Body Perception and Emotion within Clinical Eating Disorders and Non-Clinical Eating Disorder Psychopathology

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Abstract

Discontent towards one's own body has become increasingly prevalent within Western culture, with greater body dissatisfaction implicated with higher risk of disordered eating. Specifically, aberrant eating attitudes and behaviours are associated with disturbances in one's body image, which comprises the conscious representation of the body based on its perceptual, cognitive and affective evaluations. The present thesis investigates the role of sensory signals within body perception and its relationship with bodily emotions in the context of body image. This is investigated within clinical eating disorder populations, and in relation to eating disorder psychopathology within the non-clinical population. Chapter 2 investigates the role of perceptual and cognitive-affective components of body image within eating disorder groups, revealing an increased malleability of body perception accompanied by lower explicit and implicit body satisfaction compared with healthy controls. Chapter 3 explores how bodies are represented neurally in the Extrastriate Body Area amongst healthy females, in which patterns of response within this region were modulated by the interactive effect of visual perspective and body morphology. Chapter 4 further highlights the importance of visual perspective within body representation, showing that subjective embodiment towards a whole mannequin body can be induced from mere visual capture of congruent visuoproprioceptive signals when viewed from a first-person visual perspective. Chapter 5 explores the role of affective touch towards whole body ownership, with no enhancing effect of embodiment shown due to the interoceptive properties of affective touch. Finally, Chapter 6 assesses the psychometric properties of the *Eating Disorder Examination Questionnaire* in the non-clinical population, to suggest that this measure may require reassessment in accordance with updated symptomology. Together, the present thesis uses diverse experimental methods to explore the perceptual and cognitive-affective components of body image, providing new insights into the way in which such components are investigated which can be used to inform future work within this research topic.

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For Emily (1992-2015).

Author's Declaration

I declare that this thesis is a presentation of original work completed by the author, Mark Carey, under the supervision of Dr. Catherine Preston. The research presented was funded by a 3-year Departmental Teaching Studentship from the Department of Psychology, University of York. This work has not previously been presented for an award at this, or any other, University. All sources are acknowledged as References.

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Chapter 1

General Introduction

Body dissatisfaction has become increasingly common within Western society and is argued to be a potent factor in the development and maintenance of eating disorders, which are associated with serious psychological and physical impairments. Whilst eating disorders are heterogeneous in their aetiology, extreme concerns over body shape and weight is a common hallmark of the disorder which are often accompanied by an overestimation of body size and altered sensory processing pertaining to the body. Indeed, research has recently highlighted a direct link between one's perceptual appraisal of the body and their emotions held towards it. From a cognitive neuroscientific perspective, body perception is driven by the coherent integration of input from multiple sensory domains, therefore the stability of such a representation must be addressed when considering one's body image, which refers to the conscious perception and attitudes towards one's own body. Given the relationship that body image has with physical and psychological well-being, it is important to address this topic within clinical eating disorder populations. Additionally, studying this topic at the non-clinical, population level can help to inform health-related programmes to promote positive body image, and prevent adverse health outcomes associated with a clinical eating disorder.

The present chapter will first provide a brief overview of the formation of body representation via exteroceptive multisensory signals – i.e. signals from outside the body (e.g. vision and touch). This will be discussed in relation to how such sensory signals inform one's body image, and how impairments in multisensory integration may be implicated within disturbances of body image and body perception in eating disorder populations. Moreover, the role of interoception (i.e. sensory signals from within the body) will be reviewed in its contribution towards body perception and body image, before addressing how the interactive role between interoceptive and exteroceptive signals can provide a more holistic understanding of sensory processing towards body image and a stable sense of self. The above themes will be outlined in the context of the key research questions addressed within the present thesis, specifically how the subsequent empirical chapters will contribute to improving our understanding of body image within clinical and non-clinical groups.

1.1 The Sense of Body Ownership and Agency

Whilst the many senses of the "self" have long been debated from philosophical and epistemological perspectives (Descartes, 1641; James, 1890), the sense of physical self has been more recently rooted within the body. This has allowed psychologists to experimentally investigate how individuals experience a sense of body ownership - i.e. the feeling that my physical body belongs to *me*, my body is ever present, and is distinct from other's bodies (Gallagher, 2000). Despite increasing understanding of the bodily self from its original conception, scientific research has been comparatively recent in its understanding of how the body is represented in the brain, and how such feelings of body ownership arise (Gallagher, 2000; Longo, Schüür, Kammers, Tsakiris, & Haggard, 2008; Tsakiris, 2010). Moreover, an accompanying component that contributes to the bodily self is the sense of body agency (Gallagher, 2000). Agency refers to the feeling of control towards one's actions, with the experience that one is the cause of active volitional movement (Tsakiris, Schütz-Bosbach, & Gallagher, 2007), for example, *"I switched on the light switch".* Importantly, motor intentions are required for the sense of agency to occur, with the subjective experience arising when the intended and actual voluntary actions are congruent with each other (Haggard, 2017).

The contribution of body ownership and body agency are essential in forming a stable sense of bodily self (Gallagher, 2000; Synofzik, Vosgerau, & Newen, 2008b; Tsakiris et al., 2007), and would appear inherently interconnected in our everyday activities. For example, a self-generated reach towards an object (e.g. picking up a cup of tea) requires the awareness that the hand is indeed part of one's own body (i.e. body ownership), in which the individual can subsequently make a volitional reaching movement towards the cup. However, the extent to which body ownership and body agency are related remains a topic of debate. Whilst it is beyond the scope of the present thesis to extensively discuss all models related to this debate, one perspective argues that the two components are additive in their contribution to the bodily self (Tsakiris & Haggard, 2005a). Conversely, further evidence has shown that the two are qualitatively independent, as the sense of ownership and agency can be experienced separately and experimentally dissociated (Kalckert & Ehrsson, 2012, 2014a; Tsakiris, Longo, & Haggard, 2010; Tsakiris et al., 2007).

Importantly, whilst the sense of body ownership and agency appears stable and durable over time, experimental research has shown how malleable such representations can be amongst healthy individuals (Botvinick & Cohen, 1998; Kalckert & Ehrsson, 2012). Increasing research within cognitive neuroscience is using experimental methods to manipulate the sensory information that an individual receives, in order to better understand the principles within which we form a stable bodily sense of self (see Section 1.2). Furthermore, a coherent sense of body ownership and agency contribute towards the formation of our body image, which refers to the conscious representation of the body based on its perceptual, cognitive and affective evaluations (Badoud & Tsakiris, 2017). Indeed, the stability of body image is heavily linked with health and well-being (Cash, 2004), and is a topic that runs centrally throughout the present thesis (see also, Section 1.3 for further discussion).

Evidence which highlights how the sense of body ownership or body agency can be disrupted help to shed further light on how the body is represented in the brain (Braun et al., 2018). Alterations or disturbances in such body constructs are most commonly studied within neuropsychological conditions such as somatoparaphrenia (Fotopoulou et al., 2011; Jenkinson, Haggard, Ferreira, & Fotopoulou, 2013; van Stralen, van Zandvoort, Kappelle, & Dijkerman, 2013), or anosognosia for hemiplegia (Fotopoulou et al., 2008; Martinaud, Besharati, Jenkinson, & Fotopoulou, 2017), and psychiatric disorders such as eating disorders (EDs) (Cash & Deagle, 1997). Consequently, a key focus of the present thesis is to investigate how differences in the processing or integration of sensory information relate to ED psychopathology within clinical and non-clinical populations, particularly how this plays a role within body image.

1.2 The Role of Multisensory Integration in Body Representation

From a cognitive neuroscientific perspective, the sense of body ownership and agency is grounded in bodily experience via multisensory integration, which arises through a flow of incoming sensory information that is specific to the self and not available to other's bodies (de Vignemont, 2011). Such sensory signals originate outside the body via exteroceptive modalities (e.g. vision, touch) (Ehrsson, Spence, & Passingham, 2004; Tsakiris, 2010) as well as within the body via interoceptive modalities (e.g. proprioception, hunger, heart rate – see section 1.4) (Craig, 2002, 2009; Tsakiris, Tajadura-Jiménez, & Costantini, 2011), in which the brain dynamically weights and integrates such incoming bodily signals to create a coherent sense of body ownership and unified representation of the world (Azañón et al., 2016; Tsakiris, 2010).

Paradigms that provide controlled investigation and manipulation of body ownership utilise multisensory illusion experiments. The most studied of these is the Rubber Hand Illusion (RHI), in which individuals typically experience ownership over a fake rubber hand when it is stroked in temporal and anatomical synchrony with their own hand that is hidden out of view (Botvinick & Cohen, 1998). The RHI represents a three-way interaction between visual, tactile, and proprioceptive information; upon the integration of such sensory inputs, the brain matches the incoming visual and tactile sensory information it receives and fuses this into a single event, which typically updates incoming proprioceptive input towards the direction of the fake hand. Importantly, this effect does not occur, or is considerably weaker when tactile and visual strokes are administered asynchronously between the real and fake hand, thus acting as an experimental control condition. The induction of the illusion is typically quantified using subjective measures such as questionnaire items, as well as objective measures such as proprioceptive drift (i.e. an observed shift in perceived spatial location of the hand towards the rubber hand following induction to the illusion), and physiological skin conductance response (SCR) when threatening the fake body (part) (Armel & Ramachandran, 2003).

More recently, the multisensory principles of the RHI have been extended to create a Full Body Illusion (Petkova, Björnsdotter, et al., 2011; Petkova & Ehrsson, 2008; Slater, Perez-Marcos, Ehrsson, & Sanchez-Vives, 2009), in which individuals experience illusory ownership of an entire body commonly viewed from a first-person perspective (see Chapters 4 and 5). Using the discussed methods of visuo-tactile stimulation, individuals typically display an illusory ownership towards another's body when stroked synchronously with their own, unseen body (Petkova & Ehrsson, 2008). Induction of this illusion is similarly quantified by subjective reports from participants using questionnaire items, as well as objective, physiological measures such as heart rate deceleration or skin conductance response (Ehrsson, 2007; Petkova & Ehrsson, 2008; Slater et al, 2009). Taken together, the RHI and full body illusion have become powerful methods in underpinning the basis of bodily self-consciousness, allowing controlled experimental investigation of the dynamic flexibility of body representation and how it can be achieved via the integration of exteroceptive sensory signals.

Since its original inception (Botvinick & Cohen, 1998), the RHI has become a well-established model to investigate body ownership. However, despite being a fundamental component of our bodily self, the multisensory basis of the sense of agency has been comparably less researched from a neurocognitive perspective, not least with how it is experienced alongside body ownership. Therefore, a more recent model used to investigate body agency is an extension of the 'classic' RHI, called the Moving Rubber Hand Illusion (Kalckert & Ehrsson, 2012). In this paradigm, a participant's right index finger is mechanically connected to a matching finger on a fake hand placed above, such that when the participant moves their own index finger, the index finger of the seen, fake hand moves in complete synchrony. In asynchronous conditions, the mechanical connection between the real and fake hand is broken, with the movements of the fake index finger controlled by the experimenter with a temporal delay to the movements of the participant's index finger (see Chapter 2 for further methodological discussion). This paradigm provides the opportunity to systematically investigate the contribution and interaction of body ownership and body agency, by introducing active movement from the participant rather than passive visuotactile stimulation (see Chapter 2), and serves as a valuable method in the investigation of body representation (Kalckert & Ehrsson, 2012).

Importantly, neurocognitive models of ownership within body illusions suggest that the effects typically occur as an interaction between multisensory input and stored, internal models related to the body (Tsakiris, 2010). That is, the bottom-up, sensory experience of the illusion is argued to arise within the constraints of top-down contextual information – i.e. pre-existing, higher-order representations of the body. Evidence has shown such constraints which influence the perceptual experience to include the postural orientation (Ehrsson et al., 2004; Tsakiris & Haggard, 2005b), visual appearance (i.e. a corporeal object) (Haans, IJsselsteijn, & de Kort, 2008; Petkova & Ehrsson, 2008; Tsakiris, Carpenter, James, & Fotopoulou, 2010), and spatial location (Kalckert & Ehrsson, 2014b) of the embodied body (part). Indeed, the strength of the illusion has been shown to be modulated by the distance between the real and fake body (part), with greater mismatch leading to a decreased likelihood of integration between visuoproprioceptive signals (Lloyd, 2007; Preston, 2013).

Furthermore, a top-down process that is central within the present thesis is the importance of visual perspective towards embodiment (Maselli & Slater, 2013; Petkova, Khoshnevis, & Ehrsson, 2011; Preston, Kuper-Smith, & Henrik Ehrsson, 2015). Evidence has highlighted that multisensory integration during embodiment is optimally coded within egocentric reference frames (i.e. first-person visual perspective) compared with allocentric reference frames (i.e. third-person visual perspective) (Kilteni, Maselli, Kording, & Slater, 2015; Petkova, Khoshnevis, et al., 2011). Specifically, converging research has shown that violation of the first-person perspective can be sufficient in preventing body ownership within both rubber hand and full body illusion paradigms, despite synchronous visuotactile stimulation (Costantini & Haggard, 2007; Maselli & Slater, 2013; Tsakiris & Haggard, 2005b; but see Lenggenhager, Tadi, Metzinger, & Blanke, 2007 for evidence of change in self-location). Indeed, studies have shown that illusory embodiment could still be induced during multisensory illusion paradigms based purely on visual information of a fake body (part) in the absence of visuotactile stimulation, when perceived within egocentric reference frames (Kilteni et al., 2015; Longo, Cardozo, & Haggard, 2008; Pavani, Spence, & Driver, 2000; Rohde, Luca, & Ernst, 2011; Samad, Chung, & Shams, 2015). Therefore, the importance of visual perspective towards embodiment is considered and investigated within the empirical work undertaken in the present thesis (see Chapters 2, 4, & 5), particularly how egocentric (first-person) vs. allocentric (third-person) perspectives of bodies are represented in the brain (see Chapter 3).

1.3 Body Image

As previously discussed (see Section 1.1), the perception of our own body relies on the integration of multiple exteroceptive and interoceptive sensory signals, which is fundamental in contributing towards one's own body image (Zamariola, Cardini, Mian, Serino, & Tsakiris, 2017). Whilst its definition varies within the literature, a working definition of body image refers to the conscious perception, attitudes and beliefs about one's own body (Gallagher, 2006). Body image is considered to be a multifaceted construct that is commonly divided into two components (Skrzypek, Wehmeier, & Remschmidt, 2001). Perceptual body image refers to estimations of one's own body size or dimensions, and the accuracy of such estimation relative to their veridical measurement. Correspondingly, affective body image refers to attitudinal evaluation of bodily appearance, shape or weight, which commonly depicts one's subjective body satisfaction (Badoud & Tsakiris, 2017; Cash, 2004). Importantly, positive body image is significantly linked with positive well-being and mental health (Cash, 2004). Conversely, negative body image is associated with poor physical health and psychiatric disorders (see Alleva, Sheeran, Webb, Martijn, & Miles, 2015, for review), particularly contributing to the development and maintenance of clinical EDs (Cash & Deagle, 1997; Stice, 2002; Stice & Shaw, 2002).

1.3.1 Body Image Disturbances in Eating Disorders

EDs subsume a group of illnesses, broadly characterized by a severe, persistent disturbance of eating behaviour, leading to both psychological and physical impairment (American Psychiatric Association, 2013; Smink, van Hoeken, & Hoek, 2012). It is presently estimated that EDs affect more than 725,000 people in the UK, of which approximately 11% are male (Beat Charity, 2015). Currently, the three most common EDs are Anorexia Nervosa (AN), Bulimia Nervosa (BN) and Other Specified

Feeding or Eating Disorders (OSFED). Individuals often display an abnormal attitude towards food, resulting in extreme eating behaviours such as severe reductions of food intake, episodes of over-eating, or purging behaviours (American Psychiatric Association, 2013). The current efficacy of treatment amongst all EDs has proven to be mixed (Watson & Bulik, 2013), resulting in poor long-term recovery (Espie & Eisler, 2015) and high relapse (Herpertz-Dahlmann, van Elburg, Castro-Fornieles, & Schmidt, 2015). Whilst there are distinctive features between the different diagnoses of EDs, one of the common hallmarks amongst all the disorders is a dysfunctional bodily experience, referred to as body image disturbance. Much like the above definition of body image, researchers distinguish between a perceptual component of body image disturbance - characterized by difficulty in correctly estimating one's own body size (Gardner & Brown, 2014; Keizer, Smeets, Postma, van Elburg, & Dijkerman, 2014; Keizer, van Elburg, Helms, & Dijkerman, 2016; Øverås, Kapstad, Brunborg, Landrø, & Lask, 2014), and a cognitive-affective component of body image disturbance (Cash & Deagle, 1997) - characterized by intense emotional concerns over body image (i.e. body dissatisfaction), with an undue influence of shape or weight placed upon one's self-worth and self-evaluation (American Psychiatric Association, 2013; Myers & Crowther, 2009).

Historically, research has primarily investigated the subjective, cognitive-affective aspect of body image disturbances in EDs (Urgesi, 2015). Many current treatments such as cognitive-behavioural therapy (CBT) focus predominantly on techniques such as psycho-education, cognitive restructuring and self-monitoring (Alleva et al., 2015), which aim to provide patients with explicit coping strategies to combat any intrusive emotions and dysfunctional thoughts or behaviours relating to their negative body image (Martijn, Alleva, & Jansen, 2015; Murphy, Straebler, Cooper, & Fairburn, 2010). However, more recent approaches in cognitive neuroscience have offered a more scientific understanding that may underpin body image disturbances, with growing research suggesting that such distorted cognitions may well be influenced by an inaccurate perceptual experience of the body based on the processing and integration of bottom-up, sensory information (Guardia et al., 2010; Keizer et al., 2014). Moreover, whilst it has been previously argued that the two components comprising body image disturbance are independent from each other (Cash & Deagle, 1997), it has become increasingly apparent that there lies an important link between the perception of the body and the emotions held towards it (Hagman et al., 2015; Preston & Ehrsson, 2014, 2016). Subsequently, it is important that body image disturbance is studied holistically between the objective assessment of the body (i.e. perceptual) with the subjective experience towards one's bodily appearance (i.e. cognitive-affective) (Espeset, Gulliksen, Nordbø, Skårderud, & Holte, 2012; Zanetti, Santonastaso, Sgaravatti, Degortes, & Favaro, 2013).

Whilst it is suggested that perceptual body image disturbances might not be a universal factor amongst all ED patients (Cornelissen, Johns, & Tovée, 2013; Skrzypek et al., 2001), evidence has established that clinical outcomes are poorer amongst those who report greater misperception of their body (Boehm et al., 2016; Keel, Dorer, Franko, Jackson, & Herzog, 2005). Research has highlighted that alterations in perceptual bodily experience can influence the efficacy of treatment and risk of relapse amongst ED patients (Cash & Deagle, 1997; Stice, Ng, & Shaw, 2010), with such alterations shown to exist following remission or recovery (Engel & Keizer, 2017; Eshkevari, Rieger, Longo, Haggard, & Treasure, 2014). Importantly, many argue that the perceptual component of body image disturbance has not received sufficient attention within research or clinical treatment (Boehm et al., 2016; Exterkate, Vriesendorp, & de Jong, 2009; Suchan, Vocks, & Waldorf, 2015). Therefore, improvement in this experience may act as a protective factor against relapse, if the cognitive-affective coping strategies acquired in therapy were no longer effective (Bardone-Cone et al., 2010). Further research in this area may improve upon the poor clinical outcomes and high relapse rates that are currently observed amongst ED patients, which would provide important implications in clinical treatment. Accordingly, Chapter 2 investigates body image disturbance amongst ED patients from a perceptual, multisensory perspective (see Section 1.3.2 for multisensory impairments amongst ED patients), and how such perceptual components of body image may link with cognitive-affective components influencing body satisfaction.

1.3.2 Multisensory Impairments in Eating Disorders

As discussed above (see Section 1.2), a cognitive neuroscience perspective to body representation contends that body ownership is grounded in the perception and integration of multiple interoceptive and exteroceptive sensory signals (Tsakiris, 2010), which influence one's body image and bodily experience (Zamariola et al., 2017). Therefore, as body image disturbance has been highlighted as a strong predictor in the development and prognosis of EDs (Stice, Ng, et al., 2010), it is important for researchers to use experimental methods to objectively investigate sensory and neural alterations amongst ED patients, and their influence towards the pathology of the disorder (Gaudio, Brooks, & Riva, 2014).

Increasing neuroimaging evidence has sought to explore the neural correlates of body image disturbance, with numerous studies implicating altered visual processing amongst ED patients (Esposito, Cieri, di Giannantonio, & Tartaro, 2016). Specifically, the extrastriate body area (EBA) - located in the lateral occipito-temporal cortex which responds selectively to human bodies and body parts (Downing, Jiang, Shuman, & Kanwisher, 2001) - has been reported to show reduced functional activation amongst ED individuals compared with healthy controls (Uher et al., 2005). Moreover, research has highlighted reduced structural gray matter density in the EBA amongst AN patients which has been implicated specifically with perceptual body size misjudgement (Suchan et al., 2010). Indeed, Vocks and colleagues (2011) observed an increase in functional EBA activation amongst ED patients following a cognitive-behavioural body image therapy intervention (Vocks et al., 2010, 2011). Taken together, such research suggests that altered EBA activity and body-related visual processing may be implicated in body image disturbances, thus facilitating its development and maintenance within EDs (Castellini et al., 2013; Groves, Kennett, & Gillmeister, 2017; Suchan et al., 2015; Urgesi et al., 2012). Consequently, the functional role of the EBA is further addressed within Chapter 3, investigating how the visual perspective and morphology (i.e. size/shape) of perceived bodies can modulate neural response within this region, in relation to non-clinical ED psychopathology.

In addition to visual processing, research has revealed disturbances across multiple independent sensory modalities in EDs, such as tactile perception (Keizer et al., 2011; Keizer, Smeets, Dijkerman, van Elburg, & Postma, 2012), pain perception (Strigo et al., 2013), haptic perception (Grunwald, Ettrich, Assmann, et al., 2001; Grunwald, Ettrich, Krause, et al., 2001), and proprioceptive perception (Guardia et al., 2012; 2013). This further supports the argument that body image disturbances amongst ED patients are likely to exist beyond distorted cognitions pertaining to the body, and may be influenced by altered sensory perception (Larfargue & Luyat, 2014). Alongside individual sensory alterations amongst ED patients, researchers have found impairments in the integration of multisensory information which has been further implicated within body image disturbances (Gaudio et al., 2014). Indeed, ED patients were shown to display a greater susceptibility to the RHI compared with healthy controls following both illusion and control conditions, evidenced by larger proprioceptive drift and self-reported questionnaire items (Eshkevari, Rieger, Longo, Haggard, & Treasure, 2012). Similar findings were observed by Keizer and colleagues (2014), with the induction of the illusion also shown to improve initial overestimation of body size amongst patients (Keizer et al., 2014, 2016). This suggests such individuals are likely to display a greater reliance towards visual sensory input which dominates proprioceptive sensory input, thus leading to a stronger illusory experience. Furthermore, such evidence highlights that the malleable body representation observed amongst patients can lead to improvements in the perceptual estimation of one's own body size which can inform treatment interventions for body image disturbances (Keizer, Engel, Bonekamp, & Van Elburg, 2018; Keizer et al., 2016).

Importantly, increased subjective embodiment in the RHI has also been observed in recovered ED patients, with comparable embodiment with acute patients (Eshkevari et al., 2014) which suggests that such increased malleability of the bodily self persists to some degree following recovery (Engel & Keizer, 2017). Indeed, it is thus argued that such disturbance in one's body image may be a trait phenomenon associated with heightened sensitivity towards visual information which may outweigh other sensory information pertaining to the body (Eshkevari et al., 2014). This would suggest that such a trait disturbance exists *prior* to illness onset, acting as a risk factor within the pathology of the disorder.

Therefore, it is important that research investigates body image within the non-clinical population in relation to ED psychopathology and vulnerability, in helping to identify such risk factors that might precede the disorder (Mussap & Salton, 2006). This important question is a central theme that runs through three chapters within the present thesis, by investigating individual differences in sensory processing in relation to non-clinical ED psychopathology.

Taken together, the above evidence highlights how alterations in processing sensory information can play a key role within body image disturbances amongst ED patients. Importantly, research which has investigated alterations in multisensory integration has primarily focused on how this influences an individual's sense of body ownership within body representation. However, as discussed above (see Section 1.1), the sense of agency is a fundamental component towards one's body representation but remains under-researched within the clinical ED population. Therefore, the current thesis aims to contribute to the literature by investigating the stability of body ownership and body agency using a multisensory illusion paradigm (see Chapter 2). Moreover, the relationship between the two components of body image disturbance will be assessed, to better understand the link between perceptual stability and body satisfaction, with a focus on how this might relate to prognosis and clinical outcomes during recovery.

1.3.3 Body Image in the Non-Clinical Population

Whilst researchers and clinicians commonly outline the prevalence rates of clinical EDs (Beat Charity, 2015), such figures are likely to underestimate the true number of ED diagnoses, with a lack of consistency in published reporting (National Institute for Clinical Excellence, 2004) and an increasing number of clinical ED admissions (7%) per annum (Micali, Hagberg, Petersen, & Treasure, 2013). Moreover, subclinical ED symptoms do not contribute to clinical prevalence figures but can be informative in identifying those at risk of developing EDs. With the influence of the media portraying 'ultra-thin' ideal bodies in females (Bell & Dittmar, 2011; Robinson & Aveyard, 2017), and increasing desirability for leanness and muscularity amongst males (Bazzini, Pepper, Swofford, & Cochran, 2015), body dissatisfaction is rising within the population (Myers & Crowther, 2009; Stice & Shaw, 2002). With research identifying body image disturbances as a key risk factor for the onset of ED diagnosis (Jacobi, Hayward, de Zwaan, Kraemer, & Agras, 2004; Stice, Marti, & Rohde, 2010), it remains critical to research the conditions in which such risk factors are more prevalent, and thereby how they can be improved and prevented for individuals who are more vulnerable to the disorder. Consequently, it is critical to study body image in the non-clinical population, to better understand the mechanisms that might contribute to ED vulnerability and a clinical diagnosis (Combs, Pearson, Zapolski, & Smith, 2013; Evans et al., 2017; Preston & Ehrsson, 2014, 2016, 2018). In addition, given its strong association with health and well-being (Cash, 2004), studying body image within the non-clinical population can help to inform health-promotion programmes rather than focusing exclusively on adverse outcomes associated with clinical disorders and poor mental health (Mond, Hay, Rodgers, & Owen, 2009).

In line with the above evidence within ED patients, research has used experimental body illusions to investigate the relationship between body ownership and body image in healthy individuals. For example, Longo et al. (2009) highlighted that individuals who displayed a greater experience of the RHI subsequently perceived the appearance of their own hand as significantly more similar to the rubber hand, which suggests that ownership influenced changes in perceived similarity (Longo, Schüür, Kammers, Tsakiris, & Haggard, 2009). Moreover, a direct link between perceptual and cognitive-affective components of body image has been established amongst healthy females using a full body illusion, such that illusory ownership over a slimmer body led to a decrease in the perceived body width and resulted in a significant increase in subjective body satisfaction (Preston & Ehrsson, 2014, 2018). Notably, changes in emotional responses to owning an obese body significantly correlated with non-clinical ED psychopathology, such that greater changes in body satisfaction were observed in those higher in ED attitudes and behaviours (Preston & Ehrsson, 2014). Together, such findings support the relationship between perceptual and affective representations of body image, which can be investigated in non-clinical populations using experimental multisensory illusion paradigms. Indeed, this relationship between the perception of the body and the emotions held towards it runs as a central theme throughout all experimental chapters in the present thesis.

In addition, the above behavioural responses following the full body illusion were mirrored neurally during functional magnetic resonance imaging (Preston & Ehrsson, 2016). It was observed that feelings of body dissatisfaction following illusory obesity were related to activity in the anterior insula and anterior cingulate cortex, both of which are regions associated with emotional processing of body-related information (Craig, 2002). Importantly, cingulate activity during illusory obesity was shown to be reduced amongst females with high, non-clinical ED psychopathology. Activation in this region is particularly relevant, following research highlighting reduced grey matter volume in the anterior cingulate cortex amongst AN patients (Joos et al., 2011; Mühlau et al., 2007). Furthermore, such emotional processing regions were shown to be functionally connected to the posterior parietal cortex, a key brain area associated with the integration of body-related sensory information (Blanke, 2012). Taken together, the above evidence which links body perception and body satisfaction amongst healthy individuals highlights the importance of bottom-up, sensory processes interacting with top-down, cognitive-affective processes in the formation of body image, suggesting that how one perceives their own body has a direct relationship with the emotions held towards it. Additionally, such work which investigates those at risk of an ED in the non-clinical population is of clinical use in implicating functional brain areas that may be linked to the development of the disorder (Preston & Ehrsson, 2016).

Assessment tools are available to investigate ED psychopathology and vulnerability in the non-clinical population. The Eating Disorder Examination Questionnaire (EDE-Q) (Fairburn & Beglin, 1994) has become an increasingly used assessment of ED psychopathology. This 28-item self-report measure assesses eating disorder attitudes and the frequency of disordered eating behaviours within the past 28 days, with higher scores indicative of higher ED psychopathology. Accordingly, it would be of great value to both researchers and clinicians to obtain normative data from a large population using the EDE-Q within the UK, to assess the prevalence of ED psychopathology amongst a wide non-clinical sample and investigate how ED risk may vary across different demographic characteristics. Importantly, providing normative data offers an empirical context within which to assess the scores of individuals in both clinical and non-clinical populations. This is addressed in Chapter 6, in being the first study to provide EDE-Q norms across a large, wide reaching sample of males and females within the UK. Moreover, such a measure could provide early detection of ED vulnerability which has been shown to strongly increase rates of treatment and recovery (Becker, Franko, Nussbaum, & Herzog, 2004; Eisenberg, Nicklett, Roeder, & Kirz, 2011). From an experimental standpoint it would be valuable to investigate those with higher ED psychopathology in the non-clinical population, to determine how similar such individuals are on measures of body satisfaction and body representation compared with clinical ED patients.

1.4 The Role of Interoception in Body Ownership

As discussed above (see Section 1.2), the processing and integration of crossmodal sensory information pertaining to the body is integral in informing our sense of body ownership (Tsakiris, 2016). Experimental research which investigates multisensory integration towards body ownership has largely studied the process of exteroceptive sensory integration from *outside* the body (i.e. vision, touch). However, much less research has investigated the role of interoception, despite being a sensory stream of information which is essential to our body awareness. Interoception is defined as the sensory signal indicating one's physiological state from *within* the body (Craig, 2002, 2009), and is important in understanding the signals from one's visceral organs in the processing of hunger, thirst or satiety (Tsakiris et al., 2011), but also for processing external sensations such as itch, pain, and pleasure from touch (Crucianelli, Krahé, Jenkinson, & Fotopoulou, 2017). Crucially, interoception plays a key role in the adaptation and regulation of the body within one's changing environment (Tsakiris, 2016), with evidence that the coherent processing of such internal bodily signals is associated with self-awareness (Craig, 2009; Critchley, Wiens, Rotshtein, Öhman, & Dolan, 2004), regulation of emotions (Damasio, 2010), and a stable body image (see Section 1.4.1, and Badoud & Tsakiris, 2017, for review).

Increasing research has highlighted the reciprocal relationship that exteroception and interoception can have in relation to body ownership (Ainley & Tsakiris, 2013). Indeed, Tsakiris and colleagues (2011) found that lower interoceptive accuracy (i.e. ability to detect internal bodily sensations), using a heartbeat perception task (Schandry, 1981) resulted in a stronger sense of body ownership over a fake hand during the RHI, particularly on objective measures of proprioceptive drift and physiological skin temperature change (Tsakiris et al., 2011). Furthermore, Suzuki et al. (2013) found that cardio-visual feedback that was synchronous to participant's own heartbeat led to an enhanced experience of the RHI, adding credence to the importance of interoceptive signals in strengthening body ownership alongside exteroception (Suzuki, Garfinkel, Critchley, & Seth, 2013; see also, Aspell et al., 2013 for similar methodology). Importantly, these two streams of sensory information from exteroceptive and interoceptive signals have been shown to be bidirectional, in which changes in body ownership can also influence an individual's ability to accurately detect internal bodily signals. Specifically, those with poorer interoception were shown to improve their interoceptive accuracy following induction to the RHI, which relies on the processing and integration of exteroceptive bodily signals (Filippetti & Tsakiris, 2017). Thus, directed attention to exteroceptive information was argued to facilitate processing of internal states which improved interoceptive accuracy (Ainley, Tajadura-Jiménez, Fotopoulou, & Tsakiris, 2012). Together, the above research highlights the important balance in the weighting of interoceptive and exteroceptive sensory information, and the reciprocal relationship they share in contributing towards a stable bodily self. Whilst it is a growing research topic, the above work represents a small number of empirical studies, therefore the contribution and relationship between these sensory signals towards embodiment must be further investigated, which the present thesis aims to contribute to (See Chapters 4 & 5).

1.4.1 Interoception and Body Image Disturbances

Despite growing research in the psychological literature investigating somatosensory, bottom-up processes in perceptual components of body image (Gaudio et al., 2014), the role of interoception influencing body image remains poorly understood (Badoud & Tsakiris, 2017). Investigations of the role of interoception towards body image is most studied amongst clinical populations who exhibit alterations or distortions in their body image, such as EDs (Strigo et al., 2013). Indeed, poor interoceptive accuracy and/or awareness has been implicated in the pathology of the disorder (Herbert

& Pollatos, 2014; Merwin, Zucker, Lacy, & Elliott, 2010; Pollatos et al., 2008), which has been linked with body image disturbances (Badoud & Tsakiris, 2017).

Specifically, Pollatos et al. (2008) presented evidence of lower interoceptive sensitivity using a heartbeat detection task, and lower self-reported interceptive awareness amongst AN patients compared with healthy controls. Moreover, Pollatos and Georgiou (2016) observed a negative correlation between body satisfaction and interoceptive accuracy amongst AN patients (see also, Herbert & Pollatos, 2014). Furthermore, Eshkevari et al. (2012) found that greater susceptibility to the RHI amongst ED patients was predicted by poorer interoceptive awareness, which corroborates the findings of Tsakiris et al. (2011) amongst healthy individuals, on the relationship and balance between interoceptive and exteroceptive information influencing body representation (see also, Keizer et al., 2014). However, evidence of interoceptive alterations within the ED populations is not uniform across all diagnoses, with inconsistent results across differing measures within which interoception is assessed. For example, Pollatos & Georgiou (2016) found interoceptive accuracy to be comparable between healthy controls and female BN patients. Moreover, Eshkevari and colleagues (2014) found no difference in interoceptive sensitivity between ED patients (of varied diagnoses) and healthy controls, using a heartbeat detection task, which contrasts with previous findings in this population (Pollatos et al., 2008).

Nonetheless, with evidence that body image disturbance may represent a trait disturbance amongst ED patients that persists following recovery (Engel & Keizer, 2017; Eshkevari et al., 2014), it may therefore be that poor interoceptive awareness and understanding of internal bodily signals might contribute to the development of the disorder. Indeed, poor interoception has been proposed to play a key role in both the onset and maintenance of the disorder (Fassino, Pierò, Gramaglia, & Abbate-Daga, 2004), with interoceptive deficits shown to be present amongst recovered patients (Berner et al., 2018; Fischer et al., 2016; Klabunde, Acheson, Boutelle, Matthews, & Kaye, 2013). Such persistent alterations may reflect a generalized weakened interoceptive perception, or a top-down inhibition of interoceptive processing that exists independent of a clinical disorder (Badoud & Tsakiris, 2017). Thus, to investigate whether a developmental time course of interoceptive alterations exists within ED pathology, further research is required to investigate this relationship within the non-clinical, healthy population (Zamariola et al., 2017).

1.4.2 Interoception and Body Image in the Non-Clinical Population

Research has observed an association between interoceptive accuracy and body image within healthy individuals, which highlights the inherent link between interoceptive signals and their cognitive appraisal within one's body representation (Duschek, Werner, Reyes del Paso, & Schandry, 2015; Emanuelsen, Drew, & Köteles, 2015). Specifically, research has shown that interoceptive accuracy was inversely correlated with individuals' self-objectification – i.e. experiencing one's body as an object to be evaluated based on physical appearance, rather than for its effectiveness or competency (Ainley & Tsakiris, 2013). Moreover, corroborative evidence has shown a significant relationship between interoceptive accuracy and body image satisfaction amongst healthy individuals, such that individuals with lower accuracy reported greater dissatisfaction towards their body (Duschek et al., 2015; Emanuelsen et al., 2015). Finally, Zamariola and colleagues (2017) showed an interaction between interoception and exteroceptive perception of the body, in which individuals with lower interoceptive accuracy improved their ability to monitor their heartbeat after an exteroceptive, body image task. Taken together, research in both clinical ED populations and non-clinical, healthy populations suggest that interoception has an inherent link with body image, which further highlights the relationship between bottom-up multisensory processes, and top-down cognitive-affective attitudes towards one's own body representation (Zamariola et al., 2017). Specifically, such work suggests that the coherent perception of the bodily self relies on the precise weighting and balance of both interoceptive and exteroceptive sensory information pertaining to the body (Filippetti & Tsakiris, 2017).

1.4.3 Interoception and Affective Touch

Whilst typical approaches to quantifying interoception largely include cardiac-related measures (e.g. heartbeat perception task; Tsakiris et al., 2011), gastric sensitivity (Herbert, Muth, Pollatos, & Herbert, 2012), or thermal pain (Kammers, Rose, & Haggard, 2011) as a proxy for interoceptive awareness (Tsakiris & Critchley, 2016), an increasingly used method to investigate the role of interoceptive signals in body ownership is the use of affective touch. Indeed, as previously discussed, information regarding one's internal state of the body arises from within (e.g. hunger, thirst), but also from outside (e.g. pain, touch) the body, and growing psychological and neuroscientific research is investigating the role of affective touch in contributing towards of our sense of bodily self (Fotopoulou & Tsakiris, 2017).

Affective touch refers to a pleasant touch which activates specific slow-conducting, unmyelinated (C-tactile) afferent nerve fibres found only in hairy skin (Crucianelli et al, 2013; Vallbo et al, 1999). Such fibres respond selectively to slow (between 1 and 10 cm/s), soft stroking speeds (Löken et al, 2009), which induce distinct neurophysiological responses compared with discriminative, exteroceptive touch which is coded by fast-conducting, myelinated fibres (Olausson, Wessberg, Morrison, McGlone, & Vallbo, 2010). Importantly, activation of C-tactile (CT) fibres following affective touch has been associated with increased subjective pleasantness ratings (Löken et al., 2009) and implicit measures of affective state (Pawling, Cannon, McGlone, & Walker, 2017). Such fibres are argued to take a distinct pathway to the posterior insular cortex, an area associated with the early convergence of interoceptive information related to bodily signals (Craig, 2009; Crucianelli et al, 2016; Morrison et al, 2011). This information is then coded in the anterior insular, a key site for interoceptive awareness, and integrated with additional sensory information pertaining to the body (Craig, 2009; Crucianelli et al., 2013). Therefore, investigation of affective touch could provide a unique connection between an individual's outer boundaries (i.e. skin) and interoceptive, internal state (i.e. subjective pleasantness).

Importantly, affective touch has been shown to enhance body ownership within multisensory illusion paradigms. Specifically, Crucianelli et al. (2013) found that CT-optimal touch during the RHI was perceived as more pleasant than fast, CT-non-optimal touch amongst healthy individuals, and elicited a stronger subjective experience of the illusion (see also, Crucianelli et al., 2017; Lloyd, Gillis, Lewis, Farrell, & Morrison, 2013). Corroborative evidence from Van Stralen et al. (2014) showed that affective touch specific to the CT-afferent hairy skin resulted in greater proprioceptive drift towards the fake hand in the RHI set-up (van Stralen et al., 2014). Such findings have been recently extended towards a whole body using a virtual full body illusion (de Jong, Keizer, Engel, & Dijkerman, 2017), however, mixed results within this study suggest that the exact role of affective touch influencing ownership towards a full body remain equivocal, which the present thesis aims to address (see Chapter 5). Taken together, evidence suggests that interoception plays a key role in strengthening body ownership and underlines the need to investigate this sensory stream in addition to exteroception when considering the basis of the bodily self.

Recent research has shown that individuals with AN display alterations in the perception of touch, displaying reduced subjective pleasantness compared with healthy controls (Bischoff-Grethe et al., 2018; Crucianelli et al., 2016; Davidovic et al., 2018). Such differences in the interpretation of sensory input may reveal an altered top-down bodily pleasure amongst AN patients, reflective of generalized blunted emotions to hedonic information within this population (Kaye, Wierenga, Bailer, Simmons, & Bischoff-Grethe, 2013). Alternatively, reduced pleasure specifically to affective touch (Crucianelli et al., 2016) could relate to a dysfunctional CT afferent system amongst AN patients, linking with altered interoceptive bodily awareness (Jenkinson, Taylor, & Laws, 2018) and body image disturbances which commonly characterize the disorder. Importantly, it remains unknown whether such alterations in sensory processing are a cause or consequence of chronic disordered eating behaviours within this clinical population (Crucianelli et al., 2016). Indeed, as previously discussed, body representation disturbances have been shown to persist after recovery (Engel & Keizer, 2017; Eshkevari et al., 2014) which may suggest that such disturbances are a trait phenomenon that could be present prior to illness onset (Eshkevari et al., 2014). Therefore, it is clinically useful to investigate such sensory processing amongst non-clinical, healthy individuals in relation to ED psychopathology (Combs et al., 2013; Evans et al., 2017; Preston & Ehrsson, 2014, 2016, 2018). Specifically, it would be interesting to investigate whether a developmental time course exists for reduced pleasure to affective touch amongst those with higher ED vulnerability. This could help to determine whether alterations in interoceptive awareness has a causal role within disturbed body image, which would be informative for both clinical and non-clinical populations. For this reason, an important aim of the present thesis is to better understand the role of affective touch in relation to non-clinical ED psychopathology. This is addressed in Chapters 4 and 5, both of which investigate the role of affective touch in modulating embodiment within a multisensory full body illusion paradigm.

1.5 Thesis Aims and Outline

The main aims of the present thesis were to investigate the stability of body representation and body image in relation to ED psychopathology within clinical and non-clinical populations. Specifically, perceptual and cognitive-affective components of body image will be studied from a cognitive neuroscientific perspective, given the basis of body representation arising from the processing and integration of multiple exteroceptive and interoceptive signals. The review of the current literature highlights that disturbances in both the perceptual and cognitive-affective components of body image are key factors in the development and maintenance of the EDs, therefore, it is important to research the individual contribution and relationship between such components for both the clinical and non-clinical population, to identify when such alterations or disturbances may emerge. A full outline of the contributions of each thesis chapter is outlined as follows:

Whilst the perceptual stability of the sense of body ownership has been investigated in ED patients using multisensory integration experiments, the stability of the sense of agency remains poorly understood within this population, despite being a key component towards the bodily self. Therefore, **Chapter 2** investigates body ownership and agency amongst ED patients and healthy controls, using the moving rubber hand illusion (Kalckert & Ehrsson, 2012), to explore whether alterations in bodily experience observed in ED patients also influence feelings of control over bodily actions (i.e. the sense of agency). Moreover, explicit (conscious) and implicit (unconscious) body satisfaction was investigated to examine the link between perceptual and cognitive-affective components of body image, and how this may relate to ED psychopathology.

Chapter 3 uses functional magnetic resonance imaging (fMRI) to investigate how the visual perspective and morphology (i.e. size/shape) of perceived bodies is represented in the extrastriate body area (EBA) within visual cortex, amongst healthy females. Specifically, the individual contribution and interaction of such attributes were investigated in how they modulate neural response and patterns of activity within this region. Activity within the EBA was investigated in relation to higher-order, socio-cognitive evaluations made towards bodies, to determine whether this region plays a more dynamic role in aesthetic body evaluation. Finally, EBA activity was explored in relation to non-clinical ED psychopathology, following evidence that this region is structurally and functionally altered amongst clinical ED populations.

The importance of visual perspective in body representation is studied further in **Chapter 4**, by exploring the effect of congruent visuoproprioceptive signals (i.e. 'visual capture') amongst healthy females within the full body illusion (Petkova & Ehrsson, 2008). Specifically, the influence of mere visual observation of a mannequin body viewed from a first-person perspective was investigated in its role towards subjective embodiment, in the absence of synchronous visuotactile integration. The importance of congruent multisensory integration towards embodiment was further investigated by providing tactile stimulation conditions that were incongruent with perceived visuoproprioceptive signals, designed to disrupt embodiment. Such conditions investigated whether slow, affective touch on participants' own, unseen body disrupted visual capture effects to a greater degree than fast, non-affective touch. Finally, given the reported visual dominance to sensory information pertaining to the body amongst clinical ED patients, individual differences in visual capture embodiment were explored to determine whether such effects were modulated by non-clinical ED psychopathology.

In **Chapter 5**, affective touch is further investigated in its role towards subjective embodiment within the full body illusion, in healthy females. Following previous research highlighting how the velocity of touch can modulate embodiment during the rubber hand illusion, the interoceptive properties of affective touch were investigated across two experiments to determine whether such effects extended to a whole body. As a continued theme throughout the present thesis, the perceived pleasantness of touch and its effects towards embodiment were explored in relation to non-clinical ED psychopathology, to determine whether reduced pleasantness to affective touch is implicated as a trait disturbance amongst those most at risk for developing an ED, or indeed whether alterations are a consequence of the disorder.

