Visual body perception: Towards identifying objective markers of body image disturbance in brain and behaviour

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Declaration

I declare that this thesis, *‘Visual body perception: Towards identifying objective markers of body image disturbance in brain and behaviour’*, represents my own work, except where otherwise stated. None of the work referred to in this thesis has been accepted in any previous application for a higher degree at this or any other University or institution. All quotations have been distinguished by quotation marks and the sources of information specifically acknowledged.

Submitted by: Katie Groves

Signature of Candidate:

Date: 13/01/17

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Abstract

Previous research has shown that the brain processes bodies distinctively from other stimuli. Little research however, has addressed whether visual body perception is modulated by the observer’s conscious experience of their own body (body image). This thesis was therefore dedicated to investigating the relationship between body image disturbance and visual body perception, with the aim of identifying potential objective markers of body image disturbance in brain and behaviour. Initially, the suitability of headless body stimuli was assessed and electroencephalogram (EEG) was employed in order to evaluate the stability of early occipito-parietal (P1, N1) and fronto-central (VPP) visual event-related potentials (ERPs), including body-sensitive effects. A series of studies were then designed to investigate behavioural configural processing mechanisms and the early temporal dynamics of visual body perception (P1, N1, VPP), including the perception of own- and other- identity, in women with and without a history of disorders characterised by body image disturbance, such as eating disorders (EDs) and/or body dysmorphic disorder (BDD). Results confirmed the suitability of headless body stimuli, and of early visual ERP responses and their associated body-sensitivity for investigating visual body processing mechanisms. Further to this, ED participants, not controls, were found to elicit a rapid P1-N1 complex as well as gender-sensitive N1/VPP responses to other women’s bodies; effects which were associated with ED symptomatology. Moreover, results indicated rapid atypical gender-sensitive identity perception in those with EDs/BDD. Finally, behavioural evidence for configural body processing disturbance was found in those recovering from EDs and BDD, as well as in adolescents ‘at risk’ of developing such disorders. It is thus concluded that processes indicative of visual body perception, in both brain and behaviour, present atypically in women who have experienced EDs/BDD. Importantly, rapid visual ERP responses, as well as early gender-sensitive ERP effects, appear to be potential neural markers of ED symptomatology.

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Chapter 1 General Introduction

1.1 Motivation of thesis

Body Dysmorphic Disorder (BDD) and eating disorders (EDs) such as anorexia nervosa and bulimia nervosa are understood as distinct psychiatric conditions. In particular, the DSM-5 categorises anorexia and bulimia under ‘feeding and eating disorders’ given that they are characterised by a range of abnormal food- and body-related attitudes and behaviours, which lead to unhealthy eating habits such as binging, purging or fasting (see Skrzypek, Wehmeier, & Remschmidt, 2001). In comparison, BDD is classified on the obsessive-compulsive spectrum due to an intense focus on perceived flaws in appearance that are often unnoticeable or considered to be minor by others (American Psychiatric Association, 2013). Nonetheless, in both types of illness the conscious, introspective, bodily representation held, known as body image, represents a false reflection of reality (discussed further in section 1.3, see Cash, 2004). As comorbidity is common and given that many clinical features, including body image disturbance, are shared (Mitchison, Crino, & Hay, 2013), it is argued that these conditions might be better understood as interrelated body image disorders (Cororve & Gleaves, 2001). As such, subtle differences in these conditions dictate that those with an ED often overemphasise the importance of body weight and shape, focusing on their own ‘fat’ and/or ‘ugly’ body parts but directing attention to others’ ‘beautiful’ body parts (Jansen, Nederkoorn, & Mulkens, 2005). In contrast, those with BDD are concerned primarily with defects in appearance that are more likely to be related to the face or skin; although bodily concerns may also be present (American Psychiatric Association, 2013).

With that in mind, research has shown that body image disturbances experienced in those with EDs and BDD are multifaceted constructs, arising from interrelated contributions from perception, cognition, affect and behaviour (see Cash, 2004; Cash, 2012). Causes remain unclear (e.g. Stormer & Thompson, 1996) although increasing evidence suggests that there is a relationship between body image disturbance and maladapted visual processing mechanisms (see Lang, Lopez, Stahl, Tchanturia, & Treasure, 2014; Suchan, Vocks, & Waldorf, 2015b for review). In particular, alterations in activity, volume and connectivity in body-selective brain regions have been identified in anorexia (see Suchan, Vocks, & Waldorf, 2015a for review), whilst disturbances to appearance-related visual processing mechanisms have been identified in both anorexia (e.g. Urgesi et al., 2014) and BDD (see Feusner, Neziroglu, Wilhelm, Mancusi, & Bohon, 2010 for review). This thesis is therefore primarily concerned with investigating perceptual contributions to body image disturbance by assessing the relationship between how the observer feels about their own body (body image) and visual body perception.

Severe psychological distress and reduced psychosocial functioning are common symptoms of EDs and BDD (Harris & Barraclough, 1997), with reports showing the highest mortality rate of all psychiatric illnesses in anorexia (e.g. Arcelus, Mitchell, Wales, & Nielsen, 2011; Papadopoulos, Ekbom, Brandt, & Ekselius, 2009; Sullivan, 1995). It is therefore clear that identifying objective markers of body image disturbance is important. As such, whilst investigating visual body perception in those with BDD and EDs, the overarching intention was to assess potential electroencephalographic and behavioural symptom markers.

1.2 Current understanding of visual body perception

Relative to research investigating the perception of human bodies, the field of cognitive neuroscience has been largely concerned with the discussion of how human faces are processed (see Minnebusch & Daum, 2009). There are two main positions with regards to this debate, one being the ‘face specificity hypothesis,’ which proposes that there is a specialist network of brain regions dedicated to face recognition (Kanwisher, McDermott, & Chun, 1997). Alternatively, the ‘expertise-hypothesis’ proposes that these neural networks are concerned with expert processing rather than face-specific processing (Diamond & Carey, 1986). Although bodies and faces are visually different they do share common features; both are generally symmetrical and composed of essential sub-parts, of which person-specific recognition relies on second-order spatial relations between features, as well size and shape judgments. Thus, in accordance with the face processing debate (Gauthier & Bukach, 2007) similar issues have been addressed with regards to body processing (see de Gelder et al., 2010; Downing & Peelen, 2016; Minnebusch & Daum, 2009, for reviews). The question then, is whether the brain visually analyses the human body distinctively, and if so, whether this process is dissociable from visual face recognition. Within the context of this thesis, body processing should therefore be understood as the process by which the human visual system distinguishes bodies from other non-corporeal stimuli and faces.

Downing, Jiang, Shuman, and Kanwisher (2001) were the first to suggest that a distinct region of the lateral occipitotemporal cortex was specialised for the visual processing of human bodies. Their series of functional magnetic resonance imaging (fMRI) experiments revealed that activation in this region, named the extrastriate body area (EBA), was significantly stronger in response to images of the human form in comparison to inanimate objects and faces. Moreover, they found that EBA responses were stronger to line drawings of the body in comparison to control stimuli, and that EBA did not respond generally to objects that, akin to bodies, were structurally defined by sub-parts connected at flexible joints (e.g. scissors). It was therefore concluded that EBA selectivity for human bodies was not a result of structural or low-level visual features of the human form. In addition, they found no evidence of anatomical overlap between EBA and other category-selective regions such as the fusiform face area (FFA) (see Kanwisher et al., 1997), concluding that EBA is a functionally and anatomically distinct region of the human visual cortex specialised for analysing the human form.

However, body stimuli presented in Downing et al. (2001) included the head and it has been shown that even contextual cues are enough to elicit object-specific neuronal responses in human visual cortex (Cox, Meyers, & Sinha, 2004). Thus, it is possible that the presence of facial cues could have activated face-specific mechanisms. Additionally, despite EBA activation being less for the whole face in comparison to body parts, activation for face parts was similar to that of body parts (Downing et al., 2001). It is therefore unclear as to whether the combination of the body and head was critical for the reported effects or whether the results do indeed reflect a functionally specialised module for body perception.

Evidence for functional specialisation was reported by Morris, Pelphrey, and McCarthy (2006), as they directly compared the effects of ‘body-only,’ ‘face-only,’ and ‘body-face’ conditions on EBA activation. They found that EBA responses were strongest when the body was viewed without the face, and that in fact, activation decreased in both conditions that included the face. This indicates that the body is the critical factor for EBA activity, as suggested by Downing et al. (2001). Moreover, these results have methodological implications for studying neural representations of the human body. Although it has been argued that headless bodies are not naturalistic stimuli (e.g. Minnebusch & Daum, 2009) it appears that inclusion of the head impedes body-specific processing, at least in the EBA. Therefore, research in this area might benefit from presenting headless body stimuli.

Evidence suggests that a second body-selective region in the visual cortex, the fusiform body area (FBA) (Schwarzlose, Baker, & Kanwisher, 2005), contributes a functionally distinct representation of the human body (Taylor, Wiggett, & Downing, 2007) to perception. While there is some debate about the relative contributions of EBA and FBA, and about how they integrate information (e.g. Chan & Baker, 2011; Hodzic, Muckli, Singer, & Stirn, 2009; Urgesi, Calvo-Merino, Haggard, & Aglioti, 2007), there seems to be very little doubt that these areas are selective for the distinct visual perception of human bodies (see Downing & Peelen, 2016 for review).

Whilst fMRI investigations provide good spatial localisation of the metabolic activity associated with body perception, event related potential (ERP) studies are particularly effective at delineating the temporal signatures of the neural processes underlying this activity (see Lavric, Bregadze, & Benattayallah, 2011). As such, studies have shown a functional difference in early electrophysiological responses over lateral occipito-parietal and medial fronto-central electrode sites when bodies are viewed in comparison non-body stimuli (see Minnebusch & Daum, 2009 for review).

The most renowned body-related ERP response is elicited as an enhanced negative deflection peaking between 150 ms – 190 ms after a human body has been viewed (e.g. Minnebusch, Suchan, & Daum, 2009; Pourtois, Peelen, Spinelli, Seeck, & Vuilleumier, 2007; Taylor, Roberts, Downing, & Thierry, 2010; Thierry et al., 2006). The time course of such body-sensitive processing has been found to differ significantly to that of face-sensitive processing (e.g. face-sensitive N170 vs. body-sensitive N190 found in Thierry et al., 2006). Specifically, when bodies are presented with heads, body-related N1 processing often occurs significantly faster than face-sensitive processes. However, when headless stimuli are presented, body-sensitive cortical responses in the N1 time range have been found to occur significantly later than face-sensitive responses (see de Gelder et al., 2010, for review). Moreover, the body-sensitive N190 (as described by Thierry et al., 2006) reportedly differs in topography and microstate when compared to ERP responses elicited by faces and objects and has also been found to generalise across photographs, silhouettes and line drawings of the body (Thierry et al., 2006). This strongly suggests an electrophysiological dissociation between bodies and other stimuli, including faces. Furthermore, source localisation techniques (Meeren, de Gelder, Ahlfors, Hämäläinen, & Hadjikhani, 2013; Thierry et al., 2006), direct intracranial recordings (Pourtois et al., 2007), transcranial magnetic stimulation (TMS) (Sadeh et al., 2011), ERP investigations (Taylor et al., 2010) and magnetoencephalography (Ishizu, Amemiya, Yumoto, & Kojima, 2010) have all implicated EBA activity in the origins of this effect. However, as the reported timing for this effect has been variable (see de Gelder et al., 2010; Minnebusch & Daum, 2009, for review) the component will henceforth be referred to as a body-sensitive N1 rather than N190.

Body-sensitivity in the N1 time range has been linked to the configural and structural encoding of bodies (e.g. Bosbach, Knoblich, Reed, Cole, & Prinz, 2006; de Gelder et al., 2010; Eimer, 2000c; Minnebusch, Keune, Suchan, & Daum, 2010; Minnebusch et al., 2009; Soldan, Mangels, & Cooper, 2006), whilst evidence also suggests modulation according to the gender of the body. For example, larger body-sensitive N1 amplitudes have been found to female bodies in comparison to male bodies in men (Hietanen & Nummenmaa, 2011) and in women (Alho, Salminen, Sams, Hietanen, & Nummenmaa, 2015). By extension, this implies that processes other than that pertaining to the structural encoding of bodies, such as identity encoding for example, might also be represented within these early time ranges.

Body-related responses have also been observed as early as 100 ms after stimulus onset as a modulation of the first positive-going visual evoked potential (P1) (e.g. Meeren, van Heijnsbergen, & de Gelder, 2005; Righart & de Gelder, 2007; Thierry et al., 2006; van Heijnsbergen, Meeren, Grèzes, & de Gelder, 2007). Although such rapid responses are thought to reflect the processing of low-level properties of a stimulus (e.g. Tarkiainen, Cornelissen, & Salmelin, 2002), in certain circumstances it is apparent that the P1 component may also reflect categorical discrimination of bodies (Righart & de Gelder, 2007; Thierry et al., 2006) and some associated higher level processes (Meeren et al., 2005; van Heijnsbergen et al., 2007).

Reportedly, the vertex positive potential (VPP), which is evident as a positive deflection peaking at around 150 ms – 200 ms over medial fronto-central sites, is also enhanced by human body viewing (Sadeh et al., 2011; Stekelenburg & de Gelder, 2004; van Heijnsbergen et al., 2007). This response is thought to be distinct from the face-sensitive VPP (e.g. Caharel, Fiori, Bernard, Lalonde, & Rebai, 2006; Eimer, 2000a; Joyce & Rossion, 2005; Keyes, Brady, Reilly, & Foxe, 2010; Luo, Feng, He, Wang, & Luo, 2010; Rossion & Jacques, 2011) as TMS delivered to EBA resulted in VPP enhancement to bodies, not faces, whilst TMS delivered to the occipital face area (OFA) resulted in VPP modulation to faces, not bodies (Sadeh et al., 2011). Moreover, as N1 and VPP share functional response properties and are modulated in response to stimulation of category-selective brain areas (Sadeh et al., 2011), it has been suggested that these components reflect one dipolar complex (cf. Eimer, 2000b; Joyce & Rossion, 2005; Sadeh et al., 2011; Taylor, McCarthy, Saliba, & Degiovanni, 1999). Further to this, research suggests that VPP body sensitivity is modulated by emotional body posture, as enhanced VPP amplitudes are evident in response to fearful bodies (Stekelenburg & de Gelder, 2004; van Heijnsbergen et al., 2007).

Evidence for category-specific modular processing also comes from category-selective neuropsychological deficits. With regards to face processing, there is the well-known face-blindness deficit, prosopagnosia, which is characterised by the inability to recognise and/or perceive faces (Meadows, 1974). Consequently, if like faces, bodies are processed distinctively, a form of body-blindness might also be expected. However, as no such disorder has been identified, this fuels an argument against specialist mechanisms devoted to the visual processing of human bodies (de Gelder et al., 2010). Nevertheless, perhaps it is unrealistic to assume that body-blindness would present itself as obviously as face-blindness. This is because person perception is a task rarely completed on the basis of bodily cues alone, moreover, it has been shown that facial cues are relied on more so than the body (Rice, Phillips, & O'Toole, 2013). Thus, body-recognition deficits might present themselves so subtly that they are undetected unless problems with face-recognition are also present, as in the case of developmental prosopagnosics, who also have difficulty with body processing (Righart & de Gelder, 2007).

