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Investigating the Components of Body Image Disturbance within Eating Disorders

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The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest

Author contribution statement

MC and CP contributed to the conception and design of the experiment. MC collected and analysed the data under the supervision of CP. MC drafted the manuscript, and CP provided critical revisions. All authors approved the manuscript before submission.

Keywords

Eating Disorders, body image, multisensory integration, Moving rubber hand illusion, Implicit Body Satisfaction

Abstract

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Body image disturbance has been highlighted as a common characteristic within the development and maintenance of clinical eating disorders (EDs), represented by alterations in an individual's bodily experience. However, whilst the perceptual stability of the sense of body ownership has been investigated in ED patients, the stability of the sense of body agency in those with ED is yet to be examined. Therefore, body ownership and body agency were investigated using the moving rubber hand illusion, alongside measures of explicit and implicit body satisfaction. Furthermore, with evidence demonstrating a direct link between perceptual and cognitive-affective components of body image in the healthy population, the relationship between measures of body perception and body satisfaction was investigated. Results showed that both ED and healthy individuals displayed a similar subjective experience of illusory ownership and agency towards the fake hand, following voluntary movement. However, whilst both groups initially overestimated their own hand width prior to the illusion, the ED group displayed a significant reduction in hands size estimation following the illusion, which was not matched to the same degree in healthy individuals. In addition, ED individuals displayed a significantly lower body satisfaction compared with healthy females, on both an explicit and implicit level. Such implicit outcomes were shown to be driven specifically by a weaker association between the self and attractiveness. Finally, a significant relationship was observed between specific perceptual measures and implicit body satisfaction, which highlights the important link between perceptual and cognitive-affective components of one's body image. Together, such findings provide a useful foundation for further research to study the conditions in which these two components relate with regard to body image and its disturbance, particularly in relation to the prognosis and treatment of EDs.

Contribution to the field

Body image disturbance is a common symptom amongst eating disorders and is thus a key target for therapy. Many current treatments focus on cognitive components of body image disturbance; however, recent research suggests that body dissatisfaction may be influenced by an inaccurate perceptual experience of the body, which is not addressed in most treatments. Indeed, research using multisensory illusion methods in healthy individuals has shown how changes to the perception of one's body can influence the emotions related to the body. Therefore, the present experiment investigated the relationship between body perception and body satisfaction within eating disorder patients, compared with healthy controls. Participants were tested on the stability of body perception using an experimental perceptual illusion, named the Moving Rubber Hand Illusion. Perceptual estimations of one's own body size were investigated using hand width estimations, completed before and after the illusion. Links between illusion susceptibility and body satisfaction levels were explored using explicit and implicit measures. Such work aims to increase our understanding of the links between perception of the body and its influence on emotional experience, which may help identify a key risk of relapse within eating disorders.

Ethics statements

Studies involving animal subjects

Generated Statement: No animal studies are presented in this manuscript.

Studies involving human subjects

Generated Statement: The studies involving human participants were reviewed and approved by The NHS Health Research Authority (North East - York Research Ethics Committee; Project ID: 199702)
The Retreat Mental Health Care Centre, York (Research Governance Committee)
Beat Eating Disorders Charity Research Ethics Committee
The University of York Departmental Ethics Committee. The patients/participants provided their written informed consent to participate in this study.

Inclusion of identifiable human data

Generated Statement: No potentially identifiable human images or data is presented in this study.

Data availability statement

Generated Statement: All datasets generated for this study are included in the manuscript/supplementary files.

Investigating the Components of Body Image Disturbance within Eating Disorders

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Keywords: Eating Disorders, Body Image, Multisensory Integration, Moving Rubber Hand Illusion, Implicit Body Satisfaction

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Abstract

Body image disturbance has been highlighted as a common characteristic within the development and maintenance of clinical eating disorders (EDs), represented by alterations in an individual's bodily experience. However, whilst the perceptual stability of the sense of body ownership has been investigated in ED patients, the stability of the sense of body agency in those with ED is yet to be examined. Therefore, body ownership and body agency were investigated using the *moving rubber hand illusion*, alongside measures of explicit and implicit body satisfaction. Furthermore, with evidence demonstrating a direct link between perceptual and cognitive-affective components of body image in the healthy population, the relationship between measures of body perception and body satisfaction was investigated. Results showed that both ED and healthy individuals displayed a similar subjective experience of illusory ownership and agency towards the fake hand, following voluntary movement. However, whilst both groups initially overestimated their own hand width prior to the illusion, the ED group displayed a significant reduction in hands size estimation following the illusion, which was not matched to the same degree in healthy individuals. In addition, ED individuals displayed a significantly lower body satisfaction compared with healthy females, on both an explicit and implicit level. Such implicit outcomes were shown to be driven specifically by a weaker association between the self and attractiveness. Finally, a significant relationship was observed between specific perceptual measures and implicit body satisfaction, which highlights the important link between perceptual and cognitive-affective components of one's body image. Together, such findings provide a useful foundation for further research to study the conditions in which these two components relate with regard to body image and its disturbance, particularly in relation to the prognosis and treatment of EDs.

1. Introduction

A common hallmark in the development and maintenance of clinical eating disorders (EDs) is a disturbance in body image (Stice, 2002), which refers to distortions or alterations in the way in which an individual experiences their body shape or weight (American Psychiatric Association, 2013). Body image disturbance is argued to be a multidimensional construct, which is commonly divided into two key components (Cash & Deagle, 1997). The perceptual component denotes issues in estimating one's own body size and dimensions, with evidence that, at a group level, ED individuals typically overestimate the size of their own body significantly more than healthy individuals (Gardner & Brown, 2014; Øverås, Kapstad, Brunborg, Landrø, & Lask, 2014). Additionally, the cognitive-affective component is associated with negative attitudes and emotions towards one's own body, commonly displayed by extreme feelings of body dissatisfaction amongst patients (Cash & Deagle, 1997; Mai et al., 2015). Indeed, research has suggested that ED individuals lack a self-serving body image bias that is typically observed in the healthy population, which reflects a highly biased positive perception to one's own attractiveness relative to the perception from others (Jansen, Smeets, Martijn, & Nederkoorn, 2006). Importantly, such a self-serving bias in healthy individuals acts as a protective factor against poor mental health (Martijn, Alleva, & Jansen, 2015), therefore the lack of such a bias is likely to have a negative effect towards one's body satisfaction amongst EDs.

Historically, research has predominantly focused on the cognitive-affective component of body image disturbances within EDs (Cash & Deagle, 1997; Urgesi, 2015), with treatment programmes commonly targeting dysfunctional cognitions and emotions relating to the body (Martijn et al, 2015; Alleva et al, 2015; Murphy et al, 2010). However, more recent research suggests that such distorted cognitions may be influenced by an inaccurate perceptual experience of the body (Guardia et al., 2010; Keizer et al., 2014), which remains comparably less understood amongst EDs (Boehm et al., 2016). Indeed, evidence has shown that clinical outcomes are poorer amongst those who report greater misperception of their body (Boehm et al., 2016; Keel, Dorer, Franko, Jackson, & Herzog, 2005; Roy & Meilleur, 2010). Moreover, the perceptual component of body image disturbances in EDs has

primarily been investigated using visual size estimation tasks (Cash & Deagle, 1997; Gardner & Brown, 2014; Urgesi et al., 2012). However, recent neuroscientific research has revealed higher-order perceptual disturbances amongst EDs within multiple sensory domains, including tactile perception (Keizer et al., 2011; Keizer, Smeets, Dijkerman, van Elburg, & Postma, 2012), proprioception (Guardia, Carey, Cottencin, Thomas, & Luyat, 2013; Guardia, Cottencin, Thomas, Dodin, & Luyat, 2012), interoception (Badoud & Tsakiris, 2017; Pollatos et al., 2008), and the integration of multiple sensory signals (Eshkevari, Rieger, Longo, Haggard, & Treasure, 2012; Keizer et al., 2014). Therefore, it is important that research investigates how ED individuals process multisensory body information, and the role this might play within the perceptual component of body image disturbances.

Disturbances in the integration of sensory information have been observed amongst ED patients using multisensory body illusions (Eshkevari et al., 2012). The most studied of these paradigms is the *Rubber Hand Illusion* (RHI), in which individuals typically experience ownership over a fake rubber hand when it is stroked synchronously with their own hand, which is hidden out of view (Botvinick & Cohen, 1998). Crucially, ED patients have been shown to display a greater sense of ownership towards the fake hand compared with healthy controls during the RHI, following both synchronous (illusion) and asynchronous (control) conditions, with susceptibility to the illusion positively associated with ED psychopathology (Eshkevari et al., 2012). Such findings suggest that ED individuals display a greater reliance towards visual body information, which dominates proprioceptive sensory input during body ownership. More recent work has provided corroborative evidence, with induction to the RHI also shown to improve initial overestimation of hand size amongst patients (Keizer et al., 2014), which highlights that such malleability observed in patients' body representation can be developed to a more accurate estimation of one's own body size (Keizer et al., 2014; Keizer, van Elburg, Helms, & Dijkerman, 2016). Taken together, the above evidence underlines the importance of researching perceptual disturbances of body image in EDs from a multisensory perspective (Eshkevari, Rieger, Longo, Haggard, & Treasure, 2014), with improvements in the perceptual accuracy of one's own body dimensions likely to act as a protective factor against relapse if coping strategies designed to address cognitive-affective components of body image were to break down (Bardone-Cone et al., 2010).

A component which is intimately linked with body ownership in contributing towards one's coherent body representation is the sense of agency, which refers to the experience of authorship over an active, volitional bodily movement (Haggard, 2017; Synofzik, Vosgerau, & Newen, 2008; Tsakiris, Schütz-Bosbach, & Gallagher, 2007). Such a sense of control over one's motor actions is essential in contributing towards one's bodily experience and interaction with the external environment (Haggard, 2017). Indeed, disturbances in the sense of agency have been implicated as an important feature within numerous psychiatric disorders (Gentsch, Schutz-Bosbach, Endrass, & Kathmann, 2012; Voss, Chambon, Wenke, Kühn, & Haggard, 2017). Importantly, whilst research has shown that ED patients display alterations in the execution of body-scaled action with regard to unconscious sensorimotor aspects of body representation (Guardia, Metral, et al., 2013; Keizer et al., 2013; Metral et al., 2014), the conscious sense of agency has not been directly investigated within EDs, particularly how alterations in this component may play a role within body image disturbances. An existing experimental paradigm that measures the sense of body ownership and agency is the *Moving Rubber Hand Illusion* (mRHI; Kalckert & Ehrsson, 2012; 2014), which extends upon the RHI by introducing active, volitional movement to a fake model hand. In a similar manner to the classic RHI, synchronous movements typically elicit a strong sense of ownership towards the fake hand, but also a sense of agency – i.e. feeling of controlling the movement of the fake hand. Such feelings of agency are absent when voluntary movements are asynchronous with the movements of the fake hand. Therefore, the mRHI provides the opportunity to experimentally investigate the sense of body ownership and body agency, and their relationship in contributing towards a coherent body representation.