Finally, as a standardized assessment tool used to measure ED psychopathology amongst participants throughout all chapters within the present thesis, the psychometric properties of *The Eating Disorder Examination Questionnaire (EDE-Q)* measure are rigorously assessed in **Chapter 6**. EDE-Q norms have been established in several Western societies, however, norm research within the UK are currently restricted to adolescent samples. Additionally, increasing research suggests that the original four-factor structure of the EDE-Q lacks empirical support, with considerable disagreement regarding its psychometric properties. Therefore, norms of the original four-factor EDE-Q structure were provided, and the psychometric properties of the EDE-Q were assessed in a large non-clinical UK sample of females and males. Moreover, qualitative differences in interpretation of EDE-Q items between females and males were evaluated, given the differences in body ideals and attitudes between sexes. Overall, such research provides an empirical context within which to interpret EDE-Q scores presented in all chapters of the present thesis, and evaluates the validity of this measure in accurately capturing ED psychopathology within non-clinical samples.

All chapters within the present thesis correspond to individual research papers. Chapters 4 and 6 are published papers, Chapter 3 is currently under review for publication, and Chapters 2 and 5 are currently in preparation for submission. Consequently, there may be some overlapping content with the general introduction and across the introductions of certain chapters within the present thesis. However, such information is intentionally retained to frame the literature that is relevant to the research questions addressed within each specific chapter.

Chapter 2

Investigating the Components of Body Image Disturbance within Eating Disorders

2.1 Introduction

As outlined in Chapter 1, a core feature 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 et al., 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 shown that ED individuals lack a positive 'self-serving bias' towards their own body image that is typically observed amongst healthy individuals and acts as a protective factor against poor mental health (Jansen, Smeets, Martijn, & Nederkoorn, 2006; Martijn et al., 2015).

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 a negative body image (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 et al., 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, 2012), proprioception (Guardia, Carey, Cottencin, Thomas, & Luyat, 2013; Guardia, Cottencin, et al., 2012), interoception (Badoud & Tsakiris, 2017; Pollatos et al., 2008), and the integration of multiple sensory signals (Eshkevari et al., 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). The RHI relies upon the integration of multiple sensory inputs, in which the brain matches the incoming visual and tactile sensory information it receives and fuses this into a single event, which results in feelings of ownership over the fake limb (Botvinick & Cohen, 1998; Tsakiris & Haggard, 2005). This effect does not occur, or is considerably weaker, when tactile and visual strokes are administered asynchronously between the real and fake hand, thus acting as an experimental control condition.

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 within the patient group (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 improved to a more accurate estimation of one's own body size (Keizer et al., 2014, 2016). Taken together, the above evidence underlines the importance of researching perceptual disturbances of body image in EDs from a multisensory perspective (Eshkevari et al., 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).

The above evidence highlights how disturbances in the integration of multisensory signals can influence the sense of body ownership amongst ED patients (Eshkevari et al., 2012; Keizer et al., 2014). However, as outlined in Chapter 1 (see Section 1.1), 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 et al., 2008b; Tsakiris et al., 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); for example *"I am the one who switched on the light"*. Disturbances in the sense of agency have been implicated as an important feature within numerous psychiatric disorders such as schizophrenia (Voss, Chambon, Wenke, Kühn, & Haggard, 2017) and obsessive compulsive disorder (Gentsch, Schutz-Bosbach, Endrass, & Kathmann, 2012) - the latter having a high co-morbidity with EDs. 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 which measures the sense of body ownership and agency is the *Moving Rubber Hand Illusion* (mRHI; Kalckert & Ehrsson, 2012; 2014). This paradigm extends upon the RHI by introducing active, volitional movement (rather than passive sensory input), in which participants control and observe the movements of a fake model hand whilst their own hand is hidden out of view. 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. Indeed, such feelings are absent when voluntary movements made by the participant 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 et al., 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 and cannot be consciously manipulated (Vartanian, Polivy, & Herman, 2004). Indeed, 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.

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). Indeed, 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) in ED patients, however, to the author's 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 aimed to address three key questions. The first aim was to replicate and extend upon previous research assessing body ownership using multisensory illusions in ED individuals, by additionally measuring the stability of the sense of body agency within this group compared with healthy controls. 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 improve upon such estimations following the illusion, with healthy controls expected to display a stable estimation throughout. Secondly, body satisfaction was measured to investigate the cognitive-affective component of body image disturbance. Importantly, both explicit and implicit measures of body satisfaction were recorded in both groups. Here, 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), the relationship between the two components remain unclear (Mölbert et al., 2017). 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 across the whole sample.

2.2 Methods

2.2.1 Participants

The present study received ethical approval from the NHS Health Research Authority (North East - York Research Ethics Committee), 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. 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 an accepted method in previous research (Groves et al., 2017). Thirty-one gender matched 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 ≥ 2 SD above the group mean (64 years and 60 years) were excluded from data analysis. Seven HC participants were excluded from data analysis; one self-reported a current psychological disorder and six had a global EDE-Q score above the 2.8 global clinical cut-off. Participant demographic information for both groups following exclusion can be seen in Table 2.1.

Table 2.1 *Participant Demographic Information - Means (Standard Deviations) for ED group and HC group*

	ED Group (*N*=26)	HC Group (*N*=24)	*t*	*p*	Cohen's *d*
Age	23.46 (5.95)	19.13 (1.42)	3.60	.001	1.00
BMI	19.80 (4.39) [a]	20.75 (2.30)	-.96	.344	.27
Illness Duration (Years)	6.39 (5.56)	-	-	-	-
Treatment Duration (Years)	2.73 (2.22)	-	-	-	-
Restraint [b]	3.70 (2.40-4.80)	1.00 (.40-1.80)	-5.12	<.001 [c]	.72
Eating Concern [b]	3.80 (3.00-4.60)	.60 (.60-1.15)	-5.76	<.001 [c]	.81
Shape Concern [b]	5.19 (4.23-5.75)	2.35 (.93-3.10)	-5.43	<.001 [c]	.77
Weight Concern [b]	4.60 (3.50-5.40)	1.50 (.50-2.75)	-5.49	<.001 [c]	.78
EDE-Q Global [b]	4.21 (3.47-4.94)	1.55 (.69-2.23)	-5.83	<.001 [c]	.82

Note: *p* values corrected for multiple comparisons using false discovery rate (Benjamini & Hochberg, 1995).
BMI: Body Mass Index.
[a] ED Group (N=25)
[b] Median of EDE-Q subscale and global scores with interquartile range in parentheses
[c] Mann-Whitney U statistic with *r* value effect size

2.2.2 Materials

Experimental materials involved a wooden platform (35cm x 30cm x 13cm; see Figure 2.1) positioned on a table, on top of which was resting a life-sized wooden artist's right hand (measuring 30cm from base of the wrist to tip of the middle finger), wearing a latex glove with the palm faced down. Participants were seated at the table and asked to wear an identical latex glove on their right hand, which they then placed underneath the wooden platform, directly below the model hand (see Figure 2.1). The participant's left hand was in a resting position and kept still by their side. Participants wore a black cape around their neck, which occluded their right forearm and the open wrist of the fake hand on the wooden platform, to appear in an anatomically congruent position to the fake hand. A plastic finger cap was then placed on the tip of participant's right index finger which was mechanically connected to a matching finger cap on the fake hand by a thin wooden dowel passing through a small hole in the wooden platform, which was attached/detached for the respective experimental condition (see *Procedure* section). Experimental trials and responses for both the Moving Rubber Hand Illusion and Implicit Association Test were made using PsychoPy 2 (Peirce, 2007) on an Apple iMac computer (1.6GHz dual-core Intel Core i5 processor).

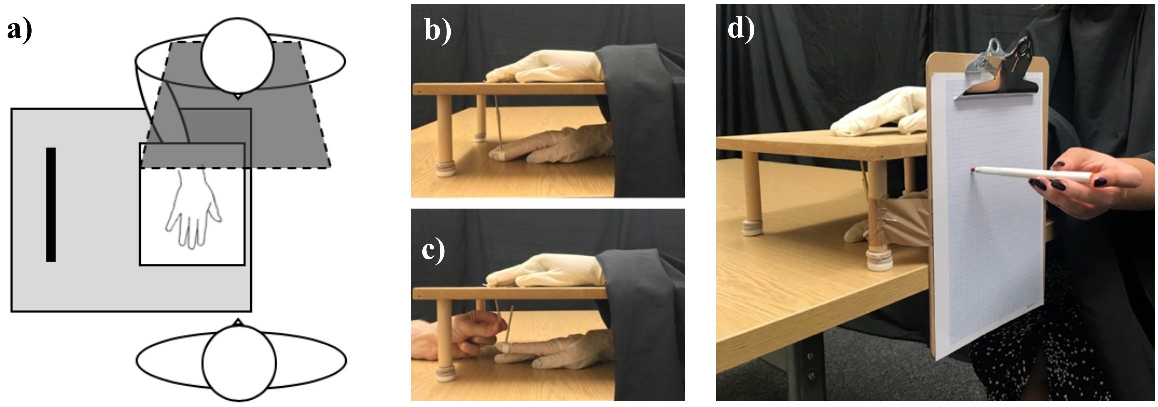

Figure 2.1 Experimental Set-up. a) Participants sat opposite the experimenter, and placed their right hand under the platform, directly below the fake hand which was viewed on top, with a black cape covering their right arm. For each measure within the illusion, participants completed synchronous (b) 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.

2.2.3 Measures

2.2.3.1 Moving Rubber Hand Illusion

2.2.3.1.1 Questionnaire

Following experimental trials, participants recorded their subjective experience of the illusion using a self-report 12-statement questionnaire (see Table 2.2), adapted from previous studies (Botvinick & Cohen, 1998; 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 individual 60-second trial they had experienced. Each statement was presented to participants in a randomised order.

Table 2.2 *Questionnaire for the moving rubber hand illusion, comprising 12 statements which participants rated on a seven-point Likert scale (-3 strongly disagree to +3 strongly agree)*

Questionnaire Statement	Category
1. I felt as if I was looking at my own hand. 2. I felt as if the rubber hand was part of my body. 3. I felt as if the rubber hand was my hand.	**Ownership**
4. I felt as if my real hand were turning rubbery. 5. It seems as if I had more than one right hand. 6. It felt as if I had no longer a right hand, as if my right hand had disappeared.	**Ownership Control**
7. The rubber hand moved just like I wanted it to, as if it was obeying my will. 8. I felt as if I was controlling the movements of the rubber hand. 9. I felt as if I was causing the movement I saw.	**Agency**
10. I felt as if the rubber hand was controlling my will. 11. I felt as if the rubber hand were controlling me. 12. It seemed as if the rubber hand had a will of its own.	**Agency Control**

2.2.3.1.2 Proprioceptive Drift

As an objective measure of the illusion, participants were asked to indicate the felt location of their right hand with a pointing movement, pre- and post-trial, to assess the degree of shift in perceived limb position towards the fake hand (i.e. 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 2.1d). 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 pre- and post-experimental trial.

2.2.3.1.3 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 moving towards each other (inwards), and 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.

2.2.3.2 Body Satisfaction

2.2.3.2.1 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). VAS items have been shown to have good convergent validity with other measures of body satisfaction (Cahill & Mussap, 2007).

2.2.3.2.2 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 2.2). 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 2.3.

Table 2.3 *Implicit Association Test categories and attributes (adapted from Gumble & Carels, 2012)*

Stimuli Category			
Self	**Other**	**Attractive**	**Unattractive**
Mine	They	Beautiful	Ugly
My	Them	Gorgeous	Unappealing
Me	Their	Good-looking	Bad-looking
Self	Other	Attractive	Unattractive

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 2.2a and 2.2b). 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.

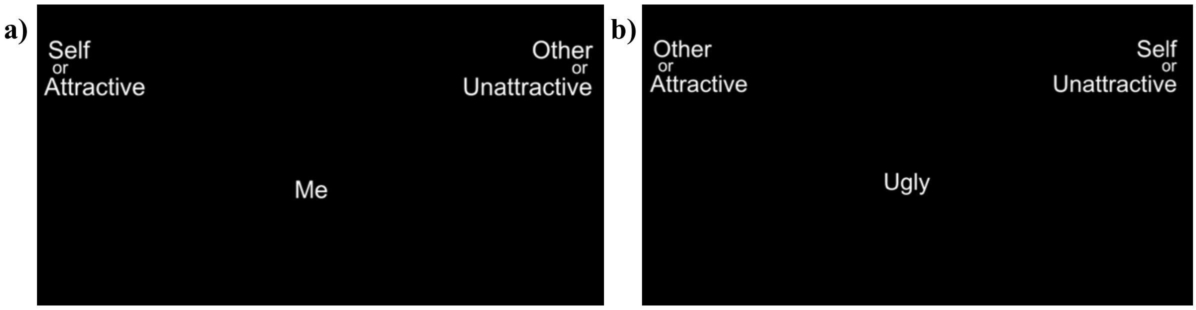

Figure 2.2 Example trials within Implicit Association Test. a) Example compatible condition, in which *Self* and *Attractive* categories (plus *Other* and *Unattractive*) are paired on the same side of the screen. b) Example incompatible condition in which *Self* and *Unattractive* categories (plus *Other* 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.

2.2.3.3 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. 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.

2.2.4 Procedure

2.2.4.1 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 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.

2.2.4.2 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.

2.2.5 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 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).

2.2.5.1 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 2.2) 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.

2.2.5.2 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 ED individuals show a reduced implicit 'self-serving bias' towards their body satisfaction within the IAT, with compatibility (compatible vs. incompatible) as the within-subjects factor, and group (ED group vs. HC group) as the between-subjects factor.

2.2.5.3 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 (i.e. EDE-Q), specifically in relation to concerns within one's body image (i.e. *Shape Concern* and *Weight Concern* EDE-Q subscales).

2.3 Results

2.3.1 Moving Rubber Hand Illusion

2.3.1.1 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, to establish whether each group had reliably experienced the illusion, ownership ratings were compared with their respective control scores for both groups. 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, the effect of visuomotor synchrony was investigated by comparing synchronous vs. asynchronous ownership scores. 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 2.3). Finally, to directly test the hypothesis that ED individuals would show greater instability in their subjective experience of ownership towards the fake hand, ownership subscale scores were compared between the ED group and HC group. 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 ($U = 283.00$, $Z = -.57$, $p = .572$, $r = .08$), which suggests that ED patients and HC displayed the same subjective experience of ownership towards the fake hand.

The same analyses were conducted for agency scores, which were first compared with their respective control scores for both groups. 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, the effect of visuomotor synchrony was tested by comparing synchronous vs. asynchronous agency scores. 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 2.3). Finally, to directly test the hypothesis that ED individuals would show greater instability in their subjective sense of agency towards the fake hand, agency subscale scores were compared between the ED group and HC group. 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.

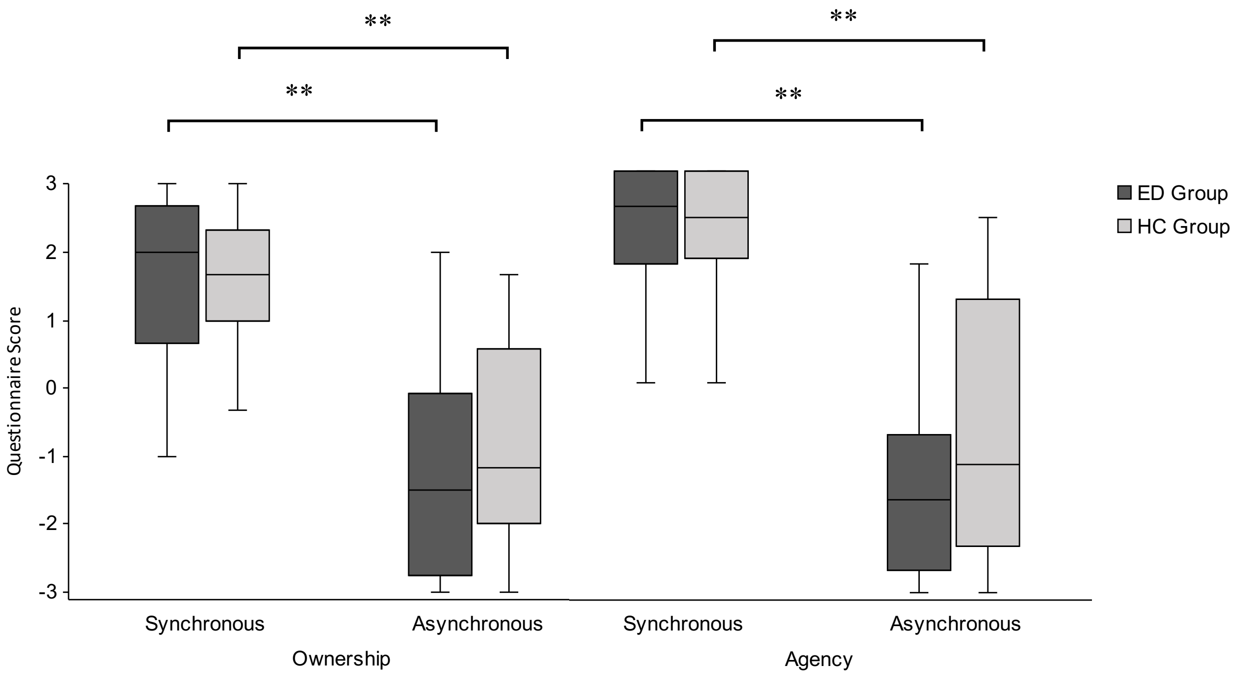

Figure 2.3 Box plot displaying ownership and agency scores from the mRHI questionnaire, presented by condition and group. Intersecting line = median; box = upper and lower interquartile range; whiskers = minimum and maximum values. ** = $p < .001$.

2.3.1.2 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, $p = .109$, $\eta_p{}^2 = .05$).

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).

2.3.1.3 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 (mm) between the ED group and the HC group (see Table 2.4) (*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 2.4). A paired samples t-test revealed that participants in the ED group significantly overestimated their own hand width, prior to the illusion (*t* (25) = -3.33, *p* = .003, *d* = .65). Additionally, a paired samples t-test revealed that 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), and did not correlate with participant BMI (*r* = .03*, p* = .852).

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, a one sample t-test revealed that participants reported a significantly lower hand size estimation 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, a one sample t-test revealed that 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 2.4).

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.

Table 2.4 *Hand size dimensions and estimations. Actual hand size dimensions (Mean and SD) of participants with baseline estimations and post-experimental estimations. Units measured in millimetres (mm).*

	ED Group (N=26)	**HC Group (N=24)**	***t***	***p***	**Cohen's *d***
Actual Hand Width	76.00 (3.53)	76.29 (3.44)	-.295	.769	.08
Baseline Estimation	83.90 (12.97)	81.60 (11.10)	.675	.506	.19
Synchronous – Post-experimental Estimation	78.79 (12.20)	78.33 (6.87)	.164	.870	.05
Asynchronous – Post-experimental Estimation	79.71 (11.44)	80.00 (9.48)	-.097	.923	.03

2.3.2 Body Satisfaction

2.3.2.1 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; $U = 33.00$, $Z = -5.42$, $p < .001$, $r = .84$).

2.3.2.2 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 as well as explicit level, compared with healthy controls. *D* scores for both groups are shown in Figure 2.4a.

To further investigate whether ED individuals show a reduced implicit 'self-serving bias' towards their body satisfaction 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, η_p^2 = .32), with significant lower reaction times following compatible vs. incompatible conditions. No main effect of group was observed (F (1, 48) = 2.15, p = .149, η_p^2 = .04). However, a significant interaction was observed between condition and group (F (1, 48) = 9.00, p = .004, η_p^2 = .16). Thus, Bonferroni-corrected independent samples t-tests (critical α = .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 2.4). 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.

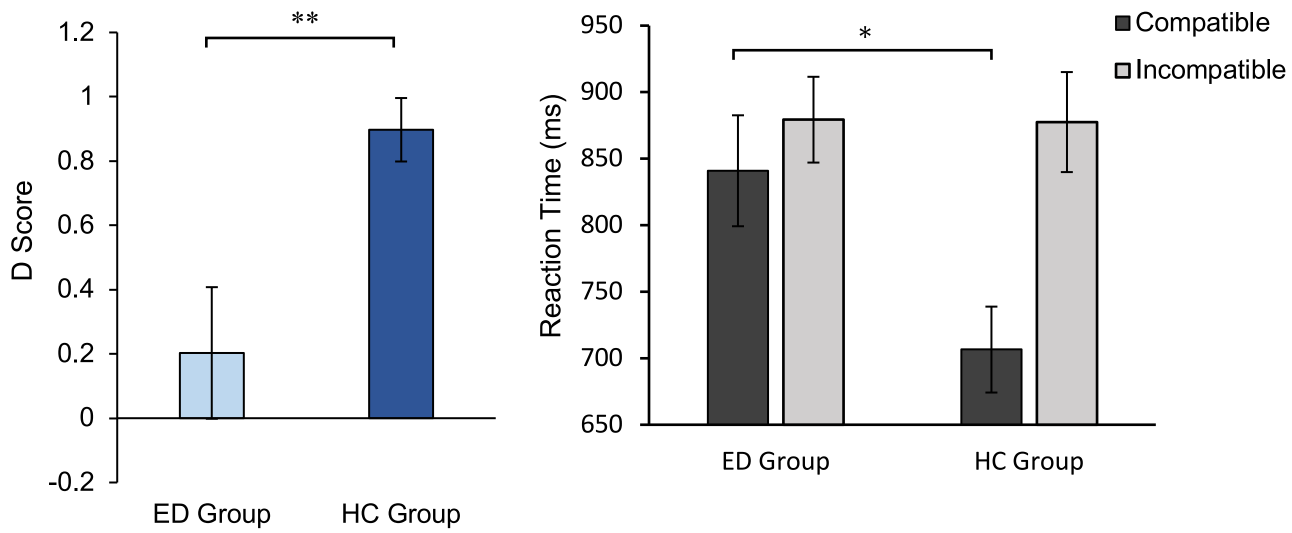

Figure 2.4 Implicit Association Test Scores. (a) Mean D scores for ED and HC groups. Higher D scores indicate higher implicit body satisfaction. (b) Mean reaction times for compatible and incompatible trials, for ED and HC groups. Error bars for both graphs show standard error. * = p < .05, ** = p < .01.

2.3.2.3 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 suggests that those with higher explicit body satisfaction also display a higher implicit body satisfaction. Furthermore, Bonferroni-corrected Spearman's Rank correlations (critical α = .025) revealed that lower state body satisfaction is associated with 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).

2.3.3 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 Material A1 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 subjective and objective 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 Material A1 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 Material A1 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 *Weight Concern* (r = -.41, p = .003) which reflect body-related attitudes, rather than attitudes towards eating behaviours (i.e. *Restraint/Eating Concern*) which showed no significant relationship with IAT D scores (see Supplementary Material A1 for full tables).

2.4 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 subjective and objective (hand size estimation, proprioceptive drift) components of 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 a 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 towards body image. 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 the sense of 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 et al., 2011). However, the observed lack of difference between groups, and indeed lack of observed 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 shown 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, 2005a). Indeed, within the present study, the contribution of sense of agency towards the sense of ownership - and vice versa - cannot be disentangled. 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. Nevertheless, the current findings using such multisensory paradigms provide a useful gateway to further dissociate the factors which are known to influence the sense of ownership and agency amongst ED populations.

Furthermore, an interesting result 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 following both synchronous (illusion) and asynchronous (control) conditions, which was not directly mirrored in healthy females. This finding is in line with previous research (Keizer et al., 2014, 2016), suggesting that such perceptual changes from ED individuals occurred irrespective of the subjective experience of the illusion, which *was* shown to significantly differ between conditions. As previously discussed, research has suggested that greater perceptual effects within multisensory illusions amongst ED populations is associated with an increased malleability of the bodily self, in which such individuals often display a visual dominance that overrides proprioceptive input during the illusion (Eshkevari et al., 2012; Keizer et al., 2014, 2016). Therefore, an increased sensory weighting towards visual input of the fake hand may have been sufficient to change size estimations of one's own hand amongst ED individuals, irrespective of the condition. Importantly, the present results support previous research which highlight an inherent instability of perceptual body representation in ED individuals. Such findings have important clinical implications within the treatment of body image disturbance in EDs, by showing that perceptual estimation of body size can be improved within this population (Keizer et al., 2018). Thus, increased perceptual accuracy of body size is likely to improve upon clinical outcomes and positively impact the cognitive-affective component of body image disturbance (Castellini et al., 2011; Exterkate et al., 2009).

It must be noted that healthy females did also initially overestimate their hand size prior to the illusion, and show a subsequent reduced hand size estimation - but following synchronous conditions only. In other words, healthy females were shown to improve their hand size estimation as consequence of illusion conditions, which reinforces the effect of multisensory integration in inducing perceptual changes in perceived body size amongst healthy individuals (Preston & Ehrsson, 2014). Importantly, the effect was different to the ED group who recorded a reduced estimation following both synchronous and asynchronous conditions, which reinforces the greater malleability of the bodily self in ED individuals compared with healthy controls. However, it is speculated that initial overestimation from the HC group - which occurred contrary to hypotheses - may be a consequence of higher ED psychopathology within the non-clinical range amongst the present sample. Whilst global EDE-Q 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. This alarming number reinforces the need to investigate ED psychopathology and vulnerability in the non-clinical population (see subsequent chapters), 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 (see Chapter 6).

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.

As hypothesised, explicit measures of state body satisfaction revealed significantly lower self-reported scores in ED groups compared with healthy females. However, to the author's 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 bias' towards their own body image (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. 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, individuals 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 2.1). 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 measures of clinical interviews and standardized questionnaires (Buhlmann et al., 2011). Indeed, increasing research is showing that interventions which target such implicit processes may have clinical efficacy in improving cognitions surrounding one's body satisfaction (Martijn et al., 2015). Furthermore, whilst the present study used appearance-related word associations within the IAT, it would be interesting for future research to dissociate such implicit biases from general cognitive measures such as self-esteem (Buhlmann, Teachman, Naumann, Fehlinger, & Rief, 2009). Indeed, a dissociation between shape or weight-related cognitions and general self-esteem would suggest that altered cognitions within this population may be specific to the body, and would provide researchers and clinicians with a clearer focus within which to target treatment (Buhlmann et al., 2011).

Finally, results revealed a relationship between perceptual and cognitive-affective components of body image across the whole sample, shown by significant positive correlations between ownership questionnaire scores and proprioceptive drift scores from the moving rubber hand illusion, with implicit body satisfaction from IAT *D* scores. This supports the argument that a direct link does exist between body perception and emotion, with such findings shown to be driven more specifically by ED group scores. However, the direction of such relationships was contrary to hypotheses, as it was predicted that ED individuals would display increased ownership - implicated with an instability in the bodily self - which would be associated with *reduced* body satisfaction. Importantly, such findings highlight the complexity of the relationship between perceptual and cognitive-affective components of body image, in which further research is required to uncover the most salient conditions in which perceptual alterations relate to emotional bodily experience.

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). Nevertheless, analysis was conducted with the sub-sample of individuals with a diagnosis of anorexia nervosa (N=18), which revealed no difference in the pattern of findings (see Supplementary Material A1, Section A1.1). 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. Within the context of the present study, alternative statistical approaches such as Bayesian analysis may help to overcome the issue of low sample sizes, to inform the probability of an effect occurring in the future, given the observed data.

In conclusion, the present study investigated perceptual and cognitive-affective components of body image within ED individuals and healthy females. Using a multisensory illusion paradigm which incorporated active, volitional movement, results showed that whilst both groups overestimated their own hand width prior to the illusion, the ED group showed a significant reduction in overestimation following both conditions within the illusion, which was not equally mirrored by healthy females. This supports previous research in highlighting the malleability of the bodily self amongst ED individuals which can be improved upon. Secondly, ED individuals displayed a significantly lower body satisfaction on an explicit and implicit level compared with healthy females, with altered implicit cognitions shown to be driven specifically by weaker associations between the self and attractiveness. Finally, results highlighted an association between body perception and body emotion, yet further research is required to determine the direct effect between these components of body image 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.

Chapter 3

Distinct Neural Response to Visual Perspective and Body Morphology in the Extrastriate Body Area

This chapter is adapted from: Carey, M., Knight, R., & Preston, C. (under review) Distinct Neural Response to Visual Perspective and Body Morphology in the Extrastriate Body Area. *Behavioural Brain Research* [1]

3.1 Introduction

Human body perception relies upon the concurrent processing of multiple inputs of sensory information, allowing us to rapidly identify features such as the gender, posture, or identity of bodies, whilst also discriminating others' bodies from our own. Recent research has identified neural correlates of visual body processing within a dedicated cortical region known as the extrastriate body area (EBA) (Downing et al., 2001), located bilaterally in the lateral occipito-temporal cortex, which responds selectively to human bodies and body parts compared with inanimate objects or faces (Downing & Peelen, 2016; Peelen & Downing, 2007).

Traditionally, the EBA has been implicated as an early category-selective region in visual body perception (Downing et al., 2001), responsible for the local processing of basic perceptual properties of bodies (Peelen & Downing, 2007). However, the precise role of the EBA in visual body processing

[1] The author, Mark Carey, contributed to the design of the experiment, collected the data, analysed the results, and wrote the manuscript under the supervision of Dr Catherine Preston.

remains contested (Downing & Peelen, 2011), with conflicting proposals for the function of this region in representing identity (Hodzic, Muckli, Singer, & Stirn, 2009; Myers & Sowden, 2008), motor control (Astafiev, Stanley, Shulman, & Corbetta, 2004; Kontaris, Wiggett, & Downing, 2009), emotion (Peelen & Downing, 2007; van de Riet, Grèzes, & de Gelder, 2009), and action goals of bodies (Kühn, Keizer, Rombouts, & Hommel, 2011; Pierno et al., 2009; Zimmermann, Verhagen, de Lange, & Toni, 2016). Interestingly, functional EBA activity has been shown to be modulated by the visual perspective of whole bodies or body parts, irrespective of body identity (own/other body) (Chan, Peelen, & Downing, 2004; Saxe, Jamal, & Powell, 2006), with evidence of increased right EBA activation in response to allocentric (i.e. third-person) perspectives of bodies compared with egocentric (i.e. first-person) perspectives (see also, Arzy, Thut, Mohr, Michel, & Blanke, 2006).

In addition, evidence has highlighted the role of the EBA in processing body morphology, such as shape and size (Downing & Peelen, 2016; Urgesi et al., 2012; Urgesi, Calvo-Merino, Haggard, & Aglioti, 2007). Importantly, the perception of body morphology in visual brain regions is likely to provide critical information for higher-order, socio-cognitive assessments of bodies such as perceived attractiveness (Di Dio, Macaluso, & Rizzolatti, 2007). Indeed, increased EBA activation has been shown to be associated with perceived body form and posture (Arzy et al., 2006; Cross, Kirsch, Ticini, & Schütz-Bosbach, 2011). However, the specific role of the EBA towards such aesthetic evaluations of bodies remains unclear. It has been traditionally argued that the EBA plays an important role within a distributed network in body perception, with such visual processing communicating with prefrontal areas of the brain which make higher-order socio-cognitive inferences towards bodies (Peelen & Downing, 2007). However, recent research has supported a more direct, dynamic role of the EBA in the aesthetic evaluation of bodies (Calvo-Merino, Urgesi, Orgs, Aglioti, & Haggard, 2010), such that disruption within this area, using repetitive Transcranial Magnetic Stimulation (rTMS), was shown to have a direct influence towards aesthetic body judgements (Calvo-Merino et al., 2010; Cazzato, Mele, & Urgesi, 2014, 2016; Cazzato, Mian, Serino, Mele, & Urgesi, 2015). Thus, research remains equivocal in determining whether the EBA plays a role primarily in discriminating between physical information of bodies, or is directly involved in higher-order, socio-cognitive evaluation of bodies.

Despite evidence highlighting the role of the EBA in processing visual perspective and body morphology independently, it is yet to be understood how the combined processing of such visual inputs interact to modulate functional EBA activity. In addition, fMRI studies which identify differences in neural response to visual perspective have employed solely univariate analyses (Chan et al., 2004; Saxe et al., 2006), therefore it is unclear whether changes in overall EBA activation also influence the pattern of response in this region. Such changes in EBA activity in response to these combined physical attributes may be key in influencing aesthetic evaluations made towards bodies (Cazzato et al., 2014), particularly one's body image which encompasses perceptual and attitudinal components of one's own body representation (de Vignemont, 2010). This research question is particularly important amongst those who experience perceptual distortions of body size, such as individuals suffering with an eating disorder (ED) (Mai et al., 2015; Mohr, Rickmeyer, Hummel, Ernst, & Grabhorn, 2016; Suchan et al., 2013). Indeed, recent neuroimaging research has directly linked atypical visual processing and body misperception within the EBA with disturbances in body image amongst ED patients (Suchan et al., 2013, 2015), with evidence of reduced functional (Uher et al., 2005) and structural (Suchan et al., 2010) EBA activity amongst ED patients compared with healthy controls (see also, Vocks et al., 2010, 2011). This suggests that alterations in EBA functioning, as a core region in visual body processing, may be implicated in the perceptual component of body image disturbances (Castellini et al., 2013; Groves et al., 2017), facilitating its development and maintenance within EDs (Urgesi et al., 2012). Crucially, it remains unclear whether such perceptual or neural alterations are a cause or consequence of EDs (Frank, 2013; Hay & Sachdev, 2011; Stice, Marti, et al., 2010). Therefore, it is critical to undertake controlled experiments within the non-clinical, healthy population to study brain regions that are implicated in EDs and investigate links between body perception and ED vulnerability (Berg, Frazier, & Sherr, 2009; Eisenberg et al., 2011; Preston & Ehrsson, 2014, 2016).

In the present study, we investigated differences in functional EBA activity following presentation of large and slim female bodies, viewed from egocentric and allocentric perspectives. In line with previous research (Chan et al., 2004; Saxe et al., 2006), we hypothesised that activity in the right EBA will be increased for allocentric perspectives compared with egocentric perspectives amongst healthy females. However, it was expected that EBA neural response will be further modulated by the combined processing of both visual perspective and body size. In addition to univariate analyses, we used multi-voxel pattern analysis (MVPA) to compare the pattern of neural response to each of our four conditions. Moreover, we wished to investigate whether EBA activity is associated with non-clinical ED psychopathology in healthy individuals, without the confounding issues surrounding a clinical ED diagnosis. Finally, behavioural ratings of aesthetic and weight evaluations of all body stimuli (recorded outside the scanner) were investigated in relation to EBA activity. If the EBA has a functional role in higher-level, socio-cognitive evaluation of bodies in visual processing, it was hypothesised that behavioural aesthetic and weight ratings would positively correlate with EBA activity.

3.2 Methods

3.2.1 Participants

32 female participants, recruited from the University of York, completed a single 1-hour study session. Data from two participants were excluded due to uncorrectable fMRI motion artefacts, therefore data from 30 participants (Mean age = 19.40, SD ± 1.25, range = 18-24) was analysed (see Table 3.1). All participants were right-handed, with normal or corrected-to-normal vision and no current or previous psychological or neurological disorders. All participants gave informed, written consent to take part in the study. The study received ethical approval from York Neuroimaging Centre (YNiC) Ethics Committee and was conducted in accordance with the Declaration of Helsinki.

3.2.2 Experimental Stimuli

Stimuli were greyscale photograph images of 10 female bodies, seated on a chair with hands placed by their sides. Real-life bodies were used as stimuli in the present experiment, providing a more ecologically valid stimulus set compared with previous methodologies (Downing et al., 2001; Uher et al., 2005). All model stimuli were photographed against a black background, and wore a white fitted t-shirt and jeans, with no other defining features. Images were taken using an SJCAM camera (SJ4000, Resolution 1920 x 1080), scaled to 460 x 460 pixels. The heads of all stimuli were excluded to ensure that the identity of each model was anonymous. Each model was photographed from an egocentric (first-person) and allocentric (third-person) visual perspective (see Figure 3.1a). Egocentric perspectives were taken by placing the camera in line with each models' eyeline and facing the lens down towards their lap. Allocentric perspectives were taken from a distance of 1.5 metres from the model. A large database of stimuli was collected prior to the experiment, with images selected based on a body mass index (BMI) of each model. Stimuli with a BMI < 25 were categorized into the Slim group (N = 5) and stimuli with a BMI > 25 were categorized into the Large group (N = 5). Slim stimuli models had a group mean BMI of 18.52 (*SD* ±1.37, range = 16.45-20.30), and large stimuli models had a group mean BMI of 27.61 (*SD* ± 1.07, range = 25.91-28.58). A significant difference in BMI was established between groups (t (8) = -11.66, p <.001). Images were presented, and responses were recorded, using *PsychoPy2* (Peirce, 2007) for both the fMRI and behavioural experiment.

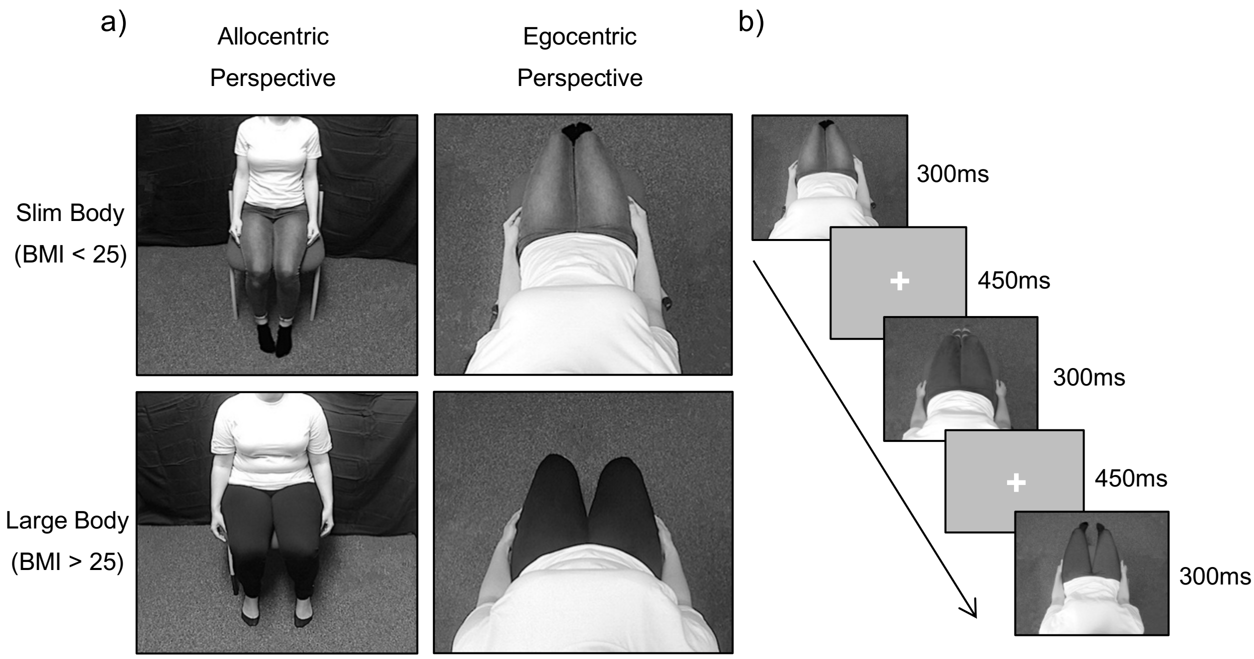

Figure 3.1 Experimental Set-up. a) Sample stimuli from the experiment. Columns show the two visual perspectives (Allocentric/Egocentric), and rows show the two body morphologies (Slim/Large). b) time series of experimental stimuli per block.

3.2.3 fMRI Experiment

fMRI data were acquired using a GE 3 Tesla Signa HD Excite MRI scanner at York Neuroimaging centre (YNiC), University of York, with an eight-channel phased array head coil tuned to 127.4 MHz. For each participant, a gradient-echo echo-planar imaging (EPI) sequence was used to acquire 38 contiguous axial slices (TR = 3000ms, TE = 32.7ms, flip angle = 90°, FOV = 288 x 288mm, matrix size = 128x128, slice thickness = 3mm). Individual stimuli in all functional runs were presented for 300ms with a 450ms inter-stimulus interval (ISI) (see Figure 3.1b), based on a previously published design (Chan et al., 2004). The total duration for each run was 387 seconds. Stimuli were presented on a 40 x 23 cm projector screen, at a viewing distance of 57cm, at the rear of the scanner, and viewed via a tilted mirror placed immediately above the participant's head.

3.2.3.1 EBA Localizer

Prior to experimental runs, participants first completed a block-designed localizer run which was used to localize the EBA for each participant, using validated stimuli (Downing et al., 2001; Peelen & Downing, 2005). One block included greyscale images of whole bodies (excluding heads) in a variety of postures, and another block included greyscale images of chairs (http://pages.bangor.ac.uk/~pss811/index.html). Each block comprised 5 exemplar images from each category, with 20 images presented within each block. The order of the stimuli within each block was randomised, with a 6-second white fixation cross between each block. Within blocks, each stimulus was presented for 300 ms, with an ISI of 450 ms. There was a total of 20 15-second blocks for the entire run; 8 repetitions of each category were presented, with blocks 1, 6, 11 and 16 fixation-only baselines. Participants performed a "one-back" repetition detection task during all localizer and experimental runs, in which they were required to press a button on the response box when two identical stimuli appeared in immediate succession within the block, which occurred once per block.

3.2.3.2 Experimental Task

The experimental task followed an identical procedure as the localizer task. Two block-designed runs, containing four conditions (Slim/Large x Egocentric/Allocentric) of greyscale body stimuli were used for the experimental task (see Figure 3.1). Block design, stimulus presentation time, ISI, and participant task was identical to the EBA localizer run.

3.2.4 Behavioural Experiment

3.2.4.1 Aesthetic and Weight Evaluations

Following the fMRI session, participants were asked to make aesthetic and weight evaluations of each of the 20 stimuli presented in the fMRI experimental task, outside of the scanner. Stimuli were presented in a randomised order within each block, with all blocks counterbalanced across participants to control for any visual adaptation (Brooks, Mond, Stevenson, & Stephen, 2016). For aesthetic evaluation blocks, stimuli were presented in the centre of the screen, with a prompt *"Please rate the attractiveness of this model"* appearing at the top of the screen. Below the image, participants were presented with a visual analogue scale (VAS), anchored by *"Very Unattractive"* and *"Very Attractive"*. Weight evaluation blocks were identically presented, with the different prompt as *"Please rate the weight of this model"*, anchored by *"Very Underweight"* and *"Very Overweight"* (Cazzato et al., 2014; Cazzato, Siega, & Urgesi, 2012). Numeric values of the scale were not presented to participants, but each VAS ranged from 0 to 100.

3.2.4.2 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 attitudes and behaviours within the past 28 days, in which there are four subscales: Restraint (5 items), Eating Concern (5 items), Shape Concern (8 items), and Weight Concern (5 items). A global score is calculated from the average of the four subscales (see Table 3.1 for participant scores). 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 measuring frequency of ED behaviours within the past 28 days, such as binge episodes, laxative misuse and self-induced vomiting. Such disordered eating behaviour items do not contribute to the above subscale scores and were not used in the present study, with ED psychopathology assessed based on the 22-item attitudinal scores.

Overall, the EDE-Q has good internal consistency, with Cronbach's alpha ranging from .78 to .93 in a non-clinical sample (Berg, Peterson, Frazier, & Crow, 2012; Peterson et al., 2007). The current data had a Cronbach's alpha of .89.

Table 3.1 *Participant Demographic Information. Means and standard deviations of participant age, BMI and eating disorder psychopathology (N=30).*

	Age	BMI	Restraint	Eating Concern	Shape Concern	Weight Concern	Global EDE-Q
Mean	19.40	22.46	1.20 [a]	.70 [a]	2.63 [a]	2.00 [a]	1.60 [a]
SD	(1.25)	(3.08)	(1.30)	(.99)	(1.63)	(1.64)	(1.64)

[a] = Median

3.2.5 Data Analysis

3.2.5.1 fMRI analysis

Univariate analysis of the fMRI data was undertaken using FEAT (FMRI Expert Analysis Tool) version 6.00 (http://www.fmrib.ox.ac.uk/fsl). The first 9 seconds (3 volumes) from all scans were discarded to avoid T1 saturation. MCFLIRT (FSL) motion correction, spatial smoothing (using a Gaussian kernel of FWHM 5mm), and temporal high-pass filtering (Gaussian-weighted least-squares straight line fitting, with sigma=50.0s) were also applied. All functional data were registered to a high resolution T1 anatomical scan taken in the same session (1.13 x 1.13 x 1 mm voxel) using FLIRT (Jenkinson, Bannister, Brady, & Smith, 2002; Jenkinson & Smith, 2001). High resolution structural images were subsequently registered onto the standard MNI152 brain using FNIRT nonlinear registration (Andersson, Jenkinson, & Smith, 2007).

3.2.5.1.1 Region of Interest

A region of interest (ROI) was established for participants in both the right and left hemisphere using an EBA localizer scan conducted immediately prior to the experimental run. Body-selective ROIs were defined by the *Bodies* > *Chairs* contrast (Downing, Wiggett, & Peelen, 2007), using the cluster of contiguous voxels, at the group level, in extrastriate cortex. To account for multiple comparisons, statistical thresholding was undertaken using clusters determined by Z > 3.1 with a corrected cluster significance of $p = 0.05$ (Worsley, 2001). The group level spatial co-ordinates ($N = 30$) of the peak left and right EBA voxel closely matched, bilaterally, with previously reported anatomical locations of the EBA (Downing et al., 2007; Myers & Sowden, 2008; Peelen & Downing, 2007) (see Figure 3.2 and Supplementary Material (A2) Table A2.1 for spatial co-ordinates). ROIs were spatially normalized to an MNI152 standard brain template to create a mask for the left and right hemisphere, which were subsequently reverse normalised to single-subject functional space for univariate analysis.