Findings from Urgesi, Berlucchi, and Aglioti (2004) support this assumption, as inhibiting EBA activity with repetitive magnetic transcranial stimulation (rTMS) was found to produce a clear impairment in discriminative reaction times for body stimuli but not for faces or objects. This strongly implies that EBA functioning is not only associated with specialised categorical processing of human bodies, but is necessary for it. Such causal evidence further strengthens claims of specialist body processing mechanisms within the visual cortex (see Downing & Peelen, 2016 for review).

The underlying mechanisms of visual perception also contribute to an understanding of whether a stimulus is processed in a specialised manner. For example, it is widely accepted that faces are perceived in a different way to objects; they are processed configurally (see Minnebusch & Daum, 2009). According to Maurer, Le Grand, and Mondloch (2002), this is driven by three mechanisms including first- and second- order relational information as well as holistic processing. Hence, a face is detected based on first-order configuration (e.g. two eyes above a nose, a nose above a mouth), which is integrated holistically, meaning that the face is perceived as a whole rather than a collection of features (see Piepers & Robbins, 2012, for review of definition). Person identification is then based on second-order information referring to the spatial distances between features (Maurer et al., 2002) as well as individual features themselves (Maurer et al., 2007).

Some of the most robust evidence for configural processing is found by observing the effects that occur from inverting stimuli, and studies have started to show that bodies, like faces, might be processed in this specialised way (e.g. Minnebusch et al., 2010; Minnebusch et al., 2009; Reed, Stone, Bozova, & Tanaka, 2003; Reed, Stone, Grubb, & McGoldrick, 2006). Thus, similarly to inverting faces, inverting bodies has been found to result in slower and less accurate behavioural responses, as well as enhanced and delayed electrophysiological responses (see Minnebusch & Daum, 2009 for review). It is thought that such inversion effects occur due to the cost associated with switching from configural processing mechanisms to feature-based analysis (Piepers & Robbins, 2012). This is because the first-order templates underpinning configural representations are based on canonical viewpoints, so they are sensitive to changes in orientation. In other words, configural processing is disturbed by inversion because although spatial relations are preserved, the coordinates of isolated parts in space are disrupted.

However, Minnebusch et al. (2009) found reverse electrophysiological inversion effects (shorter latencies and reduced amplitudes) and no behavioural inversion effects for headless body stimuli and so there is some debate about whether headless bodies are perceived configurally (see de

Gelder et al., 2010, for review). Specifically, it has been suggested that configural body processing is actually mediated by the presence of the head (Brandman & Yovel, 2010), as the sight of the head can activate face processing mechanisms (Cox et al., 2004; Morris et al., 2006), which are strongly configural. On the other hand, Robbins and Coltheart (2012) argue that headless body stimuli are processed configurally, and that the absence of behavioural inversion effects found in previous research (e.g. Minnebusch et al., 2009) may be due to a focus on non-body aspects of the stimuli (e.g. clothing). In line with this, even headless bodies appear to be represented as wholes, rather than as a sum of their parts, in body-selective brain regions (Brandman & Yovel, 2014). It appears then, that the majority of the evidence suggests that similarly to faces, the visual analysis of human bodies employs specialised visual processing mechanisms.

Taken together then, findings from neuroimaging, neurostimulation, and electrophysiological studies concur that visual body perception is a distinct process (see de Gelder et al., 2010; Minnebusch & Daum, 2009) occurring within specialised regions of the occipitotemporal cortex (see Downing & Peelen, 2016). This is supported by evidence that suggests bodies are perceived on a configural basis (e.g. Brandman & Yovel, 2014; Minnebusch et al., 2010; Reed et al., 2003; Robbins & Coltheart, 2012). With that in mind, it seems studies investigating the cortical representation of bodies should carefully consider the motivations for including headless body stimuli versus bodies with a masked face, especially as inclusion of the head might not be wholly reflective of the processing mechanisms residing in body-selective brain regions.

1.3 Evidence for altered visual body processing in body image disturbance

Own-body viewing is also a facet of visual body processing, which contributes to two distinct, multisensory constructs: ‘body schema’ and ‘body image’ (see Berlucchi & Aglioti, 2010 for short review). Described as a physical representation of the body in space, body-schema is supported and influenced by bodily movements and the environment. Body-image on the other hand, is thought to be a conscious, mental representation of the body that is associated with perception and action (Berlucchi & Aglioti, 2010; Paillard, 1999). As discussed in section 1.1, these introspective perceptions do not always reflect reality but instead manifest as the severe body image distortions evident in BDD and EDs such as anorexia and bulimia (American Psychiatric Association, 2013).

Research has shown that the body image disturbances experienced in those with EDs and BDD are multifaceted constructs, and as such, there is reason to believe that body image disturbance might be related to maladapted visual processing mechanisms (see Lang et al., 2014; Suchan et al., 2015b for review). In particular, it has been suggested that the preoccupations with specific body areas or flaws in appearance associated with body image disturbances, might reflect a bias for processing local over global information (see Lang et al., 2014 for review). In line with this, weak central coherence (WCC) has been observed in anorexia and bulimia (Lang et al., 2014). This refers to a cognitive processing style that favours detail-based, local processing over processing global information or the ‘gist.’ Moreover, WCC has not only been shown across EDs but also in recovered ED participants (Lopez, Tchanturia, Stahl, & Treasure, 2009) suggesting that it is a trait characteristic, rather than a state effect, of these disorders. WCC may therefore predispose, or help to maintain body image disturbance pathologies (Lopez et al., 2009). However, WCC in BDD is understudied, making it difficult to clarify whether this is a stable characteristic of body image disturbance or a phenomenon reserved for EDs. Nonetheless, as ED and BDD symptoms are highly comorbid (Cororve & Gleaves, 2001; Mitchison et al., 2013) it is possible that a bias towards local processing might underpin the high level of attention-to-detail required for the development and maintenance of body image disturbances in both types of condition. Studies investigating face- and body- processing in populations with high body image concern (BIC) address this possibility by means of stimulus inversion (e.g. Feusner, Moller, et al., 2010; Mundy & Sadusky, 2014; Urgesi et al., 2014). If body image distortions reflect a bias for local over global information, it is possible that corporeal stimuli are not processed in the typical configural manner but on the basis of their features. For this to be true, face- and body-processing in those with EDs and BDD should be less affected by inversion. For example, Feusner, Moller, et al. (2010) concluded that configural face processing might occur briefly in BDD but is then replaced by feature-based processing mechanisms, as inversion effects were evident in BDD participants when faces were presented for 500 ms but not for 5000 ms.

Urgesi et al. (2014) on the other hand, found typical inversion effects for faces and no inversion effects for objects. However, clinical participants showed a selective deficit for processing upright body stimuli compared to controls, whilst inverted body stimuli were discriminated comparably. Moreover, a negative correlation was found between body inversion effects and the tendency to convert a signal of punishment to a signal of reinforcement. Findings therefore indicate impaired configural body processing in anorexia, suggesting that these populations engage in a more detailed-based analysis of the human body that might help to explain obsessive bodily concerns. However, these results do not identify whether impaired configural body processing is specific to anorexia symptomology or related to body image distortions more generally. There is also no way to ascertain a causal relationship given that participants had been clinically ill prior to the study.

Mundy and Sadusky (2014) made some efforts to answer such questions with regards to BDD by presenting upright and inverted face, body and scene stimuli to non-clinical participants with high and low BICs. Typical inversion effects were found for faces and bodies in both groups, although effects were weaker in those with high BICs. This was reflected by faster responses to inverted face and body stimuli, plus more accurate responses to inverted bodies in comparison to those with low BICs. This supports Urgesi et al.

(2014), and further suggests that the appearance-related scrutiny associated with BIC may be facilitated by feature-based processing mechanisms. However, although effects were stronger for bodies, unlike anorexic participants in Urgesi et al. (2014), the high BIC group showed configural processing impairments for both bodies and faces. Whilst Mundy and Sadusky (2014) claim the results demonstrate maladaptive visual processing in populations ‘at risk’ of BDD, they do not explain how high BIC alone, is indicative of BDD instead of an ED or comorbid conditions. It is thus possible that a myriad of latent body image disorders had been assessed in their study, accounting for the difference in findings. Alternatively, if visual processing maladaptation’s precede clinical conditions as Mundy and Sadusky (2014) suggest, perhaps such deficits become more symptom-specific as a disorder develops. Furthermore, Mundy and Sadusky (2014) did not establish whether participants were clinically diagnosed with an ED or BDD. Resultantly, it is unclear whether such visual processing deficits really do precede the development of a clinical disorder, or whether they are a result of increasingly intense focus on perceived flaws. Nonetheless, perceptual deficits are clearly evident in those with body image disturbance despite ambiguity about whether or not they reflect trait, or state characteristics, and whether they are selective for appearance-related stimuli or whether they reflect a more global feature-based processing bias that might underpin the fixations with perceived flaws in appearance and ‘fat’ body parts (see Lang et al., 2014; Madsen, Bohon, & Feusner, 2013 for reviews).

In support of this, Li, Lai, Loo, et al. (2015) found evidence for a local processing bias in anorexia and BDD, as atypical early visual ERPs were evident in these populations. Specifically, reduced P1 amplitudes and reduced and delayed N170 responses were found in anorexic participants compared to controls, whilst a similar trend was seen in the BDD group. Anorexic participants also displayed significantly reduced P1 amplitudes in comparison to BDDs. Arguing that early visual components reflect early configural processing mechanisms, Li, Lai, Loo, et al. (2015) suggest that the results imply enhanced detail-based processing and deficient configural processing in participants with body image disturbance. With regards to anorexia, they suggest this is indicative of tendencies to fixate on ‘fat’ body parts at the expense of integrating the whole body. Furthermore, an association between increased delusional beliefs and reduced face-sensitive N170 amplitudes was found in BDD participants leading the authors to propose maladapted or incomplete face processing in BDD. This supports Mundy and Sadusky (2014), and suggests that perceptual distortions may underpin delusional beliefs about appearance.

In addition, Mai et al. (2015) found larger P2 amplitudes to overweight body stimuli in participants with bulimia compared to controls. This effect was related to two subscales of the Eating Disorder Inventory-II (EDI-2; Garner, 1991), ‘drive for thinness,’ and ‘body dissatisfaction,’ which specifically measure body image disturbance. Furthermore, subjective ratings of body stimuli revealed that bulimic participants were more aroused by overweight bodies than controls. As a result, it was concluded that perceptual, as well as cognitive-affective, aspects of body processing were altered in bulimia, reflecting a bias for overweight body stimuli. Early visual ERP components (Li, Lai, Bohon, et al., 2015; Li, Lai, Loo, et al., 2015) and later body-sensitive ERP responses (Mai et al., 2015) have therefore been tentatively implicated as potential biomarkers of ED symptomatology.

In keeping with this, evidence for reduced activity, volume and connectivity in brain structures that are specialised for the visual perception of human bodies, has been found in women with EDs (see Suchan et al., 2015a for review). For example, EBA has been found to be maladapted (Suchan et al., 2010) and underactive (Uher et al., 2005) in women with anorexia. Importantly, it has been shown that EBA functions via links with brain regions that have been implicated in body image, in particular, the ventral premotor cortex (vPMC; Kitada, Johnsrude, Kochiyama, & Lederman, 2009). Similarly, research has found that the neural underpinnings of person perception might differ in those who experience clinical levels of body image disturbance (see Esposito, Cieri, Giannantonio, & Tartaro, 2016; Kaplan, Rossell, Enticott, & Castle, 2013 for reviews). Castellini et al. (2013) specifically, found that anorexic participants showed reduced activation in several brain regions, including the occipital cortex, during own-body viewing. Conversely, patterns of brain activation were the same between anorexic participants and controls during observation of other-body pictures. However, it is yet to be investigated whether unfamiliar other-person perception differs in those with body image disturbance compared to controls.

Taken together, these findings reveal a consistent pattern that is indicative of enhanced local processing in BDD and EDs, which might underpin a feature-based, rather than configural, approach to processing appearance-related stimuli. As such, these biases may help to maintain or develop the perception of ‘flaws’ or ‘defects’ that perpetuate body image disturbance. However, there is limited insight into how, and if, such biases precede the onset of illness and/or continue after recovery. Furthermore, whilst WCC has been investigated in bulimia with stimuli unrelated to ED pathology (Lang et al., 2014), research into configural face- and body- processing in bulimia is sparse, so current understanding is limited. Neuroimaging and ERP studies have also shown that there are clear alterations to the structures and mechanisms involved in body perception and body image in those who experience body image disturbances. As a result, visual processing mechanisms appear to be disturbed in those who experience body image disturbance.

1.4 Research questions

As discussed, research not only shows cortical alterations and pathologically related neurological differences (such as in response to food and body stimuli) in those with body image disturbance, but also that it is possible to establish links between ERPs and ED symptomatology (e.g. Blechert, Ansorge, Beckmann, & Tuschen-Caffier, 2011; Hatch et al., 2010; Li, Lai, Loo, et al., 2015; Mai et al., 2015; Otagaki, Tohoda, Osada, Horiguchi, & Yamawaki, 1998; Pollatos, Herbert, Schandry, & Gramann, 2008; Sfärlea et al., 2016). Therefore, as it is thought that early body-sensitive ERPs arise from EBA activity (e.g. Sadeh et al., 2011; Thierry et al., 2006), an area linked to regions associated with body image disturbance (Kitada et al., 2009) that appears to be maladapted (Suchan et al., 2010) and underactive (Uher et al., 2005) in anorexic women, it is logical to hypothesise that these body-sensitive components might present atypically in populations with body image disturbance. Despite this, and even though perception is a key contributor to body image disturbance (see Cash, 2004; Cash, 2012), few studies have investigated the relationship with early temporal dynamics of visual processing (Li, Lai, Bohon, et al., 2015; Li, Lai, Loo, et al., 2015). Moreover, only one study has directly investigated the relationship with visual body processing (Mai et al., 2015).

Reports stating that anorexia nervosa has the highest death rate of all psychiatric conditions (e.g. Arcelus et al., 2011; Papadopoulos et al., 2009; Sullivan, 1995) prompted recent calls for evidence-based treatment and early interventions (World Eating Disorders Action Day, 2016). Therefore, the identification of objective, biological markers of ED symptoms would be timely. Accordingly, the primary focus of this thesis was to investigate the early temporal dynamics of visual body perception in body image disturbance. In particular, we focused on women with body image disturbance as although rates of BIC are thought to be comparable between men and women (e.g. Dakanalis & Riva, 2013; Woodside et al., 2001), aetiology and presentation is thought to be qualitatively different (Dakanalis & Riva, 2013). In addition to this, the prevalence rate of men who suffer from disorders characterised by body image disturbance, such as anorexia or bulimia, appears to be far lower (Dakanalis & Riva, 2013; Hudson, Hiripi, Pope, & Kessler, 2007).

In order to address the overarching aim, a series of research questions were devised that 1) aimed to assess potential methodological issues so the utmost experimental rigour could be pursued and 2) aimed to identify whether early electrophysiological body processing is atypical in women with body image disturbance and if so, what this might mean.

We decided headless bodies were the preferable choice of stimuli in order to reduce the possibility of activating face processing mechanisms during body viewing (Cox et al., 2004; Morris et al., 2006). However, it has been suggested that bodies with cropped heads might be confusing and non-naturalistic (e.g. Minnebusch & Daum, 2009; Minnebusch et al., 2009). As top-down processing has been known to influence electrophysiological effects (e.g. Gazzaley, Cooney, McEvoy, Knight, & D'Esposito, 2005; Hillyard & Anllo-Vento, 1998), first and foremost, as outlined in Chapter 2, we were interested in ascertaining whether headless body stimuli evoke affective responses that may confound ERP findings. Secondly, before investigating the temporal signatures of visual body processing in women with body image disturbance, we thought it important to question whether early visual ERPs and associated body-sensitive effects were stable in control individuals. We were also interested to know whether body-sensitivity in early time ranges could be linked to own-body perception (Chapter 3).