With regard to the cognitive-affective component of body image disturbance, the most commonly used assessments of ED pathology in research and treatment include self-reports (e.g. clinical interviews, standardized questionnaires) which target explicit cognitions and behaviours (Exterkate, Vriesendorp, & de Jong, 2009). However, research has shown that such explicit measures alone may not accurately reflect an individual's attitudes or behaviours towards certain concepts (Ahern, Bennett, & Hetherington, 2008; Stice, Fisher, & Lowe, 2004), particularly amongst ED patients who can display

denial towards the severity of their disorder (Vitousek, Daly, & Heiser, 1991). Therefore, it is clinically useful to supplement explicit body-related measures with implicit measures that are free from response bias (Vartanian, Polivy, & Herman, 2004). Implicit cognitive mechanisms are argued play a key role in the pathology of EDs (Aspen, Darcy, & Lock, 2013; Robinson, Safer, Austin, & Etkin, 2015), and could provide an insight into an ED individual's disordered cognitions and behaviours which cannot be obtained from self-reports (Vartanian et al., 2004). A commonly used measure to assess implicit attitudes is the *Implicit Association Test* (IAT; Greenwald, McGhee, & Schwartz, 1998), which is a computer-based reaction time task designed to measure the strength of automatic association between certain concepts (see Methods section for further details). Conceptually, it is argued that individuals typically pair target words more quickly with the category that is consistent with their own beliefs or cognitions (Greenwald et al., 1998). Therefore, the IAT provides the opportunity to tap into an individual's implicit cognitions towards certain concepts, including the self.

Whilst many studies have used the IAT to measure implicit social attitudes (Richetin, Perugini, Prestwich, & O'Gorman, 2007), studies have also measured implicit attitudes and cognitions towards the self (Greenwald & Farnham, 2000; Lane, Banaji, Nosek, & Greenwald, 2007; O'Brien, Hunter, Halberstadt, & Anderson, 2007; Richetin, Xaiz, Maravita, & Perugini, 2012). Previous research has established a relationship between implicit body satisfaction with ED symptoms in healthy individuals (Ahern et al., 2008; Gumble & Carels, 2012; Preston & Ehrsson, 2018). Moreover, previous studies have examined implicit attitudes towards body size (Cserjési et al., 2010; Parling, Cernvall, Stewart, Barnes-Holmes, & Ghaderi, 2012; Smith, Joiner, & Dodd, 2014) and food (Spring & Bulik, 2014). However, to the authors' knowledge, the present study is the first to investigate implicit body satisfaction using the IAT in an ED sample. Investigating implicit cognitions towards body satisfaction amongst ED individuals is important in understanding the multifaceted constructs which underlie body image disturbances (Urgesi, 2015), particularly how explicit and implicit cognitions relate to each other, which may have important implications for long term recovery and relapse.

Taken together, the present study examines both perceptual and cognitive-affective components of body image in EDs, extending each with agency and implicit measures respectively. Firstly, given the intrinsic link between body ownership and agency towards a coherent body representation, it is hypothesised that the predicted instability in the sense of body ownership would also feed into instability towards the sense of body agency in ED individuals. Moreover, the effect of the illusion was investigated towards perceptual estimations of hand size. In line with previous research (Keizer et al., 2014), it is predicted that ED individuals will show initial overestimation of their own hand size but increase accuracy following the illusion, with healthy controls expected to display a stable estimation throughout. Secondly, it is predicted that lower explicit body satisfaction which is expected to be displayed in ED individuals would also extend to lower body satisfaction on an implicit level, compared with healthy females. Thirdly, whilst it has been previously argued that perceptual and cognitive-affective alterations contribute independently towards body image disturbances (Cash & Deagle, 1997), increasing research has highlighted a direct link between the body perception and the emotional body experience within healthy and clinical samples (Hagman et al., 2015; Preston & Ehrsson, 2014, 2016, 2018). Therefore, the possible links between body perception and body satisfaction were investigated, in relation to the influence this may have in ED psychopathology. It is predicted that individuals with greater instability on perceptual multisensory illusion measures would display reduced scores on body satisfaction measures.

2. Methods

2.1 Participants

The present study received ethical approval from the NHS Health Research Authority (North East - York Research Ethics Committee; Project ID: 199702), The Retreat Mental Health Care Centre, York (Research Governance Committee), *Beat* Eating Disorders Charity Research Ethics Committee, and the University of York Departmental Ethics Committee. The study was conducted in accordance with the Declaration of Helsinki, with all participants providing informed consent to take part.

Twenty-eight female participants with an ED diagnosis participated in the present study (Mean age = 26.11, SD ± 11.69). The ED group consisted of 19 individuals with a diagnosis of anorexia nervosa (AN), 2 with a diagnosis of bulimia nervosa (BN), 2 with a diagnosis of binge eating disorder (BED), and 5 with Other Specified Feeding or Eating Disorder (OSFED). Of the above sample, 5 participants were recruited as inpatients via The Retreat, York (Tuke Centre and Naomi Unit), and 23 were recruited as outpatients via the *Beat* website, which is the UK's leading charity supporting those suffering with eating disorders. Specifically, the study was advertised via the *Beat* research page and promoted via the charity's email distribution list. Inclusion criteria for the ED group was a clinical diagnosis of an ED, with no restrictions on previous ED diagnosis. Participants recruited via The Retreat had a clinical diagnosis confirmed by the patients' psychiatrist, with participants recruited via *Beat* providing a self-reported ED diagnosis, with subsequent assessment from all participants using *Eating Disorder Examination Questionnaire* (EDE-Q). Such recruitment of clinical individuals via self-reported diagnosis has been used in previous research (Groves, Kennett, & Gillmeister, 2017). Thirty-one female healthy controls (HC) (Mean age = 19.10, SD ± 1.27) were recruited via the University of York, who participated in the present study in return for course credit. Inclusion criteria for the HC group were no current or previous neurological/psychological disorders (self-report). In addition, HCs were explicitly screened for the presence of an ED using an established clinical cut-off of a global EDE-Q score greater than 2.8 (Mond et al., 2008). All participants were required to be over the age of 18, with no physical condition on their arm or hand which would prevent them from performing the experiment (e.g. severe eczema, scarring, psoriasis). Two ED participants (1 x AN diagnosis; 1 x BN diagnosis) whose age was

206 ≥ 2 SD above the group mean (64 years and 60 years) were excluded from data analysis. Seven HC
207 participants were excluded from data analysis; one self-reported a current psychological disorder and
208 six had a global EDE-Q score above the 2.8 global clinical cut-off. Therefore, the final sample size for
209 analysis was 26 ED participants and 24 HC participants. Participant demographic information for both
210 groups following exclusion can be seen in Table 1.
211
212 [INSERT TABLE 1]
213
214 *2.2 Materials*
215 Experimental materials involved a wooden platform (35cm x 30cm x 13cm; see Figure 1)
216 positioned on a table, on top of which was resting a life-sized wooden artist's right hand (measuring
217 30cm from base of the wrist to tip of the middle finger), wearing a latex glove with the palm faced
218 down. Participants were seated at the table and asked to wear an identical latex glove on their right
219 hand, which they then placed underneath the wooden platform, directly below the model hand (see
220 Figure 1). The participant's left hand was in a resting position and kept still by their side. Participants
221 wore a black cape around their neck, which occluded their right forearm and the open wrist of the fake
222 hand on the wooden platform, to appear in an anatomically congruent position to the fake hand. A
223 plastic finger cap was then placed on the tip of participant's right index finger which was mechanically
224 connected to a matching finger cap on the fake hand by a thin wooden dowel passing through a small
225 hole in the wooden platform, which was attached/detached for the respective experimental condition
226 (see *Procedure* section). Experimental trials and responses for both the Moving Rubber Hand Illusion
227 and Implicit Association Test were made using PsychoPy 2 (Peirce, 2007) on an Apple iMac computer
228 (1.6GHz dual-core Intel Core i5 processor).
229
230 [INSERT FIGURE 1]
231 **Figure 1.** Experimental Set-up. a) Participants sat opposite the experimenter, and placed their right hand
232 under the platform, directly below the fake hand which was viewed on top, with a black cape covering their
233 right arm. For each measure within the illusion, participants completed synchronous (b) conditions in which

the connection between the two hands was attached, and asynchronous (c) conditions in which the connection was detached, and the experimenter moved the fake hand independently from participant's own hand. d) Proprioceptive drift measure, in which participants closed their eyes and indicated the felt location of their right index finger, using a coloured marker pen on the grid paper attached to the side of the set-up.

2.3 Measures

2.3.1 Moving Rubber Hand Illusion

2.3.1.1 Questionnaire

Following experimental trials, the subjective experience of the illusion was recorded using a 12-statement illusion questionnaire (see Table 2), adapted from previous studies (Kalckert & Ehrsson, 2012). This questionnaire was composed of two subcomponents, addressing the feeling of ownership towards the fake hand (3 items), and feeling of agency over the movements of the fake hand (3 items). A further six control statements (3 ownership control, 3 agency control) served to control for participant compliance and suggestibility. Participants were asked to rate the extent to which they agreed with each statement on a seven-point Likert scale (-3 strongly disagree to +3 strongly agree) specifically based on the previous trial. All statements were presented in a randomised order.

[INSERT TABLE 2]

2.3.1.2 Proprioceptive Drift

With eyes closed, participants estimated the perceived height of their unseen, right index finger using an A4 sheet of (millimetre grid) graph paper attached to the side of the experimental set-up (see Figure 1d). Participants were required to make one swift, but accurate pointing movement towards the graph paper using a coloured marker pen held in their left hand. Each pointing movement was completed three times, with the starting point randomised between participants' nose, shoulder, or hip, to account for learned motor movement. An average pointing estimation was calculated across the three responses, with pointing movements measured both pre- and post-experimental trial.

2.3.1.3 Hand Size Estimation

Participants were asked to estimate the width of their own hand (at the widest point) prior to the illusion (baseline estimation) and post-experimental trial (Keizer et al., 2014). Both the fake hand and the participants' own hand was hidden from view using an occluding box during all hand size estimations. For each estimation, the experimenter moved two pointers of a calliper alongside the back of the set-up, occluding their own hands to prevent any further visual cues. Estimations were made with the two pointers of the calliper, once moving towards each other (inwards), and once with pointers moving away from each other (outwards). Participants made their judgements by verbally indicating the point at which their hand would fit precisely between the two pointers. The order of calliper movement (inwards/outwards) was counterbalanced across all participants. A baseline estimation was first made before the illusion, with subsequent post-experimental estimations made following each trial. Changes in hand size estimation were calculated by subtracting the average width of post-trial estimations from the baseline estimation. Participants' actual hand size was measured at the end of the experiment.

2.3.2 Body Satisfaction

2.3.2.1 Explicit Body Satisfaction

A continuous Visual Analogue Scale (VAS), ranging from 0 to 100 was used to assess participant's explicit, state body satisfaction. Participants were asked "*Right now, how satisfied do you feel with your body?*" with the scale anchored by "*Extremely Dissatisfied*" (0) and "*Extremely Satisfied*" (100) (Durkin & Paxton, 2002; Preston & Ehrsson, 2016). VAS items have been shown to have good convergent validity with other measures of body satisfaction (Cahill & Mussap, 2007).

2.3.2.2 Implicit Body Satisfaction

Implicit body satisfaction was measured using the Implicit Association Test (IAT; Greenwald et al., 1998), in which participants were instructed to categorise target words appearing in the centre of the screen into one of four categories, using only two response options (left/right) (see Figure 2). Within the body satisfaction IAT (adapted from Gumble & Carels, 2012; Preston & Ehrsson, 2018), target

categories were *Self* and *Other*, and attribute categories were *Attractive* and *Unattractive*, with pairings from each category appearing in the top left/right corner of the screen. Target words were chosen based on pilot data from an independent sample, to ensure that words were appropriate and culturally relevant for the present study. Target words and their respective categories can be seen in Table 3.