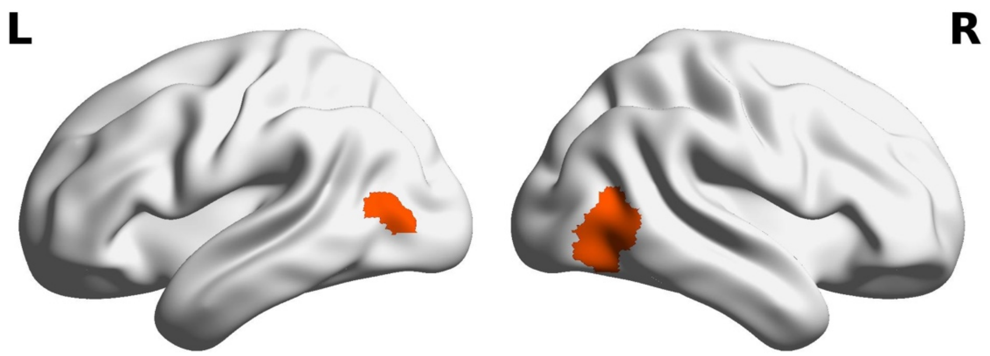

Figure 3.2 Region of interest established bilaterally using EBA localizer (*Bodies* > *Chairs* contrast). Z threshold > 3.1 with corrected cluster significance threshold ($p = 0.05$). *(L = Left; R = Right)

3.2.5.1.2 Univariate Analysis

For subsequent univariate analysis of experimental runs, percentage signal change was extracted independently from both left and right hemisphere masks within each of our conditions, using FEATquery in FSL toolbox. In addition, behavioural evaluation scores and EDE-Q scores were independently entered as covariates into higher-level analysis at the group level, within selected conditions/contrasts. Moreover, an exploratory whole brain analysis was run using the same procedure as above, to investigate whether any effects were observed outside of our ROI analysis. Z statistic images were thresholded using clusters determined by Z > 3.1 (unless stated) and a (corrected) cluster significance threshold of $p = 0.05$ (Worsley, 2001).

3.2.5.1.3 Multi-Voxel Pattern Analysis

In order to investigate the similarity in the neural pattern of responses to visual perspective and body morphology, a subsequent multi-voxel pattern analysis (MVPA) was performed and restricted to the EBA masks established from the univariate analysis. Parameter estimates were correlated across all four block conditions using a between-run split (Run 1 & Run 2). Next, a multiple regression analysis was run to assess the relative contribution of visual perspective and body morphology towards the neural pattern of responses. For each of the two conditions, a binary regressor was generated which represented a model correlation matrix. A value of one (yellow) was assigned to elements where the relevant factor was shared, and a value of zero (red) was assigned to all other elements of the correlation matrix (see Fig. 3.5a and 3.5b). Therefore, the regressors represent the extreme cases in which the patterns of response are predicted by either visual perspective or body morphology. A multiple regression analysis was then applied to the fMRI data across the whole sample, which provided beta values and standard error terms for each regressor (i.e. visual perspective and body morphology). Regressors which differ significantly from zero, using one sample t-tests, suggest that such a variable can explain a significant amount of the variance in the MVPA correlations. Further, paired-samples t-tests were run to assess the differences in variance explained between regressors in the model. All regressors and outcomes were Z-scored prior to the multiple regression analysis.

3.2.5.2 Behavioural Analysis

For aesthetic and weight evaluations, behavioural analysis was undertaken using SPSS (version 24.0). Mean rating scores were calculated for slim and large bodies, within both egocentric and allocentric perspectives, which were entered into a 2x2 repeated-measures ANOVA. Significant interactions were subsequently analysed using Bonferroni-corrected paired samples t-tests.

3.3 Results

3.3.1 Univariate analysis

3.3.1.1 fMRI Response - Visual Perspective

To first establish the role of visual perspective within the EBA, percentage signal change was extracted for each hemisphere from our ROI masks, for egocentric and allocentric conditions, collapsed across body morphology (see Figure 3.3). A 2 (Hemisphere: Left vs Right) x 2 (Perspective: Egocentric vs Allocentric) repeated-measures ANOVA revealed a significant main effect of hemisphere (F (1, 29) = 15.38, p < .001, η_p^2 = .35), showing greater activation in the right EBA compared with the left EBA. Further, a significant main effect of perspective was observed (F (1, 29) = 8.57, p = .007, η_p^2 = .23), with Bonferroni-corrected paired-samples t-tests (α = .025) revealing a significantly greater signal change to egocentric perspectives than allocentric perspectives, for both the left EBA (t (29) = 2.67, p = .012, d = .49) and right EBA (t (29) = 2.65, p = .013, d = .48). No interaction of hemisphere x perspective was observed (F (1,29) = 1.98, p = .17, η_p^2 = .06).

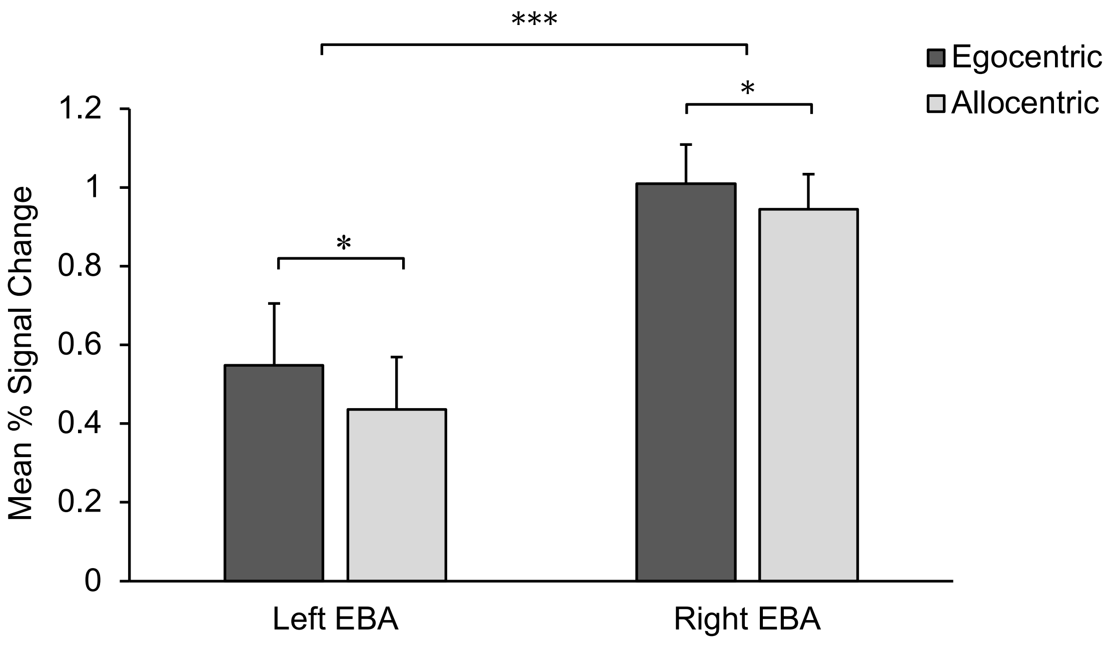

Figure 3.3 Average percentage signal change bilaterally for egocentric and allocentric perspectives, collapsed across body morphology. Error bars depict standard error of the mean. *= p < .05, ***= p <.001

3.3.1.2 fMRI Response – Visual Perspective vs. Body Morphology

3.3.1.2.1 Left EBA

For EBA activity in the left hemisphere (see Figure 3.4a), a 2 (Visual Perspective: Egocentric vs Allocentric) x 2 (Body Morphology: Slim vs Large) repeated-measures ANOVA revealed a significant main effect of perspective (F (1, 29) = 6.46, p = .017, η_p^2= .18). No significant main effect was found for body morphology (F (1,29) = 1.52, p = .227, η_p^2 = .05), however a significant interaction of perspective x body morphology was observed (F (1, 29) = 13.03, p = .001, η_p^2= .31). Bonferroni-corrected paired-samples t-tests (α = .0125) revealed a significantly larger signal change to egocentric compared with allocentric perspectives for slim bodies (t (29) = 4.51, p < .001, d = .82) but no difference was observed between perspectives for large bodies (t (29) = -.02, p = .986, d = .00). Further paired-samples t-tests revealed a significantly greater response to large bodies compared with slim bodies, from an allocentric perspective (t (29) = -3.82, p = .001, d = -.70) but no difference was observed between body morphologies from an egocentric perspective (t (29) = 1.36, p = .185, d = .25). These results suggest that the amplitude of EBA activity does not respond uniformly to all bodies but is instead determined by the interaction between the type of body and the visual perspective in which it is perceived.

3.3.1.2.2 Right EBA

For EBA activity in the right hemisphere (see Figure 3.4b), a 2 (Visual Perspective: Egocentric vs Allocentric) x 2 (Body Morphology: Slim vs Large) repeated-measures ANOVA revealed a significant main effect of perspective (F (1, 29) = 4.79, p = .037, η_p^2 = .14). No significant main effect of body morphology was observed, despite approaching significance (F (1, 29) = 4.13, p = .051, η_p^2 = .13), however a significant interaction of perspective x body morphology was observed (F (1, 29) = 16.88, p < .001, η_p^2 = .37). Bonferroni-corrected paired-samples t-tests (α = .0125) similarly revealed a significantly larger signal change to egocentric compared with allocentric perspectives for slim bodies (t (29) = 4.28, p < .001, d = .78) but no difference was observed between perspectives for large bodies (t (29) = -.73, p = .472, d = -.13). Further, paired-samples t-tests similarly revealed a significantly greater response to large bodies compared with slim bodies, from an allocentric perspective (*t* (29) = -5.87, *p* < .001, *d* = 1.07) but no difference was observed between body morphologies from an egocentric perspective (*t* (29) = .91, *p* = .370, *d* = .17). These results show that the interaction between body morphology and visual perspective in modulating EBA amplitude is a bilateral effect, with an identical pattern shown between conditions compared with the left EBA (see Figure 3.4).

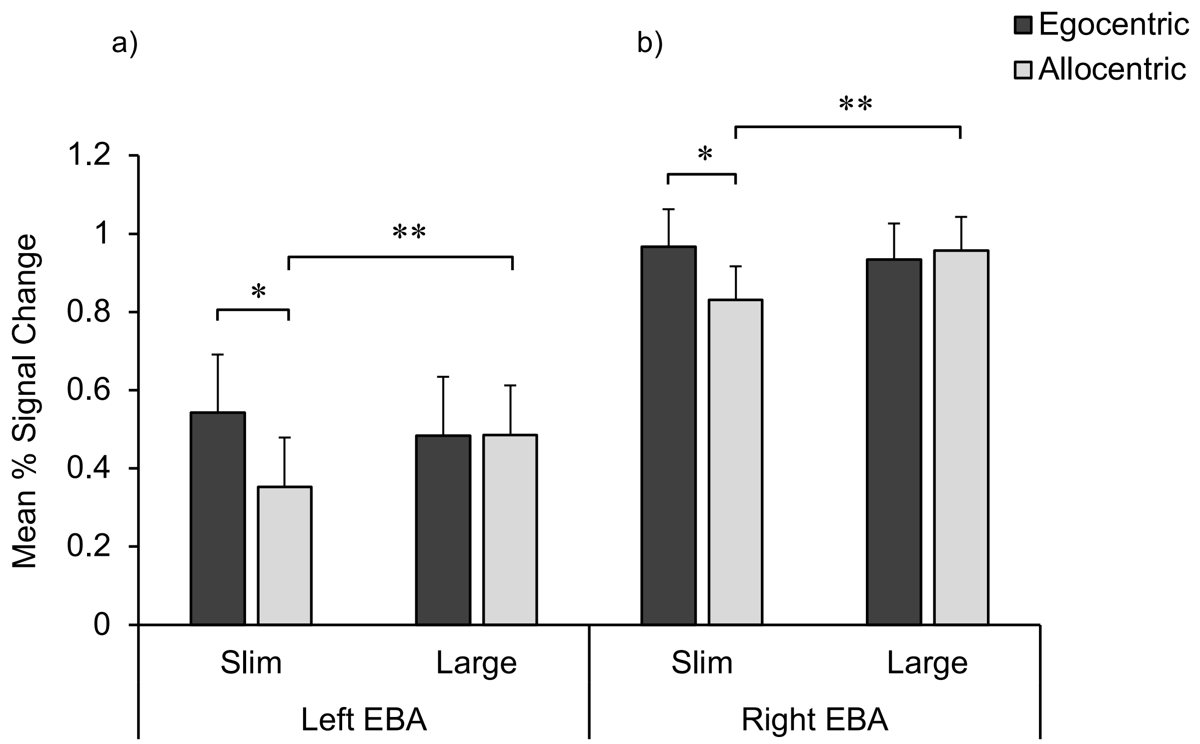

Figure 3.4 Mean percentage signal change in the a) left EBA and b) right EBA for egocentric and allocentric perspectives of slim and large bodies. Error bars depict standard error of the mean (* = *p* < .05, ** = *p* < .01).

3.3.2 EBA activity and ED Psychopathology

To determine whether there was a relationship between functional EBA activity and ED psychopathology, EDE-Q subscale (*Restraint, Eating Concern, Shape Concern, Weight Concern*) and global scores were demeaned across all participants and each used as a covariate in the group analysis of each of our four conditions, within our predefined ROI masks. However, no relationship was observed between EBA activity and EDE-Q subscale or global scores.

3.3.3 Whole Brain Analysis

An exploratory whole brain analysis was run to examine whether any significant activations were observed outside of our defined ROI analysis. For exploratory purposes, statistical thresholding was lowered, using clusters determined by $Z > 2.6$, with a corrected cluster significance of $p = 0.05$. Whole brain analyses were run on chosen contrasts based on the effects and interactions identified in the univariate ROI analysis (see Figure 3.4). Noteworthy brain regions within chosen contrasts are shown in Supplementary Material (A2 - Tables A2.2 - 2.4), which revealed significant activations in areas associated with self-awareness (superior/inferior frontal gyrus) and multisensory construction of body image (right superior parietal lobule; Case, Wilson, & Ramachandran, 2012). Anatomical localization was identified using the three-dimensional atlas of neuroanatomy (Duvernoy, 2012). Finally, demeaned EDE-Q subscale and global scores were added as a covariate in a further exploratory whole brain analysis of each of our four conditions. However, no significant relationship was observed between brain regions and EDE-Q scores.

3.3.4 Multi-Voxel Pattern Analysis

Following our univariate analysis, a correlation-based multi-voxel pattern analysis (MVPA) was conducted using a between-run split (run 1 & run 2), to assess the similarity in the pattern of neural responses to visual perspective and body morphology. MVPA was performed at the individual level using the same left and right EBA masks from the univariate analysis. As expected, patterns of responses were higher for within-category correlations, compared with between-category correlations (see Fig. 3.5c & 3.5d).

Next, to establish the relative contribution of body morphology and visual perspective towards the neural pattern of responses, we subsequently ran a multiple regression analysis. Model correlation matrices were created to represent patterns of response which are exclusively predicted by the body morphology or visual perspective of body stimuli (see Fig. 3.5a & 3.5b). These models were then used as regressors in a multiple regression analysis of the fMRI data from our present sample (See Fig. 3.5e & 3.5f). A paired samples t-test revealed that visual perspective explained significantly more variance than body morphology for both the left EBA (t (29) = 3.86, $p < .001$) and right EBA (t (29) = 5.05, $p < .001$). Further, within the left EBA, one sample t-tests revealed that visual perspective explained a significant amount of the variance in the MVPA correlation matrix (t (29) = 4.15, $p < .001$), whilst body morphology did not (t (29) = .29, $p = .77$). However, within the right EBA, one sample t-tests revealed that both visual perspective (t (29) = 8.25, $p < .001$) and body morphology (t (29) = 3.35, $p < .01$) both explained a significant amount of the variance in the MVPA correlation matrix. Thus, the results show that the pattern of activity within the right EBA appears to represent bodies based on both visual perspective and the type of body which is perceived. Whilst the regression coefficient was non-significant for body morphology in the left EBA, this null result should be taken with caution as it may be due to a lack of statistical power as a result of a smaller ROI within the left hemisphere (see discussion below).

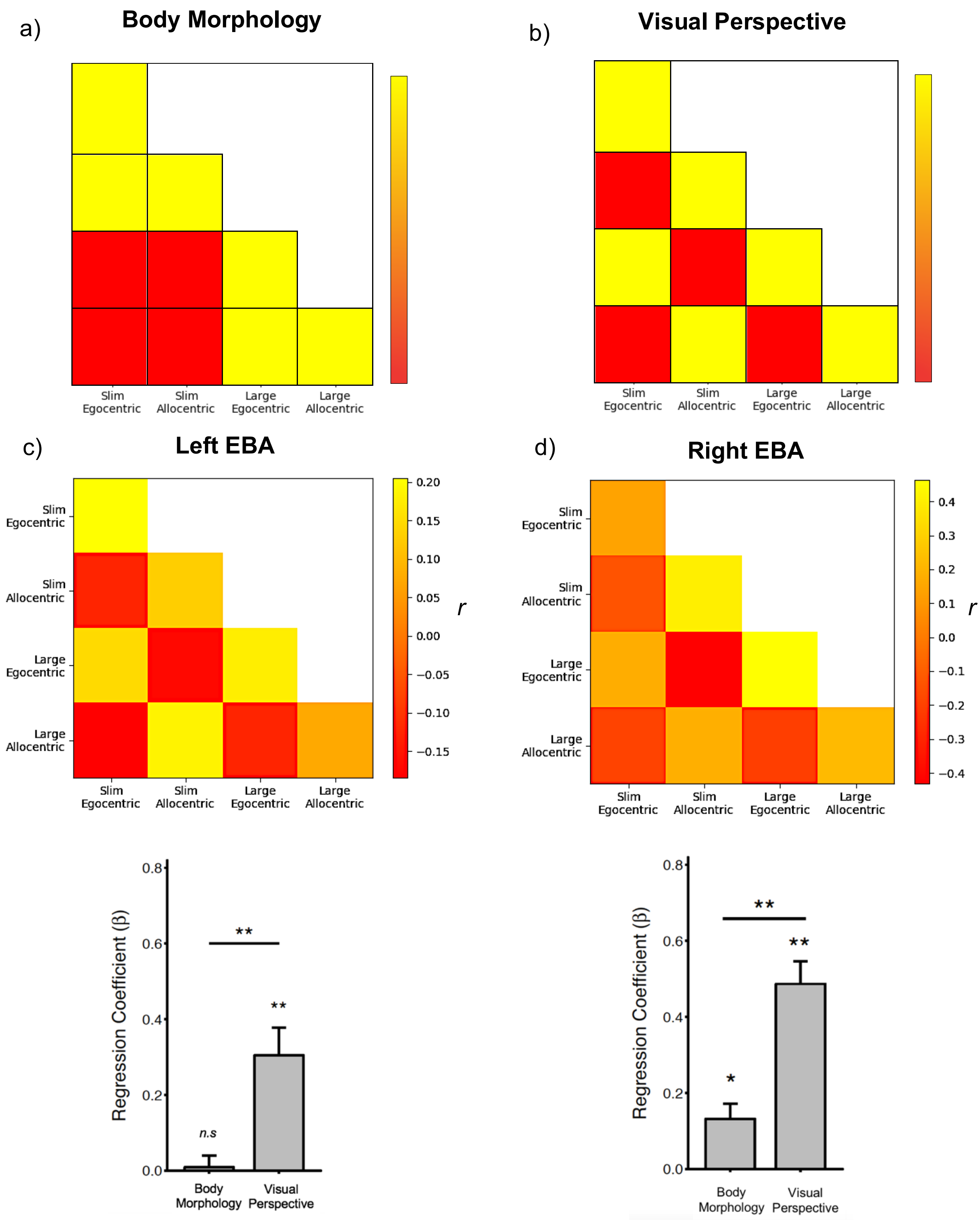

Figure 3.5 MVPA and Regression Coefficients. Binary models were created to represent the extreme cases where patterns of response are exclusively predicted by either the a) body morphology or b) visual perspective of body stimuli. Correlation matrix shows the similarity of neural patterns for within-category and between-category responses within the c) Left EBA mask and d) Right EBA mask.

Correlations were based on data from identical blocks between run 1 and run 2. These correlation matrices were compared against the binary models for both conditions using a multiple regression analysis, with regression coefficients shown for the e) Left EBA and f) Right EBA. Error bars depict standard error of the mean (*= $p < .01$, **= $p < .001$).

3.3.5 Behavioural Responses

3.3.5.1 Aesthetic Evaluations

Aesthetic evaluation ratings were compared between visual perspective and body morphology using a 2x2 repeated-measures ANOVA (see Figure 3.6a). There was a significant main effect of body morphology on ratings of attractiveness (F (1,29) = 98.03, p <.001, $\eta_p^2 = .77$), showing that participants rated slim bodies as significantly more attractive than large bodies. However, there was no significant main effect of visual perspective in ratings of attractiveness (F (1,29) = 3.99, p = .06, $\eta_p^2 = .12$). Nevertheless, there was a significant interaction between visual perspective and body morphology (F (1,29) = 24.07, p <.001, $\eta_p^2 = .45$). Post hoc Bonferroni-corrected ($\alpha = .025$) paired samples t-tests revealed no significant difference in attractiveness ratings between perspectives for slim bodies (t (29) = -1.68, p = .105, d = -.31), but participants rated large bodies as significantly less attractive from allocentric perspectives compared with egocentric perspectives (t (29) = 4.72, p < .001, d = .86). These results suggest that visual perspective is more important in influencing subjective attractiveness ratings towards larger bodies, with slim bodies rated as equally attractive irrespective of visual perspective.

3.3.5.2 Weight Evaluations

Weight evaluation ratings were also compared between visual perspective and body morphology using a 2x2 repeated-measures ANOVA (see Figure 3.6b). There was a significant main effect of body morphology on ratings of weight (F (1,29) = 282.15, p <.001, $\eta_p^2 = .91$), showing that participants rated large bodies to weigh significantly more than slim bodies. Further, there was a significant main effect of visual perspective in weight evaluations (F (1,31) = 13.48, p <.01, $\eta_p^2 = .32$), showing that participants rated bodies from allocentric perspectives as weighing significantly more than from egocentric perspectives. Finally, there was a significant interaction between visual perspective and body morphology (F (1,31) = 37.07, p <.001, η_p^2 = .56). Post hoc Bonferroni-corrected (α = .025) paired samples t-tests revealed no significant difference in weight ratings between perspectives for slim bodies (t (29) = 1.86, p = .073, d = .34), but participants rated large bodies as significantly more overweight from allocentric perspectives compared with egocentric perspectives (t (29) = -5.91, p < .001, d = -1.08). Similarly, this suggests that visual perspective has more pronounced effect in influencing the subjective perceived weight of large bodies, yet such evaluations are statistically unaffected by visual perspective towards slim bodies.

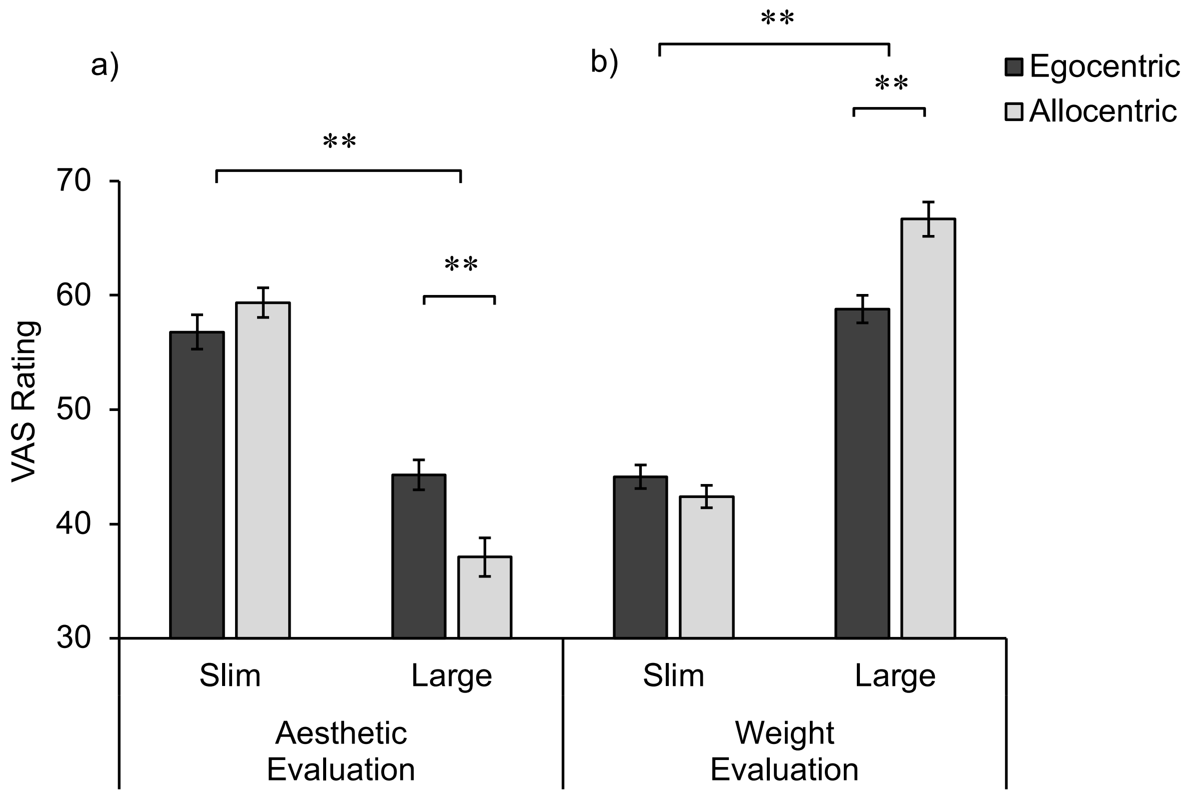

Figure 3.6 Mean VAS rating (0-100) for a) aesthetic and b) weight evaluations of slim and large body stimuli, from egocentric and allocentric perspectives. Error bars depict standard error of the mean (**= p < .001).

3.3.6 Relationship between fMRI and Behavioural Responses

To determine whether there was a relationship between EBA activity and aesthetic or weight evaluations of body stimuli, difference scores were first calculated between behavioural evaluation ratings, which reflected the appropriate fMRI contrast. Values were demeaned across all participants and used as covariates in the group analysis of contrasts *Slim Allocentric* > *Slim Egocentric* and *Large Allocentric* > *Large Egocentric*, within our predefined ROI mask. However, EBA activity showed no significant relationships with aesthetic or weight behavioural responses.

Finally, a whole brain analysis was run to explore whether any regions outside our defined ROI showed a relationship between fMRI and behavioural responses. Similarly, for exploratory purposes, statistical thresholding was lowered, using clusters determined by $Z > 2.6$, with a corrected cluster significance of $p = 0.05$. Results showed a significant relationship between *Large Allocentric* > *Large Egocentric* contrast and corresponding attractiveness ratings in the superior frontal gyrus within prefrontal cortex (see Supplementary Material A2 - Table A2.5 and Figure A2.1 for spatial MNI co-ordinates). Crucially, the above contrast showed no significant relationship in any brain regions with the corresponding weight evaluations, suggesting that the effects of aesthetic evaluations may be independent of perceived body weight. Overall, this suggests that such socio-cognitive evaluations made towards bodies may not occur in the EBA, but are instead made in higher-order, prefrontal regions of the brain.

3.4 Discussion

The aim of the present study was to investigate whether the combined processing of visual perspective and body morphology modulated neural response in the body-selective EBA brain region. Univariate results revealed an interaction between such physical body attributes, shown by greater EBA activity, bilaterally, when viewing all bodies from an egocentric perspective compared with allocentric perspective. Additionally, EBA activity was increased in response to larger bodies compared with slim bodies when viewed from an allocentric, but not egocentric perspective. Furthermore, multi-voxel pattern analysis (MVPA) highlighted distinct neural patterns in response to different conditions of body stimuli, with subsequent multiple regression analysis showing that EBA activity could be predicted by visual perspective and body morphology independently. Such findings highlight an interactive effect between multiple physical attributes in modulating EBA activity in visual body processing, with selective patterns of neural response shown to different categories of body information, rather than an absolute neural response to all human bodies. Finally, an interaction between the visual perspective and morphology of perceived bodies was supported following behavioural aesthetic and weight evaluations of bodies. Although such evaluations had no significant relationship with EBA activity, aesthetic, but not weight evaluations of large bodies viewed from different perspectives related to activation in prefrontal cortex, which is implicated in higher-order socio-cognitive assessments of bodies. This suggests that visual perspective can play a crucial role in influencing subjective aesthetic evaluations, independently of perceived body size or weight.

Previous research has found greater neural activation in the right EBA in response to allocentric views of human bodies compared with egocentric views, with no discrimination shown between perspectives in the left EBA (Chan et al., 2004; Saxe et al., 2006). The present study supports the argument that EBA response is functionally modulated by the perceived visual perspective of bodies, however, our results highlight that the role of the EBA is more complex than discriminating between visual perspective alone. Indeed, we found greater neural activation, bilaterally, to egocentric perspectives compared with allocentric perspectives in response to slim bodies only, with no discrimination between visual perspective in response to large bodies. Therefore, the sensitivity of the EBA to also discriminate between body size, and the interaction between such perceptual properties means that it is of little surprise that there are differences between previous research and the present results, given the combined processing of physical attributes in the present study. Moreover, our study has a much-improved sample size (N=30) compared with previous studies (N=10) which have examined the influence of visual perspective on EBA activity (Chan et al., 2004; Saxe et al., 2006). Such increased power improved the reliability of our own findings, particularly in the sensitivity of activation within the left EBA which was indeed shown to discriminate between visual perspectives. Our findings support the literature in highlighting the importance of visual perspective as a critical factor in modulating EBA activity (Chan et al., 2004; Saxe et al., 2006; Arzy et al., 2006), yet extend upon previous work by demonstrating a bilateral sensitivity to other physical body attributes in addition to - and in combination with - visual perspective. Consequently, future studies must consider how multiple body-related properties interact to modulate neural EBA response, which will provide a more real-world assessment of how individuals perceive bodies in everyday life.

Our univariate analyses revealed a significant interaction between visual perspective and body morphology in modulating EBA activity, yet research has highlighted that caution must be taken when interpreting neural response using this analysis alone (e.g. Peelen & Downing, 2007), as it is unclear whether changes in overall neural amplitude affects the pattern of response in this region. Therefore, in addition to our univariate results, our MVPA strengthened and extended our findings by observing distinct, selective patterns of neural EBA activity between each of our four conditions. Indeed, regression analyses showed EBA responses were significantly predicted by both visual perspective and body size independently, within the right EBA. Whilst neural response was also significantly predicted by visual perspective in the left EBA, body size did not significantly predict activity in this hemisphere. However, this null result should be treated with caution, and may be a statistical power issue given the reduced neural response in the left compared with right EBA. Indeed, such findings are in line with previous fMRI research which shows greater selectivity for bodies in the right EBA (Downing et al., 2001; Downing, Peelen, Wiggett, & Tew, 2006), particularly amongst females (Aleong & Paus, 2010). Thus, the use of MVPA provides a robust technique in identifying dissociable patterns of activity within extrastriate cortex, supporting the argument that the EBA can discriminate between both the visual perspective and morphology of perceived bodies.

Aesthetic and weight behavioural evaluations similarly showed interactions between visual perspective and body morphology in the present study, which supports our neuroimaging evidence in highlighting the complex interplay between the visual properties of multiple physical attributes in body perception. Consistent with the cultural ‘thin-ideal’ body amongst females (Ahern, Bennett, & Hetherington, 2008; Myers, Ridolfi, Crowther, & Ciesla, 2012), participants gave lower weight evaluations and higher attractive evaluations to slim bodies compared with large bodies. Importantly, the influence of visual perspective towards such behavioural ratings was dependent on the type of body that was being evaluated. We found no difference between visual perspectives in influencing weight or aesthetic ratings made towards slim bodies. However, an interesting finding revealed that large bodies were rated as significantly more overweight, and significantly less attractive, when viewed from an allocentric perspective compared with an egocentric perspective. These findings suggest that social evaluations made towards bodies are modulated by the combined contribution of visual perspective and size of the perceived body. Such an interaction between the visual properties of bodies may have important implications in influencing one's own body image, particularly amongst those with EDs or obesity, as individuals may exhibit changes in their own body satisfaction depending on the perspective in which their body is perceived (Cazzato et al., 2012).

Despite interactions observed in neural and behavioural responses independently, we did not observe a direct relationship between EBA activity and aesthetic or weight evaluations of bodies. Indeed, the pattern of interactions between the physical attributes were not mirrored neurally and behaviourally. Whilst there was a significant difference in neural activation between visual perspectives for slim bodies, behavioural responses revealed a significant difference in both aesthetic and weight evaluations between perspectives for large bodies. The different patterns of responses observed within these two tasks may suggest that such socio-cognitive evaluations of bodies do not occur in the EBA, but instead occur in brain regions associated with higher-order reasoning (Downing & Peelen, 2011; Taylor, Wiggett, & Downing, 2007). This is supported by our whole brain analysis, which revealed a significant relationship between the superior frontal gyrus in prefrontal cortex and aesthetic evaluations of large bodies viewed from different visual perspectives. This region is associated with cognitive processes including self-awareness and introspection (Goldberg, Harel, & Malach, 2006), thus supporting the argument that higher-order regions are engaged when making such cognitive evaluations of bodies (Greven, Downing, & Ramsey, 2018). The relationship shown within this particular contrast is critical, as individuals were perceiving the same bodies but simply from different perspectives. This suggests that such aesthetic appraisal of bodies is based on more than body size, and accounts for the viewpoint in which the same body type is perceived. Interestingly, we observed no brain regions that showed a significant relationship with behavioural weight ratings in the identical contrast, which supports the argument that such aesthetic evaluations may be occurring independently of perceived body size or weight.

Previous research has shown that disruption to extrastriate cortex directly influences aesthetic evaluations of bodies (Calvo-Merino et al., 2010), but not weight estimations (Cazzato et al., 2014, 2016) amongst healthy individuals, which suggests that the EBA may have an important, dynamic role in higher-order processing of human bodies (David et al., 2007). However, whilst we do not find evidence of EBA involvement in such higher-order assessments of bodies, our findings do show that the EBA is sensitive enough to discriminate between the subtleties of body size. Therefore, in addition to our whole brain analysis revealing prefrontal activation, we argue that the EBA acts as a core region at the early stage of body processing within a distributed network, which extracts important information for higher-order brain regions when making subsequent socio-cognitive assessments of bodies (Amoruso, Couto, & Ibáñez, 2011; Greven et al., 2018). Future research which investigates the functional connectivity of the EBA within a wider, distributed network is essential, using techniques such as psychophysiological interaction (PPI) analyses (Greven et al., 2018) to examine the distinct communication between brain networks during body perception.

Alternatively, no direct relationship between EBA and behavioural responses may be due to the design of the task undertaken by participants in the present study. Recent research has found dissociable EBA responses when participants were asked to make an explicit social inference of bodies, but not when those bodies were viewed in an identity recognition task (Greven et al., 2018). Thus, whilst EBA activity was modulated between the four conditions within the current study, future studies should directly investigate the influence of visual perspective and body size towards EBA response when making such aesthetic and weight inferences towards bodies in the scanner, to directly assess the role of the EBA in aesthetic evaluation.

Despite previous research finding relationships between neural responses and non-clinical ED psychopathology in body-related fMRI research (Preston & Ehrsson, 2016), our results showed that

EBA response was not functionally modulated by ED psychopathology in our sample of healthy females. Such findings may suggest that alterations in EBA functioning may be a consequence of clinical EDs rather than a predisposing risk factor (Hay & Sachdev, 2011). Indeed, additional analyses in the present study showed that participant BMI did not modulate EBA response in any conditions, which may suggest that such EBA alterations in clinical populations are not simply a consequence of changes in body weight. Thus, with increasing research looking to identify potential biomarkers of EDs (Groves et al., 2017), it is important that future research investigates neural functioning of body-related areas such as the EBA in relation to non-clinical ED psychopathology.

Behavioural research has highlighted the importance of visual perspective in its role within body ownership (Jenkinson & Preston, 2017; Preston, Kuper-Smith, & Ehrsson, 2015). Direct comparison between first-person (egocentric) and third-person (allocentric) perspectives using multisensory illusion paradigms have yielded clear findings of greatest body ownership (feelings as if the viewed body is your own body) when synchronous sensory input is coded from an egocentric reference frame within peripersonal space (Maselli & Slater, 2013; Petkova, Khoshnevis, et al., 2011). This highlights the intrinsic, robust role of visual perspective with the physical self in human body perception. Moreover, whilst many studies have argued that the EBA does not play a role in discriminating between self and others (Chan et al., 2004; Saxe et al., 2006), the perception of one's *own* body compared with another's is important to consider in relation to changes in one's body image. Indeed, body image disturbances amongst ED patients show alterations specifically in the perception of one's own body, but not of others (Castellini et al., 2013; Mai et al., 2015; Sachdev, Mondraty, Wen, & Gulliford, 2008). Thus, as participants in the present study only viewed images of others' bodies, future studies should explore the effect of visual perspective with the perception and evaluation of one's own body (e.g. Ganesh, van Schie, Cross, de Lange, & Wigboldus, 2015) compared with another's body, in relation to non-clinical ED psychopathology.

In conclusion, our results showed that the EBA plays a key role in discriminating between both visual perspective and body morphology in visual body perception. More specifically, EBA activity was functionally modulated by the interaction between such physical attributes, with distinct neural patterns shown bilaterally across each condition. Behavioural assessments of aesthetic and weight evaluations support the argument of an interaction between the visual perspective and morphology of perceived bodies, although such evaluations had no significant relationship with EBA activity. Instead, differences in aesthetic evaluations of large bodies related to activity within prefrontal cortex. Together, our findings argue that the role of the EBA in visual body processing is more complex than a simple category-selective region and represents human bodies in a more integrative manner in which it simultaneously considers multiple physical attributes of bodies. We argue that the differences observed in neural response may act as an important early step in communicating such processing to higher-order, frontal brain regions which are associated with aesthetic evaluation of bodies.

Chapter 4

The Effect of Visual Capture Towards Subjective Embodiment Within the Full Body Illusion

This chapter is adapted from: Carey, M., Crucianelli, L., Preston, C., & Fotopoulou, A. (2019) The Effect of Visual Capture Towards Subjective Embodiment within the Full Body Illusion. *Scientific Reports* [2]

4.1 Introduction

Body ownership, the feeling that our body belongs to us and is distinct from other people's bodies, is a fundamental component of our sense of self (Gallagher, 2000; Tsakiris, 2016). Intuitively, this feeling appears stable and durable amongst humans, yet scientific studies have demonstrated that the sense of body ownership is a fragile outcome of integrating multiple sensory signals. Such signals originate via exteroceptive modalities (i.e. outside the body) such as vision and touch (Ehrsson et al., 2004; Tsakiris, 2010), specifically within the boundaries of peripersonal space surrounding the body (Salomon et al., 2017; Serino et al., 2015). Additionally, incoming signals emerge via interoceptive modalities (i.e. within the body) such as heart rate, and via proprioceptive pathways (Craig, 2002, 2009; Tsakiris et al., 2011). Together, exteroceptive and interoceptive sensory signals are integrated to create a coherent sense of body ownership through which we interact with our environment (Tsakiris, 2016).

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[2] The author, Mark Carey, contributed to the design of the experiment, collected the data, analysed the results and wrote the manuscript under the supervision of Dr Catherine Preston, in collaboration with Dr Laura Crucianelli and Dr Aikaterini Fotopoulou.

Experimental paradigms have been successfully used to investigate how body ownership is shaped by the integration of incoming multisensory information. For example, in the *Rubber Hand Illusion* (RHI) (Botvinick & Cohen, 1998), individuals experience ownership over a fake (rubber) hand when placed in a congruent anatomical position and stroked in temporal synchrony with their own hand, which is hidden from view. This has been recently extended to ownership over an entire body *(Full Body Illusion)*, of which different variations exist. Participants can perceive a change in self-location which induces an illusory experience of being in a position outside of their physical body (Ehrsson, 2007), or an illusory ownership towards another's body from a third-person (allocentric) perspective (Lenggenhager et al., 2007) or first-person (egocentric) perspective (Petkova & Ehrsson, 2008; Slater, Spanlang, Sanchez-Vives, & Blanke, 2010). In such illusions, the source of tactile stimulation on one's own, unseen body (part) is attributed to the location of the visually perceived fake body (part) when the two are stroked synchronously, which is argued to give rise to subjective self-reports of illusory body ownership (Tsakiris, 2010). Importantly, such effects typically occur within the constraints of top-down contextual factors, including the orientation (Ehrsson et al., 2004; Tsakiris & Haggard, 2005b), visual perspective (Maselli & Slater, 2013; Petkova, Khoshnevis, et al., 2011; Preston et al., 2015), and appearance (Haans et al., 2008; Petkova & Ehrsson, 2008; Tsakiris, Carpenter, et al., 2010) of the embodied body (part). Indeed, research has shown that the strength of the illusion is modulated by the distance between the real and fake body (part), with greater spatial discrepancies decreasing the likelihood of integration between visuoproprioceptive signals (Bergström, Kilteni, & Slater, 2016; Lloyd, 2007; Preston, 2013).

Importantly, it has long been argued that the synchrony of the perceived touch with vision is a necessary condition for illusory ownership to occur, rather than asynchrony which is typically used as a control condition within multisensory illusion paradigms (Tsakiris & Haggard, 2005b). However, the role of synchronous visuotactile integration as a necessary component to trigger illusory embodiment remains debated (Kilteni et al., 2015; Samad et al., 2015). Research has shown that illusory embodiment could still be induced based purely on visual information of a fake body (part) in the absence of visuotactile stimulation (Longo, Cardozo, et al., 2008; Pavani et al., 2000; Samad et al., 2015), or based on merely expected but not experienced synchronous tactile stimulation (Costantini et al., 2016), and even following asynchronous visuo-tactile stimulation, provided that spatial congruence is adhered to between the real and fake body (part) (Rohde et al., 2011; see Kilteni et al., 2015, for review). Such evidence highlights that synchronous visuotactile input can strengthen illusory embodiment, by contributing to the downregulation in the weighting of proprioceptive signals regarding one's own limb position in relation to vision (Zeller, Friston, & Classen, 2016). However, from a computational perspective, congruent visuoproprioceptive cues may be sufficient to induce such embodiment, suggesting that subsequent visuotactile input may not be a necessary component to trigger this process (Giummarra, Georgiou-Karistianis, Nicholls, Gibson, & Bradshaw, 2010; Longo, Cardozo, et al., 2008; Samad et al., 2015; see Noel, Blanke, & Serino, 2018, for review).

Studies which have investigated illusory body ownership in the absence of tactile stimulation have predominantly investigated this effect during the RHI (e.g. Perez-Marcos et al., 2018; Ponzo, Kirsch, Fotopoulou, & Jenkinson, 2018; Samad et al., 2015), with little research conducted towards a whole body (Maselli & Slater, 2013). Among the latter, some have argued that synchronous visuotactile integration is a necessary condition to elicit illusory ownership in the full body illusion (Petkova & Ehrsson, 2008), while studies using virtual reality have found evidence to the contrary, following illusory ownership towards a virtual body in the absence of visuotactile integration (Maselli & Slater, 2013; Slater et al., 2010). Therefore, in the present study we wished to investigate whether subjective visual capture of embodiment could occur towards a real mannequin body with a static field of view, from a first-person visual perspective in the 'physical world'. In this context, 'visual capture' is defined as the degree of embodiment due solely to passive, visual perception of the fake body (part) viewed from a first-person perspective, independently from tactile stimulation (hereafter referred to as 'visual capture of embodiment') (Crucianelli et al., 2017; Martinaud et al., 2017).

Interestingly, a tendency to weight visual information over other somatosensory signals has been recently observed in neuropsychological, right hemisphere patients with body representation deficits (e.g. Fotopoulou et al., 2008; Martinaud et al., 2017; Tidoni, Grisoni, Liuzza, & Aglioti, 2014;

van Stralen et al., 2013). Moreover, alterations in the weighting and integration of sensory information has been implicated within neurodevelopmental disorders such as autism (Greenfield, Ropar, Smith, Carey, & Newport, 2015; Noel, Lytle, Cascio, & Wallace, 2018), and psychiatric disorders such as schizophrenia (Stevenson et al., 2017; Tschacher & Bergomi, 2011; Wynn, Jahshan, & Green, 2014), and eating disorders (EDs) (Eshkevari et al., 2012; Keizer et al., 2014). Importantly, such alterations are argued to reflect an instability in the bodily self within these populations (Noel, Stevenson, & Wallace, 2018; Serino & Dakanalis, 2017). However, whilst 'pure' visual capture conditions have been tested in right hemisphere patients, evidence for heightened visual dominance within ED patients derives from multisensory illusion studies finding that both synchronous and asynchronous visuotactile stimulation led to alterations in an individual's body image (Eshkevari et al., 2012, 2014, Keizer et al., 2014, 2016). Thus, direct investigation of visual capture of embodiment from congruent visuoproprioceptive cues alone (i.e. in the absence of tactile stimulation) has been less studied with regard to ED psychopathology.