On the basis of establishing the reliability of early visual ERPs and body-sensitivity, the third question then turned to whether these processes were atypical in women with EDs and if so, to what extent this was related to ED symptomatology such as body image disturbance (Chapter 4). Following this, our fourth question, addressed in Chapter 5, was centred on investigating the early cortical signatures of body-only identity processing in women with and without a history of body image disturbance. Finally, we were interested in whether deficits in reported configural body processing (Feusner, Moller, et al., 2010; Mundy & Sadusky, 2014; Urgesi et al., 2014) could be found in populations 'at risk' of developing and/or relapsing into disorders characterised by body image disturbance (Chapter 6).

With the robustness of data analysis in mind, in all EEG studies data were manually assessed after artefact rejection in order to ensure that at least 20 trials were present per condition, per participant before averaging and exporting the data for analysis. In the vast majority of cases, there were in excess of 100 trials per participant, per condition. Moreover, SCAN 4.5 software (Compumedics, Melbourne, Australia) would not allow averaging if a condition did not contain more than one trial.

1.5 Structure of thesis

The remainder of this thesis describes five empirical studies that were designed to answer the research questions presented. The first study, outlined in Chapter 2, was comprised of two investigations that aimed to determine whether headless bodies evoke affective responses that might confound electrophysiological findings (see Minnebusch & Daum, 2009; Minnebusch et al., 2009). An online questionnaire was devised in order to assess explicit responses to headless body stimuli and bodies with masked faces on the basis of disgust, fear, naturalness, valence and arousal. In addition, a free association task was presented as an implicit measure of thoughts towards these stimuli (Kris, 2013). Findings from this series of investigations would inform our choice of stimuli during the design phase of studies to follow. This chapter has been submitted for publication in *Journal of Cognitive Psychology,* where it is currently under review.

In the second study, presented in Chapter 3, the question of ERP reliability and own-body perception was addressed. Over a 4-week period, electroencephalography (EEG) was employed in order to measure the stability of early body-sensitive effects and visual P1, N1 and VPP responses during a task that involved own- and other-body viewing. This was done not only to inform the validity of research in the body processing field, but also to address whether these components have the potential to be trustworthy neural markers. Although, to the best of our knowledge, no study to-date has reported on the test-retest reliability of body-sensitive visual ERPs, a few studies suggest that early visual ERPs are stable (e.g. Huffmeijer, Bakermans-Kranenburg, Alink, & van Ijzendoorn, 2014; Kompatsiari, Candrian, & Mueller, 2016; Tello et al., 2010). Moreover, studies have shown reliability for face-sensitive ERPs and associated effects (Huffmeijer et al., 2014; Kuefner, de Heering, Jacques, Palmero-Soler, & Rossion, 2010) and although, as discussed, body perception is understood to be distinct from face perception (see de Gelder et al., 2010; Downing & Peelen, 2016), the underlying processes are thought to be similar (see Minnebusch & Daum, 2009). We therefore predicted that body-sensitive ERP effects would be reliable. In addition, as stronger EBA activation has been seen in response to own-body stimuli (e.g. Hodzic et al., 2009; Vocks et al., 2010) we expected an enhancement of body-sensitive N1, and possibly VPP, amplitudes during own-body viewing. Findings from this study were again influential in the design phase of studies to follow. This chapter was submitted for publication in *PLoS ONE*, where it is currently undergoing the review process.

In the third study, presented in Chapter 4, an EEG investigation was conducted in order to address whether the early temporal signatures of body-sensitive processing present atypically in women with anorexia and bulimia. The overarching aim therefore, was to identify potential biomarkers of body image disturbance. Event-related P1, N1 and VPP components were recorded in response to body and house stimuli and then correlated with responses on the EDI-2 (Garner, 1991) in order to assess the relationship with ED symptomatology. Both male and female body stimuli were included as studies have shown the gender of the observed body might modulate body-sensitive ERPs (Alho et al., 2015; Hietanen & Nummenmaa, 2011). As mentioned, previous studies have found evidence for altered face-sensitive ERPs in populations with body image disturbance (Li, Lai, Bohon, et al., 2015; Li, Lai, Loo, et al., 2015), as well as a cognitive processing bias for overweight stimuli (Mai et al., 2015). Given this, as well as evidence for altered function, structure and connectivity of body selective areas in the visual cortex (Suchan et al., 2015a), we hypothesised that early body-sensitive ERPs would differ between our ED group and controls. Furthermore, we predicted that differences would correlate with EDI-2 responses in such a way that would implicate these components as potential biomarkers of ED symptomatology. This chapter has been published in *Biological Psychology* (Groves, Kennett, & Gillmeister, 2017).

As referred to in section 1.3, there is evidence to suggest that person perception may differ in those who suffer from body image distortions (see Esposito et al., 2016; Kaplan et al., 2013 for reviews). However, to our knowledge, unfamiliar other bodily identity processing has not yet been investigated in such populations. Moreover, the temporal dynamics of body-only identity perception have been largely neglected in the cognitive neuroscience literature. Thus, in the fourth study, presented in Chapter 5, we aimed to delineate the cortical signatures of body-only, unfamiliar other-person perception, and whether this is atypical in women with body image disturbance. An ERP adaptation paradigm was employed in order to assess the effects of repeated presentation of a certain person’s body on the suppression of P1, N1, VPP and N250 responses. Again, both male and female bodies were included and inverted stimuli were presented in order to ascertain at which point in time inversion disrupts identity processing. Based on findings in the face processing literature (e.g. Caharel, d’Arripe, Ramon, Jacques, & Rossion, 2009; Jacques, d'Arripe, & Rossion, 2007; Parketny, Towler, & Eimer, 2015), we expected to see evidence of identity processing at the earliest stages of visual analysis. Moreover, we predicted that the temporal dynamics of person perception (Esposito et al., 2016; Feusner, Bystritsky, Hellemann, & Bookheimer, 2010) and the effects of inversion (e.g. Feusner, Moller, et al., 2010; Mundy & Sadusky, 2014; Urgesi et al., 2014) would differ in those with body image disturbance.

The final study, presented in Chapter 6, directly addressed whether configural processing deficits precede the onset of disorders characterised by body image disturbance and/or remain into recovery. Thus, adolescents were recruited as adolescence is thought to be a particularly vulnerable developmental period for the onset of BDD (Bjornsson et al., 2013) and EDs characterised by body image disturbance (Striegel-Moore & Bulik, 2007; Striegel-Moore et al., 2003). Reaction time (RT) and accuracy measures were recorded during a matching-to-sample task whereby body, face and house stimuli were presented to high risk teenagers, low risk teenagers and women who had experienced EDs. Risk was determined on the basis of body concern, using the Body Image Concern Inventory (BICI; Littleton & Breitkopf, 2008), and self-objectification, using the self-objectification questionnaire (SOQ; Fredrickson & Roberts, 1997). Given the findings of Urgesi et al. (2014), we expected the ED group to display a configural body processing deficit. In accordance with Mundy and Sadusky (2014), we hypothesised that high risk teenagers might present similarly to EDs and display deficits in configural body processing. We also thought that high risk teens may show evidence of disturbed configural face processing (Feusner, Moller, et al., 2010).

Each of the five empirical chapters has been written to serve as an autonomous scientific article. As a result, there may be some overlap of literature between chapters mutually, as well as between chapters and the general introduction/discussion. At this moment, Chapter 2 is under review in *Journal of Cognitive Psychology,* Chapter 3 is going through the review process in *PLoS ONE*, and Chapter 4 has been published in *Biological Psychology* (Groves et al., 2017). The remaining chapters are in preparation for submission to other leading journals. Furthermore, the basis of sections 1.2 and 1.3 of the general introduction has been published as separate discussion papers in *The Quarterly* (Groves, 2016, 2017).

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Chapter 2 Affective responses to body stimuli: Comparing male and female bodies with cropped heads and masked faces

2.1 Abstract

Considerable research has shown that the human body and face are represented by distinct neural mechanisms. As a result, there has been debate about whether or not body stimuli should be presented with or without the head (face masked). On the one hand, the presence of the head may trigger face processing mechanisms, which obscure the measurement of body-sensitive processes (Cox, Meyers, & Sinha, 2004). On the other hand, bodies without the head are claimed to be non-naturalistic and perhaps fearful stimuli (Minnebusch & Daum, 2009). Two studies were conducted in order to determine whether headless bodies evoke affective responses that might confound neuroimaging and electrophysiological findings. In Experiment 1, 224 participants used an online questionnaire to rate pictures, including headless bodies and bodies with masked faces, for disgust, fear, naturalness, valence and arousal. In Experiment 2, 38 participants completed a free association task whereby they spoke aloud all words that came to mind whilst viewing images that included headless bodies and bodies with masked faces. Results from both studies found no difference in the affective response elicited by bodies without heads and bodies with masked faces. Female bodies were thought of more positively than male bodies, however. These findings suggest that headless body stimuli are not abhorrent in any way and are thus the preferable stimuli for investigating body-sensitive perceptual processes. Our findings also suggest that differences between male and female body viewing should be considered when investigating visual body perception.

2.2 Introduction

Interest in understanding the mechanisms of visual body perception has grown over the past two decades as specialist areas of the visual cortex have been found to respond selectively to the human body and its parts (Downing, Jiang, Shuman, & Kanwisher, 2001; Schwarzlose, Baker, & Kanwisher, 2005). Moreover, research is beginning to show that body processing may be disturbed in some neurological and psychological conditions (e.g. body integrity identity disorder, Blom, Hennekam, & Denys, 2012; heterotopagnosia, Felician & Romaiguère, 2008; and somatoparaphrenia, Vallar & Ronchi, 2009) as well as psychiatric illnesses (e.g. in schizophrenia, Irani et al., 2006; depersonalization, Ketay, Hamilton, Haas, & Simeon, 2014; and in body image disturbance, Vocks et al., 2010). It is therefore increasingly important that we work towards understanding how the visual system perceives the human form.

As evidence suggests distinct neural mechanisms for face and body perception (see de Gelder et al., 2010; Downing & Peelen, 2016; Minnebusch & Daum, 2009 for reviews), studies investigating visual body representation typically present stimuli in one of two ways - with the face masked or the head cropped - in order to minimise the activation of face processing mechanisms. However, conflicting results have been found between studies that utilise the different types of stimuli, making firm conclusions about the nature of body-sensitive processing difficult to agree upon (see Minnebusch & Daum, 2009 for review).

For example, studies in which bodies are presented with a masked face often conclude that bodies, like faces, are processed configurally (see de Gelder et al., 2010 for review). According to such findings, recognition of a body relies on first-order stored templates of relations between individual features (e.g. arms attached to the top of the trunk, legs to the bottom), rather than the individual features themselves (as for face processing, see Piepers & Robbins, 2012). Evidence for this is typically found by observing the effects that occur from inverting body stimuli (e.g. Minnebusch, Keune, Suchan, & Daum, 2010; Minnebusch, Suchan, & Daum, 2009; Reed, Stone, Bozova, & Tanaka, 2003; Reed, Stone, Grubb, & McGoldrick, 2006). If bodies are processed configurally, inverting them should result in slower and less accurate behavioural responses, as well as enhanced and delayed electrophysiological responses (see Minnebusch & Daum, 2009 for review), which is thought might be due to the cost associated with switching from configural processing mechanisms to feature-based analysis (Piepers & Robbins, 2012). This is because the templates underpinning configural representations are sensitive to changes in orientation as they are based on ‘canonical viewpoints’, a term for the best view for optimal object recognition coined by Palmer and colleagues (Palmer, Rosch, & Chase, 1981). In other words, configural processing is disturbed by inversion because, although spatial relations between parts are preserved, the coordinates of those parts in space are disrupted. However, research has shown that even the presence of contextual cues of the head (e.g. a person holding a book at the height of and occluding the head) is enough to elicit face processing mechanisms (e.g. Cox et al., 2004; Morris, Pelphrey, & McCarthy, 2006). As it is understood that faces recruit configural processing mechanisms (see Maurer, Le Grand, & Mondloch, 2002), it has thus been proposed that the inversion effects observed when bodies are presented with masked faces occur as a result of the presence of the head (e.g. Brandman & Yovel, 2010). A logical line of argument therefore, would be to crop the head from body stimuli as utilising bodies with masked faces might result in a misrepresentation of distinct body processing due to the activation of face processing mechanisms.

On the other hand, it has been proposed that when bodies are presented without the head they are processed according to their features rather than as a configural whole because inversion effects are often absent (e.g. Minnebusch et al., 2009; Yovel, Pelc, & Lubetzky, 2010) or reversed (e.g. Minnebusch et al., 2009). Consequently, it has been argued that headless bodies might be confusing stimuli because without the head, they do not match stored templates (Minnebusch et al., 2009). Further to this, is has been claimed that headless bodies are unnatural stimuli (Minnebusch & Daum, 2009). This raises the concern that headless bodies are substandard stimuli for investigating the neural mechanisms that underpin body processing, especially as electrophysiological responses at time ranges that are sensitive to bodies are also known to be affected by attention, valence and arousal (e.g. Gazzaley, Cooney, McEvoy, Knight, & D'Esposito, 2005; Hillyard & Anllo-Vento, 1998; Mai et al., 2015; Meeren, van Heijnsbergen, & de Gelder, 2005; Stekelenburg & de Gelder, 2004; van Heijnsbergen, Meeren, Grèzes, & de Gelder, 2007).

That said, other lines of evidence suggest that the configural recognition of body posture does not rely on a complete template match (Reed et al., 2006). Moreover, it has been argued that a failure to find evidence for configural body processing is likely due to a fixation on non-body aspects of the stimuli such as clothing, rather than the body itself (Robbins & Coltheart, 2012). In turn, this suggests that headless stimuli are not as unnatural and confusing as previously suggested. In line with this debate, it is thus important to assess affective responses to headless body stimuli.

It is also possible that the presence of a masked face could disturb body-sensitive processes, not only by inducing face-sensitive mechanisms, but as a result of affective responses to these stimuli. ‘Meaning threat’ occurs when an unfamiliar experience or observation transpires within the context of familiarity, prompting a state of arousal such as uncanniness, dissonance, disequilibrium and uncertainty (see Proulx & Heine, 2009; Proulx, Heine, & Vohs, 2010). This has been specifically identified as occurring during the observation of absurd art, whereby faces are typically obscured, blurred or pixelated (see Proulx et al., 2010) and is linked to increased anterior cingulate cortex (ACC) function, which has been associated with increased levels of anxiety (see Tullett et al., 2013). Whilst is it has been suggested that headless body stimuli might be aversive (e.g. Minnebusch & Daum, 2009; Minnebusch et al., 2009) the same proposition could also be made with regards to masked face stimuli, on the basis that they evoke ‘meaning threat.’ Given that top-down processing has been shown to affect both the magnitude and speed of neuronal processing (Gazzaley et al., 2005; Hillyard & Anllo-

Vento, 1998) it is therefore also of interest to assess affective responses to bodies with masked faces.

Male and female body stimuli were also included as studies have shown that male and female bodies may be thought of, and even processed, differently (e.g. Bernard, Gervais, Allen, Campomizzi, & Klein, 2012; Cazzato, Mele, & Urgesi, 2014; Gervais, Vescio, Förster, Maass, & Suitner, 2012; Heflick & Goldenberg, 2014; Vaes, Paladino, & Puvia, 2011). In particular, it has been argued that women’s bodies are thought of, and perhaps processed, like objects (objectified) as appearance is the main focus. On the other hand, it’s proposed that men’s bodies are thought of more in terms of their function and competence rather than appearance (e.g. Heflick & Goldenberg, 2014; Vaes et al., 2011).