[INSERT TABLE 3]

In the compatible condition, *Self* and *Attractive* categories (plus *Other* and *Unattractive*) were paired on the same side of the screen. In the incompatible condition, the configuration of the categories was switched, in which *Self* and *Unattractive* categories (plus *Other* and *Attractive*) are paired on the same side of the screen (see Figure 2a and 2b). The strength of the participants' implicit cognitions is measured by the difference in the mean reaction times between compatible and incompatible conditions. Faster reaction times indicate that the categorisation of words was more congruent with the individual's implicit cognitions towards those concepts. Thus, higher body satisfaction equates to stronger associations (i.e. faster reaction times) between compatible condition pairings, compared with incompatible condition parings.

[INSERT FIGURE 2]

Figure 2. Screenshot depicting example trials within Implicit Association Test. a) Example compatible condition, in which *Self* and *Attractive* categories (plus *Other* and *Unattractive*) are paired on the same side of the screen. b) Example incompatible condition in which *Self* and *Unattractive* categories (plus *Other* and *Attractive*) are paired on the same side of the screen. Target words appeared in the centre of the screen, with participants responding by categorizing the target words into the left or right of the screen.

2.3.3 Eating Disorder Examination Questionnaire (EDE-Q)

The EDE-Q is a 28-item questionnaire used as a self-report measure of ED psychopathology (Fairburn & Beglin, 1994) amongst clinical and non-clinical populations. The questionnaire assesses disordered eating behaviours within the past 28 days, in which there are four subscales: *Restraint*,

Eating Concern, *Weight Concern* and *Shape Concern*. A global score is calculated from the average of the four subscales. Items are rated along a 7-point Likert scale, ranging from '0' to '6' in which higher scores signify higher ED psychopathology. This scoring is with the exemption of six items in which frequency of eating behaviour is recorded, however these items do not contribute to the subscale scores and were not used in the present study, with ED psychopathology assessed based on the 22-item attitudinal scores. The EDE-Q has been shown to have good internal consistency, with Cronbach's alpha ranging from .70 to .83 in a clinical sample (Luce & Crowther, 1999) and from .78 to .93 in a non-clinical sample (Peterson et al., 2007). In the present study, the overall global EDE-Q measure had a Cronbach's alpha of .87 for ED group and .91 for HC group.

2.4 Procedure

2.4.1 Moving Rubber Hand Illusion

Participants were first familiarized with the experimental set-up and given instructions of the task procedure. During all conditions, participants sat at the table and placed their right hand underneath the wooden platform, with a plastic finger cap placed on their right index finger. In each trial, the participant's task was to tap their right index finger in a semi-regular rhythm for 60 seconds at approximately one tap per second, and were instructed to perform an additional quick 'double tap' at random intervals to avoid perfectly regular visuo-somatic correlations, which is reported to weaken the illusion (Kalckert & Ehrsson, 2012). Participants were first required to practice the tapping movement prior to experimental trials, and were instructed to focus their gaze on the model hand for the duration of each trial.

During synchronous conditions, the mechanical connection (dowel connecting the real and fake index finger), lifted and lowered the right index finger of fake hand, such that movements of the fake hand were in synchrony with the movements of participants' own right index finger. During asynchronous conditions, the mechanical connection between the real and fake hand was detached, with the movements of the fake index finger controlled by the experimenter moving the dowel with a temporal delay (~ 500 ms) to participant's own movements. The experimental procedure consisted of

six 60-second trials; three synchronous (illusion) and three asynchronous (control). Each of the three experimental measures (see *Measures* section) were completed once per condition (3 x synchronous; 3 x asynchronous) in separate trials. Condition order was counterbalanced across participants. Between each trial, participants were given a rest period of ~ 60 seconds, in which they removed their right hand from the set-up and flexed their hand/wrist to abolish any carry-over effects.

2.4.2 Body Satisfaction

In addition to an explicit measure of state body satisfaction (see *Measures* section), participants' implicit body satisfaction was measured using the Implicit Association Test (IAT). Participants were first familiarized with the IAT task by completing practice blocks, in which only two categories were presented on the screen (i.e. top left and right of the screen). Participants were instructed to categorize the target words as quickly and accurately as possible using the '*Z*' (left) and the '*M*' (right) key, respectively. Data from practice blocks were not used in any subsequent analysis. In critical (experimental) conditions, each target word belonged to one of four categories, of which two were positioned on the left of the screen, and two were positioned on the right (see *Measures* section). All participants completed two experimental blocks of the IAT (1x Compatible; 1x Incompatible), each consisting of 120 trials. All target words were presented individually in the centre of the screen, in a randomized order within each block for all participants. The order of conditions and category configurations were counterbalanced across all participants. Following the IAT, participants completed demographic information and the EDE-Q. The duration of the experiment in total was approximately 60 minutes.

2.5 Data Analysis

Prior to analysis, all data were tested for normality using a Shapiro-Wilk test. When the assumption of normality was not violated ($p > .05$), appropriate parametric tests were used, which are described below. When normality was violated ($p < .05$) or the data were ordinal, non-parametric Wilcoxon signed-rank tests were used for within-subject analysis and Mann-Whitney U tests for between-subject analysis. Non-parametric correlations were analysed using Spearman's Rank. All

analyses which directly tested a priori hypotheses are uncorrected critical alpha (α) values, with all other analyses using Bonferroni-corrected α values (stated as necessary below). Effect sizes for parametric tests are indicated by partial eta-squared (η_p^2) or Cohen's *d*, and non-parametric (Wilcoxon signed-rank and Mann-Whitney U) tests are indicated by r values (*r*) which are equivalent to Cohen's *d* (Pallant, 2007). All statistical analyses were conducted using SPSS version 23.0 (IBM, Chicago, IL, USA).

2.5.1 Moving Rubber Hand Illusion

For the subjective measures of ownership and agency (and respective control scores) from the questionnaire ratings, scores were calculated by averaging the individual statements within their respective categories (see Table 2) to obtain a single score per subscale for each participant (Jenkinson & Preston, 2015; Kalckert & Ehrsson, 2012). First, ownership and agency ratings were compared with their respective control subscale ratings to determine the reliability of the illusion scores in each group, as control scores are not expected to score highly, irrespective of illusion conditions. Control scores are particularly important when testing patients populations, to ensure that participants are not simply complying with all trials and providing high ratings to all questionnaire items (Keizer et al., 2014). Second, ownership and agency scores were compared between synchronous (illusion) and asynchronous (control) conditions to determine the effect of visuomotor synchrony towards subjective illusory experience. Third, ownership and agency scores were independently compared between the ED group and HC group to directly test the hypothesis that ED individuals would show greater instability in their subjective experience body ownership and sense of agency towards the fake hand, following the illusion.

Proprioceptive drift was calculated by subtracting the average height of the pre-trial estimation from the post-trial estimation within the pointing task. Positive values signify an upwards drift in the participants perceived hand position, and thus an increased illusory experience (Botvinick & Cohen, 1998; Kalckert & Ehrsson, 2012). For hand size estimation measures, the hand width of the fake hand was first compared with participant's actual hand size for each group, with actual hand size subsequently compared between ED and HC groups. Moreover, to test the hypothesis that ED

individuals would display an initial overestimation of hand size prior to the illusion compared with HCs, actual hand size was compared with participant's baseline estimation of hand width within each group. Next, to investigate whether the effects of the illusion led to a decrease in hand size estimations, difference scores were calculated by subtracting post-experimental estimations from baseline estimations for each participant, per condition. Thus, positive values would signify a *decrease* in hand size estimation following experimental trials.

2.5.2 Body Satisfaction

Explicit ratings of state body satisfaction taken from VAS scores were compared between ED and HC groups to test our prediction that ED individuals would display a significantly lower explicit body satisfaction. Additionally, the Implicit Association Test (IAT) was used as a proxy for implicit body satisfaction. In line with previous research (Greenwald et al., 1998), the first two trials of each condition block with the IAT were removed along with all incorrect trials, and reaction times outside of lower (300 ms) and upper (3000 ms) boundaries. Data were transformed using a *D* score algorithm, which was calculated as the difference in mean reaction times between compatible and incompatible trials, divided by the inclusive standard deviation across both conditions (Greenwald, Nosek, & Banaji, 2003). To directly test the hypothesis that ED individuals would display a significantly lower implicit body satisfaction, *D* scores were compared between ED and HC groups. In addition, mean reaction times were analysed via a 2x2 mixed-effects ANOVA to investigate whether any group differences are driven by the compatibility of the trials, in which slower reaction times within compatible trials would signify a reduced implicit self-serving body image bias. Thus, compatibility (compatible vs. incompatible) was entered as the within-subjects factor, and group (ED group vs. HC group) entered as the between-subjects factor.

2.5.3 Correlational analyses

To directly investigate the hypothesis that perceptual and cognitive-affective components of body image would relate with each other, the association between the above measures within the moving rubber hand illusion and body satisfaction tasks were explored using a non-parametric Spearman's Rank

correlation. Moreover, correlations were also explored between perceptual and cognitive-affective measures with ED psychopathology, using the EDE-Q.

3. Results

3.1 Moving Rubber Hand Illusion

3.1.1 Questionnaire

Data from subscales within the mRHI questionnaire were ordinal and found to be non-normal in the majority of cases (Shapiro-Wilk $p < .05$), therefore appropriate non-parametric tests were used. First, a Wilcoxon signed-rank test revealed that illusory ownership was induced for both the ED group ($Z = -4.03$, $p < .001$, $r = .79$) and HC group ($Z = -3.88$, $p < .001$, $r = .79$), with significantly higher scores in response to ownership questions compared with ownership control questions, following synchronous conditions. Next, a further Wilcoxon signed-rank test revealed a significant effect of synchrony for both the ED group ($Z = -4.29$, $p < .001$, $r = .84$) and HC group ($Z = -4.29$, $p < .001$, $r = .88$), with higher ownership scores following synchronous compared with asynchronous conditions (see Figure 3). Finally, a Mann-Whitney U test revealed no significant difference between groups following synchronous conditions ($U = 300.00$, $Z = -.24$, $p = .815$, $r = .03$) or asynchronous conditions ($U = 283.00$, $Z = -.57$, $p = .572$, $r = .08$).

The same analyses were conducted for agency scores, in which a Wilcoxon signed-rank test revealed that illusory agency was induced for both the ED group ($Z = -4.46$, $p < .001$ $r = .87$) and HC group ($Z = -4.22$, $p < .001$, $r = .86$), with significantly higher scores in response to agency questions compared with agency control questions, following synchronous conditions. Next, a further Wilcoxon signed-rank test revealed a significant effect of synchrony for both ED group ($Z = -4.29$, $p < .001$, $r = .84$) and HC group ($Z = -4.20$, $p < .001$, $r = .86$), with higher agency scores following synchronous compared with asynchronous conditions (see Figure 3). Finally, a Mann-Whitney U test revealed no significant difference between groups following synchronous conditions ($U = 290.50$, $Z = -.43$, $p = .668$, $r = .06$) or asynchronous conditions ($U = 259.00$, $Z = -1.03$, $p = .301$, $r = .15$). Taken together, these results suggest that ED and HC groups show a significantly stronger illusory experience following synchronous conditions compared with asynchronous conditions, but had an equally strong subjective experience of ownership and agency towards the fake hand.

[INSERT FIGURE 3]

Figure 3. Box plot displaying ownership and agency scores from the mRHI questionnaire, presented by condition and group. Significantly greater subjective ownership and agency was observed following synchronous compared with asynchronous conditions, with no significant difference in subjective ownership or agency between ED and HC groups. Intersecting line = median; box = upper and lower interquartile range; whiskers = minimum and maximum values. ** = $p < .001$.