Importantly, greater embodiment following the RHI in acute ED patients has been shown to persist to some degree amongst recovered patients, suggesting that such heightened sensitivity to visual information pertaining to the body may be a trait phenomenon (Eshkevari et al., 2014). Therefore, such visual dominance over other sensory information may be independent from a status of malnutrition, and may occur *prior* to illness onset which could influence an individual's body perception and body satisfaction (Preston & Ehrsson, 2014, 2016, 2018). Thus, it may be that healthy individuals who display an increased visual capture of embodiment towards a fake body (part) show an increased visual dominance over other sensory information, which may link with a greater risk of developing distortions in one's body image. Consequently, the present study aimed to investigate whether non-clinical ED psychopathology and body concerns in healthy individuals may modulate the subjective embodiment shown towards a fake body as a result of mere visual capture.

In addition to research investigating visuoproprioceptive integration, the importance of interoception in multisensory integration and body ownership has only recently been investigated

(Aspell et al., 2013; Suzuki et al., 2013; Tsakiris et al., 2011). Interoception refers to information about the internal states of the body, processing sensations from within the body (e.g. hunger, thirst, heart rate), but also outside the body (e.g. itch, pain, pleasure from touch), which is conveyed by a particular afferent pathway (Craig, 2009). Affective touch - i.e. slow, caress-like touch – is associated with increased pleasantness and has been found to activate specific C-Tactile (CT) afferents found only in the hairy skin, responding maximally to stroking velocities between 1 and 10 cm/sec (Löken et al., 2009). Importantly, affective tactile stimulation appears to be dissociable from exteroceptive, discriminatory stimulation such as non-affective touch (Olausson et al., 2010). Such CT afferents are hypothesised to take a distinct pathway to the posterior insular cortex (Björnsdotter, Morrison, & Olausson, 2010; Olausson et al., 2002), an area associated with the early convergence of interoceptive information with exteroceptive bodily signals (Craig, 2009; Crucianelli et al., 2016; Morrison et al., 2011).

Increasing evidence has shown that the velocity of perceived touch during visuotactile integration plays an influential role within the sense of body ownership. Specifically, touch delivered at CT-optimal velocities has been shown to increase embodiment during the RHI paradigm compared with fast, non-affective touch (Crucianelli et al., 2017, 2013; Lloyd et al., 2013; van Stralen et al., 2014), however, evidence of this effect in the full body illusion remains equivocal (de Jong et al., 2017). Moreover, recent research has shown that individuals with anorexia nervosa (AN) display a reduced subjective pleasantness to touch, relative to healthy controls (Crucianelli et al., 2016); however, it is yet to be investigated how ED psychopathology may modulate the extent to which individuals show alterations in their experience of touch, or vice versa. Therefore, within our second experiment, individual differences in the perception of touch will be investigated in relation to non-clinical ED psychopathology.

In addition to enhancement of embodiment via interoceptive signals, evidence from patient populations with chronic pain has shown how feelings of body ownership can be disturbed (Moseley, 2005, 2008; but see Moseley, Parsons, & Spence, 2008 for review). Changes in interoceptive information (e.g. increased limb temperature) has been shown to disrupt the feelings of embodiment by *decreasing* the strength of the effect within multisensory illusions (Kammers et al., 2011). Therefore, in addition to mere visual capture towards subjective embodiment (*visual capture* condition), the present study aimed to investigate the effects of tactile stimulation administered to participants' own, unseen arm during visual observation of the mannequin body, as a control condition designed to 'disrupt' visual capture by introducing sensory information that is incongruent with participants' visual input (*tactile disruption* condition). Furthermore, we aimed to investigate whether CT-optimal, affective touch (i.e. touch administered in CT-optimal velocities) would provide additional interoceptive information on one's own body which would be expected to disrupt visual capture of embodiment to a greater extent compared with discriminatory, non-affective touch. Previous research has suggested that the perception of interoceptive signals depends on an individual's ability to regulate the balance between interoceptive and exteroceptive information in ambiguous contexts (Ainley, Apps, Fotopoulou, & Tsakiris, 2016; Crucianelli et al., 2017; Tsakiris et al., 2011). Thus, differences in an individual's sensitivity and balance between these two streams of information may determine the degree of embodiment change shown during tactile disruption conditions.

In brief, we investigated whether mere visual observation of a mannequin body would lead to subjective embodiment when visuoproprioceptive cues are congruent with one's own body. Based on previous research (Maselli & Slater, 2013; Samad et al., 2015), we predicted that a compatible first-person perspective of a mannequin body would be sufficient to elicit subjective embodiment amongst participants, independent of concomitant tactile stimulation. In addition, we investigated the extent to which subjective embodiment towards the mannequin body was reduced when visual capture of proprioception was disrupted by tactile stimulation to participant's own, unseen arm. We manipulated the velocity of tactile stimulation that participants received, to investigate whether slow, affective touch had a differential effect on the disruption of embodiment compared with fast, non-affective touch. Specifically, we predicted that the increased interoceptive information associated with affective touch would disrupt the downregulation of proprioceptive signals by visual capture to a greater extent compared to non-affective touch. Finally, we investigated whether non-clinical ED psychopathology modulated any individual differences in subjective embodiment from visual capture. We hypothesised that higher ED vulnerability would be associated with an increased weighting of visual information, and thus increased visual capture of embodiment. The above measures were replicated across two experiments, with the addition of a separate touch task in Experiment 2, designed to investigate the role of subjective pleasantness of touch in relation to non-clinical ED psychopathology. Extending upon findings from clinical populations (Crucianelli et al., 2016), we expected to observe a negative relationship between the above two measures, such that individuals with higher ED psychopathology were hypothesised to display a reduced pleasantness to both affective touch and non-affective touch.

4.2 Methods

4.2.1 Experiment 1

4.2.1.1 Participants

Forty-one healthy female participants (Mean age = 20.10, SD ± 2.48, range = 18-31) were recruited via the University of York research participation scheme and received course credit for a single 60-minute testing session. Participants had a mean BMI of 21.48 (SD ± 2.40, range = 18.30-28.60), no current or previous neurological or psychological disorders (self-report), and normal or corrected-to-normal vision. Exclusion criteria included any specific skin conditions (e.g. eczema, psoriasis) or any scarring or tattoos on the left arm. All participants gave informed consent to take part in the study. The study received ethical approval from the University of York Departmental Ethics Committee and was conducted in accordance with the Declaration of Helsinki. One participant was later excluded following a self-reported previous psychological condition, therefore, the final sample consisted of forty participants (Mean age = 20.15, SD ± 2.49, range = 18-31).

4.2.1.2 Design

The experiment employed a within-subjects design to investigate the effects of visual and tactile signals towards the subjective embodiment of a mannequin body. First, during *visual capture* trials participants visually observed the mannequin body for 30 seconds from a first-person perspective, independent of any tactile stimulation. Second, participants also undertook trials identical to the *visual capture* condition, but with the addition of tactile stimulation applied (only) to participant's own, unseen arm, designed to disrupt such visual capture (*tactile disruption* condition) for 60 seconds. In the context of the RHI, previous research has shown that 15 seconds is sufficient to elicit visual capture in some participants, as a two-way sensory integration between vision and proprioception (Martinaud et al., 2017; Ponzo et al., 2018). Furthermore, 60 seconds has been shown to be sufficient to induce changes in measures of body ownership in classic RHI and full body illusions involving synchronous touch – i.e. a three-way sensory integration between vision, proprioception, and touch (Crucianelli et al., 2013; Preston & Ehrsson, 2014). Therefore, owing to the additional use of head-mounted displays in the present study, we allowed participants 30 seconds in the two-way sensory integration 'visual capture' conditions and 60 seconds in the three-way 'tactile disruption' conditions.

Tactile stimulation was administered at two different velocities to give rise to affective (3cm/s) and non-affective (18 cm/s) *tactile disruption*. The dependent variable was the subjective embodiment experienced by participants, rated after each trial via an *embodiment questionnaire* (see *Measures* section and Table 4.1 for details). The same *embodiment questionnaire* was completed for both *visual capture* and *tactile disruption* conditions. Participants completed two *visual capture* trials, each followed by an affective or non-affective *tactile disruption* trial in counterbalanced order between participants, resulting in a total of 4 trials per participant (see Figure 4.1).

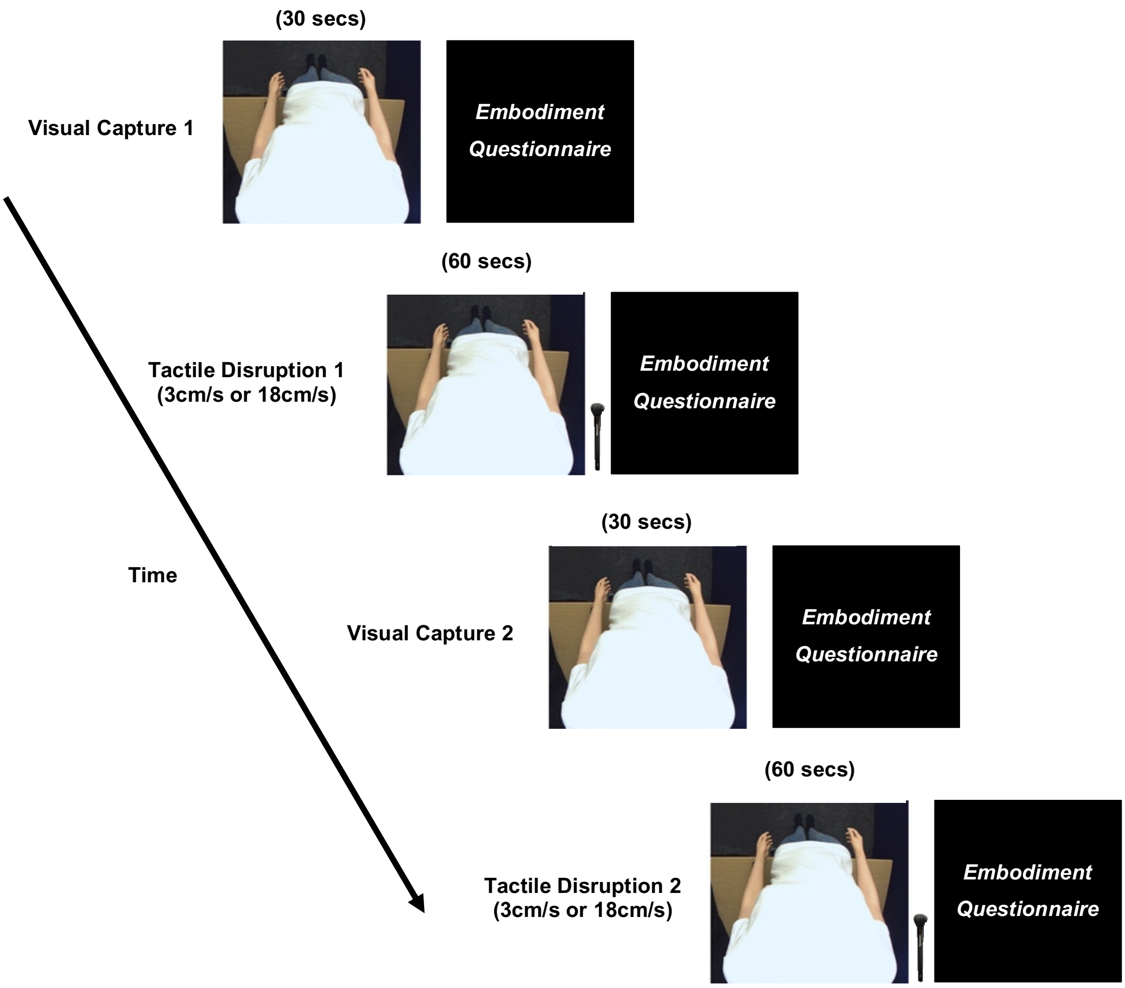

Figure 4.1 Timeline of experimental procedure. Participants completed two *visual capture* (30 secs) conditions and two *tactile disruption* (60 secs) conditions (1x affective touch; 1x non-affective touch). Tactile disruption order was counterbalanced across participants. Participants removed the HMDs following each trial and completed the *Embodiment Questionnaire* on a separate computer.

4.2.1.3 Measures

4.2.1.3.1 Embodiment Questionnaire

Following each trial, participants rated their subjective embodiment via an *embodiment questionnaire* (see Table 4.1) along a 7-point Likert scale (-3 strongly disagree to +3 strongly agree). This questionnaire (adapted from Longo et al., 2008) was composed of two subcomponents: *ownership* (i.e. the feeling that the mannequin body belongs to them) and *location* (i.e. the feeling that the mannequin body was in the position of their own body). An overall *embodiment score* was calculated by averaging the above two subcomponent scores. The final two statements were control statements, in which an overall *control score* was similarly calculated by averaging across the two control items. These scores served to control for task compliance, suggestibility, and confabulation within the visual capture condition to compare with embodiment scores. Such control statements are similar, body-related items to those of the embodiment statements, but importantly do not capture the phenomenological experience of embodiment. Consequently, comparisons between *embodiment* and *control* scores acted to indicate whether a significant sense of embodiment occurred following the *visual capture* condition.

Table 4.1 *Embodiment Questionnaire presented to participants following each trial.*

	Questionnaire Statement	Component
1.	It seemed like I was looking directly at my own body, rather than a mannequin body	Ownership
2.	It seemed like the mannequin body belonged to me	Ownership
3.	It seemed like the mannequin body was part of my body	Ownership
4.	It seemed like the mannequin body was in the location where my body was.	Location
5.	It felt like I had two bodies (at the same time)	Control
6.	It felt like my body was made out of rubber	Control

NB. The order of questionnaire statements was randomised for each trial and participant.

4.2.1.3.2 Eating Disorder Examination Questionnaire (EDE-Q)

The EDE-Q is a 28-item questionnaire used as a self-report measure of eating disorder psychopathology (Fairburn & Beglin, 1994). The questionnaire assesses frequency of disordered eating behaviours (6 items), as well as eating behaviours and attitudes (22 items) within the past 28 days, along four subscales: Restraint, Eating Concern, Weight Concern and Shape Concern, which are also averaged for a Global EDE-Q Score. Items are rated along a 7-point (0-6) Likert scale, with higher scores signifying greater eating disorder psychopathology. This measure has good internal consistency, with Cronbach's alpha ranging from .78 to .93 in a non-clinical sample (Berg et al., 2012). The overall global EDE-Q measure in the present study had a Cronbach's alpha of .95 in both Experiment 1 and Experiment 2.

4.2.1.4 Materials

A life-size female mannequin was used within the experimental set-up. The mannequin was dressed in a white t-shirt, blue jeans, and black socks, with the head removed at the neckline to enable correct positioning of the video cameras. The mannequin body was in a standing position *(Height: 159cm; Shoulders: 94cm; Hips: 87cm; Waist: 62cm)* with arms placed by their side (see Figure 4.2). During all trials, participants wore a set of head-mounted displays (HMDs) (Oculus Rift DK2, Oculus VR, Irvine, CA, USA), with a resolution of 1200 x 1080 pixels per eye, a refresh rate of 75Hz, and a corresponding nominal visual field of 100°. The HMDs were connected to a stereoscopic camera (USB 3.0 VR stereo camera, Ovrvision Pro, Japan), presenting a real-time, video image to participants. The cameras were mounted and positioned downwards, at the eyeline of the mannequin, capturing a first-person perspective of the body, compatible with looking down towards one's own body. During tactile disruption trials, tactile stimulation was applied using a cosmetic make-up brush (Natural hair Blush Brush, N◦7, The Boots Company). All experimental trials and responses were completed using PsychoPy 2 (Peirce, 2007) on an Apple iMac desktop computer (1.6GHz dual-core Intel Core i5 processor).

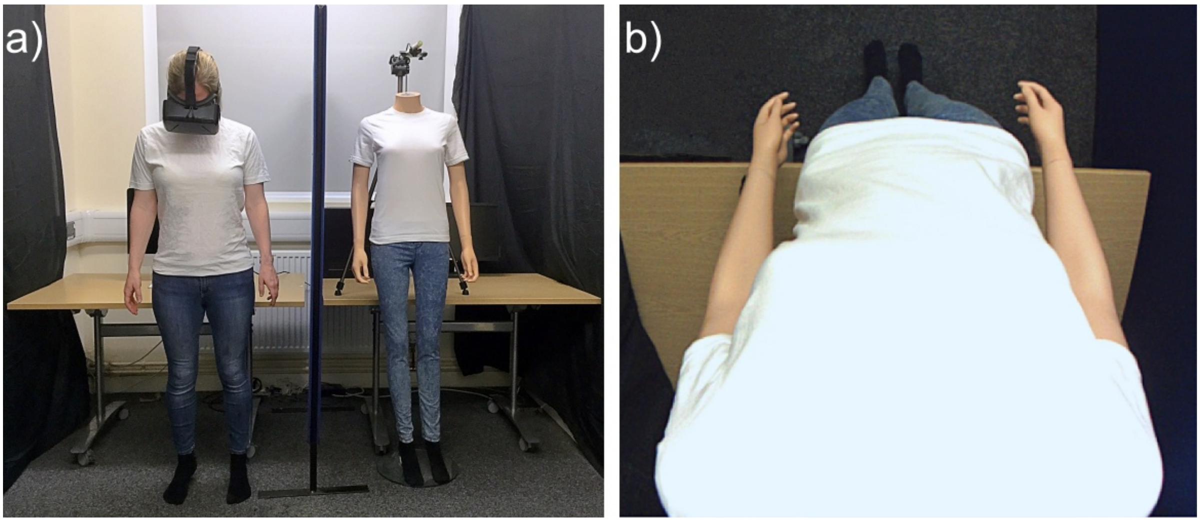

Figure 4.2 Experimental Set-up. a) In *visual capture* trials, participants stood in an identical stance to the mannequin body, separated by a screen divider. b) Participants viewed a live video image of the mannequin from a first-person perspective, via head-mounted displays.

4.2.1.5 Experimental Procedure

Prior to the experiment, two adjacent 9 x 4cm stroking areas were marked on the hairy skin of each participants' left forearm, using a washable marker pen (Crucianelli et al., 2013; McGlone et al., 2012). This provided a specific area for which to administer tactile stimulation for participants. Stimulation alternated between these two stroking areas within each tactile disruption trial, to minimise habituation, and provide the experimenter with an assigned area to control the pressure of each stroke. For all experimental trials, participants stood to the right of the mannequin body, separated by an office screen divider (see Figure 4.2a), whilst wearing the HMDs. Participants were instructed to remain still, place their arms by their side, and look down as though towards their own body. A live video image (delay ~ 60ms) of the mannequin body, viewed from a first-person perspective, appeared in place of their own body through the HMDs (see Figure 4.2b).

For *visual capture* trials, participants visually observed the mannequin body for a 30-second period, without any tactile stimulation. Immediately after the trial, participants removed the HMDs and rated their subjective embodiment towards the mannequin via the *embodiment questionnaire* (see Table 4.1) on a separate computer. Removing the HMDs following each trial also served as a rest period for participants to move freely and dissociate their subjective experience between trials. For *tactile disruption* trials, participants identically visually observed the mannequin body, with the experimenter stroking participants' own, unseen arm for a 60-second period. Stroking velocity was manipulated by administering slow, affective touch (3cm/s), and fast, non-affective touch (18cm/s). The experimenter was trained to administer each stroke at the precise speed within the assigned stroking area (9cm x 4cm), by counting the number of strokes within a window of 3 seconds per individual stimulation (i.e. one 3s-long stroke for 3 cm/s velocity, and six 0.5s-long strokes for 18 cm/s velocity). Identically, immediately after *tactile disruption* trials, participants removed the HMDs and rated their subjective embodiment towards the mannequin via the *embodiment questionnaire*. Individual questionnaire items were presented in a randomised order across all trials.

4.2.2 Experiment 2

4.2.2.1 Participants

Forty-three healthy female participants (Mean age = 18.98, SD ± .74, range = 18 - 20) were recruited via the University of York research participation scheme and received course credit for a single 60-minute testing session. Participants had a mean BMI of 21.89 (SD ± 2.67, range = 16.66-28.32), no current or previous neurological or psychological disorders (self-report), and normal or corrected-to-normal vision. Exclusion criteria included any specific skin conditions (e.g. eczema, psoriasis) or any scarring or tattoos on the left arm. All participants gave informed consent to take part in the study. The study received ethical approval from the University of York Departmental Ethics Committee and was conducted in accordance with the Declaration of Helsinki. Three participants were later excluded; one following a self-reported previous psychological condition; one excluded with scarring on their arms, and one excluded following poor comprehension with the experimental procedure. Therefore, the final sample consisted of forty participants (Mean age = 18.98, SD ± .77, range = 18 - 20).

4.2.2.2 Design, Materials, Measures, Procedure

Design, Materials, Measures and Procedures were identical to Experiment 1, with the addition of a separate *Touch Task* completed prior to the *Full Body Illusion*, which explored subjective pleasantness ratings of affective vs. non-affective touch based solely on tactile input. This measure was also investigated in relation to non-clinical eating disorder psychopathology amongst healthy females.

4.2.2.2.1 Touch Task

Participants were asked to place their left arm on the table with their palm facing down, and wore a blindfold over their eyes to prevent any visual feedback to tactile stimulation. Tactile stimulation was administered using an identical cosmetic make-up brush (see *Materials* above) for 3 seconds per trial, at the same velocities as those in the *tactile disruption* conditions (affective touch - 3 cm/sec and non-affective touch - 18 cm/sec). There was a total of six trials per velocity condition, for a total of 18 trials, with all trials presented in a randomised order for each participant. Following each trial, participants verbally reported the pleasantness of the touch, using the pleasantness rating VAS scale, anchored from 0 (*Not at all pleasant)* to 100 (*Extremely pleasant*) (Crucianelli et al., 2016). An average score across the six trials was calculated to obtain a single score, per participant, for each of the two tactile conditions.

4.2.3 Data Analysis

All statistical analyses were conducted using SPSS version 23.0 (IBM, Chicago, IL, USA). Data from the *embodiment questionnaire* were ordinal and found to be non-normal via a Shapiro-Wilk test ($p < .05$), thus, appropriate non-parametric tests were used for analysis. Data for pleasantness ratings in the *Touch Task* were normally distributed ($p > .05$), therefore parametric tests were used to analyse this data. Effect sizes for parametric tests are indicated by Cohen's *d*, and non-parametric Wilcoxon signed-rank tests are indicated by r values (*r*) which are equivalent to Cohen's *d* (Pallant, 2007).

First, to indicate whether a significant sense of subjective embodiment occurred following mere visual observation of a mannequin body (i.e. *visual capture* effect), we used a Wilcoxon signed-rank test to compare *embodiment* scores with *control* scores within the *embodiment questionnaire* (see Table 4.1 for *embodiment questionnaire* items). Such comparisons were made to ensure that positive subjective embodiment was specific to the visual capture effect and not due to task compliance or suggestibility, with control items not expected to score highly, irrespective of illusory experience. Second, to investigate whether subjective embodiment was significantly reduced when visual capture was disrupted by tactile stimulation to participant's own, unseen arm (*tactile disruption*), a further Wilcoxon signed-rank test was conducted to compare subjective *embodiment* scores between *visual capture* and *tactile disruption* conditions. Moreover, we assessed whether slow, affective touch on participants own arm led to greater disruption in subjective embodiment within participants compared with fast, non-affective touch, using a Wilcoxon signed-rank test to compare *embodiment* scores between the two stroking velocities (affective vs. non-affective *tactile disruption*). The above analyses were also conducted for individual *Ownership* and *Location* subcomponents within the *embodiment questionnaire* (see Supplementary Material A3, Sections A3.1 and A3.2). Additionally, in Experiment 2 we examined the effect of stroking velocity on pleasantness ratings using a paired-samples t-test, to first establish whether slow, affective touch was indeed perceived as significantly more pleasant that fast, non-affective touch (manipulation check). The perception of touch was then investigated in relation to non-clinical ED psychopathology (as measured by the EDE-Q), using a non-parametric Spearman's correlation.

To establish individual differences in reported visual capture of embodiment, we calculated percentage frequencies across the combined samples of Experiment 1 and 2, of those who reported visual capture of embodiment (average scores of $\geq +1$ in response to the *embodiment questionnaire*; Ehrsson et al., 2004; Kalckert & Ehrsson, 2012)), those who neither affirmed or denied embodiment (average scores of $< +1$ and > -1 in response to the *embodiment questionnaire*) and those who denied visual capture (average scores of < -1 in the *embodiment questionnaire*). Finally, we wished to explore whether such individual differences in subjective embodiment from visual capture related to non-clinical ED psychopathology (EDE-Q). Therefore, we conducted a non-parametric Spearman's correlational analysis between the psychometric EDE-Q measure and subjective embodiment scores from *visual capture*.

4.3 Results

4.3.1 Experiment 1

4.3.1.1 Embodiment Questionnaire

Preliminary analysis showed that there was no effect of trial order across visual capture trials, with a Wilcoxon signed-rank test revealing no significant difference in embodiment scores between visual capture trial 1 vs. trial 2 (Z = - .084, p = .933). Therefore, *embodiment questionnaire* scores were collapsed across the two visual capture trials to provide an overall *visual capture* embodiment score, per participant.

4.3.1.1.1 Main effect: Visual Capture

To examine the effects of mere visual capture towards subjective embodiment of the mannequin body, we compared *embodiment* scores with *control* scores in the *embodiment questionnaire*. A Wilcoxon signed-rank test revealed a main effect of visual capture, with significantly higher embodiment scores compared with control scores (Z = -4.04, p < .001, r = .64) (see Figure 4.3).

4.3.1.1.2 Main effect: Tactile Disruption

In order to determine whether tactile disruption to participants' own unseen arm would disrupt subjective embodiment, we compared *embodiment* scores between *tactile disruption* and *visual capture* conditions. A Wilcoxon signed-rank test revealed a main effect of condition, in which participants showed significantly lower subjective embodiment following *tactile disruption* trials (median = -.38) compared with *visual capture* trials (median = .82) (Z = -3.74, p < .001, r = .59).

4.3.1.1.3 Main effect: Tactile Velocity

Next, we examined whether tactile velocity had an effect in disrupting the subjective embodiment towards the mannequin body within *tactile disruption* trials. A Wilcoxon signed-rank test revealed that there was no significant difference in embodiment scores between affective (median = -.50) and non-affective (median = -.50) tactile disruption trials (Z = -.104, p = .918, r = .02), which suggests that interoceptive affective touch did not disrupt visual capture of embodiment to a greater degree than exteroceptive, non-affective touch.

4.3.2 Experiment 2

4.3.2.1 Touch Task (Manipulation Check)

A further one participant was later excluded within the *Touch Task* analysis as an extreme outlier, scoring more than 2 SD below the group mean in pleasantness ratings of affective touch (3cm/s velocity) (Ponzo et al., 2018). Therefore, the final sample for this analysis consisted of 39 participants. As expected, a paired samples t-test revealed an effect of stroking velocity within the touch task, with significantly higher subjective pleasantness ratings following affective touch (3cm/s) (mean = 74.27) compared with non-affective touch (18cm/s) (mean = 52.94) (t (38) = 7.93, p < .001, d = 1.27). Moreover, correlational analyses were conducted to investigate the relationship between pleasantness ratings and non-clinical ED psychopathology (measured by the *Eating Disorder Examination Questionnaire*; EDE-Q). First, a Spearman's rank correlation revealed an approaching significant correlation between pleasantness ratings (average affective/non-affective touch) and global EDE-Q score (r = -.316, p = .05). Next, difference scores were calculated between affective and non-affective touch pleasantness ratings to determine whether those with higher non-clinical ED psychopathology were less sensitive to differences in the affectivity of touch. However, a Spearman's rank correlation revealed no significant correlation between touch difference score and global EDE-Q (r = .014, p = .935). Thus, the results suggest a trend in which those scoring higher in non-clinical ED psychopathology may show a reduced pleasantness to all tactile stimulation, however this may not be further modulated by the affectivity of the touch that they receive.

4.3.2.2 Embodiment Questionnaire

Preliminary analysis showed that there was no effect of trial order across visual capture trials, with a Wilcoxon signed-rank test revealing no significant difference in embodiment scores between visual capture trial 1 vs. trial 2 ($Z = -.958$, $p = .338$). Therefore, *embodiment questionnaire* scores were collapsed across the two visual capture trials to provide an overall *visual capture* embodiment score, per participant.

4.3.2.2.1 Main effect: Visual Capture

To examine the effects of mere visual capture towards subjective embodiment of the mannequin body, we compared *embodiment* scores with *control* scores in the *embodiment questionnaire*. A Wilcoxon signed-rank test revealed a main effect of visual capture, with significantly higher embodiment scores compared with control scores ($Z = -4.30$, $p < .001$, $r = .68$) (see Figure 4.3).

4.3.2.2.2 Main effect: Tactile Disruption

In order to determine whether tactile disruption to participants' own unseen arm would disrupt subjective embodiment, we compared embodiment scores between *tactile disruption* and *visual capture* conditions. A Wilcoxon signed-rank test revealed a main effect of condition, in which participants showed significantly lower subjective embodiment following tactile disruption trials (median = -.23) compared with visual capture trials (median = .59) ($Z = -4.08$, $p < .001$, $r = .65$).

4.3.2.2.3 Main effect: Tactile Velocity

Next, we examined whether tactile velocity had an effect in disrupting the subjective embodiment towards the mannequin body within *tactile disruption* trials. A Wilcoxon signed-rank test revealed that there was no significant difference in embodiment scores between affective (median = -.50) and non-affective (median = -.25) tactile disruption trials ($Z = -.354$, $p = .723$, $r = .06$), which suggests that interoceptive affective touch did not disrupt embodiment to a greater degree than exteroceptive, non-affective touch.

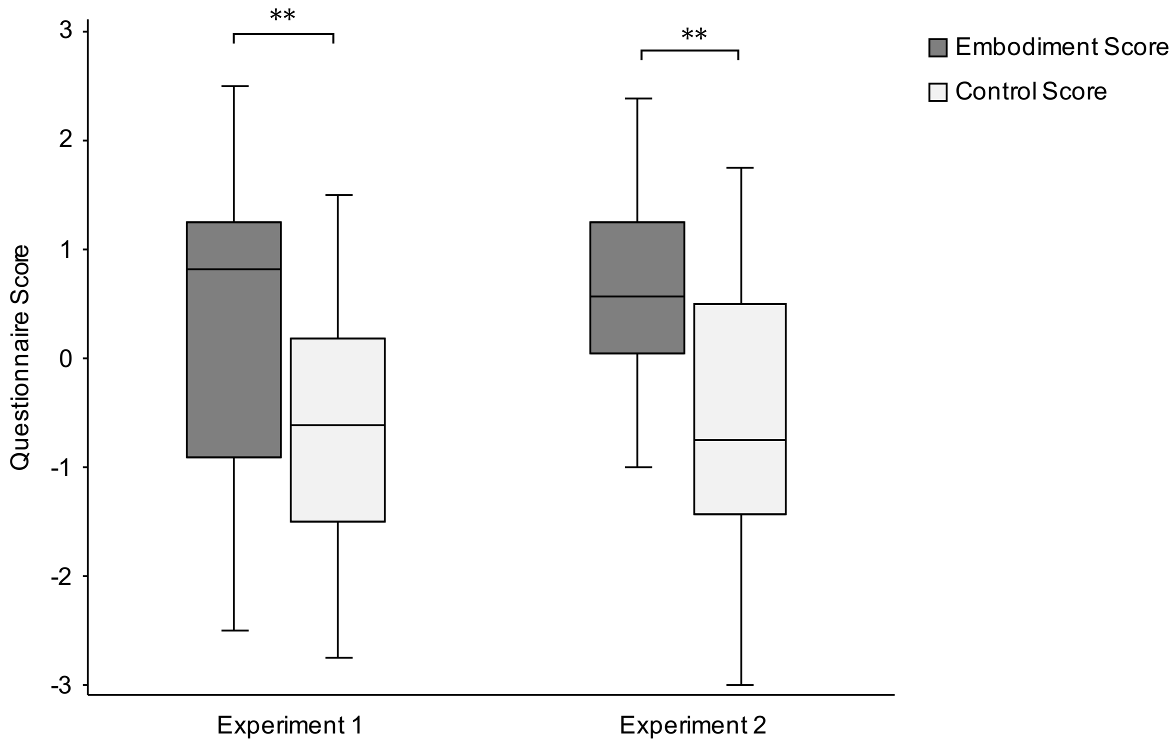

Figure 4.3 Box plot displaying embodiment scores and control scores within the embodiment questionnaire. Intersecting line = median; box = upper and lower interquartile range; whiskers = minimum and maximum values. ** = p <.001.

4.3.3 Combined Samples

4.3.3.1 Visual Capture of Embodiment – Individual Differences

Across the combined, total sample (N=80), 32 participants (40%) experienced a degree of embodiment over the mannequin from mere visual capture, with average scores of ≥ +1 in response to the *embodiment questionnaire* (hereafter referred to as 'visual capture' (VC) group). To confirm this percentage was not a consequence of participant compliance, a Wilcoxon signed rank test was conducted which revealed a significant difference between *embodiment* and *control* scores (Z = -4.71, $p < .001$, $r = .74$), with only 4 participants (12.5%) of the VC group scoring ≥ +1 in response to *control* items. 36 participants (45%) seemed to neither affirm or deny embodiment over the mannequin, with average scores of < +1 and > -1 in response to the *embodiment questionnaire* (hereafter referred to as 'borderline' group). 12 participants (15%) of the total sample denied any subjective embodiment from visual capture, with average scores of < -1 in the *embodiment questionnaire* (hereafter referred to as 'no visual capture' (no-VC) group).

4.3.3.3 Non-clinical Eating Disorder Psychopathology

Finally, correlational analyses were conducted to investigate the relationship between visual capture effects and non-clinical ED psychopathology (measured by the *EDE-Q*). EDE-Q subscale and global scores across both experiments are presented in Table 4.2. A Spearman's rank correlation revealed no significant correlation between visual capture embodiment scores and global EDE-Q scores ($r = .030$, $p = .79$), or any EDE-Q subscale scores (all $ps > .05$). Similarly, no significant correlations were observed when analysing subcomponent (*Ownership* and *Location*) scores within the *embodiment questionnaire* with EDE-Q scores (see Supplementary Material A3, Section A3.3). This suggests that non-clinical attitudes and behaviours regarding to eating and body image did not relate to the degree of subjective embodiment of a mannequin body due to mere visual capture.

Table 4.2 *Participant Demographic Information. Mean (and SD) of EDE-Q subscale and global scores*

	Total (*N*=80)	**Experiment 1 (*N*=40)**	**Experiment 2 (*N*=40)**	***t***	***p***
Age	19.56 (1.92)	20.15 (2.49)	18.98 (.77)	2.86	.006
BMI	21.70 (2.56)	21.48 (2.40)	21.93 (2.71)	-.772	.442
Restraint [a]	.80 (.20-1.80)	.80 (.20-2.15)	.90 (.25-1.75)	-.101[b]	.919
Eating Concern [a]	.60 (.20-1.40)	.60 (.20-1.40)	.60 (.20-1.55)	-.567[b]	.571
Shape Concern [a]	2.25 (1.16-3.72)	2.06 (1.25-3.63)	2.31 (1.00-3.75)	-.106[b]	.916
Weight Concern [a]	1.40 (.40-3.00)	1.40 (.40-2.55)	1.70 (.50-3.20)	-.960[b]	.337
EDE-Q Global [a]	1.33 (.60 -2.32)	1.31 (.60-2.17)	1.35 (.65-2.52)	-.380[b]	.704

[a] Median and interquartile range in parentheses

[b] Mann-Whitney U statistic

4.4 Discussion

The present study investigated the extent to which mere visual observation of a mannequin body, viewed from a first-person perspective, influenced subjective embodiment independently from concomitant visuotactile integration. Across two experiments, our results showed that congruent visuoproprioceptive cues between one's own physical body and a mannequin body was sufficient to induce subjective embodiment in 40% of our total sample. Furthermore, as expected, embodiment was significantly reduced when 'visual capture' of embodiment was disrupted by tactile stimulation to participant's own, unseen arm, confirming that the visual capture effect on embodiment was not due to confabulatory or social desirability responses. Contrary to our secondary hypothesis regarding interoception, this tactile disruption effect was not modulated by stroking velocity, with comparable changes in embodiment following slow, affective (CT-optimal) and fast, non-affective touch. Finally, non-clinical ED psychopathology was not found to modulate the effects of embodiment in visual capture or the subjective pleasantness of perceived touch.

Our findings support previous research which argues that synchronous visuotactile stimulation is not a necessary condition amongst all individuals in triggering subjective embodiment within bodily illusions. Research has shown that visual capture of proprioception can be sufficient to elicit embodiment towards a fake hand (Martinaud et al., 2017; Samad et al., 2015) and whole body (Maselli & Slater, 2013) in some individuals. Indeed, whilst Maselli and Slater (2013) have shown this effect using a full body within an immersive, virtual environment, the present study is the first to explore this effect towards a full body in the 'physical world'. Our results suggest that multisensory illusion paradigms would benefit from a baseline measure based on the mere visual observation of the fake body (part) (i.e. visual capture effect), which is unbiased by concomitant visuotactile stimulation (Crucianelli et al., 2017, 2013). Indeed, this is in support of research which argues that asynchronous stimulation in multisensory illusion paradigms is not strictly a neutral, control condition within multisensory body illusions (Perez-Marcos et al., 2018; Rohde et al., 2011), with visuotactile asynchrony instead providing somatosensory conflict (Caola, Montalti, Zanini, Leadbetter, & Martini, 2018; Rohde et al., 2011).

The present data showed that a substantial percentage of participants displayed a degree of subjective embodiment towards the mannequin body following mere visual observation. Indeed, it was confirmed that such individuals who did display visual capture of embodiment were not simply complying with all items in the *embodiment questionnaire,* shown by significantly higher responses in *embodiment* scores compared with *control* scores (see Results*,* section 4.3). However, congruent visuoproprioceptive signals did not induce subjective embodiment amongst all individuals to the same degree. We speculate that such individual differences may be due to a number of processes; for example, some individuals may have weaker proprioceptive signals which would give rise to greater sensory weighting towards the salient visual cues of the mannequin body within the illusion. Indeed, our own hypothesis that individual differences in visual capture may relate to non-clinical ED psychopathology was not confirmed (see below for further discussion). Typically, bodily illusions which involve a three-way interaction between vision, proprioception and synchronous touch are interpreted as the result of visual capture of touch and proprioception due to the synchronicity of the touch (Tsakiris, 2016). However, as it is now increasingly recognised that a two-way integration of vision and proprioception can affect ownership in some individuals following mere observation of a realistic body (part) (Panagiotopoulou, Filippetti, Tsakiris, & Fotopoulou, 2017; Ponzo et al., 2018; Samad et al., 2015), future studies should test whether such two-way effects also affect the perception of synchrony itself in some individuals. Indeed, it may be that previous research which has reported ownership changes even in asynchronous conditions may be explained by the two-way integration of proprioception and vision influencing the perception of asynchrony. Thus, further research is required to establish how individual differences in the weighting of distinct sensory cues contribute to modulating body ownership in mere visual capture conditions, and how increased visual weighting may thus influence the perception of visuotactile synchrony within typical multisensory illusion paradigms.

Furthermore, our results showed that tactile stimulation to participants own, unseen arm significantly disrupted subjective embodiment towards the mannequin body, by delivering somatosensory information that was incongruent with participants visuoproprioceptive cues. This result further highlights that the embodiment shown from visual capture conditions were not due to participant compliance, as disruption to such visual capture resulted in significantly lower embodiment scores. From a computational approach to multisensory integration (Samad et al., 2015; Zeller et al., 2016; Zeller, Litvak, Friston, & Classen, 2015), such incongruent tactile information is likely to have disrupted the sensory weighting that is occurring between visual and proprioceptive body signals (Noel, Blanke, & Serino, 2018). Indeed, predictive coding accounts of multisensory illusions argue that illusory embodiment typically occurs by the brain downregulating the precision of conflicting, bottom-up somatosensory signals, which allows top-down predictions to resolve any sensory ambiguity about the body (i.e. *the body (part) I see is mine*) (Zeller et al., 2016). Therefore, in the present study, additional tactile input to participants' own, unseen arm added further somatosensory information which could not be downregulated or "explained away" by top-down predictions, given its incongruency with the visually perceived mannequin body (Limanowski & Blankenburg, 2015), thus leading to reduced subjective embodiment.

Moreover, it was expected that the interoceptive properties associated with slow, affective touch (Crucianelli et al., 2017) would disrupt subjective embodiment to a greater degree than fast, non-affective touch. This is following evidence that affective touch led to enhanced embodiment during RHI paradigms (Crucianelli et al., 2013; Lloyd et al., 2013; van Stralen et al., 2014), which is argued to be due to the additional interoceptive information conveyed by this CT-optimal touch (Gentsch, Crucianelli, Jenkinson, & Fotopoulou, 2016). Further, research has shown that manipulation of interoceptive information (e.g. changes in body temperature) can *disrupt* feelings of body ownership (Kammers et al., 2011). However, contrary to previous findings and our own predictions, results showed that the interoceptive, affective tactile stimuli did not appear to disrupt visual capture of embodiment to a greater extent than non-affective tactile stimuli. Such findings may be because the salience of incongruent visuotactile information was sufficient in disrupting embodiment towards the mannequin, with the subtlety of increased interoceptive information from the arm following affective touch providing no additional value to multisensory integration in this context. Furthermore, the previously observed effects of affective touch in enhancing body ownership during the RHI (which involves concomitant felt and seen touch on the rubber hand) may also be explained by the vicarious affectivity of the *seen* touch in addition to the interoceptive nature of the felt touch. Indeed, CT-optimal velocities have been shown to have distinct vicarious touch effects in behavioural (Gentsch, Panagiotopoulou, & Fotopoulou, 2015) and neuroimaging (Morrison et al., 2011) studies. However, visual cues of affective touch were not present in the current study, therefore the felt affectivity of the touch within the illusion set-up may have been attenuated by participants receiving only tactile stimulation that was not visually observed.

The present results must be considered in relation to the top-down, cognitive constraints within which illusory ownership is argued to occur. Research has shown that the embodied fake body (part) must be in an anatomically plausible position (Ehrsson et al., 2004; Lloyd, 2007; Preston, 2013; Tsakiris & Haggard, 2005b), must represent a corporeal object (Haans et al., 2008; Petkova & Ehrsson, 2008; Tsakiris, Carpenter, et al., 2010), and must be viewed from a first-person (egocentric) visual perspective (Maselli & Slater, 2013; Petkova, Khoshnevis, et al., 2011; Preston et al., 2015). Indeed, it has been shown that when these constraints are violated, illusory effects diminish or disappear (Apps & Tsakiris, 2014; Kilteni et al., 2015; Makin, Holmes, & Ehrsson, 2008), suggesting that the perceived fake body (part) is required to fit with a reference model of the body based on top-down, contextual information (Tsakiris, Carpenter, et al., 2010). The above conditions were closely adhered to in the present study, which was particularly salient using the HMDs, allowing a high degree of spatial overlap by *replacing* the first-person perspective of one's own body with the identical perspective of a mannequin body. This provided a greater congruence of visuoproprioceptive cues which cannot be as closely matched within the RHI set-up without the use of computer-generated technology. However, further research should investigate the specific boundaries within which mere visual capture is sufficient in inducing embodiment towards a whole body, in the absence of visuotactile stimulation (Maselli & Slater, 2013; Petkova, Björnsdotter, et al., 2011), by systematically manipulating the above conditions within which the illusion can typically occur.

Finally, following evidence that acute ED patients display a dominance in weighting to visual information related to the body (Eshkevari et al., 2012; Keizer et al., 2014), which is shown to persist after recovery (Eshkevari et al., 2014), we explored whether this trait phenomenon would exist amongst healthy individuals, in relation to non-clinical ED psychopathology. However, no significant correlations were observed between EDE-Q scores and subjective embodiment following visual capture. This finding is in line with previous research in which those higher in non-clinical ED symptoms did not experience a stronger *subjective* embodiment within the full body illusion (Preston & Ehrsson, 2018), despite relationships observed between EDE-Q scores and subsequent behavioural measures (e.g. body satisfaction) following the illusion (see also, Keizer et al., 2016, for similar effects in AN patients). This suggests that previous findings which highlight differences in subjective embodiment in relation to ED psychopathology may be body-part specific (Eshkevari et al., 2012; Keizer et al., 2014; Mussap & Salton, 2006). Nevertheless, studying ED characteristics within healthy individuals remains clinically important to identify factors associated with the development of EDs without the confounds of physical consequences of the disorder (Frank, 2013; Hay & Sachdev, 2011).

Taken together, the present findings are in accordance with previous research which highlights the dynamic mechanisms that lead to illusory body ownership (Maselli & Slater, 2013). First, there exists a two-way interaction between visual information of the fake body (part) and proprioceptive information of one's own body (part), which is combined to inform an estimate of an individual's current spatial position. When the fake body (part) is in an anatomically plausible position with one's own body, sensory information between competing visual and proprioceptive cues is weighted in favour of the salient visual information (Kilteni & Ehrsson, 2017; Zeller et al., 2015), which for many is sufficient to induce feelings of embodiment to occur *prior* to visuotactile integration (Maselli & Slater, 2013; Samad et al., 2015). Subsequently, the addition of synchronous visuotactile information creates a three-way weighted interaction between vision, touch and proprioception, with the visually perceived touch processed in a common reference frame based on the visuoproprioceptive cues. The subsequent 'visual capture' of synchronous visuotactile stimulation acts to further weaken one's own proprioceptive signals, which can lead to increased illusory embodiment (Kilteni et al., 2015; Makin et al., 2008). Thus, future studies which compare the two-way vs. three-way interaction between sensory inputs would be informative in quantifying the additive effect that visuotactile stimulation plays within such paradigms. This could also be used to further investigate individual differences in the susceptibility to integrate visuoproprioceptive information to a greater degree than the additional integration of tactile stimuli during the illusion.