Experiment 1 assessed explicit responses to stimuli by asking participants to rate pictures on the basis of disgust, fear, naturalness, valence and arousal. Experiment 2 assessed implicit responses to stimuli as participants were instructed to freely associate all words that came to mind during observation (see Kris, 2013). Images of insects, flowers and houses were included as a control to assess whether participants were engaged with the task. With that in mind, we expected participants to respond negatively to insect stimuli and positively to flower stimuli. Furthermore, we predicted that any differences in affective responses to body stimuli would reveal that headless bodies are not thought of more negatively than bodies with masked faces. We also expected that there might be differences in the way male and female bodies were rated and that, specifically in Experiment 2, the appearance of female bodies might be referred to more so than that of male bodies (e.g. Heflick & Goldenberg, 2014; Vaes et al., 2011).

2.3 Experiment 1: Assessing explicit differences in ratings of disgust, fear, naturalness, valence and arousal

In Experiment 1 we explicitly addressed whether affective responses to body stimuli without the head differ to those with a masked face. A ratings task was therefore devised in order for pictures of flowers, insects, houses and both types of body stimuli to be rated on the basis of disgust, fear, naturalness, valence and arousal.

2.3.1 Method

2.3.1.1 Participants

In response to advertisements emailed to University of Essex mailing lists and posts on social media, 252 people volunteered to complete an online rating survey. Those who disclosed experiences of an eating disorder or body dysmorphic disorder were not included. As a result, data from 224 participants were analysed (63 men, 153 women, 2 gender-fluid individuals and 6 who did not specify this demographic detail). The average age of the sample was 28 years (SD: 11 years).

2.3.1.2 Ethical declaration

The study was conducted in line with the 2008 Declaration of Helsinki and approved by the local Ethics Committee for the Psychology Department at the University of Essex.

2.3.1.3 Apparatus and stimuli

An online picture-rating task compatible with android devices was devised using Qualtrics software (Qualtrics, Provo, UT, USA). Two pictures of insects and two pictures of flowers were downloaded from the template for the ‘Brief Implicit Association Task (IAT) with pictures’ (Sriram & Greenwald, 2009). Two pictures of houses were downloaded via *Google Images*, whilst two canonical, front-facing pictures of women’s bodies and two front-facing pictures of men’s bodies were taken from a selection of body stimuli devised for use in our lab. Stimuli were edited in *Adobe Photoshop* to remove background information and each body picture was edited so that the head was either cropped or the face masked by blurring. In order to avoid fixations on certain parts of a single stimulus that might otherwise affect ratings (e.g. toes or knees) and thus to encourage ratings of the different types of stimuli in general, both images from each category were presented together as foreground information on a black background. This created one image per category with dimensions 720 x 540 pixels (see Figure 2.1), in order to avoid fixations on certain parts of a stimulus that might otherwise affect ratings (e.g. toes or knees) and encourage ratings of stimuli in general. By means of mouse-click, or by tapping on the screen (if completed with an android device), stimuli were rated on separate 7-point scales according to five attributes. Left and right extremes of the scale were marked as follows: very disgusting vs. very delightful (disgust), very natural vs. very unnatural (naturalness), very fearful vs. very calming (fear), very rousing vs. very soothing (arousal) and very positive vs. very negative (valence), with the neutral point of each scale being 4 (e.g. very fearful, fearful, slightly fearful, neutral, slightly calming, calming, very calming). The naturalness scale was reverse scored so that higher scores were indicative of more positive ratings.

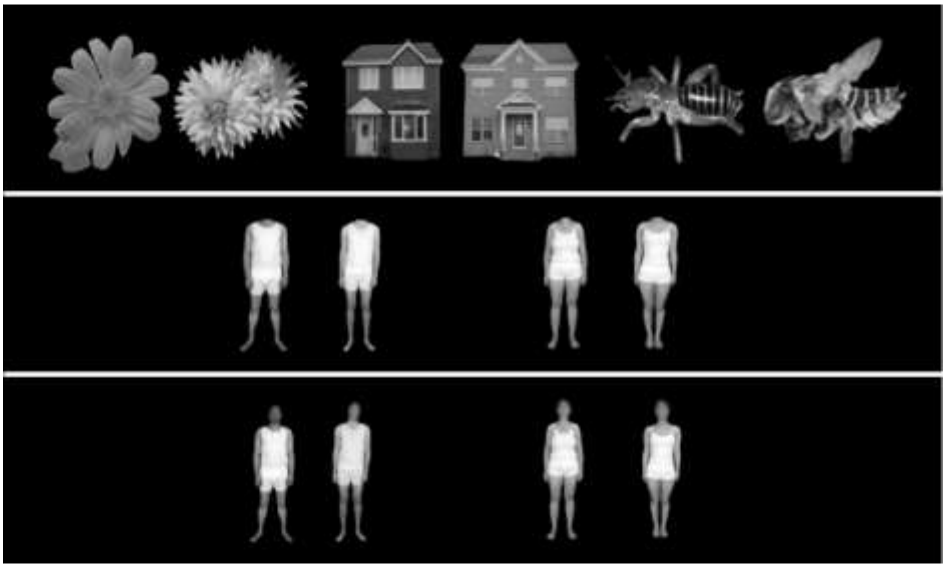

Figure 2.1. Stimuli rated for disgust, naturalness, fear, arousal and valence. From left to right and top to bottom; flowers, houses, insects, men's bodies with cropped heads, women's bodies with cropped heads, men's bodies with masked faces and women's bodies with masked faces.

2.3.1.4 Procedure

Instructions were given explaining that participation would involve rating pictures on the basis of disgust, fear, naturalness, valence and arousal. Informed consent was given via tick box to indicate that participants were at least 18 years old and that they understood their right to withdraw. Failure to provide informed consent terminated the task. In order for us to check whether participants were engaged, before ratings began each stimulus was randomly presented alongside a text box that required a brief description of the image. Following this, stimuli were presented randomly above a rating scale that corresponded to one of the five attributes measured, until all images had been rated for all five attributes. A response was always required in order to continue. Demographic information was collected and the task ended with a debrief statement and details of how to contact the researchers for further information. Completion of the entire rating task typically took between 8 and 10 minutes.

2.3.2 Results

2.3.2.1 Assessing task performance

There is debate about the appropriateness of treating Likert scale data as interval data and thus analysing them parametrically, or whether such data should be strictly treated as ordinal and analysed non-parametrically (cf. Allen & Seaman, 2007; Carifio & Perla, 2008; Jamieson, 2004; Knapp, 1990; Pell, 2005). It is argued then, that although Likert scales themselves are ordinal, the data generated are interval in nature (see Carifio & Perla, 2008; Pell,

2005) and that even when *F*-tests are used to analyse ordinal data, the results are unbiased as the *F*-test is extremely robust to violation of assumptions (Carifio & Perla, 2008; Glass, Peckham, & Sanders, 1972). With that in mind, and given that we recruited a large sample size and presented a 7-item scale (see Knapp, 1990), we were justified in treating Likert scale data as interval and analysing them parametrically.

First of all, written descriptions of the pictures were evaluated in order to determine whether participants were paying attention. We planned to discard data in instances where the content of the pictures had not been correctly identified.

In order to assess whether pictures evoked affective responses and whether participants engaged with the task, ratings for each picture (male and female bodies collapsed) were averaged and subjected to Bonferroni-adjusted one sample t-tests with a test value of 4 (neutral). T-tests are reported unsigned and Bonferroni adjustments were applied separately for each attributes group of comparisons.

All participants gave accurate descriptions of pictures and thus all data were analysed. Average ratings displayed in Table 2.1, suggest that flowers were rated quite positively, houses and corporeal pictures were rated fairly neutrally and insects were rated fairly negatively. Bonferroni adjusted one-sample t-tests revealed that flowers were rated more positively than neutral on all attributes (*t*(223) ≥ 17.844, p<.001), as were houses (*t*(223) ≥ 3.988, p<.001). Insects on the other hand, were rated more negatively than neutral on all attributes (*t*(223) ≤ 9.275, p<.001) other than naturalness, for which they were rated as more natural than neutral (*t*(223) = 12.198, p<.001). Ratings for headless bodies did not differ from neutral with regards to disgust, arousal and fear (*t*(223) ≤ 1.531, p≥.127) but they were rated as more natural and more positive than neutral (*t*(223) ≥ 3.215, p≤.001). A similar pattern was observed for bodies with masked faces as ratings did not differ from neutral with regards to disgust, arousal and fear (*t*(223) ≤ 1.480, p≥.140) but they too were rated as more natural and more positive than the neutral point (*t*(223) ≥ 2.813, p≤.005).

As expected, insects were rated negatively and flowers were rated positively, which suggests that participants were engaged with the task. The pattern of results also suggests that affective responses to headless bodies and bodies with masked faces might be similar.

Table 2.1

Average ratings across all 5 attributes for each stimulus (male and female bodies collapsed). A rating of 4 is equal to neutral, scores above 4 lean towards the positive-valence end of the spectrum (more delightful, natural, calming, positive, soothing) with 7 being the highest, whereas scores below 4 lean towards the negative-valence end of the spectrum (more disgusting, unnatural, fearful, negative, rousing) with 1 being the lowest.

Stimulus	Disgust	Naturalness	Fear	Valence	Arousal
Flowers	5.71 (1.03)	6.12 (1.18)	5.65 (1.00)	5.79 (1.00)	5.41 (1.18)
Insects	2.89 (1.30)	5.34 (1.65)	2.91 (1.03)	3.15 (1.38)	3.11 (1.12)
Houses	4.61 (1.02)	4.38 (1.45)	4.45 (.96)	4.66 (1.20)	4.36 (.96)
Bodies with cropped heads	4.06 (.57)	5.15 (1.33)	4.05 (.52)	4.17 (.78)	4.00 (.54)
Bodies with masked faces	4.06 (.56)	5.14 (1.24)	4.01 (.57)	4.15 (.80)	3.97 (.46)

Note: Standard deviation in parentheses.

2.3.2.2 Assessing differences between body stimuli

Ratings for body pictures were averaged across participants and subjected to a 2 (body type: headless vs. masked face) x 2 (gender: male body vs. female body) x 5 (attribute: disgust vs. fear vs. naturalness vs. valence vs. arousal) within-subjects ANOVA in order to assess for differences in affective responses between body stimuli specifically. Greenhouse-Geisser adjustments were applied where necessary.

Average ratings evident in Table 2.2 suggest that bodies with cropped heads and masked faces might be rated similarly, and that female bodies might be rated more positively than male bodies overall. ANOVA confirmed these observations as a main effect of body type was not found ($F(1, 223) = .763$, p

=.383, η_p^2 = .003), and did not interact with the gender of the body observed (*F*(1, 223) = .034, *p* = .885, η_p^2 < .001), or the attribute rated (*F*(1, 223) = .192, *p* = .877, η_p^2 = .001). The three-way interaction between body type, gender and attribute was also not significant (*F*(4, 892) = 1.150, *p* = .327, η_p^2 = .005).

A main effect of gender was found, however (*F*(1, 223) = 36.418, *p* <.001, η_p^2 = .140), such that female bodies were rated more positively overall than male bodies (see Table 2.2). A main effect of attribute was also found, (*F*(4, 892) = 165.279, *p* <.001, η_p^2 = .426), although not theoretically important, and is subsumed within the interaction of gender with attribute, which was also significant (*F*(4, 892) = 5.693, *p* =.001, η_p^2 = .025). Bonferroni-adjusted follow-up comparisons revealed that for disgust, valence, fear and naturalness, female body pictures were rated slightly more towards the positive end of the rating spectrum than male body pictures (*t*(223) ≥ 3.000, p ≤. 003). There were no gender differences in arousal ratings, however (*t*(223) = .730, p =. 470).

Table 2.2

Average ratings across all five attributes, for both male and female body stimuli. A rating of 4 is equal to neutral, scores above 4 lean towards the positive-valence end of the spectrum (more delightful, natural, calming, positive, soothing) with 7 being the highest, whereas scores below 4 lean towards the negative-valence end of the spectrum (more disgusting, unnatural, fearful, negative, rousing) with 1 being the lowest.

Stimulus	Disgust	Naturalness	Fear	Valence	Arousal
Men with cropped heads	3.96 (.73)	5.04 (1.48)	3.95 (.54)	4.04 (.85)	3.99 (.55)
Men with masked faces	3.97 (.63)	5.08 (1.36)	3.98 (.64)	3.97 (.87)	3.95 (.51)
Women with cropped heads	4.15 (.73)	5.27 (1.45)	4.12 (.70)	4.23 (.99)	4.01 (.73)
Women with masked faces	4.14 (.69)	5.21 (1.38)	4.13 (.67)	4.33 (1.03)	3.99 (.60)

Note: Standard deviation in parentheses.

2.3.3 Experiment 1: Interim summary of results

Our results suggest that explicit affective responses do not differ according to whether bodies are shown with the head cropped or with a masked face. Moreover, in instances where body pictures were rated differently from neutral, this was in a positive direction. This suggests that from an affective perspective, these stimuli sets are equally as adequate for investigating visual body processing. In addition, we have shown that in comparison to male bodies, female bodies seem to be held in a slightly more positive regard. This should be considered when investigating visual body perception in order to account for possible effects of top-down processing (see Gazzaley et al., 2005; Hillyard & Anllo-Vento, 1998).

2.4 Experiment 2: Free word association task

Experiment 2 aimed to address implicit affective responses to bodies with masked faces and headless body stimuli. In particular we were interested in whether the two types of stimuli were thought of differently in the absence of any particular guidance for their evaluation, as well as whether observers might comment on the appearance of the body more if the body was female compared to male. As a result, a free word association task was devised whereby participants were asked to freely speak all words that came to mind when observing pictures of flowers, insects, houses and both types of body stimuli.

2.4.1 Method

2.4.1.1 Participants

Thirty-eight University of Essex students (6 men) participated in the study in return for course credits. Those who reported a history of eating disorders or body dysmorphic disorder were not permitted to take part. The average age of the sample was 19 years (SD: 1 year).

2.4.1.2 Ethical declaration

The study was conducted in line with the 2008 Declaration of Helsinki and approved by the local Ethics Committee for the Psychology Department at the University of Essex.

2.4.1.3 Apparatus and stimuli

Stimuli as described in Experiment 1 were presented on 27 inch Apple iMacs with resolution 2560 x 1440 pixels (screen size 60 cm x 33.5 cm), running SuperLab 5. Audacity® 2.1.2 software was used to record vocal responses and transcription was completed manually.

2.4.1.4 Procedure

Standardised instructions were read, explaining that participants should vocalise words they associated with the pictures shown. It was made clear that there were no right or wrong answers and written informed consent was obtained.

Audio recording began and participants were asked to fixate on the centre of the screen. Each trial commenced with a black screen, which was displayed for 3000 ms. This was followed by a 600-ms beep, also accompanied by a black background, which served as a preparatory indication of a picture and separated trials on the audio recording. Stimuli were randomly presented in the centre of a black background for 20 s whilst participants freely spoke aloud all words that came to mind. Stimuli were shown twice each, resulting in 14 trials and a break was given after the 5th and the 10th trial. Each break ended when the participant pressed the space bar. Upon completion participants were debriefed and awarded course credit.