3.1.2 Proprioceptive Drift

Following synchronous conditions, mean proprioceptive drift was 7.68 millimetres (mm) (SD ± 24.80) for the ED group, and 9.67 mm (SD ± 17.05) for the HC group. Following asynchronous conditions, mean proprioceptive drift was 5.62 mm (SD ± 17.05) for the ED group, and -.85 mm (SD ± 22.90) for the HC group. As proprioceptive drift data were normally distributed for both groups (Shapiro-Wilk $p > .05$), a parametric 2x2 mixed-effects ANOVA was run, with visuomotor synchrony (synchronous vs. asynchronous) as the within-subjects factor, and group (ED group vs. HC group) as the between-subjects factor. In contrast with previous research, no main effect of visuomotor synchrony was observed between synchronous and asynchronous conditions (F (1,48) = 2.66, p = .109, η_p^2 = .05). Moreover, no significant main effect of group was observed (F (1, 48) = .27, p = .604, η_p^2 = .01), and no interaction between visuomotor synchrony and group was observed (F (1, 48) = 1.21, p = .277, η_p^2 = .03).

3.1.3 Hand size estimation

Hand size estimation data were normally distributed across the whole sample (Shapiro Wilk $p > .05$), therefore appropriate parametric tests were used. First, an independent samples t-test revealed that there was no significant difference in actual hand width (millimetres: mm) between the ED group and the HC group (see Table 4) (t (48) = -.295, p = .77, d = .08). Second, paired samples t-tests revealed that the width of the fake hand (74mm) was significantly narrower compared with the actual hand width of the ED group (t (25) = -2.89, p = .008, d = .57) and the HC group (t (23) = -3.26, p = .003, d = .67).

Finally, to directly test the hypothesis that ED individuals would overestimate their hand size prior to the illusion, actual hand size was compared with participants' baseline estimation of hand width for each group (see Table 4) using paired samples t-tests. Participants in the ED group significantly overestimated their own hand width, prior to the illusion (t (25) = -3.33, p = .003, d = .65). Additionally, participants in the HC group also significantly overestimated their own hand width, prior to the illusion (t (23) = -2.15, p = .043, d = .44). Hand size overestimations did not significantly differ between ED and HC groups (t (48) = .76, p = - .453, d = .21).

Next, to directly test the hypothesis that ED individuals would report a significant decrease in hand size estimation after the illusion was induced, difference scores were calculated for each group by subtracting post-experimental estimations from the baseline estimation. Difference scores were compared to zero via a one sample t-test, in which positive values would indicate a *decrease* in hand size estimation following the illusion. For the ED group, participants reported a significantly lower hand size estimations following induction of the illusion, for both synchronous conditions (t (25) = 2.84, p = .009, d = .56) and asynchronous conditions (t (25) = 2.74, p = .011, d = .54). Interestingly, for the HC group, participants also reported a significantly lower hand size estimation following induction of the illusion for synchronous conditions (t (23) = 2.09, p = .048, d = .43), but not for asynchronous conditions (t (23) = 1.10, p = .281, d = .22) (see Table 4).

Finally, post-experimental hand size estimations were compared with participant's actual hand size, to determine whether such estimations reflected a more veridical measurement of hand width. For the ED group, Paired samples t-tests revealed no significant differences between actual hand size and post-experimental estimations following synchronous (t (25) = -1.15, p = .259, d = .23) or asynchronous conditions (t (25) = -1.68, p = .106, d = .33). Crucially, baseline estimations made prior to the illusion *were* significantly different from actual hand size, therefore this non-significant result reflects a reduction in hand size estimation which is closer to ED participant's actual hand size. Similarly, for the HC group, paired samples t-tests revealed no significant differences between actual hand size and post-experimental estimations following synchronous (t (23) = -1.29, p = .208, d = .26) or asynchronous

conditions (t (23) = -1.82, p = .082, d = .37). Taken together, the above results suggest that the ED group show a significant reduction in hand size estimation following induction of the illusion following both synchronous and asynchronous conditions, which is closer to their veridical hand size. Whilst the HC group also displayed a more accurate estimation of their hand width following synchronous conditions, this was not matched following asynchronous conditions. Moreover, difference scores in the ED group were more pronounced as shown by a larger effect size, which may reflect a greater malleability of body representation within this group.

[INSERT TABLE 4]

3.2 Body Satisfaction

3.2.1 Explicit Body Satisfaction

Data from the VAS ratings were non-normally distributed across the whole sample (Shapiro Wilk $p < .05$), therefore a non-parametric Mann-Whitney U test was used to compare state body satisfaction between the ED group and HC group. As predicted, the ED group reported a significantly lower state body satisfaction (median = 15.00) compared with HC group (median = 63.00; U = 33.00, Z = -5.42, $p < .001$).

3.2.2 Implicit Body Satisfaction

To directly test the hypothesis that the ED group would display lower implicit body satisfaction compared with the HC group, D scores from the IAT were compared between groups. Note that lower D scores represent lower implicit body satisfaction. Data from the IAT were normally distributed (Shapiro Wilk $p > .05$) therefore an independent-samples t-test was run, which revealed a significantly lower D score within the ED group (mean = .20) compared with the HC group (mean = .90; t (35.86) = -3.06, p = .004, d = .43). This suggests that ED participants displayed a reduced body satisfaction on an implicit level compared with healthy controls. D scores for both groups are shown in Figure 4a.

To further investigate whether ED individuals show a reduced implicit self-serving body image bias within the IAT, mean reaction times for each condition were entered into a 2x2 mixed effects ANOVA, with condition (Compatible vs. Incompatible) as the within-subjects factor, and group (ED group vs. HC group) as the between-subjects factor. A main effect of condition was observed (F (1,48) = 22.43, $p < .001$, $\eta_p^2 = .32$), with significantly lower reaction times following compatible vs. incompatible conditions. No main effect of group was observed (F (1, 48) = 2.15, $p = .149$, $\eta_p^2 = .04$). However, a significant interaction was observed between condition and group (F (1, 48) = 9.00, $p = .004$, $\eta_p^2 = .16$). Thus, Bonferroni-corrected independent samples t-tests (critical $\alpha = .025$) revealed a significant difference between groups following compatible (t (48) = 2.52, $p = .015$, $d = .36$), but not incompatible conditions (t (48) = .04, $p = .972$, $d = .01$) (see Figure 4b). This suggests that differences in implicit attitudes between ED and HC groups are driven specifically by weaker associations between attractiveness and the self within ED individuals.

[INSERT FIGURE 4]

Figure 4. Implicit Association Test Scores. (a) Mean D scores for ED and HC groups. Higher D scores indicate higher implicit body satisfaction within the HC group compared with the ED group. (b) Mean reaction times for compatible and incompatible trials, for ED and HC groups. Group differences are shown to be driven by significantly slower reaction times in the ED group compared with the HC group, within compatible trials. Error bars for both graphs show standard error. * = $p < .05$, ** = $p < .01$.

3.2.3 Relationship Between Explicit and Implicit Body Satisfaction

To investigate whether explicit measures of body satisfaction related to performance on the IAT, a correlation analysis was run across the whole sample (N=50). A Spearman's Rank correlation revealed a significant positive correlation between state body satisfaction and D scores on the IAT across the whole sample ($r = .46$, $p = .001$), which may suggest that those with higher explicit body satisfaction also display a higher implicit body satisfaction. Furthermore, Bonferroni-corrected Spearman's Rank correlations (critical $\alpha = .025$) revealed that lower state body satisfaction is driven by performance on compatible trials (i.e. *Self* and *Attractive* categories paired) within the IAT, with a

significant negative correlation between state body satisfaction and compatible trials (r = -.34, p = .014) but not with incompatible trials (r = .10, p = .485).

3.3 Correlational analyses

To directly test the hypothesis that perceptual and cognitive-affective components of body image would relate with each other, measures from the moving rubber hand illusion (questionnaire scores, proprioceptive drift, hand size estimation) were correlated with body satisfaction measures (explicit and implicit) across the whole sample. A Spearman's Rank correlation revealed a significant positive correlation between synchronous ownership questionnaire scores and IAT *D* scores (r = .32, p = .022), which was driven by the ED group scores (see Supplementary Materials for full tables). Moreover, a significant positive correlation was observed between synchronous proprioceptive drift scores and IAT *D* scores (r = .30, p = .032), which was similarly driven by scores in the ED group. This suggests that a stronger explicit and implicit experience of the illusion is associated with increased implicit body satisfaction, which highlights that a link does exist between perceptual and cognitive-affective components of body image. No further noteworthy correlations were observed between the above measures (see Supplementary Materials for full tables).

Finally, to investigate the relationship between body perception and body satisfaction with ED psychopathology, the above measures were correlated with scores from the *Eating Disorder Examination Questionnaire (EDE-Q*) across the whole sample. A Spearman's Rank correlation revealed no noteworthy correlations between perceptual measures on the moving rubber hand illusion and EDE-Q scores across the whole sample (see Supplementary Materials for full tables). However, as expected, a significant negative relationship was observed between EDE-Q global scores and explicit body satisfaction (r = -.794, p < .001), showing that those with higher ED psychopathology reported lower state body satisfaction. Interestingly, a significant negative relationship was also observed between EDE-Q global scores and *D* scores within the IAT (r = -.35, p = .012), which suggests that those with higher ED psychopathology also display a lower implicit body satisfaction. This relationship is shown to be specifically driven by subscale scores relating to *Shape Concern* (r = -.47, p = .001) and

600 *Weight Concern* (r = -.41, p = .003) which reflect body-related attitudes, rather than attitudes towards
601 eating behaviours (i.e. *Restraint/Eating Concern*) which showed no significant relationship with IAT
602 *D* scores (see Supplementary Materials for full tables).
603

4. Discussion

The present study investigated the perceptual and cognitive-affective components of body image within ED individuals and healthy females. Specifically, the multisensory *moving rubber hand illusion* was used to assess body ownership and agency, alongside explicit and implicit measures of body satisfaction. Following induction to the illusion, results showed that both ED and HC individuals displayed a similar subjective experience of illusory ownership and agency towards the fake hand. Moreover, both groups initially overestimated their own hand width prior to the illusion, with a significant reduction in overestimation in ED group following both synchronous and asynchronous conditions, which was not mirrored to the same degree in the HC group. Secondly, ED individuals displayed significantly lower satisfaction towards their body compared with healthy females, on both an explicit and implicit level. Such implicit findings were shown to be driven specifically by a weaker association between words relating to the self and attractiveness. Finally, a significant relationship was observed between specific perceptual measures and implicit body satisfaction, which underlines the key link between body perception and body emotion. Taken together, the present findings support previous research by indicating that ED individuals have a more malleable experience of the bodily self, compared with healthy females. Moreover, novel findings show that ED individuals present with a lower implicit satisfaction towards their body that relates with perceptual experience, which may provide important implications within clinical treatment.

Using the moving rubber hand illusion, the present study builds upon previous multisensory integration research within ED groups (Eshkevari et al., 2012; Keizer et al., 2014), as being the first to investigate the sense of agency and its interaction with body ownership within this population. Whilst the 'classic' rubber hand illusion incorporates a three-way interaction between visual, tactile, and proprioceptive input (Botvinick & Cohen, 1998), the present paradigm is supplemented by efferent, kinaesthetic information from voluntary motor actions which elicits a sense of body ownership and agency towards a fake hand, both of which are key perceptual components within the bodily self (Kalckert & Ehrsson, 2014a). Results showed that both ED and HC groups displayed a strong sense of

ownership and agency towards the fake hand following synchronous illusion conditions. However, contrary to hypotheses, the two groups displayed a comparable subjective experience of ownership and agency during the task. This finding is in contrast to previous work which has investigated subjective body ownership within the 'classic' rubber hand illusion, in which ED groups displayed higher sense of ownership towards the fake hand compared with healthy controls (Eshkevari et al., 2012; Keizer et al., 2014). Together, the above results suggest that the subjective sense of ownership and agency may be similar between ED and healthy groups when incorporating voluntary movement towards body representation.