In conclusion, the present study suggests that mere visual observation of a mannequin body, viewed from a first-person perspective, can elicit subjective embodiment. Congruent visuoproprioceptive cues between one's own physical body (part) and a fake body (part) was shown to be sufficient to induce subjective embodiment in 40% of our total sample in the absence of concomitant visuotactile stimulation, which is typically used to induce illusory embodiment within multisensory illusion paradigms. In addition, tactile stimulation delivered to participants own, unseen arm acted to disrupt reported subjective embodiment, however, this was not influenced to a greater degree by slow, affective touch compared with fast, non-affective touch. This suggests that interoceptive information about one's body does not have the potency of discriminatory tactile signals, when the integration of vision and proprioception need to be moderated by touch. Future studies should explore this possibility using other interoceptive modalities such as cardiac awareness, and further investigate how the perception and integration of different sensory signals might be implicated within a distorted sense of self amongst clinical ED populations.

Chapter 5

The Role of Affective Touch in Modulating Embodiment Within the Full Body Illusion

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5.1 Introduction

The feeling that our body belongs to us (i.e. body ownership) is an essential dimension within our physical and psychological sense of self (Gallagher, 2000; Tsakiris, 2016). Research in cognitive neuroscience has predominantly studied body ownership and body awareness based upon the integration of sensory signals from outside the body (i.e. exteroception), such as vision and touch (de Vignemont, 2010; Graziano & Botvinick, 2002). However, recent studies have highlighted the fundamental contribution of sensory signals from *within* the body (i.e. interoception) towards one's body representation (Craig, 2002). Crucially, the successful integration and cognitive appraisal of both exteroceptive and interoceptive sensory channels are fundamental in contributing not only to one's sense of body ownership, but also towards one's body image (Duschek et al., 2015; Zamariola et al., 2017), which refers to the conscious representation of the body based on its perceptual, cognitive and affective evaluations (Badoud & Tsakiris, 2017).

An established experimental method to investigate multisensory integration within body ownership is demonstrated using multisensory bodily illusions. The most well studied paradigm is the Rubber Hand Illusion (RHI), in which individuals experience ownership over a fake hand when it is stroked in synchrony with the participant's own, unseen hand (Botvinick & Cohen, 1998). Such illusory ownership is argued to occur as a result of a three-way weighted interaction between vision, touch, and proprioception (i.e. sense of body position), in which the source of tactile stimulation on one's own, unseen body (part) is attributed to the location of visually perceived fake body (part) when the two are stroked synchronously. This has been more recently extended to a Full Body Illusion, in which individuals experience an illusory ownership of an entire virtual body (Slater et al., 2010), or mannequin body (Petkova & Ehrsson, 2008), typically perceived from a first-person perspective.

Whilst multisensory body illusions have traditionally focused on the role of exteroceptive information pertaining to body ownership, the role of interoception has been far less studied. Interoception is defined as the signals indicating one's physiological condition from within the body (Craig, 2002, 2009), processing internal sensations such as hunger, thirst, or satiety (Tsakiris, 2016; Tsakiris et al., 2011), but also processing external sensations such as itch, pain, and pleasure from touch (Crucianelli et al., 2017). Increasing research has established an association between interoceptive awareness and body image within healthy individuals (Duschek et al., 2015; Emanuelsen et al., 2015), which highlights the inherent link between interoceptive signals and their cognitive appraisal in relation to body concerns (see Badoud & Tsakiris, 2017, for review). Furthermore, deficits in interoceptive awareness have been associated with disturbances in body image amongst clinical eating disorder (ED) populations (Merwin, Zucker, Lacy, & Elliott, 2010; Pollatos et al., 2008, 2016), and has been regarded as a critical factor in the development and maintenance of the disorder (Stice & Shaw, 2002; Farrell et al., 2006).

Whilst exteroception and interoception had long been regarded as independent channels of sensory information (Tsakiris, 2016), recent research has highlighted the reciprocal relationship between these sensory streams in forming a stable body representation (Ainley & Tsakiris, 2013). Specifically, performance on interoceptive awareness tasks has been shown to predict susceptibility to exteroceptive multisensory body illusions (Aspell et al., 2013; Suzuki et al., 2013; Tsakiris et al., 2011). Importantly, this relationship between sensory streams has been shown to be bidirectional, in which exteroceptively driven changes in body ownership can also influence an individual's ability to accurately detect interoceptive bodily signals (Filippetti & Tsakiris, 2017). Clinical studies have further highlighted the importance of this mutual interaction, in which poorer interoceptive awareness amongst ED patients predicted greater susceptibility to the RHI compared with healthy controls (Eshkevari et al., 2012, 2014), suggesting that such patients show a greater reliance towards exteroceptive visual information pertaining to the body. This indicates that the stability of the bodily self may be influenced by the accurate balance and weighting of exteroceptive and interoceptive sensory information (see also, Keizer, Smeets, Postma, van Elburg, & Dijkerman, 2014; Keizer, van Elburg, Helms, & Dijkerman, 2016).

Although research principally uses cardiac-related measures as a proxy for interoceptive awareness (e.g. heartbeat detection task; Schandry, 1981), an increasingly used method to investigate the role of interoceptive signals in body ownership is the use of affective touch. Affective touch refers to a slow, pleasant touch which activates specific slow-conducting, unmyelinated, C-tactile (CT) afferent nerve fibres found only in hairy skin (Vallbo et al., 1999). Such fibres respond specifically to stroking velocities between 1 and 10 cm/s (Ackerley, Saar, McGlone, & Backlund Wasling, 2014; Löken et al., 2009), and are distinct from fast-conducting, myelinated fibres which respond to non-affective touch (Olausson et al., 2010). CT activation has been associated with increased subjective pleasantness ratings (Löken et al., 2009) and implicit measures of affective state (Pawling et al., 2017), with signals taking a distinct pathway to the posterior insular cortex (Björnsdotter et al., 2010; Olausson et al., 2002), which is a key area associated with the early convergence of interoceptive and exteroceptive bodily information (Craig, 2009; Crucianelli et al., 2016; Morrison et al., 2011). Therefore, affective touch could act as a useful tool to investigate body ownership by providing a unique window into an individual's interoceptive awareness and bodily self.

Research has shown that affective touch was perceived as more pleasant and elicited a stronger sense of embodiment during the RHI compared with non-affective touch, in healthy individuals (Crucianelli et al., 2017, 2013; Lloyd et al., 2013; van Stralen et al., 2014). Crucially, effects during the illusion were observed following synchronous visuotactile stimulation, but were absent following asynchronous (control) conditions. Such evidence has been recently extended, in which participants showed an increased subjective embodiment towards a virtual full body following affective, compared with non-affective touch (de Jong et al., 2017). However, such effects were not observed when asynchronous touch was introduced in addition to synchronous touch, therefore conclusions regarding affective touch influencing ownership towards a full body remain equivocal. Together, the above evidence highlights the role of interoception in strengthening one's sense of body ownership and underlines the need to further investigate the relationship between interoceptive and exteroceptive signals towards an individuals' whole-body representation.

Critically, research has shown that individuals with anorexia nervosa (AN) perceive affective touch as less pleasant relative to healthy controls (Bischoff-Grethe et al., 2018; Crucianelli et al., 2016; Davidovic et al., 2018), suggesting that altered bodily pleasure amongst AN patients may be reflective of a dysfunctional CT afferent system, which may be linked to their weakened interoception (Jenkinson et al., 2018). Furthermore, altered perception of touch within acute ED patients has been implicated with disturbances in body image, which has been shown to persist after recovery (Engel & Keizer, 2017; Eshkevari et al., 2014). Thus, with evidence that alterations in sensory processing may be a trait phenomenon that could be present *prior* to illness onset (Eshkevari et al., 2014), it is important to investigate such processing amongst healthy individuals in relation to non-clinical ED psychopathology, to better understand the mechanisms that may contribute to a clinical diagnosis (Evans et al., 2017; Preston & Ehrsson, 2014, 2016).

Taken together, the present study aimed to investigate the role of affective touch in modulating ownership during the full body illusion, across two experiments (Petkova & Ehrsson, 2008). In experiment one, participants received affective (CT-optimal) and non-affective (CT-non-optimal) touch in synchrony or asynchrony with the touch administered to a mannequin body. Experiment two provided an identical set-up, but instead used a spatially incongruent condition as an alternative control condition, rather than asynchrony (Panagiotopoulou et al., 2017). In line with previous research (Crucianelli et al., 2017, 2013; de Jong et al., 2017), it is hypothesised that affective touch would be perceived as more pleasant, and lead to greater embodiment over a whole body compared with non-affective touch. This effect is expected to occur following synchronous/congruent conditions only, with no difference in embodiment expected between asynchronous/incongruent conditions. Moreover, we wished to investigate whether the subjective perception of touch is associated with non-clinical ED psychopathology amongst healthy individuals. If alterations in interoceptive awareness are a trait feature amongst those at risk for an ED, it is hypothesised that there will be a negative relationship between perceived pleasantness of touch and ED psychopathology. Conversely, no relationship between these outcomes would suggest that a potential dysfunctional CT afferent system may be a consequence of the disorder, rather than a predisposing factor.

5.2 Methods

5.2.1 Experiment 1

5.2.1.1 Participants

Forty-one female participants (Mean age = 20.10, SD ± 2.48, range = 18-31) were recruited via the University of York research participation scheme, and received course credit for a single 60-minute testing session. All participants had no current or previous neurological or psychological disorders (self-report), and normal or corrected-to-normal vision. Participants had a mean BMI of 21.54 (SD ± 2.41, range = 18.30-28.60). Exclusion criteria included any specific skin conditions (e.g. eczema, psoriasis) or any scarring or tattoos on the left arm. All participants gave informed, written consent to take part in the study. The study received ethical approval from the University of York Departmental Ethics Committee, and was conducted in accordance with the Declaration of Helsinki. One participant was later excluded after self-reporting a previous psychological condition, and a further two participants were excluded as extreme outliers, scoring more than 2 SD below the group mean in pleasantness ratings of affective touch (3 cm/s velocity) during the illusion (Ponzo et al., 2018). Therefore, the final sample consisted of thirty-eight participants (Mean age = 19.92, SD ± 2.33, range = 18-31).

5.2.1.2 Design

The experiment used a 2 (stroking velocity: affective vs. non-affective) x 2 (stroking synchrony: synchronous vs. asynchronous) within-subjects design. Stroking velocity was manipulated by administering slow, affective touch (at 3 cm/s), and fast, non-affective touch (at 18 cm/s) (see Crucianelli et al., 2013) for 60 seconds. Prior to all experimental conditions, participants completed a condition in which no visuotactile stimulation was applied and they merely visually observed the mannequin body from a first-person perspective (*visual capture* condition). This was to determine the degree of embodiment experienced by participants due to 'visual capture' of congruent proprioceptive information of the mannequin body with one's own body position (Crucianelli et al., 2017, 2013).

Dependent variables were: 1) subjective pleasantness of stroking received on participants' arm following each illusion trial (see *Measures* section), to investigate whether affective touch was perceived as more pleasant than non-affective touch during the illusion (Crucianelli et al., 2016, 2013). 2) Subjective embodiment experienced by participants, rated after each trial via an *embodiment questionnaire* (see *Measures* section and Table 5.1 for details). For each condition, the *embodiment questionnaire* was completed pre-stroking (i.e. *visual capture* condition) and post-stroking (i.e. *illusion* condition). In line with previous studies (Crucianelli et al., 2017, 2013), an 'embodiment change' score was calculated by subtracting pre-stroking scores from post-stroking scores to determine the subjective embodiment due to visuotactile integration. Participants completed four *visual capture* conditions, and four *illusion* conditions for a total of 8 trials. The order of all experimental conditions was randomised across participants.

5.2.1.3 Measures

5.2.1.3.1 Pleasantness Ratings

Following illusion trials only, a measurement of the perceived pleasantness of the tactile stimulation was taken, in which participants were asked *"How pleasant was the touch of the brush on your arm?"* which was rated on a VAS scale anchored by *"Not at all pleasant"* (0) and "*Extremely pleasant"* (100). Tactile stimulation was delivered at 3 cm/s (CT-optimal) and 18 cm/s (CT-non-optimal), to determine whether participants perceived slow, affective touch as more pleasant than fast, non-affective touch (Crucianelli et al., 2016, 2017; Löken et al., 2009).

5.2.1.3.2 Embodiment Questionnaire

Following each trial, participants rated their subjective embodiment via an *embodiment questionnaire* along a 7-point Likert scale (-3 'strongly disagree' to +3 'strongly agree'). The same questionnaire was completed for both visual capture and illusion conditions, with the addition of one item for illusion conditions (see Table 5.1). The questionnaire (adapted from Longo, Schüür, et al., 2008) was composed of two subcomponents: *ownership* (i.e. the feeling that the mannequin body belongs to them) and *location* (i.e. the feeling that the mannequin body was in the position of their own body). An overall *embodiment score* was calculated by averaging the above two subcomponent scores (see Table 5.1). Embodiment questions were identical in both *visual capture* and *illusion* conditions, with the addition of a further embodiment (*Location*) question, regarding the referral of touch in illusion trials.

Table 5.1 *Embodiment Questionnaire presented to participants following each trial.*

	Questionnaire Statement	Component
1.	It seemed like I was looking directly at my own body, rather than a mannequin body	Ownership
2.	It seemed like the mannequin body belonged to me	Ownership
3.	It seemed like the mannequin body was part of my body	Ownership
4.	It seemed like the mannequin body was in the location where my body was.	Location
5.	It seemed like the touch I felt was caused by the brush touching the mannequin arm*	Location

NB. The order of questionnaire statements was randomised for each trial and participant.
*= Item 5 delivered following illusion trials only.

5.2.1.3.3 Eating Disorder Examination Questionnaire (EDE-Q) 6.0

The EDE-Q (Fairburn & Beglin, 1994) is a 28-item questionnaire used as a self-report measure of ED psychopathology. 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, in which a 'global' score is calculated from the average of the four subscales. Items are rated along a seven-point Likert scale (0-6), 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. This measure has good internal consistency, with Cronbach's alpha ranging from .78 to .93 in a non-clinical sample (Berg et al., 2012). The overall global EDE-Q measure in the present study had a Cronbach's alpha of .95 in both Experiment 1 and Experiment 2.

5.2.1.4 Materials

A life-size female mannequin was used to induce the *Full Body Illusion*, which was dressed in a white t-shirt, blue jeans and black socks, with the head removed at the neckline to enable correct positioning of the video cameras. The mannequin body was in a standing position *(Height: 159cm; Shoulders: 94cm; Hips: 87cm; Waist: 62cm)* with arms placed by their side (see Figure 5.1b). For all trials, participants stood to the right of the mannequin body, separated by an office screen divider (see Figure 5.1a), and wore a set of head-mounted displays (HMDs) (Oculus Rift DK2, Oculus VR, Irvine, CA, USA), with a resolution of 1200 x 1080 pixels per eye, a refresh rate of 75Hz, and a corresponding nominal visual field of 100°. The HMDs were connected to a stereoscopic camera (USB 3.0 VR stereo camera, Ovrvision Pro, Japan), presenting a real time, video image to participants. The cameras were mounted and positioned downwards, at the eye line of the mannequin, capturing a first-person perspective of the body, compatible with looking down towards one's own body. Tactile stimulation (i.e. stroking) was applied using two identical, cosmetic make-up brushes (Natural hair Blush Brush, N◦7, The Boots Company). All trials and responses following experimental trials were made using PsychoPy 2 (Peirce, 2007) on an Apple iMac desktop computer (1.6GHz dual-core Intel Core i5 processor).

Figure 5.1 Experimental Set-up. a) Visual capture trials, in which participants stood in an identical stance to the mannequin body. b) Participants viewed a live video image of the mannequin body from a first-person perspective, via head-mounted displays. c) In illusion trials, the experimenter stroked the left forearm of the mannequin body and the corresponding forearm of the participant, in temporal and anatomical synchrony.

5.2.1.5 Experimental Procedure

Prior to the experimental trials, two adjacent 9 cm x 4 cm stroking areas were marked on the hairy skin of each participants' left forearm, using a washable marker pen (consistent with previous studies; (Crucianelli et al., 2013; McGlone et al., 2012). This provided a specific anatomical area for which to administer tactile stimulation for participants. Tactile stimulation during all experimental trials was alternated between these two areas, to minimise habituation, prevent CT fibre fatigue, and provided the experimenter with an assigned area to control the pressure of each stroke. Anatomically congruent areas of tactile stimulation were applied to the mannequin arm and participants' own arm within each illusion trial.

For *visual capture* trials, participants wore the HMDs for a 30-second period whilst visually observing the mannequin body (*visual capture* condition). Following this trial, participants removed the HMDs and rated their subjective embodiment towards the mannequin via the *embodiment questionnaire* (see Table 5.1) on a separate computer. Removing the HMDs following each trial also served as a 'rest period' for participants to move freely and dissociate their subjective experience between trials. For *illusion* trials, participants identically viewed the mannequin body via the HMDs, and the experimenter stroked the left forearm of both the participant and the mannequin body for a 60-second period. In synchronous trials, the experimenter stroked the participants' forearm in complete temporal and anatomical synchrony to the mannequin forearm. In asynchronous trials, a temporal delay (i.e. offset by ~2 seconds) was applied such that the visual strokes seen by the participant on the mannequin were out of time from the felt strokes on the participants' own arm. Participants completed two synchronous trials (affective vs. non-affective) and two asynchronous trials (affective vs. non-affective). The experimenter was trained to administer each stroke at the precise speed (affective – 3 cm/s or non-affective – 18 cm/s), by counting the number of strokes within a window of 3 seconds per individual stimulation (i.e. one 3 sec-long stroke for 3 cm/s velocity, and six 0.5 sec-long strokes for 18 cm/s velocity). Following the illusion trial, participants rated their subjective experience of the illusion once again via the *embodiment questionnaire*, in addition to pleasantness ratings.

5.2.2 Experiment 2

5.2.2.1 Participants

Forty-three female participants (Mean age = 18.98, SD ± .74, range = 18 - 20) were recruited via the University of York research participation scheme, and received course credit for a single 60-minute testing session. Identical inclusion and exclusion criteria were applied as Experiment 1. Participants had a mean BMI of 21.89 (SD ± 2.67, range = 16.66-28.32). All participants gave informed consent to take part in the study. The study received ethical approval from the University of York Departmental Ethics Committee, and was conducted in accordance with the Declaration of Helsinki. One participant was later excluded after self-reporting a previous psychological condition; one was excluded because of scarring on their arms; and one was excluded following poor comprehension with the experimental procedure. A further participant was excluded as an extreme outlier, scoring more than 2 SD below the group mean in pleasantness ratings of affective touch (3 cm/s velocity) during the illusion (Ponzo et al., 2018). Therefore, the final sample consisted of thirty-nine participants (Mean age = 19.00, SD ± .76, range = 18 - 20).

5.2.2.2 Design, Materials, Procedure

Design, Materials and Procedure were identical to Experiment 1. However, in Experiment 2 the spatial congruency of visuotactile stimulation was manipulated during the *Full Body Illusion*, rather than the temporal synchrony (Experiment 1). Participants experienced visuotactile stimulation in a congruent location (i.e. left forearm of both participant and mannequin), or incongruent location (i.e. touch felt on participant left forearm and viewed on mannequin left hand). Participants experienced 2x congruent touch (identical to synchronous trials) and 2x incongruent touch within each stroking velocity (affective/non-affective touch).

5.2.3 Data Analysis

Statistical analyses were conducted using SPSS version 23.0 (IBM, Chicago, IL, USA). For pleasantness ratings, data were tested for normality and found to be normally distributed for Experiment 1 (Shapiro-Wilk $p > .05$), therefore a parametric 2 (stroking velocity: affective vs. non-affective) x 2 (stroking synchrony: synchronous vs. asynchronous) repeated-measures ANOVA was used for this analysis. As data was not normally distributed for Experiment 2 (Shapiro-Wilk $p < .05$), non-parametric Wilcoxon signed-rank tests were used to examine the main effects of (and interaction between) stroking congruency and stroking velocity towards pleasantness ratings.

For the *embodiment questionnaire,* data were ordinal and found to be non-normally distributed across pre- (*visual capture*) and post-illusion trials, therefore appropriate non-parametric Wilcoxon signed-rank tests were used to examine the main effects of (and interaction between) stroking synchrony (Experiment 1) or congruency (Experiment 2) and stroking velocity. The above analyses were also conducted for individual *Ownership* and *Location* subcomponents within the *embodiment questionnaire* (see Supplementary Material A4, Sections A4.1 & A4.2). Non-parametric correlational analyses were undertaken to investigate the relationship between pleasantness ratings and non-clinical ED psychopathology (measured using the Eating Disorder Examination Questionnaire; EDE-Q). Effect sizes for parametric tests are indicated by partial eta-squared (η_p^2), and non-parametric Wilcoxon signed-rank tests are indicated by r values (*r*) which are equivalent to Cohen's *d* (Pallant, 2007).

5.3 Results

5.3.1 Experiment 1

5.3.1.1 Pleasantness Ratings

First, we investigated the main effect of stroking velocity on pleasantness ratings to directly test the hypothesis that slow, affective touch (3 cm/sec) will be perceived as more pleasant than fast, non-affective touch (18 cm/sec) within the illusory set-up. A repeated-measures ANOVA revealed a significant main effect of stroking velocity ($F (1,37) = 4.44$, $p = .042$, $\eta_p^2 = .107$), with participants rating affective touch (mean= 61.42) as significantly more pleasant than non-affective touch (mean= 58.42). A main effect of synchrony was observed ($F (1,37) = 29.85$, $p < .001$, $\eta_p^2 = .447$), with a significantly greater perceived pleasantness following synchronous (mean = 67.22) conditions compared with asynchronous (mean = 52.62) conditions. Finally, no significant interaction was observed between the stroking synchrony and stroking velocity ($F (1,37) = .012$, $p = .914$, $\eta_p^2 = .000$).

5.3.1.2 Embodiment Questionnaire

5.3.1.2.1 Main Effects

A Wilcoxon signed-rank test revealed a main effect of stroking synchrony, with significantly greater embodiment change following synchronous (median = .88) stroking conditions compared with asynchronous (median = -.50) stroking conditions ($Z = -5.20$, $p < .001$, $r = .84$). The main effect of stroking velocity on embodiment was non-significant ($Z = -1.65$, $p = .098$, $r = .27$). To determine any interactions in embodiment change between stroking synchrony and stroking velocity, differences between synchronous and asynchronous scores were calculated for both stroking velocities. No significant difference was observed in embodiment change scores between affective and non-affective touch conditions ($Z = -.89$, $p = .375$, $r = .14$) (see Figure 5.2).

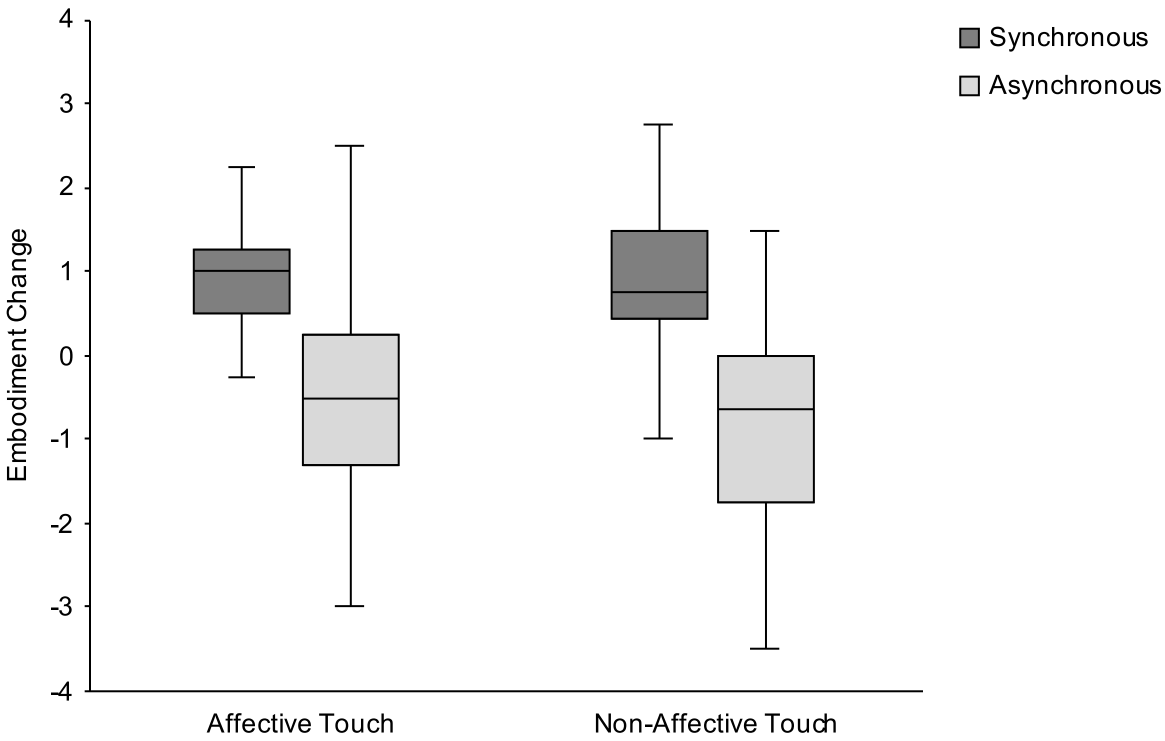

Figure 5.2 Box plot displaying change in embodiment scores following synchronous and asynchronous conditions. Intersecting line = median; box = upper and lower interquartile range; whiskers = minimum and maximum values.

5.3.1.2.2 Correlational Analysis

Finally, correlational analyses were conducted to investigate the relationship between pleasantness ratings and non-clinical ED psychopathology, measured by the *Eating Disorder Examination Questionnaire* (EDE-Q; Fairburn & Beglin, 1994). First, a Spearman's rank correlation revealed no significant correlation between pleasantness ratings (averaged across stroking synchrony/stroking velocity) and global EDE-Q score ($r = .185$, $p = .267$), or any EDE-Q subscales (all *ps* > .05). Next, difference scores were calculated between affective and non-affective touch pleasantness ratings (averaged across stroking synchrony), to investigate whether those with higher non-clinical ED psychopathology were less sensitive to differences in the affectivity of touch. A Spearman's rank correlation revealed no significant correlation between touch difference score and global EDE-Q ($r = -.023$, $p = .892$), or any EDE-Q subscales (all *ps* > .05). Additional correlations conducted between pleasantness ratings and BMI are reported in Supplementary Material (Table A4.1), with no correlations of interest identified.

5.3.2 Experiment 2

5.3.2.1 Pleasantness Ratings

To directly test the hypothesis that slow, affective touch will be perceived as more pleasant than fast, non-affective touch within the illusory set-up, we investigated the main effect of stroking velocity on pleasantness ratings. Ratings were collapsed across congruency to provide an overall score for affective (3 cm/sec) and non-affective (18 cm/sec) touch conditions. A Wilcoxon signed-rank test confirmed that participants rated affective touch (median = 77.00) as significantly more pleasant than non-affective touch (median = 60.50) ($Z = -4.13$, $p < .001$, $r = .66$).

To investigate the main effect of congruency towards pleasantness ratings, ratings were collapsed across stroking velocity to provide an overall score for congruent and incongruent conditions. A Wilcoxon signed-rank test revealed a main effect of congruency, with a significantly greater perceived pleasantness following congruent (median = 72.50) conditions compared with incongruent (median = 60.50) conditions ($Z = -3.62$, $p < .001$, $r = .59$). Interactions between stroking velocity and stroking congruency were analysed by calculating difference scores between congruent and incongruent conditions, for both affective and non-affective touch conditions. A Wilcoxon signed-rank test revealed no significant interaction ($Z = -.81$, $p = .418$, $d = .13$).

5.3.2.2 Embodiment Questionnaire

5.3.2.2.1 Main Effects

A Wilcoxon signed-rank test revealed a main effect of stroking congruency, with significantly greater embodiment change following congruent (median = .75) stroking conditions compared with incongruent (median = -.25) stroking conditions ($Z = -5.12$, $p < .001$, $r = .82$). The main effect of stroking velocity on embodiment was non-significant ($Z = -1.48$, $p = .139$, $r = .27$). To determine any interactions in embodiment change between stroking congruency and stroking velocity, differences between congruent and incongruent scores were calculated for both stroking velocities. No significant difference was observed in embodiment change scores between affective and non-affective touch conditions ($Z = -.27$, $p = .791$, $r = .04$) (see Figure 5.3).

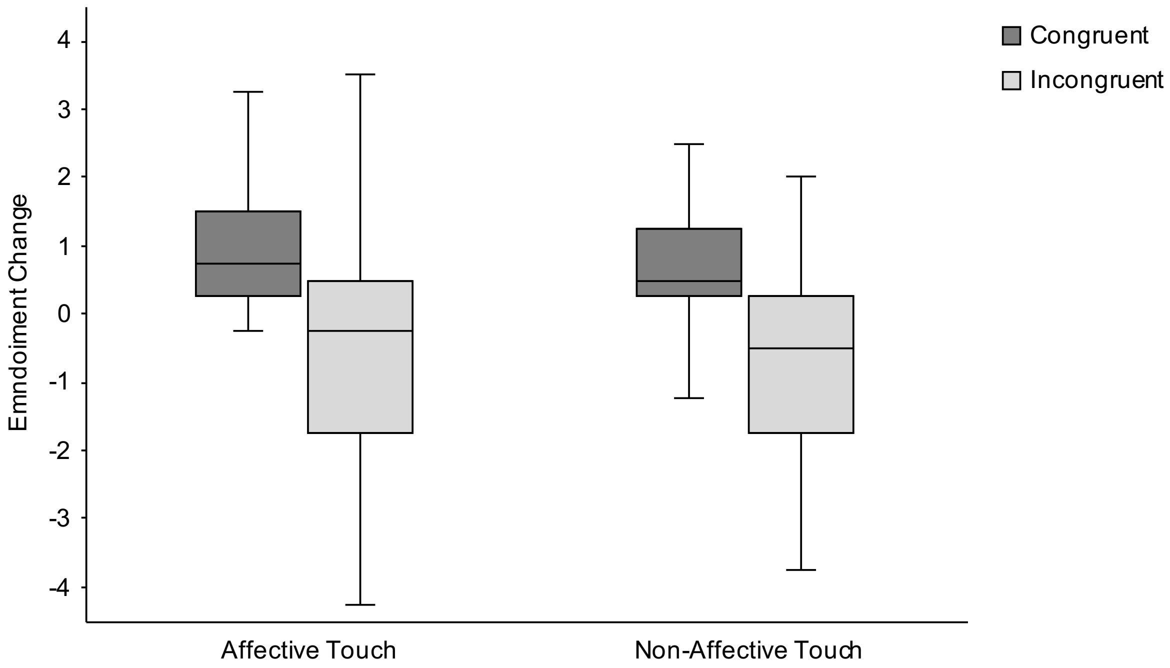

Figure 5.3 Box plot displaying change in embodiment scores following congruent and incongruent conditions. Intersecting line = median; box = upper and lower interquartile range; whiskers = minimum and maximum values.

5.3.2.2.2 Correlational Analysis

Finally, correlational analyses were conducted to investigate the relationship between pleasantness ratings and non-clinical ED psychopathology, measured by the *Eating Disorder Examination Questionnaire* (EDE-Q; Fairburn & Beglin, 1994). First, a Spearman's rank correlation revealed no significant correlation between pleasantness ratings (averaged across stroking congruency/stroking velocity) and global EDE-Q score ($r = -.275$, $p = .090$). When corrected for multiple comparisons (Bonferroni-corrected $\alpha = .013$), no significant correlations were observed between averaged pleasantness rating and any EDE-Q subscales (all *ps* > .03). Next, difference scores were calculated between affective and non-affective touch pleasantness ratings (averaged across stroking congruency), to investigate whether those with higher non-clinical ED psychopathology were less sensitive to differences in the affectivity of touch. A Spearman's rank correlation revealed no significant correlation between touch difference score and global EDE-Q ($r = .014$, $p = .931$), or any EDE-Q subscales (all *ps* >.45). Additional correlations conducted between pleasantness ratings and BMI are reported in Supplementary Material (Table A4.2), with no correlations of interest identified.

5.4 Discussion

The present study investigated the role of slow, CT-optimal, affective touch towards ownership over a whole body within the *Full Body Illusion*, across two experiments. Specifically, we investigated whether affective touch would lead to increased perceived pleasantness and enhanced subjective embodiment towards a whole mannequin body, compared with fast, non-affective touch. In line with previous research (Crucianelli et al., 2017, 2013; de Jong et al., 2017; Löken et al., 2009), our results showed that participants perceived affective touch as significantly more pleasant than non-affective touch, across both experiments. Furthermore, as expected, synchronous, and spatially congruent, visuotactile stimulation led to higher subjective embodiment towards the mannequin body compared with asynchronous (Experiment 1) or spatially incongruent (Experiment 2) visuotactile stimulation. However, contrary to our hypothesis, the velocity of perceived touch did not further modulate the subjective experience of the illusion, with comparable embodiment change scores between affective and non-affective touch conditions. Finally, it was found that the perceived pleasantness of touch was not modulated by non-clinical ED psychopathology, amongst healthy females.

In both experiments, greater subjective embodiment was reported when the multisensory information was synchronous, and spatially congruent, between participant's own body and the mannequin body, which supports the role of exteroceptive multisensory integration towards body ownership (Botvinick & Cohen, 1998; Tsakiris & Haggard, 2005b). However, in contrast to previous research using multisensory illusion paradigms (Crucianelli et al., 2017; Lloyd et al., 2013; Panagiotopoulou et al., 2017), no interaction between the synchrony, or congruency, and the velocity of touch (affective/non-affective) was observed, which suggests that touch sensitivity played no role towards the subjective embodiment of a whole body. This may suggest that the influence of affective touch in enhancing multisensory integration may be body-part specific, following previous research which has shown such effects using the hand (Crucianelli et al., 2017, 2013; Lloyd et al., 2013) or face (Panagiotopoulou et al., 2017). Indeed, the pattern of results in the present study are in line with previous research which investigated the role of affective touch applied to participants' abdomen within a virtual full body illusion (de Jong et al., 2017). Whilst de Jong et al. (2017) observed an enhanced effect of affective touch when solely manipulating stroking velocity, no such effects were observed when the additional variable of stroking synchrony was added.

Although embodiment scores following affective touch were numerically higher compared with non-affective touch in both studies, such differences were not statistically significant in either experiment. It is speculated that such findings may be due to the perceived salience of the visuotactile synchrony, and spatial congruency within the immersive set-up of the illusion, with the added affectivity of the touch not providing significant, additive information during multisensory integration. Thus, within this set-up, it may be that the subtlety of interoceptive, affective information is outweighed by the salient exteroceptive somatosensory information which was present across all illusory trials. However, whilst the present study did not observe any effects of stroking velocity modulating the subjective experience of the illusion, previous studies have observed objective, behavioural changes (i.e. proprioceptive drift) following affective touch within the RHI, in the absence of subjective, self-report changes in embodiment (van Stralen et al., 2014). Indeed, evidence has shown dissociable effects between self-report and behavioural measures within multisensory illusion paradigms (Abdulkarim & Ehrsson, 2016; Panagiotopoulou et al., 2017; Rohde et al., 2011). Whilst objective measures of the illusion (e.g. proprioceptive drift, skin temperature) were not recorded in the present study, future research should further investigate the mechanisms of affective touch in its dissociable influence towards subjective and objective components of whole-body representation (Dijkerman & de Haan, 2007).

Whilst the present study did show that participants perceived slow, affective touch as more pleasant than fast, non-affective touch, the effects of CT-optimal touch must be considered alongside top-down mechanisms, given that the perception of pleasant touch is not exclusively influenced by bottom-up CT afferents (Ellingsen et al., 2014; Ellingsen, Leknes, Løseth, Wessberg, & Olausson, 2016; Gallace & Spence, 2010; Keizer, de Jong, Bartlema, & Dijkerman, 2017). The role of top-down, social modulation of affective touch must be considered, as, unlike previous research (Crucianelli et al., 2013; de Jong et al., 2017), participants in the present study were healthy females and were tested by a male experimenter. Indeed, research has shown that an individual's beliefs of the gender of the toucher can influence their perception of the pleasantness of touch (Gazzola et al., 2012; Scheele et al., 2014). Therefore, within the present study, affective touch administered on participants' hairy skin represents a bottom-up, CT afferent process, which may also be attenuated by top-down influences of the social context (e.g. gender of the experimenter) before the subjective experience of touch is appraised. Thus, it is important for future research to further establish the role of social, top-down factors towards the perception of affective touch, in both females and males.

Furthermore, the subjective perception of pleasant touch has been shown to be attenuated - independent of the administered sensory stimulation - amongst individuals with anorexia nervosa (Bischoff-Grethe et al., 2018; Crucianelli et al., 2016; Davidovic et al., 2018). This may represent an anhedonic, reduced bodily pleasure in such individuals, which is similarly observed in other clinical disorders such as depression (Pizzagalli, Iosifescu, Hallett, Ratner, & Fava, 2008). Thus, with evidence that alterations in sensory processing may be a trait phenomenon in ED patients which could be a risk factor in the development of the disorder (Eshkevari et al., 2014), we investigated whether the perceived pleasantness of touch was related to non-clinical ED psychopathology amongst healthy individuals. Indeed, previous research has observed a reduced response to pleasant touch in healthy individuals with higher autistic-like traits (Scheele et al., 2014; Voos, Pelphrey, & Kaiser, 2013), which can be informative in identifying pre-existing personality traits amongst those with increased risk for a clinical diagnosis. However, non-clinical ED psychopathology did not modulate the subjective pleasantness of touch amongst individuals in either experiment within the present study. This may suggest that reduced pleasantness of touch in clinical ED patients is a consequence of the disorder rather than a predisposing factor, particularly within clinical populations such as EDs in which psychiatric comorbidity and anhedonia is common (Davidovic et al., 2018). Investigation of such sensory processing is important to study in relation to body image within non-clinical samples, in order to dissociate which factors might be directly linked with the pathology of the disorder, and which are implicated as a by-product of a clinical diagnosis.

In conclusion, across two experiments our findings provide supportive evidence that affective touch is perceived as more pleasant than non-affective touch amongst healthy individuals. However, such effects of stroking velocity during multisensory integration did not modulate the subjective embodiment towards a whole mannequin body within the full body illusion. We speculate that such findings may reflect the salience of exteroceptive sensory information during multisensory integration, in which the subtlety of interoceptive, CT-optimal stroking was not sufficiently potent to further influence subjective embodiment. Alternatively, as previous research has shown an enhancement of embodiment due to affective touch towards a fake hand, such effects may be body-part specific, and may not generalize to increased subjective embodiment towards a whole body. Moreover, the present study must be considered and investigated further in the context of top-down, social modulations of affective touch in addition to bottom-up sensory information. Future research should explore the relationship between interoceptive and exteroceptive sensory integration towards body ownership, body image and its distortions within clinical ED populations.

Chapter 6

Eating Disorder Examination Questionnaire (EDE-Q): Norms and Psychometric Properties in UK Females and Males

This chapter is adapted from: Carey, M., Kupeli, N., Knight, R., Troop, N. A., Jenkinson, P. M., & Preston, C. (2019) Eating Disorder Examination Questionnaire (EDE-Q): Norms and Psychometric Properties in UK Females and Males. *Psychological Assessment* [3]

6.1 Introduction

The Eating Disorder Examination Questionnaire (EDE-Q) (Fairburn & Beglin, 1994) is a well-established assessment of eating disorder (ED) psychopathology, and is widely used in both clinical and non-clinical populations. This self-report measure is derived from the Eating Disorder Examination (EDE) interview (Fairburn & Cooper, 1993), which is considered to be the gold standard in clinical ED assessment (Guest, 2000). The EDE-Q has traditionally been viewed as a reliable and valid alternative tool for identifying those most at risk for an ED (Berg et al., 2012; Mond et al., 2008), with researchers and clinicians deeming it more cost-effective than the EDE, taking approximately 15 minutes to complete whilst maintaining a comparable degree of accuracy in ED psychopathology assessment (Mond, Hay, Rodgers, & Owen, 2006).

[3] The author, Mark Carey, contributed to the design of the experiment, collected the data for Sample 1, analysed the results and wrote the manuscript under the supervision of Dr Catherine Preston, in collaboration with Dr Nicholas A. Troop, and Dr Paul M. Jenkinson. Ruth Knight and Dr Nuriye Kupeli contributed towards the collection of data for Sample 2 and 3.

The availability of contextually relevant (i.e. specific to a given country and/or culture) normative data is vital for appropriate interpretation of assessments such as the EDE-Q (Welch, Birgegard, Parling, & Ghaderi, 2011). Indeed, EDE-Q norm data in non-clinical populations are important to gather to statistically determine the accurate use of this measure as a clinical screening instrument (Mond et al., 2006), and to trace changes in the trajectory of body image attitudes over time and between cultures (Cash, Morrow, Hrabosky, & Perry, 2004; Karazsia, Murnen, & Tylka, 2017). Moreover, gathering norm data at the non-clinical, population level can help to inform health-related programmes and identify disordered eating behaviours which precede adverse health outcomes associated with a clinical diagnosis (Mond, Mitchison, & Hay, 2013). Indeed, given the strong association that disordered eating behaviours have with physical and psychological well-being (Cash, 2004), researchers argue that the largest long-term health burden exists at the general population level (Mond et al., 2009), further highlighting the importance of examining norms within non-clinical samples.

EDE-Q norms have been investigated in several non-clinical Western samples, including the USA, Portugal, Australia, and Spain (e.g. Luce, Crowther, & Michele Pole, 2008; Machado et al., 2014; Mond et al., 2006; Villarroel, Penelo, Portell, & Raich, 2011). However, norm data for the adult UK population are lacking and are currently restricted to early adolescent samples only (Carter, Stewart, & Fairburn, 2001; White, Haycraft, Goodwin, & Meyer, 2014). Although body ideals and attitudes in the UK may appear similar to other Western cultures in females (Bell & Dittmar, 2011; Robinson & Aveyard, 2017) and males (Bazzini et al., 2015), research has indicated that international differences can exist within Western culture. For example, body image concerns were shown to differ between USA and UK samples, with USA individuals more likely to engage in self-accepting body talk compared with UK individuals (Payne, Martz, Tompkins, Petroff, & Farrow, 2011). This suggests that ED behaviours and attitudes are likely to show subtle differences between countries with the same Western culture (Luce et al., 2008). Indeed, evidence has shown that EDE-Q norm scores may vary across countries and cultures (Mond et al., 2006; Welch et al., 2011). Therefore, it is important that researchers and clinicians have up-to-date, normative EDE-Q data for the specific country within which it is used, to accurately interpret the scores of a certain individual or group (AERA et al., 1999). Furthermore, research must continue to evaluate the efficacy of the EDE-Q in assessing ED symptomology in females and males independently, given the fundamental differences in body image concerns and body ideals between sexes (e.g. Jennings & Phillips, 2017; Lavender, De Young, & Anderson, 2010; Mantilla & Birgegard, 2016; Mond et al., 2014; Smith et al., 2017) and changes to ED diagnoses under the latest DSM-5 criteria (American Psychiatric Association, 2013).

Secondly, despite its wide use as a measure of ED psychopathology in non-clinical and clinical samples (Aardoom, Dingemans, Slof Op't Landt, & Van Furth, 2012; Mond et al., 2006), a limitation of the EDE-Q is the fact that it is simply a derivative of the original EDE clinician interview, with its original factor structure lacking empirical support. The original EDE-Q was proposed as a four-factor structure containing the subscales: *Restraint*, *Eating Concern*, *Shape Concern*, and *Weight Concern* (Fairburn & Beglin, 1994). However, as this factor structure was not empirically established, replication of the original factor structure is, unsurprisingly, limited (Forsén Mantilla, Birgegård, & Clinton, 2017). Moreover, the suitability of the factor structure may not be comparable between sexes, given the discrepancy in body ideals and body image concerns between females and males (Rand-Giovannetti, Cicero, Mond, & Latner, 2017; Smith et al., 2017). Indeed, as the EDE-Q was originally developed using female populations, this measure may not accurately reflect the current body ideals in males, such as increased muscularity and leanness (Jennings & Phillips, 2017), which influences ED psychopathology in a qualitatively different manner compared with females (Mitchison & Mond, 2015). Subsequently, further research is required to assess whether the current EDE-Q structure is successfully capturing ED psychopathology equally in females and males (Rand-Giovannetti et al., 2017). With increasing understanding of EDs, changes in ED diagnoses (American Psychiatric Association, 2013), and differences in the presentation of disordered eating behaviours and attitudes between females and males, it is important to continually evaluate and update the EDE-Q as an assessment measure.