2.4.1.5 Qualitative assessment of the elicited words

As in similar word association studies (e.g. Ares & Deliza, 2010; Sester, Dacremont, Deroy, & Valentin, 2013) elicited associations were assessed for themes by two experimenters. A search for recurrent terms was performed for each stimulus and terms were grouped into themes according to personal interpretation of the words and word synonymy as determined by the Oxford English dictionary. Categorisation of terms and identification of themes was agreed in person between researchers. Two themes were obvious for all stimuli, which included valence and objectification. Words were therefore categorised according to whether they referred to positive affect (e.g. happy, nice), negative affect (e.g. scary, weird), appearance (e.g. beautiful, ugly) or competence/function (e.g. good posture, flying). For body stimuli three other themes were also apparent, these included making reference to the stimulus as a body, as a person (including reference to the body as he or she), and noticing whether the body had a masked face or cropped head. Phrases such as ‘open door,’ were categorised as one item, whilst miscellaneous words such as ‘disease’ and ‘summer’ were categorised as ‘other’ so that for each participant, counts of words in each category could be normalised as a proportion of total words elicited. Repetitions of words were coded individually, such that if an insect was referred to twice as nasty during one trial, or if nasty was uttered on one insect trial and then again on another for example, this was coded as two negative words.

2.4.2 Results

2.4.2.1 Assessing task performance

In order to assess differences in affective responses between pictures, and whether participants engaged with the task, the number of words each participant uttered of each category was counted as a proportion of the total number of words uttered by that participant. Proportions were used to control for the fact that the total number of words said by participants was variable. In total, 2522 words were uttered by all participants across all trials.

The average proportion of positive and negative words elicited for each picture (male and female bodies collapsed) was subjected to a 2 (valence: positive words vs. negative words) x 5 (stimulus: flowers vs. insects vs. houses vs. headless bodies vs. bodies with masked faces) within-subjects ANOVA. Greenhouse-Geisser corrections were applied where necessary.

The average proportion of positive and negative words elicited in response to each stimulus (see Table 2.3) indicates that flowers evoked more positive than negative affective responses whereas insects evoked more negative than positive affective responses. ANOVA confirmed this observation as there was a significant interaction between stimulus and valence ($F(4, 148) = 36.387$, $p <.001$, $\eta_p^2 = .496$). Bonferroni-adjusted follow-up comparisons revealed that flowers ($t(37) = 3.647$, $p = .001$) and houses ($t(37) = 2.920$, $p < .001$) both elicited more positive affective words than negative, whilst insects elicited more negative affective words than positive (*t*(37) = 6.857, p < .001, see Table 2.3). By comparison, there were no differences between the proportion of positive and negative affective words elicited to either type of body stimuli (*t*(37) ≤ 1.700, p ≥ .114). A main effect of stimulus was also found (*F*(4, 148) = 33.419, *p* <.001, η_p^2 = .475), such that insects evoked the most affect compared to other stimuli (*t*(37) ≥ 5.050, p < .001), the number of affective responses to houses and flowers were no different to each other (*t*(37) = .700, p = 1.000), whilst body stimuli evoked the least number of affective responses overall (*t*(37) ≥ 3.000, p ≤ .031) although there were no differences between body types (*t*(37) = 2.000, p = .728). In addition, a main effect of valence was also evident (*F*(1, 37) = 13.884, *p* = .001, η_p^2 = .273) as 7% of the total words elicited were negative, compared to 3.6% that were positive.

This pattern of results suggests that participants were engaged with the task and that there were no differences in affective response to the two types of body stimuli.

Table 2.3

Average proportion of positive, negative, appearance, competence/function and other words elicited as well as the amount of participants who responded (respondents) for each stimulus (male and female bodies collapsed). Standard deviation in parentheses.

Stimulus	Positive	Negative	Appearance	Competence/Function	Other
Flowers	.074 (.102)	.011 (.036)	.357 (.232)	.034 (.063)	.524 (.246)
Respondents	18	4	34	12	37
Insects	.006 (.033)	.295 (.249)	.272 (.190)	.057 (.112)	.368 (.258)
Respondents	2	29	32	14	33
Houses	.087 (.137)	.013 (.064)	.298 (.242)	.063 (.119)	.539 (.293)
Respondents	17	3	33	13	35
Bodies with cropped heads	.004 (.015)	.008 (.019)	.423 (.205)	.035 (.076)	.290 (.265)
Respondents	3	6	35	7	26
Bodies with masked faces	.007 (.028)	.024 (.053)	.420 (.190)	.030 (.076)	.255 (.227)
Respondents	4	10	34	7	27

2.4.2.2 Assessing differences between body stimuli

Affective responses and objectification of body stimuli were assessed with two separate 2 x 2 x 2 within-subjects ANOVAs, whereby factors included either valence (positive words vs. negative words) or objectification (appearance words vs. competence words), gender of the body observed (male vs. female) and body type (cropped head vs. masked face). Three separate 2 x 2 within-subjects ANOVAs with the factors body type (headless vs. masked face) and gender of the body observed (male vs. female) investigated whether stimulus type affected the extent to which a stimulus was referred to respectively as a body; as a person; and identified as having a cropped head versus a masked face.

The 2 x 2 x 2 ANOVA conducted to investigate valence responses to body stimuli specifically, found no main effect of gender ($F(1, 37) = 1.489$, $p = .230$, $\eta_p^2 = .039$) and no main effect of valence ($F(1, 37) = 3.272$, $p = .079$, $\eta_p^2 = .081$). Although bodies with masked faces evoked more valence-related words than headless bodies on average (see Table 2.3), there was no main effect of body type ($F(1, 37) = 3.410$, $p = .073$, $\eta_p^2 = .084$). There were also no significant interactions between these factors ($F(1, 37) \leq 2.080$, $p \geq .158$, $\eta_p^2 \leq .053$). In general, body stimuli were regarded with few valence-related words and thought of neutrally on average. Thus, there were no differences in the proportion of positive- or negative- valence words used to describe male or female bodies with cropped heads or masked faces.

As can be seen in Table 2.4, the average proportion of appearance words elicited appeared to be greater than that of competence words. ANOVA confirmed this as a main effect of objectification ($F(1, 37) = 161.708$, $p < .001$, $\eta_p^2 = .814$), with appearance words elicited 42.1% of the time, compared to competence words, which were elicited 3.3% of the time. Again, there was no main effect of gender ($F(1, 37) = .812$, $p = .373$, $\eta_p^2 = .021$) or body type ($F(1, 37) = .113$, $p = .739$, $\eta_p^2 = .003$). There were also no significant interactions ($F(1, 37) \leq 2.045$, $p \geq .161$, $\eta_p^2 \leq .052$). This suggests that bodies were thought of in terms of their appearance rather than their competence regardless of the gender or of whether the body was presented with a cropped head or masked face. In order to assess whether this was specific to bodies or more likely due to the visual nature of the task, a follow-up 3 x 2 within-subjects ANOVA was conducted with picture (house, flower, insect) and objectification (appearance, function) as factors. A main effect of objectification was found ($F(1, 37) = 63.681$, $p < .001$, $\eta_p^2 = .633$), with appearance words elicited 30.9% of the time, compared to competence words, which were elicited 5.1% of the time. No other main effects or interactions were significant ($F(1, 37) \leq 3.021$, $p \geq .060$, $\eta_p^2 \leq .075$). This suggests that objectification was not necessarily specific to bodies, but that participants tended to describe what they saw in appearance-related terms for all stimuli.

An ANOVA assessing the proportion of times stimuli were referred to as a body also found no main effect of gender (*F*(1, 37) = 2.293, *p* = .138, η_p^2 = .058), no main effect of body type (*F*(1, 37) = .086, *p* = .771, η_p^2 = .002) and no interaction between these two factors (*F*(1, 37) = .016, *p* = .899, η_p^2 < .001).

Although on average, participants appeared to refer to bodies with masked faces as people more often than bodies with cropped heads, which was particularly evident for male bodies (see Table 2.4), a 2 x 2 ANOVA assessing the proportion of times bodies were referred to as people revealed no main effect of gender (*F*(1, 37) = .039, *p* = .845, η_p^2 = .001), no main effect of body type (*F*(1, 37) = 3.709, *p* = .062, η_p^2 = .091) and no interaction (*F*(1, 37) = 3.510, *p* = .069, η_p^2 = .087).

Finally, a 2 x 2 ANOVA on the proportion of references to whether the head was cropped or the face was masked also found no main effect of gender (*F*(1, 37) = 1.243, *p* = .272, η_p^2 = .033), no main effect of body type (*F*(1, 37) = .694, *p* = .410, η_p^2 = .018) and again, no interaction (*F*(1, 37) = .008, *p* = .928, η_p^2 < .001). This series of results indicate that bodies with cropped heads are not thought of as less of a body or a person in comparison to bodies with masked faces. Moreover, stated awareness of the specific manipulation of each body type did not differ.

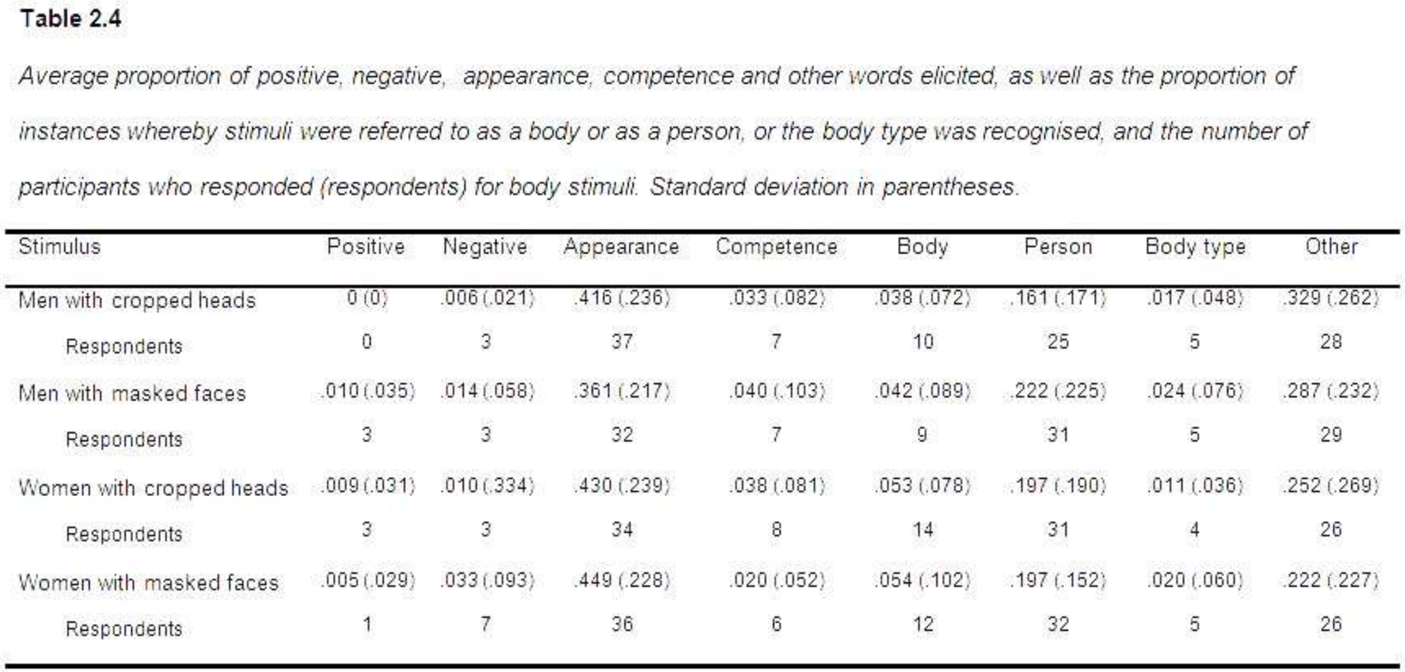

Table 2.4

Average proportion of positive, negative, appearance, competence and other words elicited, as well as the proportion of instances whereby stimuli were referred to as a body or as a person, or the body type was recognised, and the number of participants who responded (respondents) for body stimuli. Standard deviation in parentheses.

Stimulus	Positive	Negative	Appearance	Competence	Body	Person	Body type	Other
Men with cropped heads	0 (0)	.006 (.021)	.416 (.236)	.033 (.082)	.038 (.072)	.161 (.171)	.017 (.048)	.329 (.262)
Respondents	0	3	37	7	10	25	5	28
Men with masked faces	.010 (.035)	.014 (.058)	.361 (.217)	.040 (.103)	.042 (.089)	.222 (.225)	.024 (.076)	.287 (.232)
Respondents	3	3	32	7	9	31	5	29
Women with cropped heads	.009 (.031)	.010 (.334)	.430 (.239)	.038 (.081)	.053 (.078)	.197 (.190)	.011 (.036)	.252 (.269)
Respondents	3	3	34	8	14	31	4	26
Women with masked faces	.005 (.029)	.033 (.093)	.449 (.228)	.020 (.052)	.054 (.102)	.197 (.152)	.020 (.060)	.222 (.227)
Respondents	1	7	36	6	12	32	5	26

2.4.3 Experiment 2: Interim summary of results

Similar to Experiment 1, there were no differences in the verbal associations made to bodies with cropped heads and bodies with masked faces. Both types of body evoked a similar proportion of positive and negative associations, appearance and competence-related terms, and both were as likely as each other to be described as bodies or persons, or in terms of their specific type. Unlike Experiment 1, however, female bodies did not evoke more positive affect than male bodies in this free association task.

2.5 Discussion

Two experiments, comprised of two different tasks, were conducted with large samples in order to assess potential differences in how participants felt, both implicitly and explicitly, in response to body stimuli with cropped heads compared to body stimuli with masked faces. This was an important and necessary investigation in order to identify emotional responses that might confound the findings of neuroimaging and electrophysiological studies of body perception. Both male and female body forms were included as research shows that men and women’s bodies might be thought of differently (e.g., Bernard et al., 2012; Cazzato et al., 2014; Gervais et al., 2012). We predicted that bodies with cropped heads would not evoke more negative responses than those with masked faces as might be assumed (Minnebusch & Daum, 2009; Minnebusch et al., 2009) given that bodies with masked faces may evoke meaning threat (see Proulx et al., 2010). We did expect that there might be differences in affective responses according to the gender of the body observed (e.g. Cazzato et al., 2014; Groves, Kennett, & Gillmeister, 2017), and also that the appearance of female bodies might be referred to more so than that of male bodies in Experiment 2 (Heflick & Goldenberg, 2014).

Experiment 1 established that explicit affective evaluations of headless body stimuli and body stimuli with masked faces did not differ. Specifically, all body types were rated equally on the basis of disgust, fear, naturalness, valence and arousal. In instances where body pictures were rated differently from neutral, it was in a positive direction. In addition, female bodies were rated slightly more positively than male bodies, irrespective of whether the body was presented with a masked face or a cropped head.

Results from Experiment 2 support those from Experiment 1 as there were no differences in the nature or proportion of words elicited between the two types of body stimuli. Unlike Experiment 1, however, male and female bodies did not appear to be thought of differently. Bodies in general evoked more appearance words than competence words, but this was also the case for other stimuli and therefore cannot be taken as evidence for body objectification.

Overall, we found no evidence to support the argument that bodies with cropped heads are confusing or that they are not thought of as bodies because they miss a key feature of a person’s configural structure (see Minnebusch et al., 2009). In fact, in Experiment 1 all participants correctly identified both types of body stimuli as bodies, and in Experiment 2 both types of body stimuli were referred to as bodies and as persons comparably often. Further to this, we found no evidence to suggest that headless bodies were thought of as unnatural, as has been previously claimed (Minnebusch & Daum, 2009). These null findings should be viewed in the context of the many significant findings of differing affective judgement and free association word use across our different control stimulus types (i.e., flowers, insects and houses).