Similarly, despite previous research observing differences in proprioceptive drift between ED and HC groups (Eshkevari et al., 2012), the present study is in line with later work which did not observe such effects between groups (Keizer et al., 2014). Many researchers have widely accepted that subjective measures of embodiment following multisensory integration are dissociable from a perceived change in spatial location which leads to proprioceptive drift (Abdulkarim & Ehrsson, 2016; Rohde, Luca, & Ernst, 2011). However, the observed lack of difference between groups, and indeed lack of proprioceptive drift observed from the illusion may be accounted for by a task-dependency effect. Within the present study, participants were asked to make a motor response towards the perceived location of their hand. However, previous research in healthy individuals has suggested a dissociation between perceptual body judgements and motor responses, in which participants showed susceptibility to the 'classic' RHI when making a perceptual response (i.e. verbal judgement of hand location) but showed intact proprioceptive judgement when making a motor response (i.e. a pointing movement towards hand location) (Kammers, de Vignemont, Verhagen, & Dijkerman, 2009). This suggests that the two measures denote separate body representations, therefore future research should investigate whether such proprioceptive measures of the moving rubber hand illusion differ between ED and healthy groups when using perceptual, verbal responses of perceived hand location.

The present study provides a valuable foundation to further study the sense of agency within EDs, which remains a largely under-researched topic within this clinical population. Given their close

association in contributing towards a coherent body representation (Pyasik, Burin, & Pia, 2018), it is difficult to dissociate feelings of agency and feelings of ownership within voluntary movement, not least when sensory feedback of movement is likely to further enhance ownership (Tsakiris & Haggard, 2005). Within the present study, the contribution of sense of agency towards the sense of ownership - and vice versa - cannot be disentangled. Indeed, the observed lack of difference between HC and ED groups in ownership and agency may be accounted for by the enhancement of subjective ownership as a result of subjective agency following synchronous conditions within the moving rubber hand illusion. Thus, previous research which has observed greater plasticity in body ownership amongst ED patients within the 'classic' rubber hand illusion (Eshkevari et al., 2012; Keizer et al., 2014) may not be directly comparable to the present study, given the additional, interlinked component of agency influencing such subjective ownership. One method to overcome this in future research would be to first undertake the 'classic' rubber hand illusion to determine the stability of ownership between ED and HC groups from visuotactile integration (Keizer et al., 2014), before then measuring the stability of body agency when introducing voluntary movement via the moving rubber hand illusion. Indeed, research using the moving rubber hand illusion has independently investigated the factors which are known to influence the sense of ownership and agency, in healthy individuals (Jenkinson & Preston, 2015; Kalckert & Ehrsson, 2012, 2014b) and clinical groups (Marotta et al., 2017). Specifically, anatomical plausibility of the hand and mode of movement has been manipulated, comparing active movement with passive movement (in which the experimenter moves the wooden connection, thus moving the fake hand and participant's hand). Importantly, such manipulations have been shown to dissociate the sense of agency from the sense of ownership (Kalckert & Ehrsson, 2014a). Within the present study, the total number of trials within the illusion task was intentionally limited in order to reduce extensive fatigue for ED groups, therefore body ownership and agency were not independently manipulated.

Furthermore, results showed that whilst both ED and HC groups displayed an initial overestimation of hand width prior to the illusion, ED individuals displayed a significant reduction in their hand width estimation following both synchronous (illusion) and asynchronous (control) conditions, which was not directly mirrored in healthy females. This finding is in line with previous

688 research (Keizer et al., 2014, 2016), suggesting that such perceptual changes from ED individuals
689 occurred irrespective of the subjective experience of the illusion, which *was* shown to significantly
690 differ between conditions. As previously discussed, research has suggested that greater perceptual
691 effects within multisensory illusions amongst ED populations is associated with an increased
692 malleability of the bodily self, in which such individuals often display a visual dominance that overrides
693 proprioceptive input during the illusion (Eshkevari et al., 2012; Keizer et al., 2014, 2016). Therefore,
694 an increased sensory weighting towards visual input of the fake hand may have been sufficient to change
695 size estimations of one's own hand amongst ED individuals, irrespective of the condition. Importantly,
696 the present results support previous research which highlight an inherent instability of perceptual body
697 representation in ED individuals. Such findings have important clinical implications within the
698 treatment of body image disturbance in EDs, by showing that perceptual estimation of body size can be
699 improved within this population (Keizer, Engel, Bonekamp, & Van Elburg, 2018). Thus, whilst the
700 long-term effects of improved perceptual accuracy of body size remains unknown in ED patients, a
701 more veridical representation of one's own body is likely to positively impact upon clinical outcomes
702 and the cognitive-affective component of body image disturbance (Castellini et al., 2011; Exterkate et
703 al., 2009).
704
705 It must be noted that healthy females did also initially overestimate their hand size prior to the
706 illusion, and show a subsequent reduced hand size estimation - but following synchronous conditions
707 only. In other words, healthy females were shown to improve their hand size estimation as consequence
708 of illusion conditions, which reinforces the effect of multisensory integration in inducing perceptual
709 changes in perceived body size amongst healthy individuals (Preston & Ehrsson, 2014). Importantly,
710 the effect was different to the ED group who recorded a reduced estimation following both synchronous
711 and asynchronous conditions, which reinforces the greater malleability of the bodily self in ED
712 individuals compared with healthy controls. However, it is speculated that initial overestimation from
713 the HC group - which occurred contrary to hypotheses - may be a consequence of higher ED
714 psychopathology within the non-clinical range amongst the present sample. Whilst global EDE-Q
715 scores within the HC group (median = 1.55) were below the clinical cut-off (2.80; Mond et al., 2008),

such scores appear higher than other European countries which use the EDE-Q in non-clinical samples (e.g. .42; Preston & Ehrsson, 2018). Indeed, six HC participants were excluded from the present study after scoring above the clinical cut-off for an EDE-Q global score. Therefore, in addition to the hand size estimation results above, such EDE-Q scores may also, in some part, explain the non-significant effects between the ED group and HC group on measures of subjective ownership and agency towards the fake hand. Taken together, such inflated scores amongst a healthy female sample reinforces the need to investigate ED psychopathology and vulnerability in the non-clinical population, and highlights how the EDE-Q may require assessment as a clinical measure within the UK, with regard to normative scores between non-clinical and clinical samples (Carey, Kupeli, et al., 2019).

As shown above (i.e. hand size estimation effects), given the consistent findings in the ED literature which have shown perceptual effects of the illusion following both synchronous and asynchronous conditions, it would be informative for participants to undertake subjective and objective measures of embodiment following mere visual observation of the fake hand, with their own hand hidden from view. This would determine the degree of embodiment experienced by participants due to 'visual capture' of congruent visuoproprioceptive information alone, as a baseline measure made prior to visuomotor integration from illusory trials (Carey, Crucianelli, Preston, & Fotopoulou, 2019; Crucianelli, Krahé, Jenkinson, & Fotopoulou, 2017; Crucianelli, Metcalf, Fotopoulou, & Jenkinson, 2013). As previously discussed, experiment duration was minimised for ED individuals within the present study, therefore a visual capture measure of embodiment was not taken. However, given the apparent increased sensitivity to visual input amongst ED populations, future research should include such conditions which take such 'baseline' measures of embodiment following mere visual observation of a fake body (part), to more precisely delineate the role of altered multisensory integration within ED groups. This would be particularly interesting within an RHI set-up, as evidence has shown a greater perceptual malleability when using the RHI compared with a whole body illusion, in relation to ED psychopathology within healthy groups (Carey, Crucianelli, et al., 2019) and clinical ED groups (Keizer et al., 2016).

As hypothesised, explicit measures of state body satisfaction revealed significantly lower self-reported scores in ED groups compared with healthy females. However, to the authors' knowledge, the present study is the first to investigate implicit body satisfaction in an ED sample, using the IAT. Results on the IAT showed that ED individuals displayed a significantly lower implicit body satisfaction compared with healthy females, with such differences driven by weaker associations between the self and attractiveness. These findings support previous research which suggests that ED individuals lack a positive self-serving body image bias' (Jansen et al., 2006), yet builds further by suggesting that dysfunctional attitudes towards one's self-appearance are more deeply-rooted amongst ED individuals, with such implicit cognitions likely to be more resistant to change or modification compared with explicit, self-reported cognitions (Vartanian et al., 2004). Such findings can have important clinical implications for recovery and relapse, in assessing the implicit biases which are not influenced by a patient's compliance or pressure to report improvement in clinical outcomes following treatment (Buhlmann, Teachman, & Kathmann, 2011). Indeed, recovered ED patients who explicitly self-report improvement in attitudes towards weight and shape following treatment may still be at increased risk of relapse if such cognitions are not addressed on an implicit level, which may play an important role in the prognosis of the disorder (Martijn et al., 2015; Vartanian et al., 2004). This is highlighted in the present study, with implicit body satisfaction shown to be associated with ED psychopathology across the whole sample. Specifically, a significant negative correlation was observed between IAT *D* scores and global EDE-Q scores, which was driven by scores on *Shape Concern* and *Weight Concern* EDE-Q subscales, and not from eating-related subscales (i.e. *Restraint*/*Eating Concern*). Importantly, it is unlikely that this significant correlation across the whole sample was driven by group differences on the above measures, given that significant differences were shown across all EDE-Q subscales between groups (see Table 1). Therefore, such findings reinforce the link between implicit and explicit cognitions regarding body satisfaction within the pathology of EDs, and the need to address both constructs within treatment to improve upon clinical outcomes.