The above points are exemplified by empirical research which has assessed the psychometric properties of the EDE-Q and failed to support the original four-factor structure using confirmatory factor analysis (CFA) within non-clinical and clinical samples (see Rand-Giovannetti et al., 2017, for review of factor structure studies). Indeed, several studies have used exploratory factor analysis (EFA) to propose alternative factor structures by removing items that load poorly onto any one factor (Rand-Giovannetti et al., 2017). Whilst the present study does not provide an exhaustive review of all alternative factor structures, studies which do retain all 22 original subscale items include a three-factor structure (Shape Concern and Weight Concern combined) (Peterson et al., 2007), a two-factor structure (Eating Concern, Shape Concern, and Weight Concern combined) (Becker et al., 2010; Penelo, Negrete, Portell, & Raich, 2013), and a one-factor (Global EDE-Q) structure (Pennings & Wojciechowski, 2004) within clinical ED and community samples. This highlights the equivocal reliability and apparent inconsistency of the current EDE-Q scoring system. However, very few studies which propose alternative EDE-Q structures have validated such structures within an independent sample (Friborg, Reas, Rosenvinge, & Rø, 2013; Grilo et al., 2010; Hrabosky et al., 2008; Kliem et al., 2016), which may limit the external validity of proposed factor structures. Moreover, whilst the suitability of the factor structure has been investigated in both female and male samples independently (e.g. Darcy, Hardy, Crosby, Lock, & Peebles, 2013), research which statistically compares the EDE-Q structure between sexes is scarce (Grilo, Reas, Hopwood, & Crosby, 2015; Kliem et al., 2016; Penelo et al., 2013; Rand-Giovannetti et al., 2017).

Given the current limitations as outlined above, the first aim of the present study was to provide EDE-Q norms of the original, four-factor structure across a large, non-clinical sample of UK females and males. A second aim was to assess the suitability of the original four-factor structure (Fairburn & Beglin, 1994), plus alternatively proposed three-factor (Peterson et al., 2007), two-factor (Becker et al., 2010; Penelo et al., 2013), and one-factor structure (Pennings & Wojciechowski, 2004) of the EDE-Q in females and males independently, using a CFA (Phase 1). Furthermore, we compared the above factor structures between female and male samples using measurement invariance analysis, to assess whether the structures are statistically equivalent between sexes. Based upon previous research in Western samples (e.g. Lavender et al., 2010; Penelo et al., 2013; Quick & Byrd-Bredbenner, 2013), we expected females to display higher EDE-Q norm scores compared with males. Further, in line with previous research (e.g. Darcy et al., 2013; White et al., 2014), we hypothesised that CFA would fail to support the original four-factor structure for both sexes, with a poorer model fit amongst males compared with females within all of the above factor structures, given the qualitative difference in ED pathology in males (Mitchison & Mond, 2015). Following our hypothesised outcome for lack of support for previously proposed structures, we therefore conducted an EFA to obtain an optimal model fit of the EDE-Q data, in females and males independently (Phase 2). Newly-proposed factor structures were then submitted to a subsequent CFA using independent student and non-student samples, in order to validate and examine the external validity of the new structures within the broader UK population (Phase 3).

6.2 Method

6.2.1 Participants

The EDE-Q was assessed in a total of 2459 participants across three independent samples; two student samples (Samples 1 and 2) and one non-student sample (Sample 3). Student samples were recruited via internal university participation schemes, and the non-student sample was recruited via email, online social networking sites, and health and well-being forums. The study received departmental ethical approval and was conducted in accordance with the Declaration of Helsinki. Across all samples, participants whose age was ≥ 2 standard deviations (SD) above the sample mean were removed prior to analysis, to maintain homogeneity within each sample of females and males, respectively. The study was undertaken as follows:

6.2.1.1 Phase 1: EDE-Q norms and Initial Confirmatory Factor Analysis

1075 student participants (Sample 1) were recruited to provide EDE-Q norms for females and males based on the originally proposed four-factor structure. This sample contained 851 females (Mean age = 19.77, SD ± 1.73, Range = 17-29) and 224 males (Mean age = 20.34, SD ± 2.69, Range = 17-30). Table 6.1 summarizes demographic information for this sample (age, gender, BMI, and EDE-Q subscale/global scores).

Confirmatory factor analyses were also conducted in Sample 1, in females and males independently, to assess the adequacy of the original four-factor EDE-Q structure (Fairburn & Beglin, 1994), and alternative three-factor (Peterson et al., 2007), two-factor (Becker et al., 2010; Penelo et al., 2013), and one-factor (Pennings & Wojciechowski, 2004) structures.

6.2.1.2 Phase 2: Exploratory Factor Analysis

Following our initial CFA, we conducted exploratory factor analysis (EFA) on the same sample of student participants (Sample 1), to explore alternative factor solutions which provide a better fit for the EDE-Q data. This approach follows previous studies in non-clinical (Darcy et al., 2013; Forsén Mantilla et al., 2017) and clinical samples (Parker, Mitchell, O'Brien, & Brennan, 2015, 2016), where existing factor structures were not supported by an initial CFA. We used Sample 1 to conduct two separate EFAs which explored the EDE-Q structure independently in females (*N*=851) and males (*N*=224).

6.2.1.3 Phase 3: Confirmatory Factor Analysis of Newly-Proposed Factor Structures

To validate the newly-proposed female and male factor structures established from the EFA in Phase 2, further CFAs were conducted in two independent samples, comprising students (Sample 2, *N*=653) and non-students (Sample 3, *N*=731). Sample 2 (student sample) contained 489 females (Mean age = 22.16, SD ± 3.88, Range = 18 – 37) and 164 males (Mean age= 22.86, SD ± 3.69, Range = 18 – 33). Sample 3 (non-student sample) contained 561 females (Mean age = 32.68, SD ± 10.25, Range = 18 - 58) and 170 males (Mean age = 34.39, SD ± 11.08, Range = 18 - 61). Demographic information for females and males in Sample 2 and Sample 3 (age, gender, BMI, and EDE-Q subscale/global scores of original four-factor structure) are included in Supplementary Material (A5 - Tables A5.6 & A5.7).

6.2.2 Measures

6.2.2.1 Eating Disorder Examination Questionnaire (EDE-Q)

The EDE-Q is a 28-item self-report questionnaire of ED psychopathology (Fairburn & Beglin, 1994). The questionnaire assesses disordered eating attitudes and behaviours within the past 28 days, consisting of four subscales: Restraint (5 items), Eating Concern (5 items), Shape Concern (8 items), and Weight Concern (5 items). 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 exception of six items which assess the frequency of ED behaviours within the past 28 days (see Supplementary Material - Table A5.3). These six items do not contribute to the above subscales, but do provide important information regarding overall, core disordered eating behaviours (e.g. self-induced vomiting, excessive exercise) (Fairburn & Beglin, 1994; Quick & Byrd-Bredbenner, 2013). Overall, the EDE-Q subscales and global measure have shown good internal consistency, with Cronbach's alpha ranging from .78 to .93 in non-clinical samples (Berg et al., 2012; Peterson et al., 2007).

6.2.3 Procedure

Participants across all three samples were directed to an online webpage wherein they completed the EDE-Q. The questionnaire was administered using online Qualtrics survey software and took participants approximately 15 minutes to complete. Demographic information including age and sex was acquired, plus height and weight which was used to calculate body mass index (BMI) (kg/m^2). The questionnaire was presented such that participants could not skip past individual items, ensuring there were no missing data. A validity item was also embedded in the survey (i.e. *"To ensure that you are paying attention, please choose agree for this question"* (Dakanalis, Zanetti, Riva, & Clerici, 2013)), with no incorrect responses reported.

6.2.4 Data Analysis

EDE-Q norms (Samples 1-3) are presented as the mean and standard deviation (SD) of all attitudinal EDE-Q subscale and global scores, for females and males independently. Independent samples t-tests were conducted to calculate differences between sexes on subscale and global scores (see Table 6.1 and Supplementary Material - Tables A5.6 & A5.7). EDE-Q percentile ranks were calculated in addition to internal consistency using Cronbach's alpha coefficient (α) for females and males, respectively (see Supplementary Material - Tables A5.1 & A5.2). Frequency of disordered eating behaviours were also calculated based on the diagnostic items that are independent from the EDE-Q subscales, with chi-square (χ^2) and Fisher's exact tests conducted to calculate differences in the proportion of reported disordered eating behaviours between females and males (see Supplementary Material - Table A5.3).

Confirmatory factor analysis was conducted using AMOS software (Arbuckle, 2014; Version 23.0), to assess the goodness of fit for each factor structure in females and males independently. A model may be regarded as an acceptable fit if the Goodness of Fit Index (GFI), Normed Fit Index (NFI) and Comparative Fit Index (CFI) are all above .90; Adjusted Goodness of Fit Index (AGFI) is above .80 (Byrne, 1994), and Root Mean Square Error of Approximation (RMSEA) is below .10 (Browne & Cudeck, 1993). If the chi-square test (χ^2) is non-significant, the model can be regarded as acceptable, with lower statistics for the ratio of chi-square to degrees of freedom (χ^2/df) indicative a better model fit (Browne & Cudeck, 1993). For each of the four previously proposed models (Phase 1), measurement invariance was also calculated between sexes, to examine whether the factor structure presented as equivalent for females and males (Cheung & Rensvold, 2002; see Supplementary Material A5.5).

For data that revealed a poor fit in the initial CFAs (Phase 1), subsequent exploratory factor analysis (EFA) was conducted using principal axis factoring (PAF) with oblique (Promax) rotation (Phase 2). Examination of Kaiser's criterion (Kaiser, 1961) with eigenvalues above 1, in conjunction with Horn's Parallel Analysis (PA; Horn, 1965) provided a robust method in determining the optimal number of extracted factors for both sexes (Watkins, 2005). Items loading below .40, or cross-loading items of .32 or above (Forsén Mantilla et al., 2017; Tabachnick, Fidell, & Osterlind, 2001) were removed from further analyses.

6.3 Results

6.3.1 Phase 1: EDE-Q norms and Initial Confirmatory Factor Analysis

6.3.1.1 EDE-Q Norms and Descriptive Statistics (Sample 1)

Means and standard deviations for all original, four-factor subscale and global EDE-Q scores, and descriptive data are presented in Table 6.1. Independent samples t-tests revealed mean subscale and global scores as significantly higher (p <.001) for females compared with males. An independent samples t-test revealed females' mean age as significantly lower than males, with no significant difference between sexes for BMI (see Table 6.1). Percentile ranks, and clinical significance cut-offs are reported in Supplementary Material (Table A5.1, A5.2, & A5.4). Cronbach's alpha coefficients were acceptable (α > .70) across all subscales and global score for both sexes (see Supplementary Material - Tables A5.1 & A5.2). Percentages of females and males who reported 'any' or 'regular' occurrence of disordered eating behaviours are presented in Supplementary Material (Table A5.3). Chi-square or Fisher's exact tests showed that significantly more females reported self-induced vomiting and laxative misuse (any occurrence) compared with males. Moreover, significantly more females reported regular occurrence of objective binge episodes and dietary restraint compared with males (see Supplementary Material - Table A5.3).

Table 6.1 *Descriptive Data - Means (and SD) for original, four-factor EDE-Q subscales and global score, for female (N=851) and male (N=224) students (Sample 1).*

	Females (*N*=851)	**Males (*N*=224)**	***t***	***p***	**Cohen's *d***
Age	19.77 (1.73)	20.34 (2.69)	3.011	.003	.252
BMI	22.60 (4.11)[a]	23.04 (3.88)[b]	1.411	.158	.110
Restraint	1.37 (1.34)	1.05 (1.25)	-3.218	.001	.246
Eating Concern	1.03 (1.11)	0.60 (0.84)	-6.342	<.001	.436
Shape Concern	2.51 (1.58)	1.69 (1.59)	-6.905	<.001	.518
Weight Concern	2.10 (1.57)	1.31 (1.39)	-7.391	<.001	.535
EDE-Q Global	1.75 (1.25)	1.16 (1.11)	-6.896	<.001	.500

Note: *p* values corrected for multiple comparisons using false discovery rate (Benjamini & Hochberg, 1995).
BMI: Body Mass Index.
[a] Females (*N*= 816); [b] Males (*N*= 216).

6.3.1.2 Initial Confirmatory Factor Analysis

The EDE-Q factor structure was assessed independently for females and males (Sample 1) using a CFA. As the assumption of multivariate normality was not met, maximum-likelihood (ML) estimation was used and the data were bootstrapped (see Table 6.2 for fit indices). The original four-factor model containing the 22 attitudinal items was shown to be invalid for both samples due to Heywood cases, in which the standardized regression weights were larger than 1 for loadings onto item 8 (*Preoccupation with Shape or Weight*). This was therefore treated as a specification error, and item 8 was removed from further analysis within the four-factor model. The four-factor model provided a poor fit to the data for both females and males (Table 6.2), with all fit indices below the accepted threshold, and a significant chi-square statistic (Browne & Cudeck, 1993). CFA was also undertaken for a three-factor (Shape Concern and Weight Concern combined), two-factor (Eating Concern, Shape Concern, and Weight Concern combined) and one-factor (Global EDE-Q) model. Similarly, the fit for all alternative models was unacceptable for females and males, with minimal change to fit indices (see Table 6.2). Such inflated chi-square values may be caused by large sample sizes as present for both sexes in the current study (Ullman, 2001). However, examination of the fit indices does indicate a poor data fit for each of the models tested.

Model measurement invariance analysis was undertaken to determine whether the EDE-Q factor structure was equivalent between female and male samples. All four models revealed significant differences, suggesting that female and male respondents may be interpreting EDE-Q items in a conceptually different manner. See Supplementary Material (Table A5.5) for full analysis details.

Table 6.2 *Fit statistics for four models of EDE-Q data in female (N=851) and male (N=224) students (Sample 1).*

		No. of items	χ^2 (df)	*p*	χ^2 /df	RMSEA	GFI	AGFI	NFI	CFI
Four Factor	**Females**	21*	2301.732 (183)	<.001	12.578	.117	.771	.711	.823	.835
	Males	21*	762.575 (183)	<.001	4.167	.119	.746	.679	.773	.816
Three Factor	**Females**	22	2648.098 (206)	<.001	12.855	.118	.753	.696	.807	.819
	Males	22	872.926 (206)	<.001	4.238	.120	.731	.670	.754	.799
Two Factor	**Females**	22	2878.955 (208)	<.001	13.841	.123	.727	.668	.790	.802
	Males	22	943.298 (208)	<.001	4.535	.126	.704	.640	.735	.779
One Factor	**Females**	22	3557.472 (209)	<.001	17.021	.137	.667	.597	.741	.752
	Males	22	1062.709 (209)	<.001	5.085	.135	.664	.594	.701	.743

Note: χ^2: chi-square; df: degrees of freedom; RMSEA: Root Mean Square Errors of Approximation; GFI: Goodness of Fit Index; AGFI: Adjusted Goodness of Fit Index; NFI: Normed Fit Index; CFI: Comparative Fit Index.

* = item 8 removed from analysis of four-factor model due to Heywood cases, thus 21 items were entered for the CFA.

6.3.2 Phase 2: Exploratory Factor Analysis

As the data provided an inadequate fit for all previously proposed models using a CFA, a subsequent exploratory factor analysis (EFA) was conducted independently for both females and males (Sample 1) on all 22 attitudinal EDE-Q items.

6.3.2.1 Females

Parallel analysis confirmed that a three-factor model would be the optimal fit for female data. Items 6 (*Flat Stomach*) and 10 (*Fear of Weight Gain*) did not adequately load onto any factor (<.40), and items 12 (*Desire to Lose Weight*) and 21 (*Social Eating*) showed high cross-loadings. Thus, these four items were removed from analysis, meaning a PAF was re-run with Promax rotation on 18 items. Kaiser-Meyer-Olkin measure verified sampling adequacy for the analysis (KMO = .92), and Bartlett's Test of Sphericity was significant ($p < .001$). This model cumulatively explained 66.26% of the variance (see Table 6.3). Factor one was comprised of items related to Shape Concern and Weight Concern subscales, with the addition of one item (Item 2 - *Guilt about Eating*) from the Eating Concern subscale. Accordingly, this factor was termed Shape and Weight Concern. Factor two was comprised of items related to a preoccupation and eating concern, with the addition of two items (Item 5- *Empty Stomach* and Item 2- *Avoidance of Eating*). This factor was termed Preoccupation and Eating Concern. Factor three was comprised of items related to dietary restriction and was termed Restriction.

6.3.2.2 Males

A three-factor model was also found to be the optimal fit for the male data. Iterative analyses were made from the original 22 items, with items 2 (*Avoidance of Eating*), 5 (*Empty Stomach*), 6, (*Flat Stomach*), 9 (*Fear of losing control over eating*), and 10 (*Fear of Weight Gain*) removed due to not adequately loading onto any factor (<.40), and item 12 (*Desire to Lose Weight*) removed due to cross-loading, meaning a PAF was re-run with Promax rotation on 16 items. Kaiser-Meyer-Olkin measure verified sampling adequacy for the analysis (KMO = .91), and Bartlett's Test of Sphericity was significant ($p < .001$), with the model cumulatively explaining 67.38% of the variance (see Table 6.3). Similar to the factor structure found in the female sample, factor one was comprised of items related to

Shape Concern and Weight Concern subscales, thus termed Shape and Weight Concern. Factor two was comprised of items related to a preoccupation and eating concern, thus termed Preoccupation and Eating Concern. Factor three was comprised of items related to dietary restriction, thus also termed Restriction. Therefore, the factor structure was replicated in female and male samples, albeit that fewer items were retained in the factor solution for males.

Table 6.3 *Pattern Matrix of PAF analysis of female* (*N*=851) *(18 items) and male* (*N*=224) *(16 items) EDE-Q items (Sample 1).*

	Females (*N* = 851)				**Males (*N* = 224)**		
	Shape and Weight Concerns	**Preoccupation and Eating Concern**	**Restriction**		**Shape and Weight Concerns**	**Preoccupation and Eating Concern**	**Restriction**
	Factor 1	Factor 2	Factor 3		Factor 1	Factor 2	Factor 3
(27) Discomfort seeing body	**.921**	-.017	-.056	*(26)* Dissatisfaction with shape	**.919**	-.100	.066
(26) Dissatisfaction with shape	**.902**	-.107	.065	*(28)* Avoidance of exposure	**.874**	.090	-.119
(28) Avoidance of exposure	**.888**	-.062	-.038	*(22)* Importance of weight	**.859**	-.084	-.002
(25) Dissatisfaction with weight	**.853**	-.066	.084	*(25)* Dissatisfaction with weight	**.807**	-.029	.117
(23) Importance of shape	**.746**	.117	-.025	*(23)* Importance of shape	**.803**	-.050	.115
(24) Reaction to prescribed weighing	**.732**	.045	-.120	*(27)* Discomfort seeing body	**.782**	.152	-.074
(22) Importance of weight	**.721**	.153	-.019	*(24)* Reaction to prescribed weighing	**.778**	.011	-.185
(11) Feelings of fatness	**.669**	-.011	.196	*(11)* Feelings of fatness	**.588**	.040	.253
(20) Guilt about eating	**.480**	.286	.094	*(19)* Eating in secret	-.134	**.723**	-.078
(7) Preoccupation with food, eating or calories	-.063	**.849**	-.126	*(20)* Guilt about eating	.143	**.625**	.132
(8) Preoccupation with shape or weight	.170	**.689**	-.066	*(7)* Preoccupation with food, eating or calories	-.077	**.611**	.058
(9) Fear of losing control over eating	.007	**.660**	.095	*(8)* Preoccupation with shape or weight	.162	**.567**	.063
(5) Empty stomach	-.056	**.609**	.185	*(21)* Social eating	.159	**.528**	-.086
(2) Avoidance of eating	-.067	**.463**	.202	*(1)* Restraint over eating	-.013	-.103	**.891**
(19) Eating in secret	.181	**.406**	-.039	*(3)* Food avoidance	-.085	.054	**.817**
(3) Food avoidance	-.001	-.034	**.884**	*(4)* Dietary Rules	.015	.051	**.629**
(1) Restraint over eating	.025	-.018	**.864**				
(4) Dietary Rules	-.023	.107	**.692**				
Eigenvalue	8.98	1.73	1.26		7.84	1.58	1.37
% of variance	49.67	9.62	6.98		48.97	9.84	8.57
Cronbach's Alpha	.94	.82	.87		.94	.78	.80

Note: Values in bold represent highest loadings which comprise the respective factor.

EDE-Q item number (Fairburn & Beglin, 1994) in italicized parentheses.

6.3.3 Phase 3: Confirmatory Factor Analysis of Newly-Proposed Factor Structures

6.3.3.1 Student Sample (Sample 2)

Consistent with our initial student sample (Sample 1), independent samples t-tests revealed mean subscale and global EDE-Q norm scores for the original, four-factor structure as significantly higher for females compared with males ($p < .001$) within an independent, non-clinical student sample (Sample 2) (see Supplementary Material – Table A5.6). Moreover, EDE-Q scores are provided based on the newly-proposed, three-factor structure for females and males, respectively (see Supplementary Material – Tables A5.8 & A5.9).

A subsequent CFA was run to evaluate the newly-proposed three-factor models established from the EFA using an independent, student sample (Sample 2). The assumption of multivariate normality was not met for either sample, therefore maximum-likelihood (ML) estimation was used and the data were bootstrapped. Within the new female sample, the newly-proposed three-factor model showed improved fit indices compared with the previously assessed EDE-Q models, although fit statistics remained marginally outside of the accepted threshold (Browne & Cudeck, 1993). However, follow-up analyses were undertaken to assess parameters with modification indices above 10.00 (Heene, Hilbert, Harald Freudenthaler, & Bühner, 2012), with several highly-correlated error terms within the same factor subsequently co-varied within the model, before re-running the analyses (see Supplementary Material Figure A5.1a for model covariances). Such modification of the model significantly improved the model fit, with necessary fit indices above the accepted .90 threshold and AGFI above .80 (Hu & Bentler, 1999) (see Table 6.4).

CFA analysis was also undertaken within the new male sample, using the newly-proposed three-factor model. Results showed similarly improved fit compared with previously assessed EDE-Q models, yet this also remained below the accepted threshold (see Table 6.4). Modification indices were similarly assessed, with necessary co-variances made between error terms (see Supplementary Material Figure A5.1b), and further improvements made to the model, yet this did not reach the necessary threshold for good model fit (Browne & Cudeck, 1993).

6.3.3.2 Non-student Sample (Sample 3)

Consistent with Sample 1 and Sample 2, independent samples t-tests revealed mean subscale and global EDE-Q norm scores for the original, four-factor structure as significantly higher for females compared with males ($p < .001$) within an independent, non-clinical, non- student sample (Sample 3) (see Supplementary Material – Table A5.7). EDE-Q scores are also provided based on the newly-proposed, three-factor structure for females and males, respectively (see Supplementary Material – Tables A5.8 & A5.9).

A further CFA was run to evaluate the newly-proposed models established from the EFA using an independent, non-student sample (Sample 3) of non-clinical females and males, respectively. Once again, the assumption of multivariate normality was not met for either sample, therefore maximum-likelihood (ML) estimation was used and the data were bootstrapped. Within both non-student samples, the newly-proposed three-factor model showed similar fit statistics, which remained marginally outside of the accepted threshold (Browne & Cudeck, 1993). However, follow-up analyses were once again undertaken based on modification indices and further improvements were made to both models (see Supplementary Material Figure A5.1c & A5.1d). Such modifications significantly improved the model fit in both female and male models, with necessary fit indices above the accepted .90 threshold and AGFI above .80 (Hu & Bentler, 1999) (see Table 6.4).

Table 6.4 *Fit statistics for newly-proposed three-factor models of EDE-Q data in student (Sample 2) and non-student (Sample 3) females and males.*

			No. of items	χ^2 (df)	*p*	χ^2 /df	RMSEA	GFI	AGFI	NFI	CFI
Student sample	**New Three Factor**	Females (*N*=489) (without modification)	18	970.22 (132)	<.001	7.35	.114	.833	.784	.866	.882
		Females (*N*=489) (with modification)	18	375.16 (122)	<.001	3.13	.066	.923	.890	.948	.964
	New Three Factor	Males (*N*=164) (without modification)	16	307.30 (101)	<.001	3.04	.112	.818	.756	.796	.851
		Males (*N*=164) (with modification)	16	222.08 (98)	<.001	2.27	.088	.864	.811	.853	.911
Non-student sample	**New Three Factor**	Females (*N*=561) (without modification)	18	1306.17 (132)	<.001	9.90	.126	.798	.738	.844	.857
		Females (*N*=561) (with modification)	18	445.02 (114)	<.001	3.90	.072	.924	.886	.947	.924
	New Three Factor	Males (*N*=170) (without modification)	16	325.10 (101)	<.001	3.22	.115	.811	.745	.803	.854
		Males (*N*=170) (with modification)	16	135.37 (94)	.003	1.44	.051	.901	.858	.918	.973

Note: χ^2: chi-square; df: degrees of freedom; RMSEA: Root Mean Square Errors of Approximation; GFI: Goodness of Fit Index; AGFI: Adjusted Goodness of Fit Index; NFI: Normed Fit Index; CFI: Comparative Fit Index

6.4 Discussion

The present study provided EDE-Q norms of the originally proposed four-factor structure, and assessed the psychometric properties of the EDE-Q factor structure within a non-clinical UK sample of females and males. Given the inconsistency of previously reported psychometric properties of the EDE-Q, the present study conducted a CFA to test the original (Fairburn & Beglin, 1994) and alternatively proposed (Becker et al., 2010; Penelo et al., 2013; Pennings & Wojciechowski, 2004; Peterson et al., 2007) EDE-Q structures (Phase 1), followed by an EFA to determine an optimal fit for both female and male student samples (Phase 2). Importantly, the present study aimed to validate our newly-proposed female and male factor structures by conducting subsequent CFAs within independent student and non-student samples (Phase 3).

EDE-Q norm scores of the originally proposed four-factor structure were shown to be significantly higher amongst UK females compared with males, within both student and non-student samples. Such findings are consistent with previously published non-clinical norms comparing between sexes in Western samples (Penelo et al., 2013; Quick & Byrd-Bredbenner, 2013). Indeed, to the authors' knowledge, the present findings are the first to provide EDE-Q norms in a non-clinical UK adult sample, with global scores shown to be comparable with other non-clinical Western norms scores in females (Luce et al., 2008; Quick & Byrd-Bredbenner, 2013; Welch et al., 2011). Results suggest that UK male EDE-Q norms were marginally higher than previously published norms within non-clinical Western male samples (Lavender et al., 2010; Quick & Byrd-Bredbenner, 2013; Reas, Øverås, & Rø, 2012), yet future research should look to investigate whether such norms differ statistically between countries. Indeed, higher male norms in the present study support previous research which suggests that differences in EDE-Q norms may exist between countries within Western cultures (Mond et al., 2006), and further highlights the need to provide normative data within different countries, in order to provide an empirical context to interpret an individual's score within a certain country. Greater investigation of cultural and international differences in ED psychopathology is particularly important to undertake amongst males, given the paucity of EDE-Q norm research in males compared with females (Lavender, Brown, & Murray, 2017).

In line with our hypothesis, a CFA failed to support the original four-factor structure (Fairburn & Beglin, 1994) for both sexes. This is consistent with previous literature in clinical and non-clinical samples (Aardoom et al., 2012; Forsén Mantilla et al., 2017; Rand-Giovannetti et al., 2017; White et al., 2014), which reinforces the argument that the original, theoretically derived EDE-Q structure may lack empirical support. Additionally, the current results replicated Allen et al. (2011) by failing to support alternative three, two, and one-factor models, which have been previously shown to provide the best fit to the data amongst clinical and non-clinical samples (Peterson et al., 2007; Penelo et al., 2013; Pennings & Wojciechowski, 2004). This would suggest that alternative structures which include all 22 attitudinal items are sub-optimal in capturing ED psychopathology, in both females and males. Indeed, Allen et al. (2011) concluded that a brief, 8-item, single-factor structure provided an adequate fit for the EDE-Q. Whilst this simplified structure may not capture the richness and complexity of ED psychopathology, our study conducted EFA of the full 22 attitudinal items in a large sample of female and males, to assess which items did not clearly load onto any one factor.

The EFA revealed that a three-factor model - *Shape and Weight Concern*, *Preoccupation and Eating Concern*, and *Restriction* - was the most appropriate fit to the data for both females and males, using an 18-item and 16-item model, respectively. Whilst such findings do not suggest the model should contain as few items as previous literature has proposed (Allen et al., 2011; Gideon et al., 2016; Grilo et al., 2015; Kliem et al., 2016), it is supportive in suggesting that the EDE-Q would benefit from a revised, briefer version than the current 22-item attitudinal measure, whilst maintaining a comparable degree of assessment value. Indeed, newly-proposed EDE-Q scores are provided for all samples based on the respective three-factor structure for both sexes (see Supplementary Material – Tables A5.8 & A5.9), which similarly reflects higher subscale and global scores amongst females compared with males. Given such differences between sexes, our results suggest that males may require a different, validated scoring of this measure to reflect the difference in ED psychopathology compared with females.

Moreover, EFA results within the present study support previous research which combines Shape Concern and Weight Concern subscales (Rand-Giovannetti et al., 2017; Forsén Mantilla et al., 2017; Peterson et al., 2007), suggesting that individuals in the non-clinical population interpret shape and weight as closely associated within a generalized body concern. Indeed, Shape Concern and Weight Concern items accounted for approximately half of the model variance explained for both sexes. This is particularly important to consider with regard to the interpretation of normative EDE-Q data within the non-clinical population, given that scores on Shape Concern and Weight Concern are typically the highest of the original, four EDE-Q subscales (e.g. see Table 6.1). Consequently, a high proportion of individuals can display norm scores above the clinical cut-off (≥4; Mond et al., 2006) which presents a false positive in the number of cases falling within clinical significance. Indeed, within the present study, almost 1 in 4 non-clinical females scored above this clinical cut-off on Shape Concern alone (see Supplementary Material Table A5.4). This suggests that clinical cut-off thresholds need to be reassessed, and further underpins the need to provide up-to-date normative data from both clinical and non-clinical populations, to statistically determine the accurate use of this measure as a clinical screening instrument (Mond et al., 2006).

Despite several studies undertaking EFA to determine a new EDE-Q factor structure (e.g. Forsén Mantilla et al., 2017; Machado et al., 2014; White et al., 2014; Darcy et al., 2013), to the authors' knowledge, only three studies have subsequently validated their own newly-proposed EDE-Q structure within an independent sample (Friborg et al., 2013; Hrabosky et al., 2008; Kliem et al., 2016). In the present study, we aimed to assess our own newly-proposed factor structure across two independent, multi-site samples for both females and males. Given the congruency in EDE-Q norms with other Western samples, and validation of our newly-proposed three-factor structure in independent, multi-site samples of both student and non-student females, our results suggest that this factor structure could be applied to the general, non-clinical female population. Whilst similar validation was shown for non-student males, fit indices were marginally below the accepted CFA threshold for student males. This may be, in part, due to the smaller sample size in males ($N = 164$) influencing fit indices, however, it was ensured prior to analysis that the number of male participants across all samples provided sufficient statistical power to conduct a CFA (Bentler, 1995; Kline, 2014; Munro, 2005). Nevertheless, future research is encouraged to assess the newly-proposed factor structures for both females and males, which would further validate such models in wider non-clinical samples.

Further, high covariances were observed between error terms within the *Shape and Weight Concern* factor in both of the validated CFA models. This is likely to reflect the highly similar item wording within EDE-Q subscales, particularly within Shape Concern and Weight Concern subscales. At its most extreme, items within these subscales could be interpreted by respondents as qualitatively equivalent, with certain items only differing in the words "shape" or "weight" within an otherwise identical question (e.g. item 25 & 26). Indeed, this is supported by the EFA models in the present study which combine Shape Concern and Weight Concern subscales, in line with previous research in non-clinical samples (e.g. Rand-Giovannetti et al., 2017; White et al., 2014; Darcy et al., 2013). Such issues could lead to biases in factor loading estimates and subsequently affect the interpretability of EDE-Q subscale scores. Thus, a version of the EDE-Q which includes fewer items, particularly within Shape Concern and Weight Concern subscales, without reducing the variance explained by the model is likely to provide a more reliable assessment measure.

Importantly, it is not suggested that the EDE-Q is without assessment and diagnostic value. However, the factor structure based on the 22 attitudinal items appears to cluster differently to the original, theoretically-proposed structure (Fairburn & Beglin, 1994). The factors extracted from the present EFA do closely resemble the originally proposed factors, but indicate that the EDE-Q may benefit from revision based on current body image ideals, using empirically driven methods. For example, items 6 *(Flat Stomach),* 10 (*Fear of Weight Gain*), and 12 (*Desire to Lose Weight*) were removed from both female and male EFA models. For males, this may reflect a more recent focus on leanness and muscularity in male body ideals (Pope, Phillips, & Olivardia, 2002), with less concern towards weight loss. In females, such poor item loading may be a consequence of the EDE-Q design, which may not fully capture the broader ED diagnoses under the new DSM-5 criteria (Vo, Accurso, Goldschmidt, & Le Grange, 2017). The EDE-Q was originally designed to assess anorexia nervosa (AN) and bulimia nervosa (BN) symptoms (Cooper, Cooper, & Fairburn, 1989). However, since its conception, ED diagnosis now incorporates new disorders characterised by different symptomatology. For example, binge eating disorder (BED) has only recently been introduced as a distinct diagnosis in the DSM-5, characterised by individuals eating large quantities of food and regularly experiencing loss of control over eating (American Psychiatric Association, 2013). Whilst select BED characteristics are captured in disordered eating behaviour items (e.g. objective binge episodes), the BED profile is not addressed in the attitudinal items which contribute to EDE-Q norm scores (Carrard, Lien Rebetez, Mobbs, & Van der Linden, 2015). This is particularly important when considering sex differences, given that, unlike AN and BN, BED affects males and females equally (Mitchison & Mond, 2015).

Nevertheless, whilst it is advised that methods of assessment in ED psychopathology should be revised in line with up-to-date diagnostic criteria, it is important to note that the above conclusions drawn in the present study are made based on non-clinical samples only. Previous research has provided a strong rationale for investigating such measures within the non-clinical population which delivers valuable information in promoting positive health-related outcomes (Mond et al., 2013), and provides reference data to map onto clinical ED assessment and diagnosis (Mond et al., 2009). However, future research should also investigate the factor structure and measurement invariance across clinical ED samples with differing symptomology, according to the latest DSM-5 criteria.

As noted in previous research (Mond et al., 2014; Reas et al., 2012), the sensitivity of the EDE-Q within male populations requires further evaluation. EDE-Q items focus largely on shape and weight concerns which are designed to assess a thinner body (e.g. *Restraint*). However, male body concerns are often based on reversed ideals, with a desire to increase muscularity and body mass (Lavender et al., 2017; Smith et al., 2017). Therefore, lower scores and ED prevalence amongst males may not be due to lower incidence of disordered eating attitudes *per se*, but rather that male body concerns are not adequately captured within EDE-Q items. Indeed, measurement invariance analysis of the previously proposed factor structures between sexes in the initial CFA (Phase 1) offers statistical support for females and males interpreting items in a conceptually different manner (see Supplementary Material A5.5). These different conceptual interpretations may also be evident in disordered 'compensatory' behaviour responses, as 'excessive exercise' might reflect increased muscle mass for males, but increased weight loss for females (Lavender et al., 2010; Murray, Griffiths, & Mond, 2016). Thus, whilst male norms were lower than female norms in the present study, differences in the expression of ED symptomology may be better captured by accompanying assessment tools measuring body image concerns and ED psychopathology in males (Darcy et al., 2013; Jennings & Phillips, 2017; Mond et al., 2014). Moreover, future studies must establish accurate, empirically derived clinical EDE-Q cut-offs (see Supplementary Material A5.4), based on norms from clinical and non-clinical samples for females and males independently (Machado et al., 2014; Welch et al., 2011).

Studying ED vulnerability in student samples is of great importance, given the increased rates of body dissatisfaction (Berg et al., 2009) and ED symptoms within this population (Lipson & Sonneville, 2017). Whilst the present study maintained a homogeneous sample in the initial CFA and subsequent EFA (Sample 1), the use of an exclusively student sample may have limited the generalizability of these findings to other non-clinical samples. However, we aimed to externally validate each of the newly-proposed factor structures in independent student (Sample 2) and non-student (Sample 3) samples, which is a key strength of our design. Moreover, the present pattern of findings is in line with previous research which investigates EDE-Q norms and factor structure in non-clinical samples across different countries (Quick & Byrd-Bredbenner., 2013; Allen et al., 2011; White et al., 2014; Forsén Mantilla et al., 2017).

However, limitations must be considered within the present study. Whilst efforts were made to improve the generalizability of our results across independent samples, our study employed convenience sampling which may not fully generalize to the general population. Thus, future research which assesses the newly-proposed factor in more heterogeneous samples is advised. Indeed, an aim within the present study was to maintain homogeneity in the age of our samples (see *Methods* section), to provide greater reliability when comparing EDE-Q norms and factor structures between females and males. However, whilst there is a large body of evidence investigating the age of onset for a clinical ED diagnosis (Micali et al., 2013), and ED pathology over the lifespan (Cash & Smolak, 2011), research which specifically investigates the impact of age towards EDE-Q scores is scarce (Rø, Reas, & Rosenvinge, 2012) and should be increasingly investigated to statistically explore the effects of age on ED pathology. Finally, each of the samples used in the present study had a significantly larger ratio of females compared with males. Whilst it was ensured that the number of participants across all samples provided sufficient statistical power to conduct a CFA and EFA (Kline, 1994; Bentler, 1995; Munro, 2005), it would be beneficial for future research to assess the newly-proposed three-factor model in a larger male sample.

In conclusion, the present study provides an important contribution to the wider EDE-Q literature as the first to provide EDE-Q norms of the original, four-factor structure for females and males within a non-clinical UK adult sample. Such data is valuable in providing an empirical context to appropriately interpret EDE-Q scores in non-clinical and clinical populations within the UK, and helps to facilitate comparisons in ED psychopathology with other countries and cultures. Consistent with previous research, EDE-Q norm scores were higher amongst females compared with males. However, psychometric assessment suggested that the original four-factor EDE-Q structure was sub-optimal for both sexes, with a three-factor structure shown to be the most appropriate fit to the data for both females and males, using an 18-item and 16-item model, respectively. Given the ongoing changes in ED diagnostic criteria since the introduction of the original EDE-Q measure, the psychometric properties should be reassessed in accordance with such developments, within both clinical and non-clinical samples. Moreover, given the established differences in body ideals between females and males, increased research is required in the non-clinical male population, to further determine whether EDE-Q items are interpreted qualitatively differently between sexes.

Chapter 7

General Discussion

The overarching objective of the present thesis was to investigate how the perception of the body relates with emotions held towards it, particularly how such components inform one's body image and the stability of the bodily self. This was investigated using a combination of behavioural, functional magnetic resonance imaging, and psychometric methods. An integral theme running throughout such empirical work was to consider how the perception and appraisal of body-related information related to ED psychopathology within clinical and non-clinical samples. The stability of body perception was most commonly assessed using multisensory body illusions within the present thesis, which provide a valuable paradigm to experimentally investigate multiple components of bodily experience in the context of multisensory integration. Specifically, the empirical work which used such paradigms aimed to better understand the sense of body ownership and agency within ED individuals (Chapter 2), the role of congruent visuoproprioceptive signals towards embodiment (Chapter 4), and the role of affective touch towards interoceptive and exteroceptive integration in relation to the bodily self (Chapter 5). Moreover, the representation of bodies was investigated neurally to better understand how the interaction of multiple physical bodily attributes modulated neural response within the body-selective region of visual cortex (Chapter 3). Finally, as an important clinical measure of ED psychopathology, Chapter 6 provided a rigorous assessment of the *Eating Disorder Examination Questionnaire* (EDE-Q). EDE-Q norm scores were provided within the non-clinical UK population, with psychometric analysis showing that the currently used factor structure may require reassessment in line with up-to-date diagnoses and qualitative differences in body ideals between females and males.

Within the final chapter, an outline of all empirical chapters will be presented with a summary of the main findings from each experiment. Additionally, strengths and limitations of the above methodologies and themes will be discussed, highlighting the implications of such empirical work and providing ideas for future directions within this research area.

7.1 Summary of Thesis Findings

As a common hallmark within the development and maintenance of clinical EDs, **Chapter 2** investigated key components of body image disturbance within ED individuals, compared with healthy controls. Specifically, the stability of body perception was investigated using the *moving rubber hand illusion*, which incorporated active movement to assess an individual's sense of body ownership and sense of body agency. Susceptibility to the illusion was assessed using subjective questionnaire measures, alongside objective measures of proprioceptive drift and hand size estimation recorded before and after the illusion. Furthermore, both explicit and implicit body satisfaction was recorded to investigate whether these two measures present different patterns of responses, or share the same underlying construct towards one's body image. Finally, the relationship between measures of body perception and body satisfaction was investigated, following evidence demonstrating a direct link between perceptual and cognitive-affective components of body image in the healthy population (Preston & Ehrsson, 2014, 2016, 2018). 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 controls. Such findings support previous research in suggesting that ED individuals have a more malleable experience of the bodily self compared with healthy individuals, in which overestimation of body size can be improved upon using interventions that target such perceptual alterations. 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, and may thus provide important implications within clinical treatment and assessment of recovery. 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. 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.

Next, with evidence that alterations in the extrastriate body area (EBA) have been associated with disturbances in body image amongst ED patients, and disruptions to EBA activity amongst healthy individuals have been shown to influence aesthetic evaluations made towards bodies, the functional role of the EBA was investigated amongst healthy females in **Chapter 3**. Specifically, independent research has shown that the visual perspective and morphology of perceived bodies influence EBA activation, yet this chapter was the first to investigate the combined processing of these physical attributes towards the neural response within this region. Moreover, the role of the EBA was investigated in relation to how such visual processing may influence higher-order, socio-cognitive evaluation of bodies, and how differences in EBA activation may relate to non-clinical ED psychopathology. In this experiment, participants viewed images of slim and large female bodies viewed from egocentric (first-person) and allocentric (third-person) perspectives. In addition, participants provided behavioural aesthetic and weight evaluations of all body stimuli, following the fMRI experiment. Univariate results revealed a bilateral interaction between visual perspective and body morphology towards EBA activity, with multi-voxel pattern analysis strengthening such findings by discriminating distinct, selective patterns of neural EBA response between each of the four conditions of body stimuli. However, EBA activity did not relate to non-clinical ED psychopathology in our healthy sample, which suggests that neural alterations within this region may be a consequence of malnutrition or cortical thinning within clinical EDs, rather than a risk factor for the disorder. No direct relationship was found between EBA activity and behavioural evaluations of body stimuli; however, a whole brain analysis revealed that higher-order, prefrontal regions were associated with cognitive evaluations of large bodies. Overall, results within Chapter 3 suggest that the EBA - as a core region in visual body processing - can discriminate between multiple physical attributes of the body. Therefore, with evidence that disruption in EBA functioning has been implicated with disturbances in body image and aesthetic evaluations made towards bodies, such an interaction in visual processing between visual perspective and body morphology may have important implications towards higher-order assessment of bodies, and one's own body satisfaction.

Chapter 4 further highlighted the importance of visual perspective in relation to the body, by investigating the extent to which 'visual capture' of congruent visuoproprioceptive body information influenced subjective embodiment. Whilst many multisensory illusion experiments argue that synchronous visuotactile integration is necessary to induce illusory embodiment, few studies have investigated how the mere first-person visual observation of the perceived body (part) would result in some degree of embodiment. Therefore, across two experiments, visual observation of a mannequin body, viewed from a first-person perspective, was investigated towards subjective embodiment independently from concomitant visuotactile integration. Moreover, this chapter explored whether the type of touch administered to participants' own, unseen body (without concomitant touch on the seen mannequin) influenced the disruption of visual capture. Specifically, whether slow, affective touch - known to activate interoceptive pathways - disrupted visual capture effects to a greater degree than fast, discriminatory non-affective touch. Finally, with evidence that clinical ED individuals typically show heightened sensitivity to visual information pertaining to the body, and a reduced subjective pleasantness to touch, the above measures were examined in relation to non-clinical ED psychopathology. In total, 40% of participants experienced subjective embodiment towards the mannequin body following mere visual observation, and this effect was significantly higher than conditions which included touch to participants own, unseen body. The velocity of the touch that participants received (affective/non-affective) did not differ in modulating visual capture effects. Furthermore, the effects of visual capture and perceived pleasantness of touch were not modulated by non-clinical ED psychopathology. Overall, this chapter suggests that congruent visuoproprioceptive cues (i.e. viewing the body from a first-person perspective) can be sufficient to induce subjective embodiment of a whole body, in the absence of visuotactile integration and beyond mere confabulatory responses. Moreover, findings suggest that altered perception of touch, and visual dominance towards body-related information observed in EDs may be a consequence of the disorder, rather than a predisposing factor which could increase the risk of a clinical diagnosis.