Taken together then, the pattern of results suggests that there are no differences between affective responses to bodies with cropped heads and masked faces. Importantly, both types of stimuli were thought of rather neutrally and therefore appear equally adequate for investigating visual body processing with regards to the affect that they evoke. As a result, it is unlikely that the effects of differential valence or arousal can explain the inconsistent findings evident in studies that used the two different types of stimuli (e.g., Alho, Salminen, Sams, Hietanen, & Nummenmaa, 2015; Minnebusch et al., 2009; Robbins & Coltheart, 2012; Yovel et al., 2010). It is possible that attentional processes may account for these differences instead, as it has been shown that unusual aspects of a stimulus are fixated on more quickly and for longer (Rayner, Castelhano, & Yang, 2009). Therefore, with evidence to suggest that images of bodies with blurred, pixelated or obscured faces are thought of as unusual (Proulx et al., 2010), perhaps attention is drawn to the blurred face rather than to the body. Given that even contextual cues of the head can elicit face processing mechanisms (e.g. Cox et al., 2004; Morris et al., 2006) and as findings from our study suggest that headless bodies are not thought of as more strange than bodies with blurred faces, headless body stimuli may avoid some problems that bodies with blurred faces pose. Nonetheless, the debate would benefit from further research into the attentional processes associated with observing body stimuli with masked faces compared to those where features are made absent rather than unusual, such as bodies with cropped heads. Moreover, given the fact that face processing mechanisms are activated by the presence of the head (Cox et al., 2004; Morris et al., 2006), bodies with cropped heads also appear to be a wise choice of stimuli in order to investigate the distinct mechanisms underlying body representations.

We also found some evidence to suggest that female bodies are held in a slightly more positive regard than male bodies, although we found no evidence to support the idea that female bodies are objectified to a greater extent than male bodies (e.g. Heflick & Goldenberg, 2014; Vaes et al., 2011). It is not entirely clear why women’s bodies might be thought of more positively than men’s bodies, at least when explicitly evaluated. This pattern could be driven by a societal paradigm shift that encourages positive body image and is typically aimed at reshaping the way the female form is evaluated, especially by women (e.g. Paxton, McLean, Gollings, Faulkner, & Wertheim, 2007; Stice, Marti, Spoor, Presnell, & Shaw, 2008; Wood-Barcalow, Tylka, & Augustus-Horvath, 2010). As a consequence, perhaps media messages and early interventions encouraging positive evaluation of the female form irrespective of weight and shape (see also McKelle-Fischer, 2015, for example) results in women's bodies being thought of in a more positive light than men's bodies. As our sample consisted of a female majority, this might have been especially true. This is largely speculative, however, as limited research exists that has evaluated the efficacy or consequences of these campaigns, especially from a psychological perspective (e.g. Beaudoin, Fernandez, Wall, & Farley, 2007; Heiss, 2011). Further research is required so as to determine why there are affective differences in how male and female bodies are rated in explicit tasks, as well as why such differences are absent in free word associations, which measure affective evaluations more implicitly.

It is also possible that female bodies were rated more positively because they were thought of as being more attractive. This is supported by evidence that suggests increased attractiveness is associated with increased positive valence as well as positive cognition (Eagly, Ashmore, Makhijani, & Longo, 1991; Langlois et al., 2000; Zebrowitz & Franklin, 2014). Furthermore, it has also been shown that the subjective experience of sexuality and/or sexual orientation does not necessarily dictate the perception of attractiveness (see Rieger, Savin-Williams, Chivers, & Bailey, 2016). Future studies should therefore seek to address whether the affective differences observed towards male and female bodies might be related to how attractive the perceiver reports the body to be.

Taken together, our findings add to a growing literature recommending that stimulus gender be considered when investigating visual body perception. Visual cortical processing mechanisms can differ according to the gender of the body observed (e.g. Alho et al., 2015; Gervais et al., 2012; Groves et al., 2017; Heflick & Goldenberg, 2014; Hietanen & Nummenmaa, 2011), and it has been shown that even the earliest of electrophysiological responses from visual cortex can be modulated by top-down processes (e.g. Meeren et al., 2005; van Heijnsbergen et al., 2007). As a result, if female bodies receive different affective evaluations than male bodies, even early cortical effects may differ.

2.6 Conclusion

There do not appear to be differences in the way participants feel about bodies with cropped heads versus bodies with masked faces. Thus, it seems more appropriate to investigate the behavioural and neurophysiological mechanisms associated with body processing with headless body stimuli. Our results also highlight the importance of considering the gender of the observed body when analysing results and forming conclusions.

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Chapter 3 Early visual ERPs show own-body sensitivity and stable body-sensitive patterns over a 4-week test period

3.1 Abstract

Event-related potential (ERP) studies feature among the most cited papers in the field of body representation, with recent research highlighting the potential of ERPs as neuropsychiatric biomarkers. Despite this, the question whether early visual ERPs and body-sensitive effects are reliable over time has been overlooked. This study aimed to assess the stability of early body-sensitive effects and visual P1, N1 and VPP responses during a task that investigated the effects of own- and other-body viewing. Participants were asked to identify pictures of their own bodies, other bodies and houses during an EEG test session that was completed at the same time, once a week, for four consecutive weeks. Results showed an enhanced body-sensitive N1 in response to own-body stimuli compared to other-body stimuli, whilst amplitude and latency of early visual components and their associated body-sensitive effects were stable over the 4-week period. Correlational analyses revealed that amplitude might be more reliable than latency and specific electrode sites might be more robust indicators of body-selective cortical activity than others. These findings suggest that own-body viewing holds a special status during the structural encoding of the human form and that visual P1, N1 and VPP responses, alongside body-sensitive N1/VPP effects, are robust indications of neuronal activity. We conclude that these components are eligible to be considered as electrophysiological biomarkers.

3.2 Introduction

In a pioneering study, a bilateral region in the lateral occipito-temporal cortex (extrastriate body area; EBA) was identified as a module for body processing, as it was found to respond strongly and selectively to images of the human body and human body parts (Downing, Jiang, Shuman, & Kanwisher, 2001). Subsequent research has revealed that EBA activity is likely involved with processing body parts and body shape as well as possibly distinguishing identity and emotion (see Downing & Peelen, 2011; Downing & Peelen, 2016 for review). The fusiform body area (FBA), a second body-selective region found ventrally on the fusiform gyrus, was described a few years later (Schwarzlose, Baker, & Kanwisher, 2005). It has been suggested that FBA and EBA contribute functionally distinct representations of the body to person perception (Taylor, Wiggett, & Downing, 2007) although this is somewhat debated (e.g. Chan & Baker, 2011; Hodzic, Kaas, Muckli, Stirn, & Singer, 2009; Urgesi, Calvo-Merino, Haggard, & Aglioti, 2007). Nonetheless, it is widely accepted that the visual perception of human bodies recruits highly specialised and selective neuronal networks in the occipital cortex (see Downing & Peelen, 2011 for review).

Event related potential (ERP) studies have corroborated these findings, with reports of a functional difference in early electrophysiological responses over occipito-parietal and fronto-central electrodes when bodies are viewed in comparison to other stimuli (see Minnebusch & Daum, 2009 for review). This study was particularly interested in these early electrophysiological indicators of body representation. Temporal differences between responses to bodies and other stimuli have been reported as early as 100 ms after stimulus onset (e.g. Thierry et al., 2006). Most typically however, body-sensitive ERP responses are reported as an enhanced negative deflection peaking at around 150 ms – 190 ms after body viewing in comparison to viewing non-body stimuli (e.g. Minnebusch, Suchan, & Daum, 2009; Pourtois, Peelen, Spinelli, Seeck, & Vuilleumier, 2007; Taylor, Roberts, Downing, & Thierry, 2010; Thierry et al., 2006). Evidence from source localisation techniques (e.g. Meeren, de Gelder, Ahlfors, Hämäläinen, & Hadjikhani, 2013; Thierry et al., 2006), direct intracranial recordings (e.g. Pourtois et al., 2007), magnetoencephalography (e.g. Ishizu, Amemiya, Yumoto, & Kojima, 2010) and transcranial magnetic stimulation (TMS) (e.g. Sadeh et al., 2011) has implicated EBA activity in the origins of this effect. The reported timing of the component has seen body-sensitive responses variably referred to as N1, N170 or N190 (see also de Gelder et al., 2010; see Downing & Peelen, 2016 for review). We will refer to this component as a body-sensitive N1 throughout this paper.

In addition, reports have described a body-sensitive enhancement of the vertex positive potential (VPP), evident over fronto-central sites, when participants view bodies in comparison to non-body stimuli (e.g. Sadeh et al., 2011; Stekelenburg & de Gelder, 2004; van Heijnsbergen, Meeren, Grèzes, & de Gelder, 2007). Studies on the selective processing of faces suggest that VPP responses are generated by the same neural sources as N1 responses and thus reflect the same process (e.g. Joyce & Rossion, 2005). Although this has been questioned (e.g. Eimer, 2000b; Taylor, McCarthy, Saliba, & Degiovanni, 1999), TMS delivered to EBA has been found to increase VPP amplitudes to bodies but not to faces, whereas TMS delivered to the occipital face area (OFA) resulted in the reverse pattern (Sadeh et al., 2011). This therefore suggests that, similarly to the body-sensitive N1, body-sensitive VPP responses may also arise from EBA activity.

Investigations into body-sensitive ERP effects have typically focused on whether responses are modulated by emotion, and whether they provide an indication of the visual processing mechanisms employed during body perception (i.e., whether bodies are processed as a sum of their parts or whether they are processed on a feature-by-feature basis) (e.g. Minnebusch, Keune, Suchan, & Daum, 2010; Minnebusch et al., 2009; Stekelenburg & de Gelder, 2004; Taylor, Roberts, et al., 2010; van Heijnsbergen et al., 2007). The value of these findings is heavily reliant on the validity and reliability of the ERPs measured; in other words, the extent to which they can be considered trustworthy. A trustworthy measure must be both reliable (yields the same outcome when repeated) and valid (measures only what it claims to measure), with the validity of a scientific measurement dependent on its reliability (Howell, 2012).

Reliability is a serious concern for ERP research (see Luck, 2014), which is important to consider not only in order to establish whether reported effects are trustworthy, but also in order to ascertain whether ERPs and their associated effects are stable within individuals. It is therefore surprising that research into the reliability of visual ERPs is sparse. To the best of our knowledge, no study has investigated the test-retest reliability of body-sensitive ERPs, whilst very few studies have investigated the test-retest reliability of early visual ERPs in themselves (Huffmeijer, Bakermans-Kranenburg, Alink, & van Ijzendoorn, 2014; Kompatsiari, Candrian, & Mueller, 2016; Muthukumaraswamy, Singh, Swettenham, & Jones, 2010; Tello et al., 2010). This is a rather worrying oversight as ERP studies produce some of the most cited papers in the field of face and body representation. Not only this, but there is preliminary evidence to suggest that early visual processing as indexed by P1 and N1 components, may provide a ‘bio-signature’ of an important phenotype in disorders of body image such as anorexia, bulimia and BDD (Li et al., 2015). Furthermore, Groves, Kennett, and Gillmeister (2017) have also suggested that gender-sensitive body processing in N1 and VPP amplitudes may be potential ERP markers of body image disturbances in both bulimia and anorexia (unlike Alho, Salminen, Sams, Hietanen, & Nummenmaa, 2015; Hietanen & Nummenmaa, 2011, who suggest early gender-sensitivity is a trigger for sexual behaviour).

The electroencephalogram (EEG) is already a useful tool in the clinical, routine assessment of neurological conditions such as cerebrovascular disease, dementia and epilepsy (Nuwer, 1997). At least two studies have reported encouraging results for the use of ERPs as ‘neuromarkers’ or ‘vital signs’ of cognitive (dys)function (Ghosh Hajra et al., 2016; Williams et al., 2005). As a move towards more objective neuropsychiatric evaluation techniques gathers momentum, ERPs have been proposed as a promising tool for the assessment of cognitive processes (Connolly & D'Arcy, 2000). With calls for the identification of objective, biological markers of the symptoms associated with body image disturbances (e.g. Smeets, 1997; World Eating Disorders Action Day, 2016) the identification of neural markers is timely. However, such measures cannot be applied until their reliability has been established.

Thus, the primary aim of this study was to address the test-retest reliability of early visual ERPs, namely the P1, N1 and VPP, as well as the test-retest reliability of body-sensitive ERP effects. The reason for this was not only to inform the validity of research in the body processing field, but also to address whether these components have the potential to be trustworthy neural markers.

Previous research has found the amplitudes of early and late visual and auditory components, early face-sensitive components and error-related components to be highly reliable, whilst the latencies are less reliable (e.g. Fallgatter et al., 2001; Gaspar, Rousselet, & Pernet, 2011; Huffmeijer et al., 2014; Kompatsiari et al., 2016; Kooi & Bagchi, 1964; Tello et al., 2010; Walhovd & Fjell, 2002). As a result, we expected P1, N1 and VPP amplitudes to be highly reliable, whilst latencies might be somewhat less so.

Reliable ERP responses to emotional face stimuli within individuals have been reported, as one study found no changes in N170, VPP, medial frontal negativity (MFN), feedback-related negativity (FRN), P3, and late positive potential (LPP) amplitude over a 4-week period (Huffmeijer et al., 2014). Also, it has been reported that face-sensitive ERP responses are stable at 4 years, 17 years and adulthood, as P1, N170 and N250 amplitude, latency and topography presented similarly in all three age groups (Kuefner, de Heering, Jacques, Palmero-Soler, & Rossion, 2010). Although body perception is understood to be distinct from face perception (see de Gelder et al., 2010; Downing & Peelen, 2016; Reed, Stone, Grubb, & McGoldrick, 2006; Sadeh et al., 2011; Thierry et al., 2006), the underlying processes are thought to be similar (see Minnebusch & Daum, 2009). Therefore, we predicted that body-sensitive ERP effects would be reliable.

The ultimate purpose of body-sensitive visual processing is person perception, namely the perception of and distinction between different bodily identities. The pinnacle of person perception is arguably self-recognition. If visual ERPs are sensitive to own-body viewing and they are stable over time, then they can be taken as reliable indices of the visual perception of one’s bodily self. This is of interest because own-body identity is disturbed in disorders such as somatoparaphrenia, which is characterised by the monothematic belief that certain body parts, or an entire side of the body, belong to another person (see Vallar & Ronchi, 2009 for review), ‘pointing to body parts’ disorders such as heterotopagnosia, whereby own- and other-body representations are confused (see Felician & Romaiguère, 2008 for review) and body integrity identity disorder, which is understood as a severe incongruence between a person’s body image and their physical body (see Blom, Hennekam, & Denys, 2012). Additionally, some aspects of visual self-recognition are destabilised in certain psychological conditions (e.g. in schizophrenia, Irani et al., 2006; in depersonalization, Ketay, Hamilton, Haas, & Simeon, 2014; and in body image disturbance, Vocks et al., 2010b). As far as we are aware, no study to date has investigated whether body-sensitive ERPs are sensitive to the observation of one’s own body. A modulation by own- vs other-body stimuli may be expected under the assumption that body-sensitive N1 and VPP responses arise from EBA activity (see Ishizu et al., 2010; Pourtois et al., 2007; Sadeh et al., 2011; Thierry et al., 2006), which has been found responsive to (self) identity (cf. Castellini et al., 2013; David et al., 2009; Devue et al., 2007; Hodzic, Kaas, et al., 2009; Vocks et al., 2010a) and viewing perspective (Chan, Peelen, & Downing, 2004 2004; Saxe, Jamal, & Powell, 2006 2006). Furthermore, as these findings have been somewhat mixed, for example with respect to hemispheric differences (Hodzic, Kaas, et al., 2009; Hodzic, Muckli, Singer, & Stirn, 2009; Vocks et al., 2010b) and as Downing and Peelen (2011) propose that EBA/FBA do not explicitly represent identity beyond the shape of a body, an assessment of body-sensitive ERPs may be informative to the debate about whether and how own-body stimuli demand privileged analysis during EBA-related processing stages.