Computer-based paradigms such as the IAT can be a cost-effective method used to assess and improve upon dysfunctional implicit cognitions within ED treatment, alongside traditional, explicit

772 measures of clinical interviews and standardized questionnaires (Buhlmann et al., 2011). Indeed,
773 increasing research is showing that interventions which target such implicit processes may have clinical
774 efficacy in improving cognitions surrounding one's body satisfaction (Martijn et al., 2015).
775 Furthermore, whilst the present study used appearance-related word associations within the IAT, it
776 would be interesting for future research to dissociate such implicit biases from general cognitive
777 measures such as self-esteem (Buhlmann, Teachman, Naumann, Fehlinger, & Rief, 2009). Indeed, a
778 dissociation between shape or weight-related cognitions and general self-esteem would suggest that
779 altered cognitions within this population may be specific to the body, and would provide researchers
780 and clinicians with a clearer focus within which to target treatment (Buhlmann et al., 2011).
781
782 Finally, results revealed a relationship between perceptual and cognitive-affective components
783 of body image across the whole sample, shown by significant positive correlations between ownership
784 questionnaire scores and proprioceptive drift scores from the moving rubber hand illusion, with implicit
785 body satisfaction from IAT *D* scores. This supports the argument that a direct link does exist between
786 body perception and emotion, with such findings shown to be driven more specifically by ED group
787 scores. However, the direction of such relationships was contrary to hypotheses, as it was predicted that
788 ED individuals would display increased ownership - implicated with an instability in the bodily self -
789 which would be associated with *reduced* body satisfaction. Whilst the explanation for this effect
790 remains unclear, it could be speculated that individuals with a greater instability in their body perception
791 (i.e. ED individuals) may have less negative implicit attitudes towards their own body because they are
792 attaining their idealised, yet unhealthy, ultra-thin body. This would be particularly relevant amongst
793 individuals with anorexia nervosa, in which a strong drive for thinness is a key characteristic within
794 such a diagnosis, with increasingly prevalent 'thinspiration" media websites positively reinforcing such
795 aberrant weight loss (Boepple & Thompson, 2016; Tiggemann & Miller, 2010). Importantly, such
796 findings highlight the complexity of the relationship between perceptual and cognitive-affective
797 components of body image, in which further research is required to uncover the most salient conditions
798 in which perceptual alterations relate to emotional bodily experience.
799

Given the present findings highlighting a relationship between perceptual and cognitive-affective components of body image, future research should investigate how this behavioural relationship is represented in the brain. Recent neuroscientific research has significantly increased our understanding of the neural basis of eating disorders, with several studies highlighting structural and functional correlates of body image disturbance (Gaudio, Dakanalis, Fariello, & Riva, 2018). Specifically, alterations in posterior parietal areas, associated with the integration of sensory information, have been implicated with the perceptual component of body image disturbance amongst AN patients (Gaudio, Brooks, & Riva, 2014; Gaudio & Quattrocchi, 2012). Moreover, prefrontal cortex and insula alterations have been implicated with the affective component of body image disturbance. Therefore, following neuroimaging evidence which has highlighted the interaction between perceptual and affective representations amongst healthy individuals (Preston & Ehrsson, 2016), future research should investigate the functional connectivity within the brain amongst eating disorder patients, to determine whether alterations in the communication between the above neural regions would link with the prognosis of the disorder.

The above findings must be considered within the context of limitations of the present study. Whilst a large percentage of the ED group presented with a diagnosis of anorexia nervosa (~70%), the heterogeneity in diagnosis (e.g. bulimia nervosa, binge eating disorder) and treatment received (e.g. inpatient/outpatient) from ED individuals may have impacted the results within this group. Given the complexity and heterogeneity of clinical populations, this is a typical methodological issue within the ED literature. Indeed, similar research has shown effects of perceptual instability when using an ED group with varied diagnoses (Eshkevari et al., 2012). However, the sample size within the present study was smaller than previous research which has included varied ED diagnoses, therefore future research should undertake such work amongst larger, homogeneous samples of independent ED diagnoses.

In conclusion, the present study is one of the first to investigate the independent roles, and relationship between perceptual and cognitive-affective components of body image, amongst ED and HC groups. Using a multisensory illusion paradigm which incorporated active, volitional movement,

our results support previous research in highlighting the malleability of the perceptual bodily self amongst ED individuals. Secondly, ED individuals displayed disturbances in their cognitive-affective component of body image, shown by significantly lower body satisfaction on both an explicit and implicit level compared with healthy females, with altered implicit cognitions shown to be specifically driven specifically by weaker associations between the self and attractiveness. Finally, results highlighted an association between the perceptual and cognitive-affective components of body image, yet further research is required to determine the direct effect between these components within both clinical and non-clinical groups. Taken together, such findings can provide important clinical implications in the treatment of body image disturbance, in identifying perceptual alterations amongst this population which are possible to change, and assess more deeply-rooted, negative implicit cognitions which should be targeted alongside typical self-reported measures of recovery in EDs.

Conflict of Interest:

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Author Contributions

MC and CP contributed to the conception and design of the experiment. MC collected and analysed the data under the supervision of CP. MC drafted the manuscript, and CP provided critical revisions. All authors approved the manuscript before submission.

853 **References:**

854 Abdulkarim, Z., & Ehrsson, H. H. (2016). No causal link between changes in hand position sense and
855 feeling of limb ownership in the rubber hand illusion. *Attention, Perception, and Psychophysics*,
856 *78*(2), 707–720. https://doi.org/10.3758/s13414-015-1016-0

857 Ahern, A. L., Bennett, K. M., & Hetherington, M. M. (2008). Internalization of the Ultra-Thin Ideal:
858 Positive Implicit Associations with Underweight Fashion Models are Associated with Drive for
859 Thinness in Young Women. *Eating Disorders*, *16*(4), 294–307.
860 https://doi.org/10.1080/10640260802115852

861 Alleva, J. M., Sheeran, P., Webb, T. L., Martijn, C., & Miles, E. (2015). A Meta-Analytic Review of
862 Stand-Alone Interventions to Improve Body Image. *Plos One*, *10*(9), e0139177.
863 https://doi.org/10.1371/journal.pone.0139177

864 American Psychiatric Association. (2013). *Diagnostic and statistical manual of mental disorders*
865 *(DSM-5®)*. American Psychiatric Pub.

866 Aspen, V., Darcy, A. M., & Lock, J. (2013). A review of attention biases in women with eating
867 disorders. *Cognition and Emotion*, *27*(5), 820–838.
868 https://doi.org/10.1080/02699931.2012.749777

869 Badoud, D., & Tsakiris, M. (2017). From the body's viscera to the body's image: Is there a link
870 between interoception and body image concerns? *Neuroscience and Biobehavioral Reviews*,
871 *77*(December 2016), 237–246. https://doi.org/10.1016/j.neubiorev.2017.03.017

872 Bardone-Cone, A. M., Harney, M. B., Maldonado, C. R., Lawson, M. a., Robinson, D. P., Smith, R.,
873 & Tosh, A. (2010). Defining recovery from an eating disorder: Conceptualization, validation,
874 and examination of psychosocial functioning and psychiatric comorbidity. *Behaviour Research*
875 *and Therapy*, *48*(3), 194–202. https://doi.org/10.1016/j.brat.2009.11.001

876 Boehm, I., Finke, B., Tam, F. I., Fittig, E., Scholz, M., Gantchev, K., … Ehrlich, S. (2016). Effects of
877 perceptual body image distortion and early weight gain on long-term outcome of adolescent
878 anorexia nervosa. *European Child & Adolescent Psychiatry*, *25*(12), 1319–1326.
879 https://doi.org/10.1007/s00787-016-0854-1

880 Boepple, L., & Thompson, J. K. (2016). A Content Analytic Comparison of Fitspiration and

Thinspiration Websites. *International Journal of Eating Disorders*, *49*, 98–101. https://doi.org/10.1002/eat.22403

Botvinick, M., & Cohen, J. (1998). Rubber hand feels touch that eyes see. *Nature*, *391*, 756. https://doi.org/10.1038/35784

Buhlmann, U., Teachman, B. A., & Kathmann, N. (2011). Evaluating implicit attractiveness beliefs in body dysmorphic disorder using the Go/No-go Association Task. *Journal of Behavior Therapy and Experimental Psychiatry*, *42*(2), 192–197. https://doi.org/10.1016/j.jbtep.2010.10.003

Buhlmann, U., Teachman, B. A., Naumann, E., Fehlinger, T., & Rief, W. (2009). The meaning of beauty: Implicit and explicit self-esteem and attractiveness beliefs in body dysmorphic disorder. *Journal of Anxiety Disorders*, *23*, 694–702. https://doi.org/10.1016/j.janxdis.2009.02.008

Cahill, S., & Mussap, A. J. (2007). Emotional reactions following exposure to idealized bodies predict unhealthy body change attitudes and behaviors in women and men. *Journal of Psychosomatic Research*, *62*(6), 631–639. https://doi.org/10.1016/j.jpsychores.2006.11.001

Carey, M., Crucianelli, L., Preston, C., & Fotopoulou, A. (2019). The Effect of Visual Capture Towards Subjective Embodiment Within the Full Body Illusion. *Scientific Reports*, *9*(1), 2889. https://doi.org/10.1038/s41598-019-39168-4

Carey, M., Kupeli, N., Knight, R. E., Troop, N., Jenkinson, P. M., & Preston, C. E. J. (2019). Eating Disorder Examination Questionnaire (EDE-Q): norms and psychometric properties in UK females and males. *Psychological Assessment*.

Cash, T. F., & Deagle, E. A. (1997). The nature and extent of body-image disturbances in anorexia nervosa and bulimia nervosa: A meta-analysis. *International Journal of Eating Disorders*, *22*(2), 107–125. https://doi.org/10.1002/(SICI)1098-108X(199709)22:2<107::AID-EAT1>3.0.CO;2-J

Castellini, G., Lo Sauro, C., Mannucci, E., Ravaldi, C., Rotella, C. M., Faravelli, C., & Ricca, V. (2011). Diagnostic crossover and outcome predictors in eating disorders according to DSM-IV and DSM-V proposed criteria: a 6-year follow-up study. *Psychosomatic Medicine*, *73*(3), 270–279. https://doi.org/10.1097/PSY.0b013e31820a1838

Crucianelli, L., Krahé, C., Jenkinson, P. M., & Fotopoulou, A. (Katerina). (2017). Interoceptive ingredients of body ownership: Affective touch and cardiac awareness in the rubber hand

illusion. *Cortex*, 1–13. https://doi.org/10.1016/j.cortex.2017.04.018

Crucianelli, L., Metcalf, N. K., Fotopoulou, A., & Jenkinson, P. M. (2013). Bodily pleasure matters: Velocity of touch modulates body ownership during the rubber hand illusion. *Frontiers in Psychology*, *4*, 1–7. https://doi.org/10.3389/fpsyg.2013.00703

Cserjési, R., Vermeulen, N., Luminet, O., Marechal, C., Nef, F., Simon, Y., & Lénárd, L. (2010). Explicit vs. implicit body image evaluation in restrictive anorexia nervosa. *Psychiatry Research*, *175*(1–2), 148–153. https://doi.org/10.1016/j.psychres.2009.07.002

Durkin, S. J., & Paxton, S. J. (2002). Predictors of vulnerability to reduced body image satisfaction and psychological wellbeing in response to exposure to idealized female media images in adolescent girls, *53*, 995–1005.

