
29. First MB, Spitzer RL, Gibbon M, Williams JBW. Structured Clinical Interview for DSM-IV-TR Axis-I Disorders, Research Version, Patient Edition. (SCID-I/P). New York: Biometrics research, New York State Psychiatric Institute.; 2002.
30. Garner DM. Eating Disorder Inventory-3 (EDI-3). Florida: Psychological Assessment Resources Inc.; 2004.
31. Noll SM, Fredrickson BL. A mediational model linking self-objectification, body shame, and disordered eating. Psychology of Women Quarterly. 1998;22(4):623-36.
32. Miner-Rubino K, Twenge JM, Fredrickson BL. Trait self-objectification on women: Affective and personality correlates. Journal of Research in Personality 2002;36:147-72.
33. Geller J, Cockell SJ, Goldner EM. Inhibited expression of negative emotions and interpersonal orientation in anorexia nervosa. Int J Eating Disord. 2000;28(1):8-19.
34. Lovibond SH, Lovibond PF. Manual for the depression anxiety stress scales. Sydney: Psychology Foundation; 1995.
35. Oldfield RC. The assessment and analysis of handedness: the Edinburgh inventory. Neuropsychologia. 1971;9:97-113.
36. Ernst MO, Banks MS. Humans integrate visual and haptic information in a statistically optimal fashion. Nature. 2002;415(6870):429-33.
37. van Beers RJ, Wolpert DM, Haggard P. When feeling is more important than seeing in sensorimotor adaptation. Curr Biol. 2002;12(10):834-7.
38. Sims K, Henderson SE, Morton J, Hulme C. The remediation of clumsiness. II. Is kinaesthesis the answer? Dev Med Child Neurol. 1996;38(11):988-97.
39. Treasure J, Claudino AM, Zucker N. Eating disorders. Lancet 2010;375(9714):583-93.

Tables

Table 1

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

Figure captions

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.

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.

Acknowledgements

EE was supported in part by the Butterfly Foundation, a charity that provides support for Australians who suffer from eating disorders and negative body image issues and their carers. The funding sponsor did not play a role in the study design; in the collection, analysis and interpretation of data; or in the writing and submission of this article.

Financial disclosures

All authors report no biomedical financial interests or potential conflicts of interests.