In sum, the present study therefore aimed to test the reliability of early visual ERPs and body-sensitive effects. Finding stable ERPs and body-sensitive effects would suggest that these electrophysiological responses could potentially serve as neuropsychiatric biomarkers. Furthermore, we aimed to investigate bodily self-identity perception by assessing whether electrophysiological body sensitivity is modulated by viewing one's own vs another person's body. Participants were invited to complete the same image classification task, once a week for four consecutive weeks (as stable visual responses have been found within this time frame, Muthukumaraswamy et al., 2010), whilst we recorded their brain's EEG response to own-body, other-body and non-body (house) stimuli. We chose to include whole body stimuli as well as body part stimuli because studies that found stronger EBA activity to 'own' bodies had presented whole body stimuli (Hodzic, Muckli, et al., 2009; Vocks et al., 2010a) whereas studies that manipulated viewpoint and found evidence to the contrary, typically presented parts of bodies (Chan et al., 2004; Saxe et al., 2006). As both EBA activity and body-sensitive N1 amplitudes may respond linearly to the number of body parts visible (Taylor, Roberts, et al., 2010; Taylor et al., 2007) we included both types of stimuli in order to control for the possibility that this could be one explanation of the difference between findings. Whole-house stimuli and house-part stimuli were also included in order to balance the task, but were not included in the identity analyses. Reaction time (RT) and accuracy were also monitored in order to ascertain whether potential ERP effects were related to behaviour. In addition, participants were asked to complete the Body Consciousness Questionnaire (Miller, Murphy, & Buss, 1981) as a control for the possibility that more conscious awareness of one's own body may explain potential effects related to identity processing. In line with previous research, we predicted that early visual ERP amplitudes and body-sensitive effects (i.e. amplitude differences between body and non-body stimuli) would be reliable, whereas early visual ERP latencies may be less reliable. Based on studies that revealed stronger EBA activation to own-body stimuli (Hodzic, Muckli, et al., 2009; Vocks et al., 2010a) we thought it likely that body-sensitive N1, and possibly VPP, amplitudes would be enhanced by own-body viewing.

3.3 Method

3.3.1 Participants

Seven men and seven women were recruited to participate from the University of Essex. Demographic information such as age, exercise habits and area of work and/or study were collected in order to determine whether participants were primed by their lifestyle to recognise or focus on their own body and/or those of others. The average age of male participants was 26 years (SD: 4 years) and for female participants was 31 years (SD: 6 years). The average amount of exercise per week was approximately 7 hours (SD: 3 hours) for men, and 6 and a half hours (SD: 5 hours) for women. For all participants this was generally aerobic in nature. One man and one woman reported an area of study with particular focus on the body: ‘Sports Science.’ Participants were paid £54 as reimbursement for their time.

3.3.1.1 Exclusion criteria

Those who reported a clinical history of body perception disorders, eating disorders, or a major psychiatric disorder such as schizophrenia or bipolar disorder, were not permitted to take part.

One male participant failed to return after the first session so his data were not included. During the study, another participant disclosed a transgender identity and informed us that they were beginning the gender reassignment procedure. We felt the conflict between the physical sex of the body and gender identity could be a potential confound to recognising one's own body and thus excluded these data. Therefore, data were analysed from six men and six women who completed the full 4-week test-retest protocol.

3.3.2 Ethical declaration

The study was conducted in line with the 2008 Declaration of Helsinki, and was approved by the Ethics Committee for the Department of Psychology at the University of Essex. Informed written consent was obtained from each participant before the study commenced and all participants consented to photographs of their body (without the head) being used as stimuli.

3.3.3 Apparatus and stimuli

3.3.3.1 Questionnaires

The ‘Body Consciousness Questionnaire’ (BCQ) (Miller et al., 1981) was used to assess body awareness. The 15-item measure is constructed of three 5-item subscales that relate to ‘private body consciousness,’ ‘public body consciousness’ and ‘body competence’. Respondents self-report using a 5-point Likert scale from 0 (extremely uncharacteristic) to 4 (extremely characteristic) with higher scores indicative of greater body awareness. This was included to control for the possibility that a stronger sense of body awareness may influence the ability to recognise oneself as it is reportedly a widely used, valid and reliable tool (Mehling et al., 2009).

A ‘week-to-week comparison’ questionnaire was also devised and administered for the purpose of this study. It consisted of self-report questions designed to probe how focused, stressed, tired and hungry the participants were from one session to the next. It also assessed caffeine and medication intake whilst giving the opportunity for participants to report ‘any other information’ that they thought may affect their performance. This was done in order to assess consistency between sessions and also to act as a reminder to the participant about the importance of controlling as many of these factors as possible from week to week.

3.3.3.2 EEG stimuli

Using a Minolta Dimage A2 camera, participants were photographed standing, sitting and lying in white vest top and briefs that were provided by the experimenter. This photoshoot was conducted against a black background that was lit by two 3x36W fluorescent units, with a cool white colour temperature of 4100K. Images were edited using *Adobe PhotoShop* to ensure backgrounds were completely black and the head was cropped.

In total, 11 pictures of each participant's full body, without the head, were used. These included 3 standing, 3 sitting and 3 lying down, with views of each position from the front, side and back. There were also 2 kneeling positions included; 1 to the front and 1 to the side. In addition, 16 pictures of each participant's body parts were used. These depicted varying viewpoints and included 3 of the extended torso (neck to mid-thigh), 2 of the stomach, 1 of the chest, 1 of the torso (neck to hips), 2 of the leg bent at the knee, 3 of the whole legs and 4 of the whole arm.

Two stimulus sets were created, one for male participants and one for female participants, whereby 'other' bodies and 'other' body parts were images of the 'other' participants of the same gender. Thus, a set of 66 'whole other-body' stimuli, 11 'whole own-body' stimuli, 96 'other-body part' stimuli and 16 'own-body part' stimuli was created for each participant (see Figure 3.1 for examples).

In addition, 66 whole-house images of varying viewpoints were downloaded from the Worldwide Web. To reflect the ‘body parts’ condition, 96 images of house parts were also downloaded; this included 14 conservatories, 14 doors, 14 porches, 14 roofs, 14 windows, 13 images of the top half of a house and 13 images of the bottom half of a house (see Figure 3.1). No own-house stimuli were shown. All stimuli were 1024 pixels in width (max. 20 cm) and 768 pixels (max. 13 cm) in height and had their brightness adjusted to control for luminance across all images.

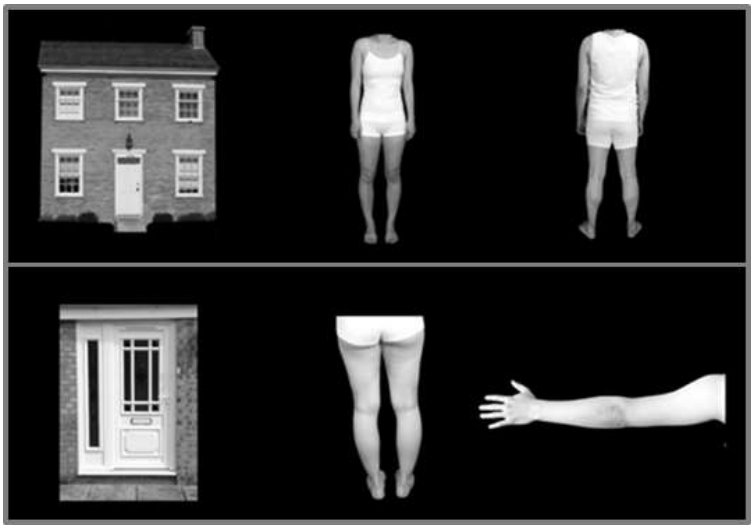

Figure 3.1 Example stimuli controlled for overall image brightness. (Top: whole stimuli, bottom: parts of stimuli, far left panel: house stimuli, middle panel: female body stimuli, far right panel; male body stimuli).

3.3.4 Procedure

Participants were asked to individually attend five sessions; one photo session, and four EEG test sessions that ran at the same time for four consecutive weeks. Prior to participation, each individual was fully briefed on the procedure of each session via email.

3.3.4.1 Photograph session

The duration of the photo session was one hour. Written instructions were given upon arrival, and participants were given the opportunity to ask questions before written consent was obtained. Following this, each participant was shown to a private booth where they changed into a white vest top and white briefs provided by the experimenter. Sizes had been requested in advance. All jewellery was removed and long hair was tied back. Those who requested to wear white underwear underneath the clothing provided were permitted to.

Participants were directed by the experimenter to pose in the centre of the photographic set-up. Each participant was given the option to view the images and delete those they did not find satisfactory before leaving the session. None did so.

3.3.4.2 Test sessions

Participants returned for the first test session from between 1 week to 1 month after the photograph session. A standardised overview of procedures was read and written consent was obtained at the start of each session. The week-to-week questionnaire and the BCQ were completed during EEG preparation. The BCQ was only completed in the first week; this was the only difference between test sessions.

Participants were seated approximately 60 cm (30° 18' 0.49'' visual angle) from the screen to complete an identification task in which they had to decide whether the image shown was of their own body, another body or a house. Emphasis was placed on speed and accuracy. They were asked to fixate on the centre of the screen whereby a white cross was presented for 250 ms on a black background. Stimuli were then shown for 250 ms, followed by a 1500 ms response interval that terminated once a response was given. A random intertrial interval of between 300 ms and 700 ms separated individual trials.

Participants were instructed to give one of three responses by pressing either the ‘O’ key to ‘other’ with the right index finger, the ‘S’ key to ‘self’ with the left index finger, or the space bar to ‘house’ with both thumbs.

Own-body stimuli (11 ‘whole own-body’ images, 16 ‘own-body part’ images) were shown 6 times, ‘other’ body stimuli taken from the 6 other participants of the same gender (66 ‘whole other-body’ images, 96 ‘other-body part’ images), and house stimuli (66 ‘whole houses,’ 96 ‘house parts’) were shown once. Thus, there were 486 trials in total, separated into 12 blocks of 40 trials and a final block of 6 trials. The timing between blocks was at the participant’s discretion. Stimuli were randomized with a cumulative summary of detection times and errors displayed during inter-block intervals.

3.3.5 ERP/EEG recording

3.3.5.1 EEG acquisition

Continuous EEG was sampled at a rate of 500 Hz from 64 Ag/AgCl electrodes placed according to the international 10-10 system (EASYCAP GmbH, Herrsching, Germany). Online, the signal was referenced to the left earlobe with impedances kept below 10 kΩ. Signals from the right earlobe were also recorded. Bipolar channels recorded vertical (VEOG) and horizontal (HEOG) electro-oculogram from above and below the midpoint of the right eye and beside the outer canthi of both eyes. Recording and offline analysis of EEG and EOG data was conducted with Neuroscan Synamps2 system and SCAN 4.5 software (Compumedics, Melbourne, Australia).

Offline, EEG and EOG signal were digitally filtered using a 30-Hz lowpass filter with 12 dB slope, then re-referenced to the average of the left and right earlobes.

3.3.5.2 Segmentation

The data were divided into 600-ms epochs beginning 100 ms prior to stimulus onset and baseline corrected against the mean voltage during the 100 ms pre-stimulus period.

3.3.5.3 Artifact detection

Trials with horizontal eye movements (HEOG exceeding ± 50 µV relative to baseline), eye blinks or other artefacts (a voltage exceeding ± 100µV at any electrode relative to baseline) were rejected from further analysis.

3.3.6 Statistical analyses

3.3.6.1 Behavioural analyses

Both accuracy and RT data were subjected to a separate 4 x 6 (week vs. picture type) repeated measures ANOVA in order to assess how accurate and how fast participants were at identifying ‘own-body,’ ‘other-body,’ and ‘house’ stimuli, including ‘parts,’ across the weeks.

3.3.6.2 Electrophysiology

3.3.6.2.1 Assessing the reliability of visual ERPs and body-sensitive effects

ERP waveforms were averaged across the viewing conditions to be included in analyses (all body stimuli collapsed and all house stimuli collapsed). In order to assess the reliability of early visual ERPs and body-sensitive processing, amplitude and latency data were analysed in P1, N1 and VPP time ranges (time windows determined on the basis of the aggregated grand average, P1: 100 ms – 130 ms, N1: 155 ms – 195 ms, VPP: 155 ms – 195 ms) at all electrodes previously implicated in body processing. These included *O1/2, PO3/4, PO5/6, PO7/8, P7/8, P5/6, TP7/8, CP5/6* for P1 and N1 (e.g. Minnebusch et al., 2010; Minnebusch et al., 2009; Soria Bauser, Thoma, & Suchan, 2012; Soria Bauser, Schriewer, & Boris, 2015; Soria Bauser & Suchan, 2013; Stekelenburg & de Gelder, 2004; Thierry et al., 2006; van Heijnsbergen et al., 2007) and F1/2, F3/4, FC1/2, FC3/4, C1/2, Fz, Fcz, Cz, CPz and Pz for the VPP (Kovács et al., 2006; Sadeh et al., 2011; Stekelenburg & de Gelder, 2004; van Heijnsbergen et al., 2007). Topographic maps of individual visual components in the current sample confirmed this selection for occipito-parietal electrodes, whilst suggesting VPP activity might not be as posterior as has been found in other studies (see Figure 3.2).

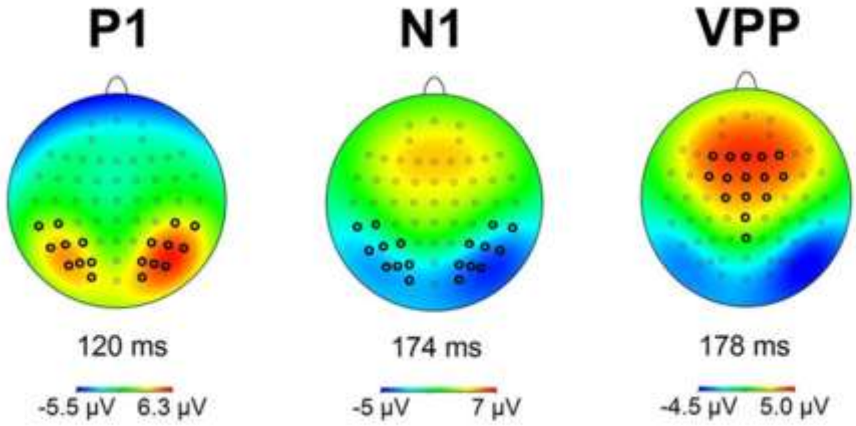

Figure 3.2. Voltage maps for the time window of the visual P1 component, visual N1 component and visual VPP component peaks (P1 at 120 ms, N1 at 174 ms, VPP at 178 ms), collapsed over viewing conditions, confirming areas of strongest activation. Electrodes analysed, which were selected primarily based on previous literature, have been highlighted.