Eshkevari, E., Rieger, E., Longo, M. R., Haggard, P., & Treasure, J. (2012). Increased plasticity of the bodily self in eating disorders. *Psychological Medicine*, *42*(4), 819–828. https://doi.org/10.1017/S0033291711002091

Eshkevari, E., Rieger, E., Longo, M. R., Haggard, P., & Treasure, J. (2014). Persistent body image disturbance following recovery from eating disorders. *International Journal of Eating Disorders*, *47*(4), 400–409. https://doi.org/10.1002/eat.22219

Exterkate, C. C., Vriesendorp, P. F., & de Jong, C. A. J. (2009). Body attitudes in patients with eating disorders at presentation and completion of intensive outpatient day treatment. *Eating Behaviors*, *10*(1), 16–21. https://doi.org/10.1016/j.eatbeh.2008.10.002

Fairburn, C. G., & Beglin, S. (1994). Assessment of eating disorders: interview or self- report questionnaire? *Int J Eat Disord*, *16*(4), 363–370. https://doi.org/10.1002/1098-108X(199412)16:4

Gardner, R. M., & Brown, D. L. (2014). Body size estimation in anorexia nervosa: A brief review of findings from 2003 through 2013. *Psychiatry Research*, *219*(3), 407–410. https://doi.org/10.1016/j.psychres.2014.06.029

Gaudio, S., Brooks, S. J., & Riva, G. (2014). Nonvisual Multisensory Impairment of Body Perception in Anorexia Nervosa: A Systematic Review of Neuropsychological Studies. *PLoS ONE*, *9*(10), e110087. https://doi.org/10.1371/journal.pone.0110087

Gaudio, S., Dakanalis, A., Fariello, G., & Riva, G. (2018). Neuroscience, Brain Imaging, and Body Image in Eating and Weight Disorders: A Guide to Assessment, Treatment, and Prevention Chapter. https://doi.org/10.1007/978-3-319-90817-5

Gaudio, S., & Quattrocchi, C. C. (2012). Neural basis of a multidimensional model of body image distortion in anorexia nervosa. *Neuroscience and Biobehavioral Reviews*, *36*(8), 1839–1847. https://doi.org/10.1016/j.neubiorev.2012.05.003

Gentsch, A., Schutz-Bosbach, S., Endrass, T., & Kathmann, N. (2012). Dysfunctional forward model mechanisms and aberrant sense of agency in obsessive-compulsive disorder. *Biological Psychiatry*, *71*(7), 652–659. https://doi.org/10.1016/j.biopsych.2011.12.022

Greenwald, A. G., & Farnham, S. D. (2000). Using the Implicit Association Test to Measure. *Jounal of Personality and Social Psychology*, *79*(6), 1022–1038. https://doi.org/10.1037//0022-3514.79.6.I022

Greenwald, A. G., McGhee, D. E., & Schwartz, J. L. (1998). Measuring individual differences in implicit cognition: the implicit association test. *Journal of Personality and Social Psychology*, *74*(6), 1464–1480. https://doi.org/10.1037/0022-3514.74.6.1464

Greenwald, A. G., Nosek, B. A., & Banaji, M. R. (2003). Understanding and Using the Implicit Association Test: I. An Improved Scoring Algorithm. *Journal of Personality and Social Psychology*, *85*(2), 197–216. https://doi.org/10.1037/0022-3514.85.2.197

Groves, K., Kennett, S., & Gillmeister, H. (2017). Evidence for ERP biomarkers of eating disorder symptoms in women. *Biological Psychology*, *123*, 205–219. https://doi.org/10.1016/j.biopsycho.2016.12.016

Guardia, D., Carey, A., Cottencin, O., Thomas, P., & Luyat, M. (2013). Disruption of Spatial Task Performance in Anorexia Nervosa. *PLoS ONE*, *8*(1). https://doi.org/10.1371/journal.pone.0054928

Guardia, D., Cottencin, O., Thomas, P., Dodin, V., & Luyat, M. (2012). Spatial orientation constancy is impaired in anorexia nervosa. *Psychiatry Research*, *195*(1–2), 56–59. https://doi.org/10.1016/j.psychres.2011.08.003

Guardia, D., Lafargue, G., Thomas, P., Dodin, V., Cottencin, O., & Luyat, M. (2010). Anticipation of

body-scaled action is modified in anorexia nervosa. *Neuropsychologia*, *48*(13), 3961–3966. https://doi.org/10.1016/j.neuropsychologia.2010.09.004

Guardia, D., Metral, M., Pigeyre, M., Bauwens, I., Cottencin, O., & Luyat, M. (2013). Body distortions after massive weight loss: lack of updating of the body schema hypothesis. *Eating and Weight Disorders - Studies on Anorexia, Bulimia and Obesity*, *18*(3), 333–336. https://doi.org/10.1007/s40519-013-0032-0

Gumble, A., & Carels, R. (2012). The harmful and beneficial impacts of weight bias on well-being: The moderating influence of weight status. *Body Image*, *9*(1), 101–107. https://doi.org/10.1016/j.bodyim.2011.07.005

Haggard, P. (2017). Sense of agency in the human brain. *Nature Reviews Neuroscience*, *18*(4), 196–207. https://doi.org/10.1038/nrn.2017.14

Hagman, J., Gardner, R. M., Brown, D. L., Gralla, J., Fier, J. M., & Frank, G. K. W. (2015). Body size overestimation and its association with body mass index, body dissatisfaction, and drive for thinness in anorexia nervosa. *Eating and Weight Disorders - Studies on Anorexia, Bulimia and Obesity*, (MAY). https://doi.org/10.1007/s40519-015-0193-0

Jansen, A., Smeets, T., Martijn, C., & Nederkoorn, C. (2006). I see what you see: The lack of a self-serving body-image bias in eating disorders. *British Journal of Clinical Psychology*, *45*(1), 123–135. https://doi.org/10.1348/014466505X50167

Jenkinson, P. M., & Preston, C. (2015). New reflections on agency and body ownership: The moving rubber hand illusion in the mirror. *Consciousness and Cognition*, *33*, 432–442. https://doi.org/10.1016/j.concog.2015.02.020

Kalckert, A., & Ehrsson, H. H. (2012). Moving a Rubber Hand that Feels Like Your Own: A Dissociation of Ownership and Agency. *Frontiers in Human Neuroscience*, *6*(March), 1–14. https://doi.org/10.3389/fnhum.2012.00040

Kalckert, A., & Ehrsson, H. H. (2014a). The moving rubber hand illusion revisited: Comparing movements and visuotactile stimulation to induce illusory ownership. *Consciousness and Cognition*, *26*(1), 117–132. https://doi.org/10.1016/j.concog.2014.02.003

Kalckert, A., & Ehrsson, H. H. (2014b). The spatial distance rule in the moving and classical rubber

hand illusions. *Consciousness and Cognition*, *30*, 118–132. https://doi.org/10.1016/j.concog.2014.08.022

Kammers, M. P. M., de Vignemont, F., Verhagen, L., & Dijkerman, H. C. (2009). The rubber hand illusion in action. *Neuropsychologia*, *47*(1), 204–211. https://doi.org/10.1016/j.neuropsychologia.2008.07.028

Keel, P. K., Dorer, D. J., Franko, D. L., Jackson, S. C., & Herzog, D. B. (2005). Postremission predictors of relapse in women with eating disorders. *American Journal of Psychiatry*, *162*(12), 2263–2268. https://doi.org/10.1176/appi.ajp.162.12.2263

Keizer, A., Engel, M. M., Bonekamp, J., & Van Elburg, A. (2018). Hoop training: a pilot study assessing the effectiveness of a multisensory approach to treatment of body image disturbance in anorexia nervosa. *Eating and Weight Disorders - Studies on Anorexia, Bulimia and Obesity*, *0*(0), 0. https://doi.org/10.1007/s40519-018-0585-z

Keizer, A., Smeets, M. A. M., Dijkerman, H. C., Uzunbajakau, S. A., van Elburg, A., & Postma, A. (2013). Too Fat to Fit through the Door: First Evidence for Disturbed Body-Scaled Action in Anorexia Nervosa during Locomotion. *PLoS ONE*, *8*(5), e64602. https://doi.org/10.1371/journal.pone.0064602

Keizer, A., Smeets, M. A. M., Dijkerman, H. C., van den Hout, M., Klugkist, I., van Elburg, A., & Postma, A. (2011). Tactile body image disturbance in anorexia nervosa. *Psychiatry Research*, *190*(1), 115–120. https://doi.org/10.1016/j.psychres.2011.04.031

Keizer, A., Smeets, M. A. M., Dijkerman, H. C., van Elburg, A., & Postma, A. (2012). Aberrant somatosensory perception in Anorexia Nervosa. *Psychiatry Research*, *200*(2–3), 530–537. https://doi.org/10.1016/j.psychres.2012.05.001

Keizer, A., Smeets, M. a. M., Postma, A., van Elburg, A., & Dijkerman, H. C. (2014). Does the experience of ownership over a rubber hand change body size perception in anorexia nervosa patients? *Neuropsychologia*, *62*, 26–37. https://doi.org/10.1016/j.neuropsychologia.2014.07.003

Keizer, A., van Elburg, A., Helms, R., & Dijkerman, H. C. (2016). A Virtual Reality Full Body Illusion Improves Body Image Disturbance in Anorexia Nervosa. *Plos One*, *11*(10), e0163921. https://doi.org/10.1371/journal.pone.0163921

Lane, K. a., Banaji, M. R., Nosek, B. a., & Greenwald, A. G. (2007). Understanding and Using the Implicit Association Test: IV What We Know (So Far) about the Method. *Implicit Measures of Attitudes*, 59–102.

Luce, K. H., & Crowther, J. H. (1999). The reliability of the Eating Disorder Examination - Self-report Questionnaire Version (EDE-Q), *25*(3), 349–351.

Mai, S., Gramann, K., Herbert, B. M., Friederich, H. C., Warschburger, P., & Pollatos, O. (2015). Electrophysiological evidence for an attentional bias in processing body stimuli in bulimia nervosa. *Biological Psychology*, *108*, 105–114. https://doi.org/10.1016/j.biopsycho.2015.03.013

Marotta, A., Bombieri, F., Zampini, M., Schena, F., Dallocchio, C., Fiorio, M., & Tinazzi, M. (2017). The Moving Rubber Hand Illusion Reveals that Explicit Sense of Agency for Tapping Movements Is Preserved in Functional Movement Disorders. *Frontiers in Human Neuroscience*, *11*(June), 291. https://doi.org/10.3389/fnhum.2017.00291

Martijn, C., Alleva, J., & Jansen, A. (2015). Improving Body Satisfaction. Do Strategies Targeting the Automatic System Work?, (January). https://doi.org/10.1027/1016-9040/a000206

Metral, M., Guardia, D., Bauwens, I., Guerraz, M., Lafargue, G., Cottencin, O., & Luyat, M. (2014). Painfully thin but acting inside a fatter body: emphasis of sensorimotor abnormalities in anorexia nervosa between weight loss and regain. *BMC Psychiatry*, *7*(1), 1–11. https://doi.org/10.1186/1756-0500-7-707

Mond, J. M., Myers, T. C., Crosby, R. D., Hay, P. J., Rodgers, B., Morgan, J. F., … Mitchell, J. E. (2008). Screening for eating disorders in primary care: EDE-Q versus SCOFF. *Behaviour Research and Therapy*, *46*(5), 612–622. https://doi.org/10.1016/j.brat.2008.02.003

Murphy, R., Straebler, S., Cooper, Z., & Fairburn, C. G. (2010). Cognitive behavioral therapy for eating disorders. *Psychiatric Clinics of North America*, *33*(3), 611–627. https://doi.org/10.1016/j.psc.2010.04.004

O'Brien, K. S., Hunter, J. A., Halberstadt, J., & Anderson, J. (2007). Body image and explicit and implicit anti-fat attitudes: The mediating role of physical appearance comparisons. *Body Image*, *4*(3), 249–256. https://doi.org/10.1016/j.bodyim.2007.06.001

Øverås, M., Kapstad, H., Brunborg, C., Landrø, N. I., & Lask, B. (2014). Memory versus perception

of body size in patients with anorexia nervosa and healthy controls. *European Eating Disorders Review*, *22*(2), 109–115. https://doi.org/10.1002/erv.2276

Pallant, J. (2007). *SPSS Survival Manual: A Step by Step Guide to Data Analysis Using SPSS for Windows Version 15*.