Leading on from the above chapter, **Chapter 5** investigated the influence of affective touch towards subjective embodiment within the full body illusion. Whilst the role of exteroceptive sensory signals in multisensory integration are well established, research has only recently highlighted the importance of interoceptive sensory signals contributing towards one's body representation. Specifically, affective touch has become an increasingly used experimental modality within body ownership, which provides a unique window into an individual's interoceptive awareness. Previous studies have highlighted that affective touch can enhance embodiment during multisensory integration within the 'classic' rubber hand illusion paradigm. However, the role of affective touch in modulating embodiment towards a whole body remains equivocal. Moreover, with evidence that that individuals with anorexia nervosa display a reduced pleasantness towards affective touch relative to healthy controls - which may be linked to their weakened interoceptive perception (Crucianelli et al., 2016) – it remains important to investigate such perceived pleasantness of touch amongst healthy individuals, in relation to non-clinical ED psychopathology. Therefore, Chapter 5 investigated whether affective touch would lead to increased perceived pleasantness and enhanced subjective embodiment within the full body illusion, compared with fast, non-affective touch. In Experiment 1, participants were stroked on their forearm in synchrony or asynchrony with a mannequin body, viewed from a first-person perspective, with affective or non-affective velocity touch. In Experiment 2, the spatial congruence of stroking was manipulated rather than synchrony, in addition to touch velocity. Both experiments showed that participants perceived affective touch as more pleasant than non-affective touch during the illusion. Furthermore, synchronous, and spatially congruent, visuotactile stimulation led to higher subjective embodiment towards the mannequin body compared with asynchronous (Experiment 1) or spatially incongruent (Experiment 2) visuotactile stimulation. However, the velocity of perceived affective touch did not further modulate the subjective experience of the illusion, with comparable embodiment change scores between affective and non-affective touch conditions. Finally, it was found that the perceived pleasantness of touch was not modulated by non-clinical ED psychopathology. Taken together, these findings suggest that enhancement of embodiment due to affective touch may be body-part specific, and may not generalize to increased ownership towards a whole body. Additionally, such findings support previous chapters in suggesting that attenuated subjective pleasantness of touch observed in ED groups may be a state phenomenon which is intimately linked with a clinical diagnosis, rather than a predisposing risk factor associated with the development of body image disturbances.

Finally, as the investigation of ED psychopathology runs as a central theme throughout the present thesis, **Chapter 6** rigorously examined one of the key measurement tools used to assess ED symptomology and body image. Specifically, the *Eating Disorder Examination Questionnaire* (EDE-Q) is a widely used assessment of ED psychopathology; however, EDE-Q norms are yet to be provided within a non-clinical UK adult sample. Given the changes in body image attitudes over time and between cultures, it is integral that normative data is provided in the non-clinical population to trace the trajectory of body image concerns and ensure that the EDE-Q is accurately interpreted as a clinical measure. Secondly, there is considerable disagreement regarding the psychometric properties of this measure – specifically regarding the empirical support for the original four subscales/factors (*Restraint*, *Eating Concern*, *Weight Concern*, and *Shape Concern*) which inform overall ED psychopathology on this measure. Several alternative factor structures have been previously proposed, but very few have subsequently validated their new structure in independent samples which is likely to limit their external validity. Therefore, in Chapter 6, norms of the original four-factor EDE-Q structure were provided, and the psychometric properties of the EDE-Q were subsequently assessed in females and males using a large non-clinical UK sample. Results showed that EDE-Q norms were consistently higher in females compared with males across all samples. In addition, initial confirmatory factor analyses did not support the original four-factor structure for females or males (Phase 1). However, subsequent exploratory factor analyses revealed a three-factor structure as being the optimal fit for both females and males, using an 18-item and 16-item model, respectively (Phase 2). For females, the newly-proposed 18-item structure was validated within an independent student sample and further validated in an additional non-student sample. The 16-item three-factor male structure was also validated within an independent non-student sample but was marginally below accepted fit indices within an independent student sample

(Phase 3). Taken together, the findings within Chapter 6 were the first to provide EDE-Q norms in a non-clinical UK adult sample, to be used as an accurate interpretation alongside other non-clinical Western norms and provide an empirical context within which to interpret EDE-Q scores as a clinical measure in the UK. Additionally, the above findings suggest that the EDE-Q factor structure may require further reassessment, with greater focus on the qualitative differences in interpretation of EDE-Q items between females and males.

7.2 Thesis Implications

The empirical chapters within the present thesis provide a novel contribution towards the understanding of perceptual and cognitive-affective components of body image. Therefore, it is important that such findings are discussed in the context of previous research, clinical implications, and neurocognitive models. Consequently, the key points of discussion derived from the present thesis are summarised below.

7.2.1 Understanding the Sense of Agency in Eating Disorders

Using the multisensory *moving rubber hand illusion* paradigm, Chapter 2 showed that ED individuals and healthy females displayed no difference in their subjective sense of agency towards a fake hand, when movements were synchronous with their own. Whilst previous research has highlighted that ED individuals show a stronger illusory experience of ownership during the 'classic' rubber hand illusion, findings within the present thesis suggest that the stability of sense of agency remains preserved amongst ED individuals during action. Nevertheless, conclusions made within Chapter 2 are based on the paradigm that was used, which measured an explicit, self-reported judgement of agency at a conceptual level (Synofzik, Vosgerau, & Newen, 2008a). Other paradigms which investigate agency employ implicit measures which capture the non-conceptual 'feeling of agency' arising from sensorimotor processes due to efferent motor signals (Haggard, 2017). Within such paradigms, participants are not explicitly asked about their judgement of agency, but instead their agentic experience is inferred based on their performance in a specific task (Braun et al., 2018). The most commonly used implicit measures include sensory attenuation paradigms (Blakemore, Wolpert, & Frith, 1998), in which changes in the perceived intensity of sensory feedback are used to infer an individual's sense of agency; and intentional binding paradigms (Haggard, Clark, & Kalogeras, 2002), which refers to the subjective shift in the perception of time between a voluntary action and an external sensory outcome (Moore, 2016). Together, such implicit measures provide the opportunity to capture different constructs within the complex phenomenal structure of agency, in their contribution towards the stability of one's body image.

As outlined in Chapter 2 using the *Implicit Association Test* to measure body satisfaction, implicit paradigms allow researchers to exclude potential confounding factors associated with explicit responses such as demand characteristics, suggestibility, or compliance. Implicit agency has been investigated within other clinical groups, including schizophrenia (Renes et al., 2015; Voss et al., 2010; see Klaver & Dijkerman, 2016, for review) and functional movement disorders (Macerollo et al., 2015), which highlights the importance of studying this phenomenon in the context of health and well-being. However, to the author's knowledge, implicit agency is yet to be investigated within ED research. Therefore, whilst the present thesis observed no difference in the subjective experience of agency within the moving rubber hand illusion, future research should look to further explore the sense of agency within EDs to determine whether alterations might exist on an implicit level. It is speculated that altered implicit agency may indeed be present within EDs, given previous evidence observing disturbances in unconscious, body-scaled action within anorexia nervosa, which showed an escalated effect in patients' perceptual judgements regarding the passability of a door-like aperture (Guardia et al., 2010; Guardia, Conversy, et al., 2012; Keizer et al., 2013). Furthermore, research has shown that explicit and implicit measures of agency may be dissociable, and may thus represent different underlying mechanisms in their contribution towards a coherent body representation (Dewey & Carr, 2013; Moore, Middleton, Haggard, & Fletcher, 2012). Therefore, it would be interesting for future work to investigate whether explicit and implicit measures of agency are equally (un)affected amongst the ED population.

7.2.2 Interactive Functional Role of the Extrastriate Body Area

As a key neural region in the visual perception of bodies, the functional role of the extrastriate body area (EBA) was investigated in greater detail within Chapter 3, amongst healthy females. Importantly, functional and structural alterations have been previously highlighted within this region amongst ED patients, which provides important clinical implications to better understand the operational role of the EBA within visual body perception. A key strength of this experiment was the use of complimentary statistical analyses which assessed brain activation, namely univariate analysis and multi-voxel pattern analysis (MVPA). Both statistical techniques converged on the same findings to highlight the interaction, and distinct contributions between physical body attributes towards EBA activity. Specifically, the use of MVPA provides higher sensitivity to detect the patterns of activity within and between conditions, rather than averaged neural amplitude as shown by univariate analyses. Indeed, MVPA within Chapter 3 revealed distinct neural patterns in response to different the conditions of body stimuli, which implicates a more complex role for the EBA by highlighting its ability to discriminate between both the visual perspective and morphology of perceived bodies. Nevertheless, to better understand the distributed neural networks involved in the higher-order representation of human bodies, future research should examine the neural connectivity and interactions between the EBA and other brain regions, using fMRI analysis. For example, dynamic casual modelling is an analysis technique applied under a Bayesian framework, designed to measure the interaction between specific cortical regions in order to make inferences about their relationship during a specific context. Moreover, psychophysiological interaction analysis (PPI) similarly provides the opportunity to identify voxels which correlate with the activity in a seed region (e.g. EBA) following a certain psychological context, thus implicating functional connectivity between particular brain regions. Importantly, PPI analysis is a method for investigating changes in the relationship between neural response in different brain regions that are specific to the task.

Consequently, when considering the relationship between visual processing and higher-order socio-cognitive evaluations of bodies, the decision was made to not undertake PPI analysis within Chapter 3, given the design of the experiment in which participants performed an attentional (one-back recognition) task within the scanner, rather than making a cognitive appraisal of body stimuli. Indeed, recent fMRI research has shown no evidence of network connections between EBA and prefrontal networks when participants perform such attentional body-related tasks; however, when participants were required to form an impression of the perceived body, small effects of functional connectivity were observed between the EBA and temporal regions (Greven et al., 2018). Therefore, further investigation of functional integration in body perception could be undertaken by adapting the design of the task shown in Chapter 3. Specifically, participants could be exposed to a longer stimulus duration of slim vs. large bodies viewed from egocentric vs. allocentric perspectives, followed by explicit evaluation ratings of bodies made *within* the scanner. This would be designed to directly investigate the functional interplay between the perceptual properties of perceived bodies and its relationship with non-visual, higher-order representations following intentional, explicit evaluation of bodies, using PPI analysis. Such empirical work would help to better understand the neural trajectory between perceptual and cognitive-affective components of body image.

7.2.3 First-Person Visual Perspective Towards Embodiment

As outlined throughout the present thesis, an integral feature within one's self-consciousness is the invariable first-person visual perspective that we have of our own body. Not only does this visual perspective provide a unique perceptual experience of the self that is not available to others, but such an experience is incomparable with the perception of other's bodies, which can be viewed from multiple visual perspectives (e.g. from behind). Research has highlighted the importance of a first-person visual perspective within embodiment, with evidence that incoming multisensory information is coded optimally within egocentric (first-person) spatial reference frames (Petkova, Khoshnevis, et al., 2011; Slater et al., 2010). A key strength within the present thesis is the corroborative methodologies in which visual perspective was investigated, both neurally (Chapter 3) and behaviourally (Chapter 4).

Previous research has shown that activity in the EBA can be modulated by the visual perspective in which bodies are viewed (Chan et al., 2004; Saxe et al., 2006). Specifically, greater activation within the right EBA was previously observed when bodies were viewed from an allocentric (third-person) perspective. However, findings within the present thesis provide a more comprehensive approach by showing an increased EBA activation, bilaterally, when viewing bodies from an egocentric perspective. Furthermore, the activity of perceiving such a visual perspective interacted with the perceived morphology (i.e. size) of the body, which provides a more inclusive understanding of this neural region. Findings may suggest that increased EBA activation when viewing bodies from an egocentric visual perspective may be implicated in the sensation of body ownership and self-recognition, as such a perspective is congruent with the perspective in which an individual would typically perceive their own body. Indeed, whilst previous research has argued that the EBA does not discriminate between self and other's bodies (Chan et al., 2004), more recent work has observed differential EBA response between one's own body compared with another's (Vocks et al., 2010). Therefore, future research should expand upon the findings from Chapter 3 by further investigating the interactive role of visual perspective and body morphology, specifically how the two may present different neuronal responses when processing bodies of the self vs. another's body. Importantly, such investigation may have important clinical implications with regard to ED populations, in which impaired reference frame processing (i.e. egocentric vs. allocentric) of one's own body has been implicated within the pathology of the disorder (Riva, 2012) and may thus influence the perceptual experience of one's body image (see further discussion below).

Furthermore, in Chapter 4 the importance of first-person visual perspective towards body ownership was further highlighted by showing that subjective embodiment of a whole body can be induced to some degree by mere congruency of visual and proprioceptive body signals. Whilst previous research has shown that synchronous visuotactile stimulation and a humanoid shape alone are not sufficient to elicit ownership towards a body (Blanke, 2012), findings within Chapter 4 are the first to directly investigate the role of mere first-person visual perspective towards ownership of a whole mannequin body. Overall, this finding supports previous research which has used typical visuotactile stimulation within the full body illusion (Petkova, Khoshnevis, et al., 2011), in suggesting that the visual perspective is an integral factor towards whole body ownership. Furthermore, such evidence highlights that the salience of first-person visual perspective could be sufficient to induce embodiment, particularly amongst those who might assign more weight to visual input compared with other sensory body information. Therefore, a key outcome of this finding may inform future research which uses multisensory integration paradigms, in underpinning the need to first record a baseline measure of embodiment due to visuoproprioceptive signals, before the additive effect of embodiment following synchronous visuotactile stimulation. Taken together, Chapters 3 and 4 highlight the importance of visual perspective in the representation of bodies, observing distinct patterns of neural activity in response to different visual perspectives, and underlining how the first-person visual perspective is an integral factor within embodiment and body self-consciousness.

7.2.4 Social Influence of Affective Touch

Across all experimental chapters within the present thesis (Chapters 2-5), data were collected for female participants only. This decision was made to maintain coherence in the justification and interpretation of empirical work within the experimental chapters, given the qualitative difference in body ideals and ED expression between females and males within Western society (Mitchison & Mond, 2015). Moreover, a greater prevalence of clinical EDs and ED vulnerability is widely reported to be higher amongst females compared with males (Smith et al., 2017; Striegel-Moore, Rosselli, Perrin, DeBar, & Wilson, 2009), thus providing a larger population to target within the present empirical work. Indeed, whilst the importance of investigating ED psychopathology in males must not be underestimated, Chapter 6 highlights the consistently higher scores on the *Eating Disorder Examination Questionnaire* amongst females compared with males in the non-clinical population. Nevertheless, the decision to exclusively test female participants using a male experimenter must be considered in light of top-down, social influences of touch within Chapters 4 and 5. As discussed in Chapter 5, research has shown that the perception of CT-optimal, affective touch can be modulated by factors including the relationship with the touch provider (Gazzola et al., 2012; Scheele et al., 2014). Specifically, perceived pleasantness of touch has been shown to lead to autonomic changes (i.e. heart deceleration) and attenuation of pain perception within romantic couples (Krahé, Mohr, Gentsch, Guy, & Vari, 2018; Triscoli, Croy, Olausson, & Sailer, 2017). Importantly, the topography of acceptable social touching has been shown to be linearly dependent on the emotional bond with the touch provider (Suvilehto, Glerean, Dunbar, Hari, & Nummenmaa, 2015). Therefore, whilst perceived pleasantness of touch was shown to be greater following affective touch compared with non-affective touch within the present thesis, the degree to which perceived pleasantness from bottom-up, somatosensory information was attenuated by the social context of an unknown experimenter of the opposite sex was not directly measured.

Whilst previous studies have made explicit efforts to control for gender effects between participant and experimenter within studies investigating affective touch (Krahé et al., 2018; von Mohr, Kirsch, & Fotopoulou, 2017), the independent influence of top-down and bottom-up information towards the hedonic value of touch perception remains unclear (Ellingsen et al., 2016). Research has shown that male participants rated touch as more pleasant when they believed the touch was delivered by a female experimenter, compared with a male experimenter (Gazzola et al., 2012; Scheele et al., 2014); however, to the author's knowledge the reverse participant/experimenter gender effect has not been explored. Therefore, future research could systematically investigate how the perceived pleasantness of touch based on somatosensory information may be mitigated by the social context within which it is received (Keizer et al., 2017). Specifically, this could be investigated between-gender and within-gender, to determine the role of top-down vs. bottom-up factors in influencing the perception of touch.

7.2.5 Measure of Eating Disorder Psychopathology

As discussed in Chapter 6, the *Eating Disorder Examination Questionnaire* (EDE-Q) is a widely used measure of disordered eating behaviours and attitudes, with many researchers regarding it as a valuable assessment tool to evaluate those at risk for EDs (Quick & Byrd-Bredbenner, 2013). Consequently, the EDE-Q was used throughout all experimental chapters within the present thesis to assess whether individual differences in perceptual body-related tasks would be modulated by ED psychopathology within clinical (Chapter 2) and non-clinical (Chapters 3-5) samples. However, despite previous research highlighting relationships between body-related perception and non-clinical ED psychopathology (Preston & Ehrsson, 2014, 2016, 2018), no significant relationships were observed between EDE-Q scores and behavioural measures amongst non-clinical samples (Chapters 3-5) within the present thesis. No such relationship may reflect a lack of variation in EDE-Q scores across each experimental sample, as all non-clinical participants that were recruited were healthy females who had no current or previous psychological conditions. However, yielding false negative results is an unlikely outcome, given the consistent lack of relationship between EDE-Q scores and multiple experimental measures within the present thesis. Furthermore, previous research has observed relationships between affective components of body image with ED psychopathology amongst samples with a smaller variance in EDE-Q scores (Preston & Ehrsson, 2014, 2016, 2018).

Alternatively, the lack of relationship between non-clinical ED psychopathology and measures of body image within the present thesis may represent aspects of bodily experience that are a consequence of a clinical ED diagnosis, and do not act as a direct risk factor towards disturbances within one's body image amongst the healthy population. Indeed, previous research which *has* observed significant relationships with non-clinical ED psychopathology have manipulated direct, explicit bodily experiences such as perceived body size (i.e. slimmer/larger body), which is likely to induce more salient emotional changes related to ED psychopathology (Preston & Ehrsson, 2014, 2016, 2018). In comparison, the measures within the present thesis captured more indirect aspects of bodily experience (i.e. visual capture of embodiment, perception of touch) which are argued to be implicated within clinical EDs, but do not appear to be predisposing factors for a clinical ED diagnosis. Therefore, findings within the present thesis provide important implications towards body image and its disturbances, by dissociating aspects of perceptual and cognitive-affective components of body image that are implicated as risk factors for an ED from those which may be a consequence, or by-product of the disorder.

Importantly, as shown in Chapter 6, rigorous assessment of the psychometric properties of the EDE-Q measure suggested that the original four-factor structure was sub-optimal amongst non-clinical samples. Furthermore, exploratory factor analysis showed that certain EDE-Q items did not load adequately onto any one factor, and were subsequently removed within this chapter in order to determine an optimal factor structure with such samples. This suggests that a number of questionnaire items may be superfluous in the assessment of disordered eating attitudes, despite such items currently contributing to the currently-used global EDE-Q score. This is particularly important with regard to *Shape Concern* and *Weight Concern* items, which appear to be interpreted as qualitatively equivalent within non-clinical samples (see Chapter 6), and regarded as more general body image concerns. Therefore, such focus on body image concerns might be over-inflating the scores which contribute to the current global EDE-Q score, with the lack of relationship between behavioural results and the ED psychopathology potentially due to the unsupported four-factor structure which informs the current global EDE-Q. Consequently, behavioural measures within the present thesis were re-analysed using the new three-factor EDE-Q structure outlined in Chapter 6, to determine whether the new model would lead to significant relationships between such behavioural measures and ED psychopathology. However, non-significant correlation results remain unchanged when using the three-factor EDE-Q structure, which suggests that the observed lack of relationship was not a consequence of the EDE-Q measure. Instead, this supports the hypothesis that alterations within the measures of body image investigated within the present thesis may represent aspects of bodily experience that are a consequence of a clinical ED diagnosis, and may not be a risk factor towards body image disturbances amongst the healthy population. As disordered eating behaviours are strongly linked with physical and psychological well-being, it is important that ED psychopathology is accurately measured within non-clinical samples, not only to identify risk factors for the disorder, but to inform health-related prevention programmes prior to any adverse health outcomes which are associated with a clinical diagnosis.

Overall, given its wide use as an assessment tool amongst clinicians and researchers, the EDE-Q was chosen as a reliable standardized measure to evaluate ED psychopathology across all experimental chapters within the present thesis. However, as shown in Chapter 6, such an assessment tool may require modification following empirically determined evaluation of its psychometric properties within the present thesis. Specifically, such modification should reflect up-to-date diagnostic criteria which spans across the broader pathology of EDs, and account for the changes over time towards body image attitudes and body ideals within females and males. This is likely to lead to more appropriate diagnoses for clinical populations, and a more accurate proxy of ED psychopathology within non-clinical samples.

7.3 Future Directions

In addition to the above discussion which offers novel ideas for future research in light of findings with the present thesis, the broader scope for future directions towards the understanding and treatment of body image and its disturbances within EDs are briefly discussed below.

7.3.1 The Use of Virtual and Augmented Reality in the Treatment of Body Image

The use of three-dimensional, multisensory illusion paradigms to investigate body image has been a valuable method afforded to researchers in recent years. With the rapid progression and availability of modern technology, immersive virtual and augmented-reality techniques (e.g. Oculus Rift) are becoming an increasingly popular and cost-efficient tool to investigate body perception, providing a non-invasive approach to accurately manipulate sensory input and measure perceptual and emotional changes (Gardner & Brown, 2014). Using such experimental techniques, previous research has been able to modulate the size and appearance of the owned body (part), and establish a direct link between perceptual and emotional changes related to the body amongst healthy individuals (Ehrsson, Kito, Sadato, Passingham, & Naito, 2005; Hagman et al., 2015; Preston & Ehrsson, 2014, 2016, 2018).

Indeed, Normand et al. (2011) provided evidence that participants temporarily perceived their own stomach to be larger following synchronous visuotactile stimulation of a virtual body with a larger stomach (see also, Piryankova et al., 2014, for similar methodology). This shows that despite a typically stable body representation amongst healthy individuals, multisensory techniques can, to some degree, temporarily change the perception of body size and thus body satisfaction.

Additionally, such techniques have been used within research (Keizer et al., 2016; Serino et al., 2016) and in the treatment (Gutiérrez-Maldonado, Ferrer-García, Dakanalis, & Riva, 2017; Gutiérrez-Maldonado, Wiederhold, & Riva, 2015) of body image disturbances within the clinical ED population, which have provided short-term efficacy in improving such altered perception to date (Serino & Dakanalis, 2017). Nevertheless, the future scope of using such techniques provides a promising strategy to objectively determine the differences between one's perceived current body image compared with their ideal body image, and address any perceptual inaccuracies that patients may be experiencing within a controlled, experimental setting (Riva & Dakanalis, 2018). Taken together, the use of multisensory body illusions via virtual and augmented reality offers new insights into treatment interventions which could target perceptual body image disturbances amongst ED patients. From the above evidence, links between body perception and body satisfaction amongst healthy individuals and ED groups highlight the importance of perceptual and cognitive-affective relations with regard to body image. This strengthens the argument for treatments to use more neuroscientific, perceptual methodologies that target inaccurate body-related experiences, which can subsequently improve upon cognitive-affective outcomes (e.g. body dissatisfaction) within therapeutic programmes, which currently remain poor (Castellini et al., 2011). Despite some progress being made in treating EDs, it is widely agreed that there remains considerable room for improvement (Fairburn et al., 2009). Therefore, beyond a greater understanding of multisensory perception towards body image, such an experimental technique could offer useful clinical implications in targeting the separate routes of body representation with the aim to improve prognosis of the disorder.

7.3.2 Restoring Coherent Reference Frame Processing in Eating Disorders

Increasing research has proposed separate routes for updating the human body representation based on information from first-person and third-person perspectives (Riva, 2012). Indeed, evidence within Chapter 3 of the present thesis has shown how different visual perspectives of perceived bodies can modulate neural response within higher-order regions of visual cortex (EBA). Recent evidence has suggested that accurate updating of body perception can be achieved through viewing the body from a different visual angle, as an observer or using a mirror (Ehrsson, 2007; Jenkinson & Preston, 2015; Preston et al., 2015). For example, somatoparaphrenia patients, who deny ownership of their own limbs, show temporary restoration of limb ownership when viewing it in a mirror (Fotopoulou et al., 2011). This dissociation between visual perspectives has also been related to a neuroscientific model within ED research, regarding the *allocentric lock hypothesis* (Guardia et al., 2013; Riva, 2012). This hypothesis attempts to explain inaccuracies of body size perception observed in EDs, suggesting that patients' representations of their own body are based on inaccurate memories locked in an allocentric, third-person perspective which are not updated by bottom-up perception-driven input from an egocentric, first-person perspective (Riva & Gaudio, 2012; Serino et al., 2015). Thus, the processing and integration of egocentric (first-person) and allocentric (third-person) visual perspectives of the body may be problematic in maintaining a stable body representation within this population. Moreover, it is reported that some ED patients can recognize their emaciation when inadvertently viewing their reflection, but not when viewing their body from a normal first-person perspective (Espeset et al., 2012).

Consequently, using the techniques discussed above, future research should aim to experimentally modulate the visual perspective of the body with a view to improving ED patients' perceptual accuracy of their own body. One such method could provide individuals with an illusory experience of ownership over another human's body and view their own body as an observer, using the body swap illusion (Petkova & Ehrsson, 2008). In this experiment, participants sit directly opposite the experimenter whilst wearing a virtual reality headset connected to a stereo camera strapped to the experimenter's head. This enables participants to see a live video feed from the cameras which capture the experimenter's perspective, thus viewing their own physical body from an alternate visual angle. In illusion conditions, the participant and the experimenter squeeze each other's hands at the same time with participants typically reporting an illusory experience of being in the new body, i.e. the body of the experimenter (Petkova & Ehrsson, 2008). Consequently, the body swap illusion provides an alternative visual angle from which individuals can view their own body. Given the disturbed perceptual experience commonly observed amongst ED patients, viewing their own body from a different perspective may target a separate route in updating one's body representation (Marco, Perpiñá, & Botella, 2013). Indeed, as shown in Chapter 3, viewing bodies from a third-person (allocentric) visual perspective is processed differently from a first-person (egocentric) perspective within the brain. It would be anticipated that a third-person perspective of one's own body may provide patients with a more objective perception of their own body which could lead to an improved representation within the perceptual component of body image. If this is the case, such work could improve upon the understanding of body image disturbances within EDs and offer new insights for interventions and clinical treatment.

7.4 Conclusion

The present thesis investigated the role of perceptual and cognitive-affective components of body image, in relation to clinical EDs and non-clinical ED psychopathology. Body image was investigated using a multifaceted approach of behavioural, functional magnetic resonance imaging, and psychometric methods. Findings within the present thesis contributed to the research literature in ED groups, in supporting previous work which highlights the malleability of the bodily self within this clinical population. Crucially, novel findings showed that these individuals also display a deeply-rooted, lower implicit body satisfaction compared with healthy females, which can have important clinical implications within treatment and prognosis within the disorder. The importance of visual perspective was a central theme throughout the thesis, with findings showing that the first-person and third-person perspective of bodies display different patterns of neural response within the visual cortex of the brain, amongst healthy females. Moreover, the role of the first-person visual perspective was shown to be a sufficient factor in inducing embodiment towards a whole mannequin body. Finally, assessment of ED psychopathology within the non-clinical population suggest that body image concerns do remain high, in which such assessment measures should aim to more accurately capture the broader spectrum of ED psychopathology in line with current diagnostic criteria and current attitudes towards body image.

Overall, in the context of historical research investigating clinical EDs and ED vulnerability, studying body image from a cognitive neuroscience perspective remains in its infancy. Moreover, studying multiple components of body image in the context of non-clinical ED psychopathology within healthy samples is essential in determining which aspects are implicated as risk factors within the pathology of the EDs, and which are a consequence of the physical and psychological effects of the disorder. Indeed, the current work provides an important contribution to the research literature by finding that indirect perceptual measures of body image such as functional EBA activity (Chapter 3), visual dominance of body-related information (Chapter 4), and subjective perception of touch (Chapter 4 & 5) show no relationship with ED psychopathology in non-clinical samples. Therefore, observed alterations within these perceptual measures amongst ED populations may be a consequence of the disorder, as there is presently no evidence to suggest that individual differences within such measures act as a predisposing factor for a clinical ED diagnosis. Together, the present thesis offers novel methods and insights into the investigation of body image within clinical and non-clinical populations, which can be built upon to inform future work within this research topic.

Appendices

A1. Chapter 2 Supplementary Material

Table S2.1 Additional Spearman's Rank correlations for perceptual and body satisfaction measures (N=50) (*p* values are uncorrected).

		Ownership Score Asynch	Agency Score Synch	Agency Score Asynch	Prop Drift Synch	Prop Drift Asynch	Baseline Hand Misestimation	Post Synch Misestimation	Post Asynch Misestimation	State Body Satisfaction	IAT Comp	IAT Incomp	IAT D Score
Ownership Score Synch	Correlation Coefficient	.258	.304*	.035	.081	.074	-.175	-.226	-.090	.003	-.287*	-.009	.324*
	p value	.071	.032	.811	.575	.607	.225	.115	.533	.984	.044	.952	.022
Ownership Score Asynch	Correlation Coefficient		-.009	.438**	-.020	-.159	-.403**	-.305*	-.246	.127	-.093	-.017	.107
	p value		.949	.001	.889	.269	.004	.031	.085	.378	.523	.907	.461
Agency Score Synch	Correlation Coefficient			.122	.020	.070	.018	.071	.070	-.038	-.127	-.091	.093
	p value			.398	.893	.628	.902	.626	.628	.791	.381	.530	.521
Agency Score Asynch	Correlation Coefficient				.076	-.095	-.232	.041	.118	.255	-.050	.151	.164
	p value				.602	.512	.106	.776	.412	.074	.729	.296	.255
Prop Drift Synch	Correlation Coefficient					.088	.250	.056	.134	.042	-.266	.072	.303*
	p value					.541	.080	.699	.353	.770	.062	.620	.032
Prop Drift Asynch	Correlation Coefficient						-.063	-.062	.007	-.034	-.131	-.080	-.003
	p value						.663	.669	.960	.817	.364	.580	.985
Baseline Hand Misestimation	Correlation Coefficient							.633**	.526**	-.195	.051	-.036	-.070
	p value							.000	.000	.175	.728	.804	.629
Post Synch Misestimation	Correlation Coefficient								.804**	-.088	.200	.022	-.152
	p value								.000	.543	.164	.881	.293
Post Asynch Misestimation	Correlation Coefficient									-.060	.155	.051	-.120
	p value									.677	.281	.723	.407
State Body Satisfaction	Correlation Coefficient										-.344*	.101	.455**
	p value										.014	.485	.001
IAT Comp	Correlation Coefficient											.542**	-.426**
	p value											.000	.002
IAT Incomp	Correlation Coefficient												.447**
	p value												.001

Table S2.2 Additional Spearman's Rank correlations for perceptual and body satisfaction measures within the ED group (N=26) (*p* values are uncorrected).

		Ownership Score Asynch	Agency Score Synch	Agency Score Asynch	Prop Drift Synch	Prop Drift Asynch	Baseline Hand Misestimation	Post Synch Misestimation	Post Asynch Misestimation	State Body Satisfaction	IAT Comp	IAT Incomp	IAT D Score
Ownership Score Synch	Correlation Coefficient	.139	.364	-.243	.064	.246	-.037	-.047	-.049	.254	-.323	.127	.457*
	p value	.499	.067	.233	.757	.227	.858	.819	.813	.211	.108	.538	.019
Ownership Score Asynch	Correlation Coefficient		-.102	.198	-.070	-.281	-.388	-.272	-.349	.159	-.103	-.063	-.009
	p value		.619	.333	.733	.164	.050	.179	.080	.437	.618	.761	.967
Agency Score Synch	Correlation Coefficient			.003	.184	-.021	.159	.026	.124	-.182	-.095	-.053	.213
	p value			.987	.368	.919	.438	.898	.547	.373	.646	.796	.296
Agency Score Asynch	Correlation Coefficient				.146	-.248	-.041	-.386	-.396*	.271	.057	.257	.123
	p value				.477	.221	.844	.051	.045	.180	.780	.206	.549
Prop Drift Synch	Correlation Coefficient					.160	.670**	.544**	.549**	-.058	-.474*	-.031	.443*
	p value					.435	.000	.004	.004	.778	.014	.879	.024
Prop Drift Asynch	Correlation Coefficient						.104	-.031	.040	.249	-.280	.007	.288
	p value						.612	.879	.848	.220	.165	.974	.154
Baseline Hand Misestimation	Correlation Coefficient							.728**	.763**	-.315	-.214	-.116	.144
	p value							.000	.000	.117	.294	.574	.482
Post Synch Misestimation	Correlation Coefficient								.913**	-.360	-.177	-.002	.187
	p value								.000	.071	.388	.991	.361
Post Asynch Misestimation	Correlation Coefficient									-.395*	-.157	-.062	.143
	p value									.046	.443	.764	.486
State Body Satisfaction	Correlation Coefficient										.132	.463*	.292
	p value										.520	.017	.148
IAT Comp	Correlation Coefficient											.389*	-.636**
	p value											.049	.000
IAT Incomp	Correlation Coefficient												.380
	p value												.056

Table S2.3 Additional Spearman's Rank correlations for perceptual and body satisfaction measures within the HC group (N=24) (*p* values are uncorrected).

		Ownership Score Asynch	**Agency Score Synch**	**Agency Score Asynch**	**Prop Drift Synch**	**Prop Drift Asynch**	**Baseline Hand Misestimation**	**Post Synch Misestimation**	**Post Asynch Misestimation**	**State Body Satisfaction**	**IAT Comp**	**IAT Incomp**	**IAT D Score**
Ownership Score Synch	Correlation Coefficient	.361	.256	.316	.138	-.009	-.306	-.041	-.238	-.300	-.312	-.034	.262
	p value	.083	.227	.132	.521	.966	.146	.849	.262	.154	.137	.874	.217
Ownership Score Asynch	Correlation Coefficient		.116	.753**	-.032	.036	-.489*	-.288	-.288	-.020	.038	.101	.179
	p value		.589	.000	.881	.868	.015	.172	.173	.927	.860	.639	.402
Agency Score Synch	Correlation Coefficient			.267	-.118	.204	-.135	-.181	-.271	.176	-.282	-.104	.058
	p value			.207	.583	.339	.531	.398	.201	.409	.183	.628	.788
Agency Score Asynch	Correlation Coefficient				-.050	.096	-.419*	-.329	-.439*	.218	-.006	.068	.141
	p value				.815	.657	.041	.117	.032	.306	.979	.751	.512
Prop Drift Synch	Correlation Coefficient					.089	-.281	-.317	-.250	-.212	.013	.219	.234
	p value					.680	.183	.132	.238	.321	.953	.304	.271
Prop Drift Asynch	Correlation Coefficient						-.228	-.197	-.081	-.057	-.184	-.211	-.250
	p value						.285	.357	.707	.793	.390	.321	.239
Baseline Hand Misestimation	Correlation Coefficient							.716**	.751**	-.126	.224	.013	-.261
	p value							.000	.000	.557	.293	.950	.218
Post Synch Misestimation	Correlation Coefficient								.829**	-.270	-.138	-.334	-.334
	p value								.000	.202	.521	.110	.111
Post Asynch Misestimation	Correlation Coefficient									-.410*	-.027	-.228	-.286
	p value									.047	.902	.285	.176
State Body Satisfaction	Correlation Coefficient										-.184	-.080	.027
	p value										.388	.709	.899
IAT Comp	Correlation Coefficient											.732**	.100
	p value											.000	.642
IAT Incomp	Correlation Coefficient												.663**
	p value												.000

Table S2.4 Additional Spearman's Rank correlations for perceptual measures and ED psychopathology (N=50) (*p* values are uncorrected).

		BMI	Restraint	Eating Concern	Shape Concern	Weight Concern	Global EDEQ
Ownership Score Synchronous	Correlation Coefficient	.044	.136	.092	-.016	-.044	.050
	p value	.765	.347	.525	.913	.764	.731
Ownership Score Asynchronous	Correlation Coefficient	.147	.063	-.110	-.104	-.070	-.053
	p value	.313	.666	.448	.473	.628	.716
Agency Score Synchronous	Correlation Coefficient	.071	.009	-.037	.122	.072	.059
	p value	.626	.951	.800	.400	.621	.685
Agency Score Asynchronous	Correlation Coefficient	-.018	-.042	-.054	-.066	-.071	-.060
	p value	.902	.773	.710	.648	.623	.679
Proprioceptive Drift Synchronous	Correlation Coefficient	.056	.169	.088	.049	.039	.081
	p value	.704	.240	.543	.735	.790	.576
Proprioceptive Drift Asynchronous	Correlation Coefficient	.047	.329*	.235	.120	.117	.209
	p value	.751	.020	.100	.408	.417	.146
Baseline Hand Misestimation	Correlation Coefficient	-.097	.145	.094	.198	.197	.184
	p value	.509	.314	.516	.169	.171	.201
Post Synchronous Hand Misestimation	Correlation Coefficient	-.060	.067	.067	.086	.087	.091
	p value	.684	.643	.646	.555	.549	.528
Post Asynchronous Hand Misestimation	Correlation Coefficient	-.132	.103	.126	.099	.094	.111
	p value	.366	.475	.383	.496	.518	.445

Table S2.5 Additional Spearman's Rank correlations for perceptual measures and ED psychopathology within the ED group (N=26) (*p* values are uncorrected).

		BMI	Restraint	Eating Concern	Shape Concern	Weight Concern	Global EDEQ
Ownership Score Synchronous	Correlation Coefficient	-.178	.135	.025	-.304	-.390*	-.098
	p value	.395	.511	.903	.132	.049	.633
Ownership Score Asynchronous	Correlation Coefficient	.324	.131	-.203	-.184	.004	-.040
	p value	.114	.524	.320	.369	.985	.844
Agency Score Synchronous	Correlation Coefficient	.265	-.150	-.136	.120	.101	-.044
	p value	.200	.466	.509	.560	.623	.830
Agency Score Asynchronous	Correlation Coefficient	.028	.048	.050	.039	.161	.066
	p value	.895	.814	.807	.850	.432	.750
Proprioceptive Drift Synchronous	Correlation Coefficient	-.001	.294	.094	.033	.141	.169
	p value	.997	.145	.646	.871	.491	.409
Proprioceptive Drift Asynchronous	Correlation Coefficient	.057	.236	.163	-.234	-.160	.020
	p value	.788	.246	.426	.250	.434	.923
Baseline Hand Misestimation	Correlation Coefficient	-.187	.271	.070	.342	.249	.299
	p value	.372	.180	.735	.087	.220	.138
Post Synchronous Hand Misestimation	Correlation Coefficient	-.105	.090	-.019	.195	.096	.069
	p value	.619	.662	.927	.340	.640	.738
Post Asynchronous Hand Misestimation	Correlation Coefficient	-.033	.044	.008	.250	.143	.101
	p value	.874	.831	.967	.219	.486	.625

Table S2.6 Additional Spearman's Rank correlations for perceptual measures and ED psychopathology within the HC group (N=24) (*p* values are uncorrected).

		BMI	Restraint	Eating Concern	Shape Concern	Weight Concern	Global EDEQ
Ownership Score Synchronous	Correlation Coefficient	.446*	.195	.176	.211	.153	.214
	p value	.029	.360	.411	.321	.475	.315
Ownership Score Asynchronous	Correlation Coefficient	-.172	.328	.156	.148	.028	.195
	p value	.421	.117	.467	.492	.898	.361
Agency Score Synchronous	Correlation Coefficient	-.148	.057	-.199	.103	.011	.051
	p value	.489	.790	.350	.633	.958	.812
Agency Score Asynchronous	Correlation Coefficient	-.171	.141	.168	.071	.007	.119
	p value	.424	.511	.434	.741	.976	.578
Proprioceptive Drift Synchronous	Correlation Coefficient	.162	.348	.431*	.341	.166	.320
	p value	.450	.095	.035	.103	.439	.128
Proprioceptive Drift Asynchronous	Correlation Coefficient	.165	.246	.032	.116	.115	.192
	p value	.440	.247	.881	.590	.592	.368
Baseline Hand Misestimation	Correlation Coefficient	.121	-.102	-.139	.008	.115	-.038
	p value	.572	.635	.517	.971	.592	.861
Post Synchronous Hand Misestimation	Correlation Coefficient	.262	.033	-.070	.188	.410*	.189
	p value	.217	.878	.744	.379	.046	.376
Post Asynchronous Hand Misestimation	Correlation Coefficient	.078	-.013	-.128	.037	.167	.034
	p value	.716	.952	.550	.863	.435	.875

Table S2.7 Additional Spearman's Rank correlations for body satisfaction measures and ED psychopathology (N=50) (*p* values are uncorrected).

		BMI	Restraint	Eating Concern	Shape Concern	Weight Concern	Global EDEQ
State Body Satisfaction	Correlation Coefficient	.019	-.620**	-.726**	-.809**	-.803**	-.794**
	p value	.895	.000	.000	.000	.000	.000
IAT Compatible Trials	Correlation Coefficient	-.097	.203	.223	.308*	.298*	.262
	p value	.509	.158	.119	.030	.036	.066
IAT Incompatible Trials	Correlation Coefficient	-.124	.077	.060	-.077	-.042	-.028
	p value	.398	.596	.677	.596	.770	.847
IAT D Score	Correlation Coefficient	.051	-.186	-.198	-.465**	-.409**	-.353*
	p value	.727	.196	.169	.001	.003	.012
BMI	Correlation Coefficient		-.229	-.131	-.028	.088	-.087
	p value		.113	.370	.851	.547	.553
Restraint	Correlation Coefficient			.802**	.707**	.746**	.886**
	p value			.000	.000	.000	.000
Eating Concern	Correlation Coefficient				.819**	.812**	.920**
	p value				.000	.000	.000
Shape Concern	Correlation Coefficient					.936**	.932**
	p value					.000	.000
Weight Concern	Correlation Coefficient						.943**
	p value						.000
Global EDEQ	Correlation Coefficient						
	p value						

Table S2.8 Additional Spearman's Rank correlations for body satisfaction measures and ED psychopathology within the ED group (N=26) (*p* values are uncorrected).

		BMI	Restraint	Eating Concern	Shape Concern	Weight Concern	Global EDEQ
State Body Satisfaction	Correlation Coefficient	-.161	.028	-.189	-.693**	-.538**	-.408*
	p value	.441	.893	.354	.000	.005	.038
IAT Compatible Trials	Correlation Coefficient	.000	-.274	-.382	-.036	-.117	-.268
	p value	1.000	.175	.054	.863	.569	.185
IAT Incompatible Trials	Correlation Coefficient	-.117	-.049	-.114	-.345	-.238	-.287
	p value	.578	.811	.578	.084	.243	.155
IAT D Score	Correlation Coefficient	.062	.183	.298	-.295	-.050	.016
	p value	.767	.372	.139	.143	.810	.937
BMI	Correlation Coefficient		-.252	.103	.240	.462*	.145
	p value		.224	.623	.248	.020	.489
Restraint	Correlation Coefficient			.494*	.027	.268	.686**
	p value			.010	.897	.185	.000
Eating Concern	Correlation Coefficient				.367	.542**	.807**
	p value				.065	.004	.000
Shape Concern	Correlation Coefficient					.806**	.644**
	p value					.000	.000
Weight Concern	Correlation Coefficient						.780**
	p value						.000
Global EDEQ	Correlation Coefficient						
	p value						

Table S2.9 Additional Spearman's Rank correlations for body satisfaction measures and ED psychopathology within the HC group (N=24) (*p* values are uncorrected).

		BMI	Restraint	Eating Concern	Shape Concern	Weight Concern	Global EDEQ
State Body Satisfaction	Correlation Coefficient	-.317	-.468*	-.263	-.402	-.353	-.398
	p value	.131	.021	.215	.051	.091	.054
IAT Compatible Trials	Correlation Coefficient	-.104	.183	.008	.078	.089	.075
	p value	.629	.393	.972	.716	.679	.728
IAT Incompatible Trials	Correlation Coefficient	-.031	.178	.192	-.044	-.023	.024
	p value	.886	.407	.369	.840	.916	.910
IAT D Score	Correlation Coefficient	-.010	.103	.181	-.261	-.211	-.124
	p value	.965	.634	.398	.217	.323	.563
BMI	Correlation Coefficient		.219	.080	.112	.316	.190
	p value		.304	.711	.601	.132	.375
Restraint	Correlation Coefficient			.436*	.741**	.699**	.852**
	p value			.033	.000	.000	.000
Eating Concern	Correlation Coefficient				.596**	.373	.631**
	p value				.002	.073	.001
Shape Concern	Correlation Coefficient					.841**	.949**
	p value					.000	.000
Weight Concern	Correlation Coefficient						.895**
	p value						.000
Global EDEQ	Correlation Coefficient						
	p value						

Results – Anorexia Nervosa (AN) Patents (N=18) vs. Healthy Controls (N=24)

A1.1 Moving Rubber Hand Illusion

A1.1.1 Questionnaire

A Wilcoxon signed-rank test revealed that illusory ownership was induced for both the AN group (Z = -3.36, 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, the effect of visuomotor synchrony was investigated by comparing synchronous vs. asynchronous ownership scores. A further Wilcoxon signed-rank test revealed a significant effect of synchrony for both the AN group (Z = -3.62, p < .001, r = .85) and HC group (Z = -4.29, p < .001, r = .88), with higher ownership scores following synchronous compared with asynchronous conditions. Finally, a Mann-Whitney U test revealed no significant difference between groups following synchronous conditions (U = 206.50, Z = -.24, p = .808, r = .04) or asynchronous conditions (U = 176.50, Z = -1.01, p = .313, r = .16), which suggests that AN patients and HC displayed the same subjective experience of ownership towards the fake hand.