Parling, T., Cernvall, M., Stewart, I., Barnes-Holmes, D., & Ghaderi, A. (2012). Using the Implicit Relational Assessment Procedure to Compare Implicit Pro-Thin/Anti-Fat Attitudes of Patients With Anorexia Nervosa and Non-Clinical Controls. *Eating Disorders*, *20*(2), 127–143. https://doi.org/10.1080/10640266.2012.654056

Peirce, J. W. (2007). PsychoPy—Psychophysics software in Python. *Journal of Neuroscience Methods*, *162*(1–2), 8–13. JOUR. https://doi.org/http://dx.doi.org/10.1016/j.jneumeth.2006.11.017

Peterson, C. B., Crosby, R. D., Wonderlich, S. A., Joiner, T., Crow, S. J., Mitchell, J. E., … Grange, D. le. (2007). Psychometric Properties of the Eating Disorder Examination-Questionnaire: Factor Structure and Internal Consistency. *The International Journal of Eating Disorders*, *40*(2), 386–389. https://doi.org/10.1002/eat

Pollatos, O., Kurz, A. L., Albrecht, J., Schreder, T., Kleemann, A. M., Schöpf, V., … Schandry, R. (2008). Reduced perception of bodily signals in anorexia nervosa. *Eating Behaviors*, *9*(4), 381–388. https://doi.org/10.1016/j.eatbeh.2008.02.001

Preston, C., & Ehrsson, H. H. (2014). Illusory Changes in Body Size Modulate Body Satisfaction in a Way That Is Related to Non-Clinical Eating Disorder Psychopathology. *PLoS ONE*, *9*(1), e85773. https://doi.org/10.1371/journal.pone.0085773

Preston, C., & Ehrsson, H. H. (2016). Illusory obesity triggers body dissatisfaction responses in the insula and anterior cingulate cortex. *Cerebral Cortex*, 1–11. https://doi.org/10.1093/cercor/bhw313

Preston, C., & Ehrsson, H. H. (2018). Implicit and explicit changes in body satisfaction evoked by body size illusions : Implications for eating disorder vulnerability in women. *PloS One*, *13*(6), 1–31. https://doi.org/e0199426

Pyasik, M., Burin, D., & Pia, L. (2018). On the relation between body ownership and sense of agency:

A link at the level of sensory-related signals. *Acta Psychologica*, *185*(January), 219–228. https://doi.org/10.1016/j.actpsy.2018.03.001

Richetin, J., Perugini, M., Prestwich, A., & O'Gorman, R. (2007). The IAT as a predictor of food choice: The case of fruits versus snacks. *International Journal of Psychology*, *42*(3), 166–173. https://doi.org/10.1080/00207590601067078

Richetin, J., Xaiz, A., Maravita, A., & Perugini, M. (2012). Self-body recognition depends on implicit and explicit self-esteem. *Body Image*, *9*(2), 253–260. https://doi.org/10.1016/j.bodyim.2011.11.002

Robinson, A., Safer, D. L., Austin, J. L., & Etkin, A. (2015). Does implicit emotion regulation in binge eating disorder matter? *Eating Behaviors*, *18*, 186–191. https://doi.org/10.1016/j.eatbeh.2015.05.011

Rohde, M., Luca, M., & Ernst, M. O. (2011). The rubber hand illusion: Feeling of ownership and proprioceptive drift Do not go hand in hand. *PLoS ONE*, *6*(6). https://doi.org/10.1371/journal.pone.0021659

Roy, M., & Meilleur, D. (2010). Body image distortion change during inpatient treatment of adolescent girls with restrictive anorexia nervosa. *Eating and Weight Disorders : EWD*, *15*(1–2), e108-15. https://doi.org/7133 [pii]

Smith, A. R., Joiner, T. E., & Dodd, D. R. (2014). Examining implicit attitudes toward emaciation and thinness in anorexia nervosa. *International Journal of Eating Disorders*, *47*(2), 138–147. https://doi.org/10.1002/eat.22210

Spring, V. L., & Bulik, C. M. (2014). Implicit and explicit affect toward food and weight stimuli in anorexia nervosa. *Eating Behaviors*, *15*(1), 91–94. https://doi.org/10.1016/j.eatbeh.2013.10.017

Stice, E. (2002). Risk and maintenance factors for eating pathology: A meta-analytic review. *Psychological Bulletin*, *128*(5), 825–848. https://doi.org/10.1037/0033-2909.128.5.825

Stice, E., Fisher, M., & Lowe, M. R. (2004). Are Dietary Restraint Scales Valid Measures of Acute Dietary Restriction? Unobtrusive Observational Data Suggest Not. *Psychological Assessment*, *16*(1), 51–59. https://doi.org/10.1037/1040-3590.16.1.51

Synofzik, M., Vosgerau, G., & Newen, A. (2008). I move, therefore I am: A new theoretical

framework to investigate agency and ownership. *Consciousness and Cognition*, *17*(2), 411–424. https://doi.org/10.1016/j.concog.2008.03.008

Tiggemann, M., & Miller, J. (2010). The Internet and Adolescent Girls ' Weight Satisfaction and Drive for Thinness. *Sex Roles*, 79–90. https://doi.org/10.1007/s11199-010-9789-z

Tsakiris, M., & Haggard, P. (2005). Experimenting with the acting self. *Cognitive Neuropsychology*, *22*(3–4), 387–407. https://doi.org/10.1080/02643290442000158

Tsakiris, M., Schütz-Bosbach, S., & Gallagher, S. (2007). On agency and body-ownership: Phenomenological and neurocognitive reflections. *Consciousness and Cognition*, *16*(3), 645–660. https://doi.org/10.1016/j.concog.2007.05.012

Urgesi, C. (2015). Multiple Perspectives on Body Image Research, *20*(1), 1–5. https://doi.org/10.1027/1016-9040/a000223

Urgesi, C., Fornasari, L., Perini, L., Canalaz, F., Cremaschi, S., Faleschini, L., … Brambilla, P. (2012). Visual body perception in anorexia nervosa. *International Journal of Eating Disorders*, *45*(4), 501–511. https://doi.org/10.1002/eat.20982

Vartanian, L. R., Polivy, J., & Herman, C. P. (2004). Implicit cognitions and eating disorders: Their application in research and treatment. *Cognitive and Behavioral Practice*, *11*(2), 160–167. https://doi.org/10.1016/S1077-7229(04)80027-0

Vitousek, K. B., Daly, J., & Heiser, C. (1991). Reconstructing the internal world of the eating-disordered individual: Overcoming denial and distortion in self-report. *International Journal of Eating Disorders*, *10*(6), 647–666.

Voss, M., Chambon, V., Wenke, D., Kühn, S., & Haggard, P. (2017). In and out of control: Brain mechanisms linking fluency of action selection to self-agency in patients with schizophrenia. *Brain*, *140*(8), 2226–2239. https://doi.org/10.1093/brain/awx136

Figure 1.JPEG

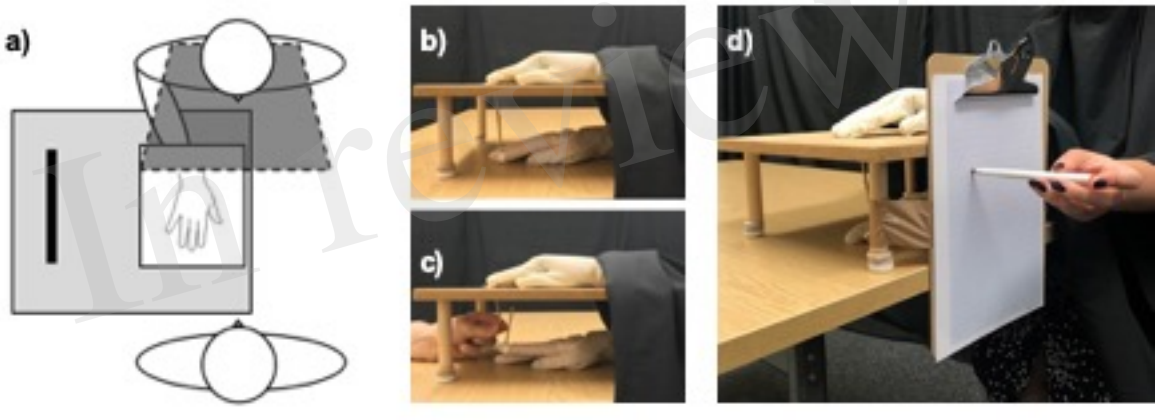

Figure 2.JPEG

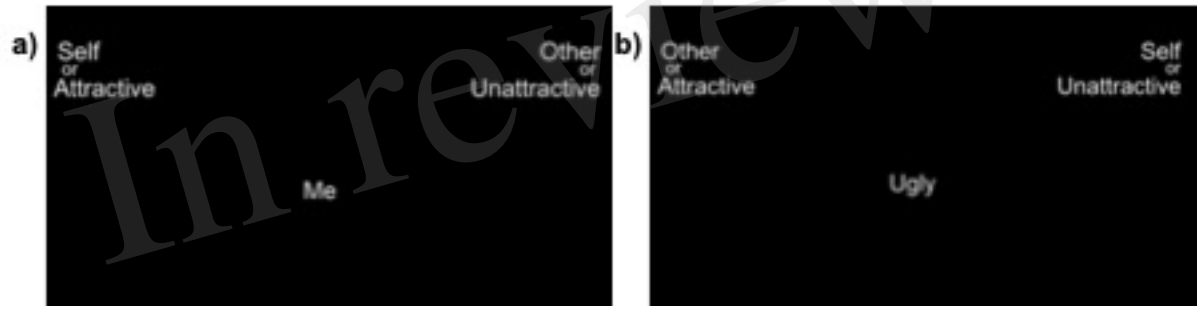

Figure 3.JPEG

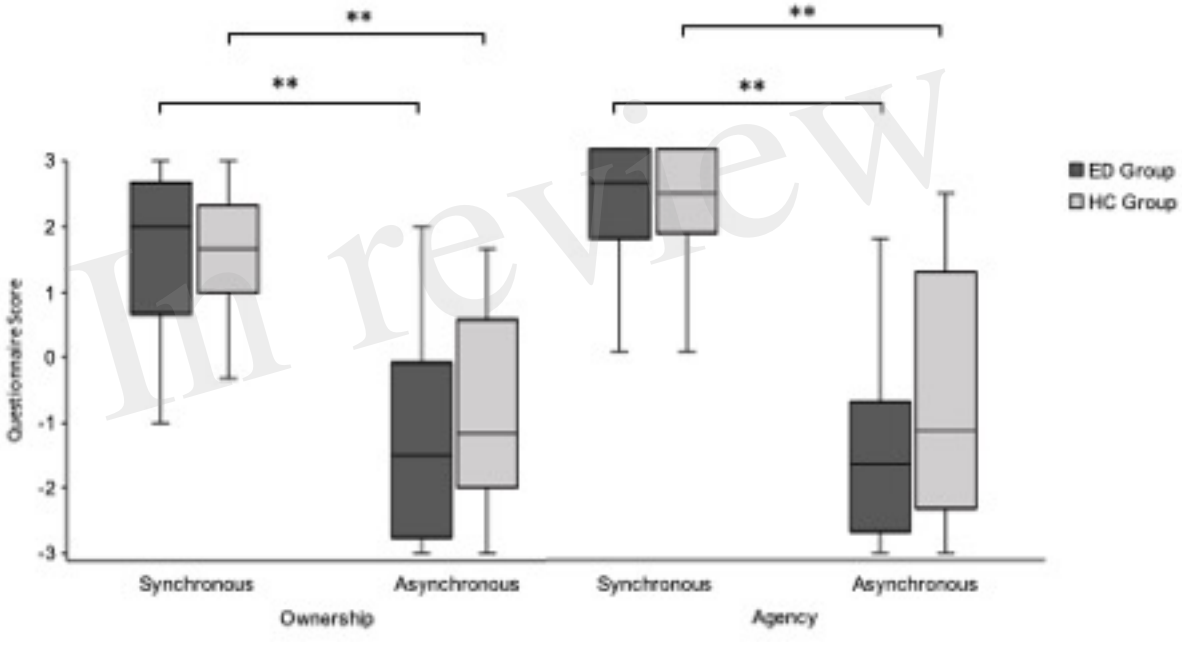

Figure 4.JPEG