The same analyses were conducted for agency scores. A Wilcoxon signed-rank test revealed that illusory agency was induced for both the AN group (Z = -3.73, p < .001 r = .88) 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, the effect of visuomotor synchrony was tested by comparing synchronous vs. asynchronous agency scores. A further Wilcoxon signed-rank test revealed a significant effect of synchrony for both AN group (Z = -3.52, p < .001, r = .83) and HC group (Z = -4.20, p < .001, r = .86), with higher agency scores following synchronous compared with asynchronous conditions. Finally, a Mann-Whitney U test revealed no significant difference between groups following synchronous conditions (U = 214.00, Z = -.05, p = .959, r = .01) or asynchronous conditions (U = 159.50, Z = -1.44, p = .149, r =.22).

A1.1.2 Proprioceptive Drift

Following synchronous conditions, mean proprioceptive drift was 7.35 millimetres (mm) (SD ± 27.63) for the AN group, and 1.63 mm (SD ± 7.09) for the HC group. Following asynchronous conditions, mean proprioceptive drift was 5.04 mm (SD ± 17.92) for the AN group, and .38 mm (SD ± 5.03) 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 (AN group vs. HC group) as the between-subjects factor. No main effect of visuomotor synchrony was observed between synchronous and asynchronous conditions (F (1,40) = 2.19, p = .147, η_p^2 = .05). Moreover, no significant main effect of group was observed (F (1, 40) = .13, p = .721, η_p^2 = .00), and no interaction between visuomotor synchrony and group was observed (F (1, 40) = .893, p = .350, η_p^2 = .02).

A1.1.3 Hand size estimation

First, an independent samples t-test revealed that there was no significant difference in actual hand width (mm) between the AN group and the HC group (t (40) = -.55, p = .59, d = .09). Second, paired samples t-tests revealed that the width of the fake hand (74mm) was not significantly narrower compared with the actual hand width of the AN group (t (17) = -1.79, p = .092, d = .42), but was significantly narrower compared with the HC group (t (23) = -3.26, p = .003, d = .67). Finally, to directly test the hypothesis that AN 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. A paired samples t-test revealed that participants in the AN group significantly overestimated their own hand width, prior to the illusion (t (17) = -3.41, p = .003, d = .80). Additionally, a paired samples t-test revealed that 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 AN and HC groups (t (40) = 1.34, p = .189, d = .21).

Next, to directly test the hypothesis that AN 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 AN group, a one sample t-test revealed that participants reported a significantly lower hand size estimation following induction of the illusion, for both synchronous conditions (t (17) = 3.27, p = .005, d = .77) and asynchronous conditions (t (17) = 2.95, p = .009, d = .69). Interestingly, for the HC group, a one sample t-test revealed that 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).

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 AN group, paired samples t-tests revealed no significant differences between actual hand size and post-experimental estimations following synchronous (t (17) = -1.86, p = .081, d = .44) but estimations remained significantly different following asynchronous conditions (t (17) = -2.20, p = .042, d = .52). 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). Crucially, baseline estimations made prior to the illusion *were* significantly different from actual hand size, therefore the above non-significant result reflects a reduction in hand size estimation which is closer to participant's actual hand size.

A1.2 Body Satisfaction

A1.2.1 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 AN group and HC group. As predicted, the AN group reported a significantly lower state body satisfaction (median = 16.00) compared with HC group (median = 63.00; U = 26.50, Z = -4.82, $p < .001$, r = .74).

A1.2.2 Implicit Body Satisfaction

To directly test the hypothesis that the AN 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 AN group (mean = .12) compared with the HC group (mean = .90; t (21.88) = -2.77, $p = .011$, $d = .44$).

To further investigate whether AN individuals show a reduced implicit 'self-serving bias' towards their body satisfaction 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 (AN group vs. HC group) as the between-subjects factor. A main effect of condition was observed (F (1,40) = 16.55, $p < .001$, $\eta_p^2 = .29$), with significant lower reaction times following compatible vs. incompatible conditions. No main effect of group was observed (F (1, 40) = 2.15, p = .151, $\eta_p^2 = .05$). However, a significant interaction was observed between condition and group (F (1, 40) = 9.52, $p = .004$, $\eta_p^2 = .19$). Thus, Bonferroni-corrected independent samples t-tests (critical α = .025) revealed a significant difference between groups following compatible (t (40) = 2.49, $p = .017$, d = .39), but not incompatible conditions (t (40) = .11, $p = .915$, $d = .02$).

A1.3 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=42). A Spearman's Rank correlation revealed a significant positive correlation between state body satisfaction and *D* scores on the IAT across the whole sample ($r = .47$, $p = .002$), which suggests 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 associated with 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 = -.39, p = .011) but not with incompatible trials (r = .05, p = .774).

A2. Chapter 3 Supplementary Material

A2.1 Functional Localizer - Region of Interest

Body-selective ROIs for EBA masks were defined by the bodies minus chairs contrast (Downing et al., 2007), with Z statistic images thresholded using clusters determined by Z > 3.1 and a (corrected) cluster significance threshold of $p = 0.05$.

Table A2.1 MNI co-ordinates of the peak voxel with each ROI for left and right EBA

Anatomical Region	MNI Co-ordinates			Cluster Size	Z Max	*p* value
	X	Y	Z			
Left EBA	-52	-78	6	218	5.37	0.000955
Right EBA	50	-70	0	736	5.39	3.64e-09

Whole Brain Analysis

Exploratory whole brain analysis for the chosen contrasts, based on the significant effects of our univariate analysis within EBA masks. fMRI data processing was carried out using FEAT (FMRI Expert Analysis Tool) Version 6.00, part of FSL (FMRIB's Software Library, www.fmrib.ox.ac.uk/fsl). For exploratory purposes, Z statistic images were thresholded using clusters determined by $Z > 2.6$ and a (corrected) cluster significance threshold of $p = 0.05$. Anatomical localization was identified using the three-dimensional atlas of neuroanatomy (Duvernoy, 2012).

Table A2.2 Contrast: Large Allocentric Body > Large Egocentric Body

Anatomical Region	**Hemisphere**	**MNI Co-ordinates**			**Cluster Size**	**Z Max**	***p* value**
		X	**Y**	**Z**			
Occipital Fusiform Gyrus/ Middle Occipital Gyrus	Right	30	-88	-12	18826	7.44	0
Inferior Frontal Gyrus	Right	46	14	24	9615	5.61	1.29E-37
Lateral orbital gyrus	Left	-48	42	0	5931	5.14	5.6E-27
Superior Temporal Gyrus	Right	56	-44	8	4685	5.21	6.63E-23

Table A2.3 Contrast: Slim Egocentric Body > Slim Allocentric Body

Anatomical Region	Hemisphere	MNI Co-ordinates			Cluster Size	Z Max	*p* value
		X	Y	Z			
Temporal Occipital Fusiform Cortex	Left	-36	-50	-22	2386	5.52	6.36E-13
Occipital Fusiform Gyrus	Right	42	-62	-12	2042	5.42	1.49E-11
Occipital Pole	Right	18	-94	6	1184	6.82	6.7E-11
Superior Parietal Lobule	Left	-32	-54	54	1181	5.21	1.19E-07
Occipital Pole	Left	-12	-96	6	476	6.56	0.00088
Middle Temporal Gyrus	Right	62	-6	-28	297	4.37	0.0166
Superior Parietal Lobule	Right	28	-46	36	244	4	0.0435

Table A2.4 Contrast: Large Allocentric Body > Slim Allocentric Body

Anatomical Region	Hemisphere	MNI Co-ordinates			Cluster Size	Z Max	*p* value
		X	Y	Z			
Superior Occipital Gyrus	Left	-12	-94	-6	21347	5.87	0
Temporal Occipital Fusiform Cortex	Left	-38	-52	-24	5083	6.16	2.27E-23
Inferior Frontal Gyrus	Left	-42	42	4	3354	4.7	1.79E-17
Superior Frontal Gyrus	Left	-8	26	46	1408	4.18	2.33E-09
Inferior Frontal Gyrus	Right	44	12	22	1124	4.51	5.96E-08

Whole Brain Analysis: Relationship between fMRI and Behavioural Responses

Exploratory whole brain analysis for Large Allocentric > Large Egocentric contrast with corresponding behavioural attractiveness difference rating added into the model as a covariate. fMRI data processing was carried out using FEAT (FMRI Expert Analysis Tool) Version 6.00, part of FSL (FMRIB's Software Library, www.fmrib.ox.ac.uk/fsl). Z statistic images were thresholded using clusters determined by Z > 2.6 and a (corrected) cluster significance threshold of $p = 0.05$.

Table A2.5 Contrast: Large Allocentric Body > Large Egocentric Body with corresponding behavioural covariate (attractiveness ratings)

Anatomical Region	Hemisphere	MNI Co-ordinates			Cluster Size	Z Max	*p* value
		X	Y	Z			
Superior frontal gyrus	Right	32	22	46	361	3.8	0.00247

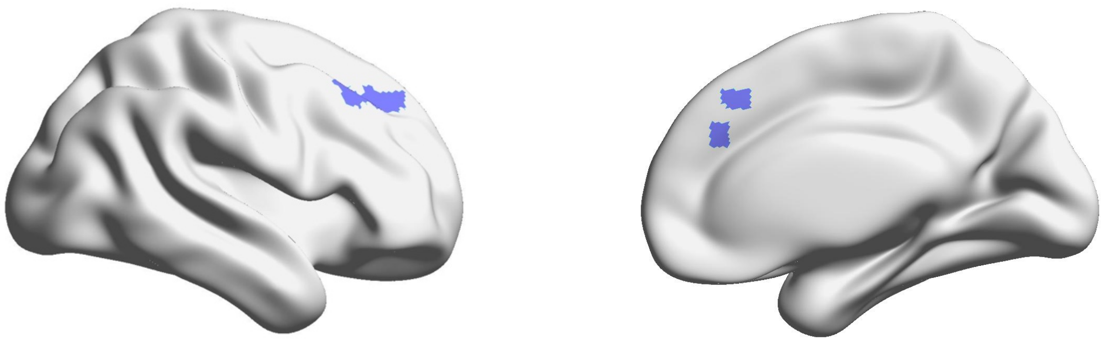

Figure A2.1 Whole brain correlation analysis between Large Allocentric Body > Large Egocentric Body contrast and corresponding behavioural attractiveness ratings. Peak voxel of significant cluster (Right Hemisphere) can be viewed in Table A2.5.

A3. Chapter 4 Supplementary Material

A3.1 Results - Experiment 1

A3.1.1 Embodiment Questionnaire - Ownership Sub-component Analysis

Preliminary analysis showed that there was no effect of trial order across visual capture trials, with a Wilcoxon signed-rank test revealing no significant difference in *Ownership* scores between visual capture trial 1 vs. trial 2 (Z = - .825, p = .409). Therefore, *Ownership* questionnaire scores were collapsed across the two visual capture trials to provide an overall *Ownership visual capture* score, per participant.

A3.1.1.1 Main effect: Visual Capture

To examine the effects of mere visual capture towards subjective ownership of the mannequin body, we compared *Ownership* scores with *Control* scores in the *embodiment questionnaire*. A Wilcoxon signed-rank test revealed a main effect of visual capture, with significantly higher *Ownership* scores compared with *Control* scores (Z = -2.64, p = .008, r = 42).

A3.1.1.2 Main effect: Tactile Disruption

In order to determine whether tactile disruption to participants' own unseen arm would disrupt subjective ownership, we compared *Ownership* scores between *tactile disruption* and *visual capture* conditions. A Wilcoxon signed-rank test revealed a main effect of condition, in which participants showed significantly lower subjective ownership following *tactile disruption* trials (median = -1.17) compared with *visual capture* trials (median = .33) (Z = -3.88, p < .001, r = .61).

A3.1.1.3 Main effect: Tactile Velocity

Next, we examined whether tactile velocity had an effect in disrupting the subjective ownership towards the mannequin body within *tactile disruption* trials. A Wilcoxon signed-rank test revealed that there was no significant difference in *Ownership* scores between affective and non-affective tactile disruption trials (Z = -.309, p = .757, r = .05), which suggests that interoceptive affective touch did not disrupt visual capture of ownership to a greater degree than exteroceptive, non-affective touch.

A3.1.2 Embodiment Questionnaire - Location Sub-component Analysis

Preliminary analysis showed that there was no effect of trial order across visual capture trials, with a Wilcoxon signed-rank test revealing no significant difference in *Location* scores between visual capture trial 1 vs. trial 2 (Z = - 1.60, p = .111). Therefore, *Location* questionnaire scores were collapsed across the two visual capture trials to provide an overall *visual capture Location* score, per participant.

A3.1.2.1 Main effect: Visual Capture

To examine the effects of mere visual capture towards subjective ownership of the mannequin body, we compared *Location* scores with *Control* scores in the *embodiment questionnaire*. A Wilcoxon signed-rank test revealed a main effect of visual capture, with significantly higher *Location* scores compared with *Control* scores (Z = -5.33, p < .001, r = 84).

A3.1.2.2 Main effect: Tactile Disruption

In order to determine whether tactile disruption to participants' own unseen arm would disrupt subjective location, we compared *Location* scores between *tactile disruption* and *visual capture* conditions. A Wilcoxon signed-rank test revealed a main effect of condition, in which participants showed significantly lower felt location towards the mannequin following *tactile disruption* trials (median = 1.25) compared with *visual capture* trials (median = 2.00) (Z = -2.59, p = .01, r = .41).

A3.1.2.3 Main effect: Tactile Velocity

Next, we examined whether tactile velocity had an effect in disrupting the subjective location that participants felt within *tactile disruption* trials. A Wilcoxon signed-rank test revealed that there was no significant difference in *Location* scores between affective and non-affective tactile disruption trials (Z = -1.04, p = .300, r = .16), which suggests that interoceptive affective touch did not disrupt felt location to a greater degree than exteroceptive, non-affective touch.

A3.2 Results - Experiment 2

A3.2.1 Embodiment Questionnaire - Ownership Sub-component Analysis

Preliminary analysis showed that there was no effect of trial order across visual capture trials, with a Wilcoxon signed-rank test revealing no significant difference in *Ownership* scores between visual capture trial 1 vs. trial 2 (Z = - .651, p = .515). Therefore, *Ownership* questionnaire scores were collapsed across the two visual capture trials to provide an overall *Ownership visual capture* score, per participant.

A3.2.1.1 Main effect: Visual Capture

To examine the effects of mere visual capture towards subjective ownership of the mannequin body, we compared *Ownership* scores with *Control* scores in the *embodiment questionnaire*. A Wilcoxon signed-rank test revealed a main effect of visual capture, with significantly higher *Ownership* scores compared with *Control* scores (Z = -3.26, p = .001, r = 51).

A3.2.1.2 Main effect: Tactile Disruption

In order to determine whether tactile disruption to participants' own unseen arm would disrupt subjective ownership, we compared *Ownership* scores between *tactile disruption* and *visual capture* conditions. A Wilcoxon signed-rank test revealed a main effect of condition, in which participants showed significantly lower subjective ownership following *tactile disruption* trials (median = -.67) compared with *visual capture* trials (median = .25) (Z = -3.98, p < .001, r = .63).

A3.2.1.3 Main effect: Tactile Velocity

Next, we examined whether tactile velocity had an effect in disrupting the subjective ownership towards the mannequin body within *tactile disruption* trials. A Wilcoxon signed-rank test revealed that there was no significant difference in *Ownership* scores between affective and non-affective tactile disruption trials (Z = -.411, p = .681, r = .06), which suggests that interoceptive affective touch did not disrupt visual capture of ownership to a greater degree than exteroceptive, non-affective touch.

A3.2.2 Embodiment Questionnaire - Location Sub-component Analysis

Preliminary analysis showed that there was no effect of trial order across visual capture trials, with a Wilcoxon signed-rank test revealing no significant difference in *Location* scores between visual capture trial 1 vs. trial 2 (Z = -.52, p = .604). Therefore, *Location* questionnaire scores were collapsed across the two visual capture trials to provide an overall *visual capture Location* score, per participant.

A3.2.2.1 Main effect: Visual Capture

To examine the effects of mere visual capture towards subjective ownership of the mannequin body, we compared *Location* scores with *Control* scores in the *embodiment questionnaire*. A Wilcoxon signed-rank test revealed a main effect of visual capture, with significantly higher *Location* scores compared with *Control* scores (Z = -5.21, p < .001, r = 82).

A3.2.2.2 Main effect: Tactile Disruption

In order to determine whether tactile disruption to participants' own unseen arm would disrupt subjective location, we compared *Location* scores between *tactile disruption* and *visual capture* conditions. A Wilcoxon signed-rank test revealed a main effect of condition, in which participants showed significantly lower felt location towards the mannequin following *tactile disruption* trials (median = 1.00) compared with *visual capture* trials (median = 2.00) (Z = -3.47, p = .001, r = .55).

A3.2.2.3 Main effect: Tactile Velocity

Next, we examined whether tactile velocity had an effect in disrupting the subjective location that participants felt within *tactile disruption* trials. A Wilcoxon signed-rank test revealed that there was no significant difference in *Location* scores between affective and non-affective tactile disruption trials (Z = -.054, p = .957, r = .01), which suggests that interoceptive affective touch did not disrupt felt location to a greater degree than exteroceptive, non-affective touch.

A3.3 Results – Combined Samples

A3.3.1 Non-clinical Eating Disorder Psychopathology - Ownership Sub-component Analysis

A Spearman's rank correlation revealed no significant correlation between visual capture *ownership* scores and global EDE-Q scores (r = .043, p = .71), or any EDE-Q subscale scores (all *ps* > .05).

A3.3.2 Non-clinical Eating Disorder Psychopathology - Location Sub-component Analysis

A Spearman's rank correlation revealed no significant correlation between visual capture *location* scores and global EDE-Q scores (r = .038, p = .74), or any EDE-Q subscale scores (all *ps* > .05).

A4. Chapter 5 Supplementary Material

A4.1 Results - Experiment 1

A4.1.1 Embodiment Questionnaire – Ownership Subcomponent Analysis

A4.1.1.1 Main Effects

A Wilcoxon Signed Rank test revealed a main effect of stroking synchrony, with significantly greater ownership change following synchronous (median = 1.00) stroking conditions compared with asynchronous (median = -.50) stroking conditions ($Z = -5.22$, $p < .001$, $r = .85$). The main effect of stroking velocity on embodiment was not significant ($Z = -1.13$, $p = .261$, $r = .18$). To determine any interactions in ownership change between stroking synchrony and stroking velocity, differences between synchronous and asynchronous scores were calculated for both stroking velocities. No significant difference was observed in ownership change scores between affective and non-affective touch conditions ($Z = -.66$, $p = .511$, $r = .11$).

A4.1.2 Embodiment Questionnaire – Location Subcomponent Analysis

A4.1.2.1 Main Effects

A Wilcoxon Signed Rank test revealed a main effect of stroking synchrony, with significantly greater location change following synchronous (median = .50) stroking conditions compared with asynchronous (median = .00) stroking conditions ($Z = -3.73$, $p < .001$, $r = .61$). The main effect of stroking velocity on felt location was not significant ($Z = -1.83$, $p = .067$, $r = .30$). To determine any interactions in ownership change between stroking synchrony and stroking velocity, differences between synchronous and asynchronous scores were calculated for both stroking velocities. No significant difference was observed in location change scores between affective and non-affective touch conditions ($Z = -.94$, $p = .348$, $r = .15$).

Table A4.1 Additional Spearman's Rank correlations for additional variables in Experiment 1 (*p* values are uncorrected).

		Average Pleasantness Rating	Difference Score (Affective – Non-affective)	BMI	Restraint	Eating Concern	Shape Concern	Weight Concern	Global EDEQ
Average Pleasantness Rating	Correlation Coefficient		.243	.208	.181	.203	.111	.169	.185
	p value		.142	.209	.276	.223	.507	.310	.267
Difference Score (Affective – Non-affective)	Correlation Coefficient			.077	-.057	-.023	.048	-.034	-.023
	p value			.644	.734	.889	.776	.841	.892
BMI	Correlation Coefficient				-.052	.213	.015	.138	.020
	p value				.756	.198	.928	.410	.906
Restraint	Correlation Coefficient					.654**	.636**	.585**	.835**
	p value					.000	.000	.000	.000
Eating Concern	Correlation Coefficient						.681**	.681**	.800**
	p value						.000	.000	.000
Shape Concern	Correlation Coefficient							.847**	.922**
	p value							.000	.000
Weight Concern	Correlation Coefficient								.885**
	p value								.000
Global EDEQ	Correlation Coefficient								
	p value								

A4.2 Results - Experiment 2

A4.2.1 Embodiment Questionnaire – Ownership Subcomponent Analysis

A4.2.1.1 Main Effects

A Wilcoxon Signed Rank test revealed a main effect of stroking synchrony, with significantly greater ownership change following synchronous (median = 1.00) stroking conditions compared with asynchronous (median = -.34) stroking conditions (Z = -5.09, p < .001, r = .82). The main effect of stroking velocity on embodiment was not significant (Z = -1.69, p = .091, r = .27). To determine any interactions in ownership change between stroking synchrony and stroking velocity, differences between synchronous and asynchronous scores were calculated for both stroking velocities. No significant difference was observed in ownership change scores between affective and non-affective touch conditions (Z = -.69, p = .487, r = .11).

A4.2.2 Embodiment Questionnaire – Location Subcomponent Analysis

A4.2.2.1 Main Effects

A Wilcoxon Signed Rank test revealed a main effect of stroking synchrony, with significantly greater location change following synchronous (median = .50) stroking conditions compared with asynchronous (median = .00) stroking conditions (Z = -3.93, p < .001, r = .63). The main effect of stroking velocity on felt location was not significant (Z = .322, p = .747, r = .05). To determine any interactions in ownership change between stroking synchrony and stroking velocity, differences between synchronous and asynchronous scores were calculated for both stroking velocities. No significant difference was observed in location change scores between affective and non-affective touch conditions (Z = -.91, p = .362, r = .15)

Table A4.2 Additional Spearman's Rank correlations for additional variables in Experiment 2 (*p* values are uncorrected).

		Average Pleasantness Rating	**Difference Score (Affective – Non-affective)**	**BMI**	**Restraint**	**Eating Concern**	**Shape Concern**	**Weight Concern**	**Global EDEQ**
Average Pleasantness Rating	Correlation Coefficient		-.141	-.126	-.106	-.126	-.311	-.340*	-.275
	p value		.392	.445	.520	.446	.054	.034	.090
Difference Score (Affective – Non-affective)	Correlation Coefficient			.066	-.095	-.043	.124	.001	.014
	p value			.688	.565	.794	.453	.994	.931
BMI	Correlation Coefficient				.491**	.519**	.442**	.479**	.511**
	p value				.002	.001	.005	.002	.001
Restraint	Correlation Coefficient					.650**	.720**	.719**	.831**
	p value					.000	.000	.000	.000
Eating Concern	Correlation Coefficient						.725**	.692**	.806**
	p value						.000	.000	.000
Shape Concern	Correlation Coefficient							.950**	.961**
	p value							.000	.000
Weight Concern	Correlation Coefficient								.958**
	p value								.000
Global EDEQ	Correlation Coefficient								
	p value								

A5. Chapter 6 Supplementary Material

Phase 1: EDE-Q Norms and Confirmatory Factor Analysis of Original Structure (Sample 1)

Table A5.1 Percentile Ranks for raw EDE-Q global and subscale scores - Females (*N*=851)

	Restraint	Eating Concern	Shape Concern	Weight Concern	EDE-Q Global
Cronbach's alpha (α)	.827	.784	.913	.861	.950
Percentile Rank					
5	-	-	0.25	-	0.15
10	-	-	0.50	0.20	0.31
15	-	-	0.75	0.40	0.46
20	0.20	0.20	1.00	0.60	0.59
25	0.40	0.20	1.25	0.60	0.71
30	0.40	0.20	1.38	0.80	0.87
35	0.60	0.40	1.63	1.20	0.99
40	0.60	0.40	1.88	1.40	1.77
45	0.80	0.60	2.00	1.60	1.32
50	1.00	0.60	2.25	1.80	1.49
55	1.20	0.80	2.63	2.00	1.68
60	1.20	1.00	2.88	2.40	1.87
65	1.60	1.00	3.13	2.80	2.04
70	1.80	1.20	3.50	3.00	2.33
75	2.20	1.40	3.75	3.20	2.65
80	2.60	1.80	4.00	3.60	2.94
85	3.00	2.20	4.40	4.00	3.21
90	3.40	2.80	4.88	4.40	3.61
95	4.00	3.40	5.25	5.00	4.11
99	5.40	4.80	5.90	5.80	5.00

Table A5.2 Percentile Ranks for raw EDE-Q global and subscale scores - Males (*N*=224)

	Restraint	**Eating Concern**	**Shape Concern**	**Weight Concern**	**EDE-Q Global**
Cronbach's alpha (α)	.761	.745	.921	.837	.942
Percentile Rank					
5	-	-	-	-	-
10	-	-	-	-	0.06
15	-	-	0.25	-	0.13
20	-	-	0.38	-	0.23
25	-	-	0.40	0.20	0.28
30	-	-	0.50	0.20	0.36
35	0.20	-	0.63	0.40	0.43
40	0.20	0.20	0.75	0.40	0.56
45	0.40	0.20	1.00	0.60	0.69
50	0.60	0.20	1.25	0.80	0.80
55	0.60	0.20	1.50	1.00	0.99
60	1.00	0.40	1.63	1.20	1.14
65	1.20	0.60	1.88	1.60	1.33
70	1.30	0.80	2.13	1.80	1.48
75	1.80	0.95	2.50	2.00	1.73
80	2.20	1.20	2.88	2.60	2.04
85	2.60	1.40	3.40	3.05	2.48
90	3.10	1.60	4.50	3.40	2.86
95	3.60	2.35	4.98	4.35	3.48
99	4.75	4.05	5.98	5.45	4.68

A5.3 EDE-Q Disordered Eating Behaviours (Sample 1)

'Any' occurrence was defined as at least once, but less than regular occurrence over the past 28 days (Luce et al., 2008; Quick & Byrd-Bredbenner, 2013). 'Regular' occurrence of Excessive Exercise was defined as exercising in a "driven" or "compulsive" way as a means of controlling weight, shape or amount of fat, or to burn off calories ≥20 days over the past 28 days. 'Regular' occurrence of Dietary Restraint (item 2) was defined as going for long periods of time (≥8 waking hours) without eating anything at all for ≥13 days over the past 28 days. 'Regular' occurrence of Objective Binge Episodes, Self-induced Vomiting and Laxative Misuse was defined as ≥4 occurrences over the past 28 days (Luce et al., 2008). With the exception of *Dietary Restraint* item, responses to disordered eating behaviours were via single-line entry, in which participants responded largely with numerical values. Of those who responded by text entry (e.g. "*a few/many times"*), such answers were coded as 'any' rather than 'regular' occurrence, to maintain objective coding of responses (Kelly, Cotter, Lydecker, & Mazzeo, 2017). Percentage frequencies of 'any' and 'regular' occurrence were calculated, with Chi-square (χ^2) and Fisher's exact tests conducted to calculate differences in the proportion of reported disordered eating behaviours between females and males (see Table A5.3).

Table A5.3 Proportion of female (*N*=851) and male (*N*=224) students engaging in disordered eating behaviours (Sample 1)

Key Behaviour	Any Occurrence (%)				Regular Occurrence (%)			
	Females	Males	χ^2 (df)	*p*	Females	Males	χ^2 (df)	*p*
Objective Binge Episodes	23.6	21.4	.478 (1)	.489	24.3	15.2	8.528 (1)	.003
Self-induced Vomiting	3.2	0	-	.003[e]	1.3	0	-	.133[e]
Laxative Misuse	2.1	0	-	.020[e]	1.8	0	-	.051[e]
Excessive Exercise	32.8	29.9	.671 (1)	.413	2.8	4.5	1.565	.211[e]
Dietary Restraint	21.9	18.3	1.344 (1)	.246	5.6	2.2	4.395 (1)	.036

Note: *p* values corrected for multiple comparisons using false discovery rate (Benjamini & Hochberg, 1995).
[e]= Fisher's exact test reported, as expected frequencies were less than 5.

A5.4 Clinical Significance (Sample 1)

Percentages of individuals scoring above the cut-off for clinical significance are shown in Table A5.4. Clinical significance using the EDE-Q measure commonly use a cut-off of ≥4 (on any of four subscales and/or global score) to classify individuals within the clinical range (Carter et al., 2001; Mond et al., 2006). However, an alternative method used to assess clinical significance is to use a statistically derived cut-off based on individuals within the sample who score 2 SDs above the mean ($\mu + 2\sigma$) within the normal population (formula B; (Jacobson & Truax, 1991)). Based on this method, any individual scoring above this statistic are considered to be outside the normal population (Bauer, Lambert, & Nielsen, 2004). As shown in Table A5.4, using this method ($\mu + 2\sigma$) within a non-clinical population appears sub-optimal. With high scores on Shape Concern and Weight Concern subscales in the present sample, particularly amongst females, this method appears to normalize eating disorder traits if such an elevated criterion were to be used.

Table A5.4 Percentage of females (*N*=851) and males (*N*=224) scoring above cut-offs for clinical significance (Sample 1)

	Clinical Significance Cut-off (≥ 4)				Clinical Significance Cut-off ($\mu + 2\sigma$)			
	Females (*N*=851)		Males (*N*=224)		Females (*N*=851)		Males (*N*=224)	
	Cut-off	% Above cut-off	Cut-off	% Above cut-off	Cut-off	% Above cut-off	Cut-off	% Above cut-off
Restraint	≥ 4.0	5.41	≥ 4.0	3.13	≥4.05	4.23	≥3.56	7.59
Eating Concern	≥ 4.0	2.82	≥ 4.0	0.89	≥3.26	5.41	≥2.27	4.91
Shape Concern	≥ 4.0	22.09	≥ 4.0	13.39	≥5.68	1.76	≥4.86	6.70
Weight Concern	≥ 4.0	16.10	≥ 4.0	5.80	≥5.25	2.94	≥4.09	5.36
EDE-Q Global	≥ 4.0	5.76	≥ 4.0	2.23	≥4.26	3.76	≥3.39	5.80

A5.5 Measurement Invariance Between Females and Males (Sample 1)

Measurement invariance analysis was undertaken to determine whether the EDE-Q factor structure was equivalent, thus measuring the same underlying construct, between female (N=851) and male (N=224) samples (Sample 1). The data for the four previously-proposed factor structures were fitted to four measurement invariance models: Configural, Metric (weak), Scalar (strong), and Strict (residual) invariance. Configural invariance indicates whether the two groups have the same factor structure. Metric invariance indicates whether the two groups have the same factor loadings. Scalar invariance indicates whether the two groups have the same item intercepts. Finally, strict invariance indicates whether the two groups have the same item residual variance. The fit of each of these models were compared using a chi-square difference test, which can be seen below in Table A5.5.

Table A5.5 Measurement invariance statistics for four models of EDE-Q data in females (*N*=851) and males (*N*=224) (Sample 1)

		χ^2	*df*	RMSEA	TLI	CFI	SRMR	χ^2 diff (*df*)	*p*
Four Factor	Configural	3064.72	366	.083	.806	.831	.077	-	-
	Metric	3135.82	387	.081	.813	.828	.091	71.10 (21)	< .001
	Scalar	3356.06	408	.082	.810	.815	.094	220.24 (21)	< .001
	Strict	3495.18	429	.082	.812	.808	.082	139.12 (21)	< .001
Three Factor	Configural	3521.49	412	.084	.793	.815	.079	-	-
	Metric	3596.76	434	.082	.800	.812	.092	75.27 (22)	< .001
	Scalar	3813.69	456	.083	.798	.800	.084	216.93 (22)	< .001
	Strict	3957.82	478	.082	.800	.793	.083	144.13 (22)	< .001
Two Factor	Configural	3822.75	416	.087	.775	.797	.080	-	-
	Metric	3924.90	438	.086	.781	.793	.093	102.15 (22)	< .001
	Scalar	4127.80	460	.086	.781	.782	.095	202.90 (22)	< .001
	Strict	4262.51	482	.085	.784	.775	.084	134.71 (22)	< .001
One Factor	Configural	4620.52	418	.097	.724	.750	.082	-	-
	Metric	4725.56	440	.095	.732	.745	.101	105.04 (22)	< .001
	Scalar	4927.90	462	.095	.734	.734	.103	202.34 (22)	< .001
	Strict	5041.41	484	.094	.741	.729	.090	113.51 (22)	< .001

NB: χ^2: chi-square; df: degrees of freedom; RMSEA: Root Mean Square Errors of Approximation; TLI: Tucker–Lewis Index; CFI = Comparative Fit Index; SRMR = Standardized Root Mean Square Residual.

Configural model - factor loadings and intercepts free to vary between sexes.

Metric model - factor loadings constrained to be equal between sexes, but intercepts free to vary between sexes.

Scalar model - factor loadings and intercepts constrained to be equal between sexes.

Strict model - residual variances constrained to be equal between sexes in addition to the above constraints.

Phase 3: EDE-Q Norms of Original Four-Factor Structure (Samples 2 & 3)

Table A5.6 Descriptive Data - Means (Standard Deviations) for original, four-factor EDE-Q subscales and global score, for female (*N*=489) and male (*N*=164) students (Sample 2).

	Females (*N*=489)	Males (*N*=164)	*t*	*p*	Cohen's *d*
Age	22.16 (3.88)	22.86 (3.69)	2.039	.042	.184
BMI	23.25 (4.99) [a]	24.40 (4.97) [b]	2.539	.011	.231
Restraint	1.65 (1.60)	1.08 (1.33)	-4.490	<.001	.387
Eating Concern	1.16 (1.31)	0.53 (0.79)	-7.331	<.001	.582
Shape Concern	2.68 (1.79)	1.75 (1.44)	-6.663	<.001	.573
Weight Concern	2.18 (1.67)	1.27 (1.28)	-7.224	<.001	.612
EDE-Q Global	1.91 (1.44)	1.16 (1.03)	-7.303	<.001	.600

Note: *p* values corrected for multiple comparisons using false discovery rate (Benjamini & Hochberg, 1995).
BMI: Body Mass Index.
[a] Females (*N*= 488); [b] Males (*N*= 161).

Table A5.7 Descriptive Data - Means (Standard Deviations) for original, four-factor EDE-Q subscales and global score, for female (*N*=561) and male (*N*=170) non-students (Sample 3).

	Females (*N*=561)	Males (*N*=170)	*t*	*p*	Cohen's *d*
Age	32.68 (10.25)	34.39 (11.01)	1.878	.061	.160
BMI	26.03 (6.73) [a]	25.73 (4.27) [b]	-.535	.500	.053
Restraint	1.86 (1.58)	1.28 (1.29)	-4.851	<.001	.401
Eating Concern	1.34 (1.52)	0.55 (0.85)	-8.715	<.001	.647
Shape Concern	2.91 (1.82)	1.66 (1.37)	-9.598	<.001	.775
Weight Concern	2.46 (1.70)	1.27 (1.23)	-9.992	<.001	.799
EDE-Q Global	2.14 (1.46)	1.19 (0.97)	-9.878	<.001	.769

Note: *p* values corrected for multiple comparisons using false discovery rate (Benjamini & Hochberg, 1995).
BMI: Body Mass Index.
[a] Females (*N*= 557); [b] Males (*N*= 168).

Table A5.8 Female means (Standard Deviations) for newly-proposed, 18-item, three-factor EDE-Q subscales and global score across three samples.

	Students (Sample 1) (*N*=851)	Students (Sample 2) (*N*=489)	Non-Students (Sample 3) (*N*=561)
Shape and Weight Concerns	2.46 (1.63)	2.59 (1.74)	2.91 (1.80)
Preoccupation and Eating Concern	.72 (.97)	.88 (1.25)	.99 (1.34)
Restriction	1.90 (1.79)	2.14 (2.00)	2.52 (2.08)
EDE-Q Global	1.69 (1.25)	1.87 (1.43)	2.14 (1.44)

Table A5.9 Male means (Standard Deviations) for newly-proposed, 16-item, three-factor EDE-Q subscales and global score across three samples.

	Students (Sample 1) (*N*=224)	Students (Sample 2) (*N*=164)	Non-Students (Sample 3) (*N*=170)
Shape and Weight Concerns	1.78 (1.61)	1.80 (1.49)	1.61 (1.37)
Preoccupation and Eating Concern	.59 (.85)	.52 (.73)	.51 (.81)
Restriction	1.52 (1.79)	1.52 (1.83)	1.87 (1.92)
EDE-Q Global	1.30 (1.18)	1.28 (1.08)	1.32 (1.02)

A5.10 Modifications to EDE-Q Factor Structures (Samples 2 & 3)

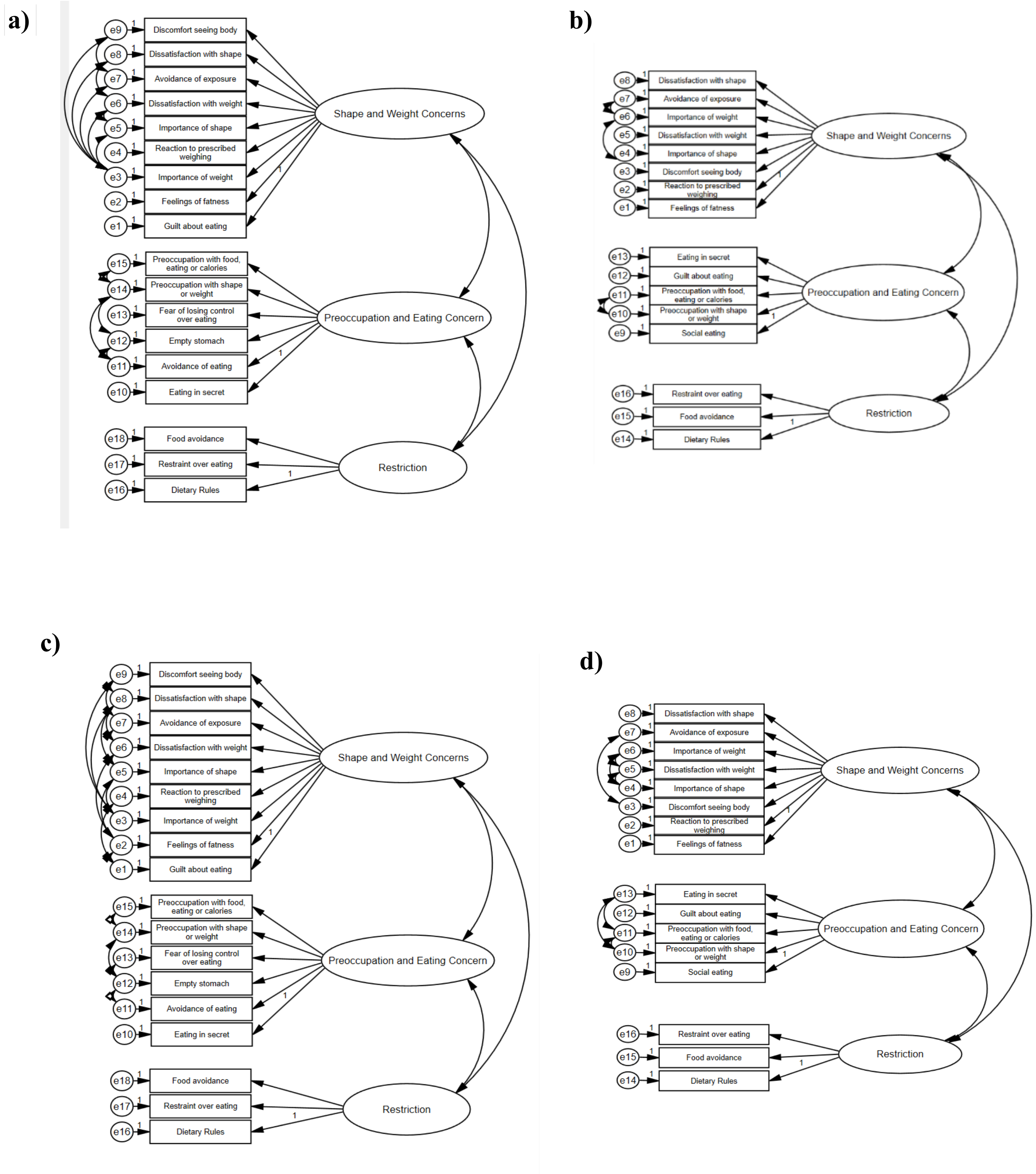

Figure A5.1 Path diagram showing co-variances made between error terms for student sample of females (a) and males (b), and non-student sample of females (c) and males (d).

A6. Eating Disorder Examination Questionnaire (EDE-Q)

Instructions: The following questions are concerned with the past four weeks (28 days) only. Please read each question carefully. Please answer all of the questions. Please only choose one answer for each question. Thank you.

Questions 1 to 12: Please circle the appropriate number on the right. Remember that the questions only refer to the past four weeks (28 days) only.

	On how many of the past 28 days…	**No days**	**1-5 days**	**6-12 days**	**13-15 days**	**16-22 days**	**23-27 days**	**Every day**
1	Have you been deliberately trying to limit the amount of food you eat to influence your shape or weight (whether or not you have succeeded)?	0	1	2	3	4	5	6
2	Have you gone for long periods of time (8 waking hours or more) without eating anything at all in order to influence your shape or weight?	0	1	2	3	4	5	6
3	Have you tried to exclude from your diet any foods that you like in order to influence your shape or weight (whether or not you have succeeded)?	0	1	2	3	4	5	6
4	Have you tried to follow definite rules regarding your eating (for example, a calorie limit) in order to influence your shape or weight whether or not you have succeeded)?	0	1	2	3	4	5	6
5	Have you had a definite desire to have an empty stomach with the aim of influencing your shape or weight?	0	1	2	3	4	5	6
6	Have you had a definite desire to have a totally flat stomach?	0	1	2	3	4	5	6
7	Has thinking about food, eating or calories made it very difficult to concentrate on things you are interested in (for example, working, following a conversation, or reading)?	0	1	2	3	4	5	6
8	Has thinking about shape or weight made it very difficult to concentrate on things you are interested in (for example, working, following a conversation, or reading)?	0	1	2	3	4	5	6
9	Have you had a definite fear of losing control over eating?	0	1	2	3	4	5	6
10	Have you had a definite fear that you might gain weight?	0	1	2	3	4	5	6
11	Have you felt fat?	0	1	2	3	4	5	6
12	Have you had a strong desire to lose weight?	0	1	2	3	4	5	6

Questions 13-18: Please fill in the appropriate number in the boxes on the right. Remember that the questions only refer to the past four weeks (28 days).

Over the past four weeks (28 days) …….

13	Over the past 28 days, how many times have you eaten what other people would regard as an unusually large amount of food (given the circumstances)?	……………..
14	…. On how many of these times did you have a sense of having lost control over your eating (at the time that you were eating)?	……………..
15	Over the past 28 days, on how many DAYS have such episodes of overeating occurred (i.e. you have eaten an unusually large amount of food and have had a sense of loss of control at the time)?	……………..
16	Over the past 28 days, how many times have you made yourself sick (vomit) as a means of controlling your shape or weight?	……………..
17	Over the past 28 days, how many times have you taken laxatives as a means of controlling your shape or weight?	……………..
18	Over the past 28 days, how many times have you exercised in a "driven" or "compulsive" way as a means of controlling your weight, shape or amount of fat or to burn off calories?	……………..

Questions 19-21: Please circle the appropriate number. Please note that for these questions the term "binge eating" means eating what others would regard as an unusually large amount of food for the circumstances, accompanied by a sense of having lost control over eating.

19	Over the past 28 days, on how many days have you eaten in secret (i.e., furtively)?......Do not count episodes of binge eating	**No days**	**1-5 days**	**6-12 days**	**13-15 days**	**16-22 days**	**23-27 days**	**Every day**
		0	1	2	3	4	5	6
20	On what proportion of the times that you have eaten have you felt guilty (felt that you've done wrong) because of its effect on your shape or weight? ......Do not count episodes of binge eating	**None of the times**	**A few of the times**	**Less than half**	**Half of the times**	**More than half**	**Most of the time**	**Every time**
		0	1	2	3	4	5	6
21	Over the past 28 days, how concerned have you been about other people seeing you eat? ......Do not count episodes of binge eating	**Not at all**	**Slightly**		**Moderately**		**Markedly**	
		0	1	2	3	4	5	6

Questions 22-28: Please circle the appropriate number on the right. Remember that the questions only refer to the past four weeks (28 days)

	On how many of the past 28 days…	Not at all	Slightly		Moderately		Markedly	
22	Has your weight influenced how you think about (judge) yourself as a person?	0	1	2	3	4	5	6
23	Has your shape influenced how you think about (judge) yourself as a person?	0	1	2	3	4	5	6
24	How much would it have upset you if you had been asked to weigh yourself once a week (no more, or less, often) for the next four weeks?	0	1	2	3	4	5	6
25	How dissatisfied have you been with your weight?	0	1	2	3	4	5	6
26	How dissatisfied have you been with your shape?	0	1	2	3	4	5	6
27	How uncomfortable have you felt seeing your body (for example, seeing your shape in the mirror, in a shop window reflection, while undressing or taking a bath or shower)?	0	1	2	3	4	5	6
28	How uncomfortable have you felt about others seeing your shape or figure (for example, in communal changing rooms, when swimming, or wearing tight clothes)?	0	1	2	3	4	5	6

What is your weight at present? (Please give your best estimate) ....

What is your height? (Please give your best estimate)..

If female: Over the past three-to-four months have you missed any menstrual periods?...............................

If so, how many? ....

Have you been taking the "pill"? ....

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