ERPs to body and house stimuli were compared to assess for sensitive responses to bodies over occipito-parietal (P1 and N1 components) and fronto-central (VPP component) electrodes. Body-sensitive effects and overall amplitudes and latencies of these components were compared between weeks to assess whether early visual components and/or body processing effects are stable over time. Reliability analyses thus addressed two questions; first, whether early visual components are stable and second, whether body-sensitive effects are stable. Consequently, both amplitude and latency data for each component were subjected to a repeated measures ANOVA with week (week 1 responses vs. responses through to week 4), picture type (houses vs. bodies) hemisphere (left vs. right for P1/N1 analyses only) and electrode (as above) as within-subjects factors (mean amplitudes are reported, although it should be noted that peak amplitude data yielded the same results). To get a comprehensive idea of the robustness of each ERP at individual electrode sites, amplitudes and latencies of each component were subject to Pearson's product-moment correlations between weeks, separately at each electrode.

3.3.6.2.2 Assessing identity effects on body-sensitive components

ERP waveforms were averaged across the viewing conditions to be included in analyses (own whole body stimuli, own-body part stimuli, other whole body stimuli and other-body part stimuli). In order to assess the effect of own-body viewing versus other-body viewing, data from the electrodes showing both maximal and most significant responses for each component were analysed. Accordingly, P7/8 (-1.737 μV vs. $\geq$ -1.368 μV, r (10) $\geq$ .842, p $\leq$ .001) was analysed for the N1, P5/6 (4.868 μV vs. $\leq$ 4.686 μV, r (10) $\geq$ .752, p $\leq$ .005) was analysed for the P1, and F1/2 (3.175 μV vs. $\leq$ 3.151 μV, r (10) $\geq$.924, p < .001) was analysed for the VPP.

As no latency differences were observed during visual inspection of the grand averages, mean amplitudes only were analysed. Thus, P1, N1 and VPP amplitudes were compared between own-body viewing and other-body viewing, including whole bodies and body parts, in order to further profile body-sensitive processing. As images of participants' own houses were not included in the task and as house stimuli were not relevant to the hypothesis, houses were omitted from these analyses. Two questions were therefore addressed: whether body identity modulates body-sensitive processing, and whether potential effects of body identity are modulated according to whether the whole body or parts of the body are viewed (e.g. Chan et al., 2004; Hodzic, Muckli, et al., 2009; Saxe et al., 2006; Taylor, Roberts, et al., 2010; Taylor et al., 2007; Vocks et al., 2010a).

On the basis of finding stable early visual ERPs and stable body-sensitive effects, data were collapsed across weeks and subjected to a repeated measures ANOVA with body identity (own vs. other), part-whole (wholes vs. parts), hemisphere (left vs. right for P1/N1 analyses only) and electrode (as above) as within-subjects factors. For the sake of brevity, non-significant statistics are not reported, and hemisphere and electrode effects are only reported if they interacted meaningfully with picture type or group. Greenhouse-Geisser adjustments to the degrees of freedom were applied when necessary and partial eta squared is reported as the measure of effect size. Pairwise comparisons were Bonferroni corrected.

3.3.6.2.3 Correlations between identity effects, behavioural performance and how conscious the observer reported to be of their body

Following ERP modulation effects as a result of own-body viewing, we conducted Pearson product-moment correlations between behavioural responses, ERP responses (whole bodies and body parts collapsed as there were no effects of this variable) and scores on the BICI in order to discern whether the temporal dynamics of bodily identity perception is related to behaviour and how conscious the observer is of their body. As it has been shown that men and women might feel differently about their bodies (e.g. Furnham, Badmin, & Sneade, 2002) we conducted these correlational analyses separately for each gender. The false discovery rate (FDR) method of correction for multiple comparisons (Benjamini & Hochberg, 1995) was applied to correlation results. Results that did not survive correction are not reported.

3.4 Results

3.4.1 Behavioural results

3.4.1.1 Accuracy analyses

The 4 x 6 (week vs. picture type) repeated measures ANOVA revealed that participants were equally accurate each week ($F(3, 33) = .442$, $p = .659$, $\eta_p^2 = .039$), for each picture (picture type*week $F(15, 165) = 2.275$, $p = .105$, $\eta_p^2 = .171$) (see Figure 3.3). A main effect of picture type was also evident ($F(5, 55) = 12.821$, $p < .001$, $\eta_p^2 = .538$), with Bonferroni corrected follow-up comparisons showing that ‘own’ and ‘other’ body stimuli were recognised similarly, as were ‘wholes’ and parts.’ Participants were however, more accurate when responding to house stimuli than to all corporeal stimuli, ($t(11) \geq 3.865$, $p \leq .039$), (see Figure 3.3).

3.4.1.2 Reaction time (RT) analyses

A 4 x 6 (week vs. picture type) repeated measures ANOVA also revealed a main effect of picture type ($F(5, 55) = 30.528$, $p < .001$, $\eta_p^2 = .735$). Bonferroni adjusted follow-up comparisons showed no differences between viewing own and other bodies and no differences between viewing parts and wholes, but responses were significantly faster to all house stimuli than all corporeal stimuli ($t(11) \geq 5.346$, $p \leq .004$), (see Figure 3.3). A main effect of week was also found ($F(3, 33) = 38.223$, $p <.001$, $\eta_p^2 = .777$), with follow-up comparisons showing that responses were quicker as the weeks progressed (see Figure 3.3) although there were no significant differences between weeks 3 and 4 ($t(11) = 0.316$, $p = 1.000$). These effects interacted ($F(15, 165) = 3.463$, $p = .008$, $\eta_p^2 = .239$), such that the pattern of RT across the weeks varied between picture types. As Figure 3.3 suggests, this variation was not systematic, however.

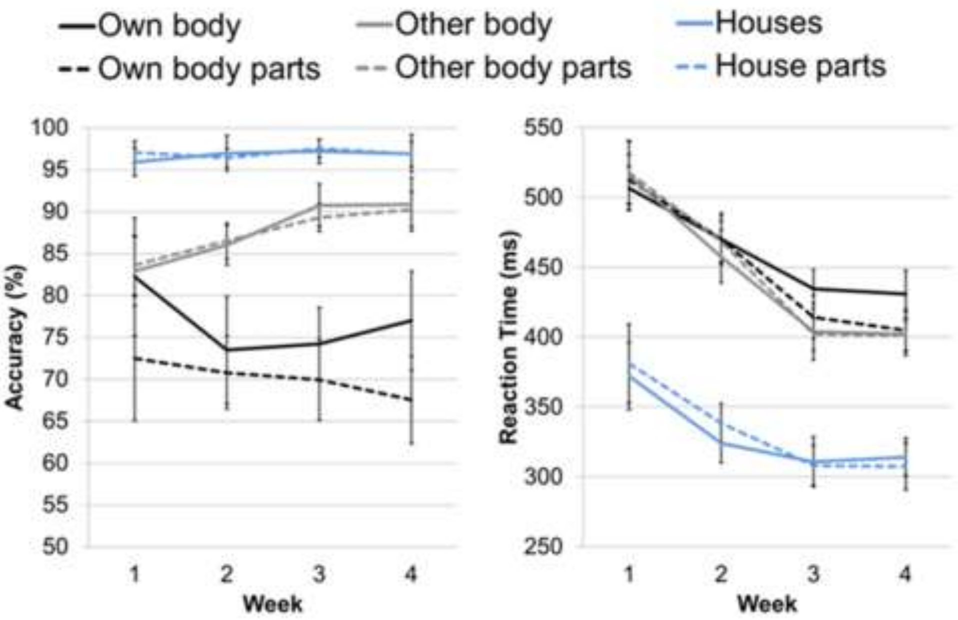

Figure 3.3. Top panel shows legend for both charts. Left panel shows task accuracy in percent over the 4 testing weeks. Participants were more accurate to identify house stimuli (blue lines) than corporeal stimuli. No statistical differences were observed between own-body (black lines) and other-body stimuli (grey lines), or between whole stimuli (solid lines) and part stimuli (dashed lines). Right panel shows RT in ms over the four testing weeks, which systematically decreased. Participants responded faster to houses (blue lines) than to corporeal stimuli. No statistical differences were observed between own-body (black lines) and other-body stimuli (grey lines), or between whole stimuli (solid lines) and part stimuli (dashed lines).

3.4.2 ERP results

3.4.2.1 Assessing the reliability of ERPs and body-sensitive effects

Both amplitude and latency data for each component were subjected to a repeated measures ANOVA with week (week 1 responses vs. responses through to week 4), picture type (houses vs. bodies) hemisphere (left vs. right for P1/N1 analyses only) and electrode (as above) as within-subjects factors.

3.4.2.1.1 P1 mean amplitude

P1 amplitudes were found to be stable over time as ANOVA found no effect of week ($F(3, 33) = 2.036$, $p =.128$, $\eta_p^2 = .156$). Furthermore, amplitudes were not modulated by picture type ($F(1, 11) = .101$, $p =.756$, $\eta_p^2 = .009$), which was a stable finding as this did not interact with week ($F(3, 33) = .778$, $p =.489$, $\eta_p^2 = .066$). Picture type did interact with electrode however, ($F(7, 77) = 7.747$, $p =.012$, $\eta_p^2 = .413$), with Bonferroni-adjusted follow-up comparisons revealing larger amplitudes to houses (M ≥ 2.153 μV) than to bodies (M ≥ 1.941 μV) at electrodes TP7/8, CP5/6, P5/6 and O1/2 ($F(1, 11) \geq 4.925$, $p \leq .048$, $\eta_p^2 \geq .309$). This suggests that there may be some distinction between bodies and other stimuli as early as the P1 time range over some electrode sites (see Figure 3.4). Hemispheric differences were also found,($F(1, 11) = 7.999$, $p =.016$, $\eta_p^2 = .42$), as amplitudes were larger in the right hemisphere (4.263 μV) compared to the left hemisphere (3.306 μV). In sum, P1 amplitudes are seemingly stable, are larger in the right hemisphere, and differentiate between bodies and other stimuli over some electrodes only.

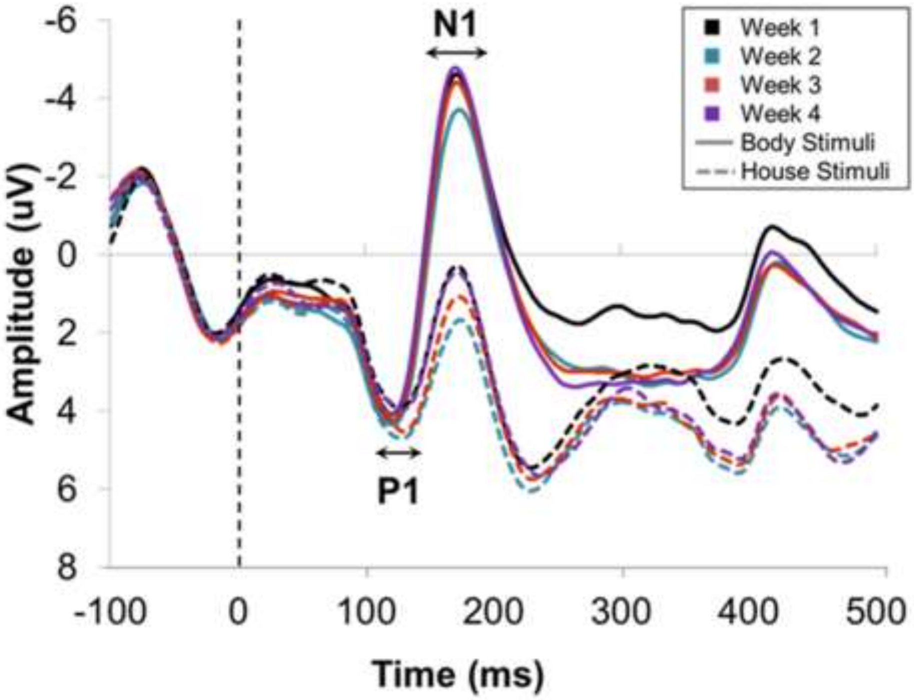

Figure 3.4. Grand averaged ERP responses during house and body viewing over the four weeks (bodies with solid lines, houses with dotted lines and week 1 to week 4 colour coded) collapsed over electrodes *O1/2, PO3/4, PO5/6, PO7/8, P7/8, P5/6, TP7/8, CP5/6*. A body-sensitive N1 response is evident each week, whilst amplitudes and latencies for both components were not found to differ between weeks.

3.4.2.1.2 P1 peak latency

P1 latencies were found to be stable over time as ANOVA revealed no effect of week ($F(3, 33) = .009$, $p = .970$, $\eta_p^2 = .001$). Body-sensitive effects were not observed on P1 latency ($F(1, 11) = 1.020$, $p = .334$, $\eta_p^2 = .085$), which was a stable finding as there was no interaction with week ($F(3, 33) = .969$, $p = .387$, $\eta_p^2 = .081$) (see Figure 3.4). Picture type did interact with electrode however, ($F(7, 63) = 14.558$, $p < .001$, $\eta_p^2 = .570$) with faster responses to bodies compared to houses at more lateral sites TP7/8, CP5/6, P7/8 and P5/6 (F(1, 9) ≥ 5.997, p ≤.032, η_p^2 ≥ .353). Accordingly, P1 latencies appear to be stable and there may be some distinction between bodies and other stimuli over specific electrode sites.

3.4.2.1.3 N1 mean amplitude

ANOVA revealed that N1 amplitudes were stable over time as no effect of week was found (F(3, 33) = 1.335, p =.283, η_p^2 = .108). Body-sensitivity was identified as a main effect of picture type (F(1, 11) = 42.658, p <.001, η_p^2 = .795), such that amplitudes were more negative to bodies (M = -3.467 µV) in comparison to houses (M = 1.524µV). This was a stable finding as there was no interaction between picture type and week (F(3, 33) = .461, p =.669, η_p^2 = .040) (see Figure 3.4). Thus, N1 amplitudes appear to be stable and reliably body-sensitive.

3.4.2.1.4 N1 peak latency

ANOVA found N1 peak latencies to be stable over time as there was no effect of week (F(3, 33) = 1.975, p =.137, η_p^2 = .152). There was also no difference in latency between body viewing and house viewing (F(1, 11) = .154, p =.702, η_p^2 = .014), which was a stable finding as this did not interact with week (F(3, 33) = 1.696, p =.205, η_p^2 = .134) (see Figure 3.4). In sum, N1 latencies appear to be stable over time without differentiating between bodies and other stimuli.

3.4.2.1.5 VPP mean amplitude

ANOVA found VPP amplitudes were stable over time as there was no effect of week ($F(3, 33) = 1.404$, $p = .267$, $\eta_p^2 = .113$). A body-sensitive effect was found (see Figure 3.5), such that amplitudes were more positive to bodies (M = 4.043 μV) in comparison to houses (M = 1.357 μV) (main effect of picture type: $F(1, 11) = 19.590$, $p =.001$, $\eta_p^2 = .640$). This effect was also stable as picture type was not found to interact with week ($F(3, 33) = .389$, $p =.757$, $\eta_p^2 = .034$) (see Figure 3.5). A picture type by electrode interaction was also found ($F(14, 154) = 19.908$, $p <.001$, $\eta_p^2 = .644$), with Bonferroni-adjusted follow-up comparisons revealing body-sensitive effects at all electrodes ($F(1, 11) \geq 9.490$, $p \leq .010$, $\eta_p^2 \geq .463$) except CPz and Pz ($F(1, 11) \leq 2.326$, $p \geq .155$, $\eta_p^2 \geq .175$). These findings therefore suggest that VPP amplitudes and body-sensitive effects over the VPP are stable, although such body-sensitivity might not occur over more posterior regions in all studies.

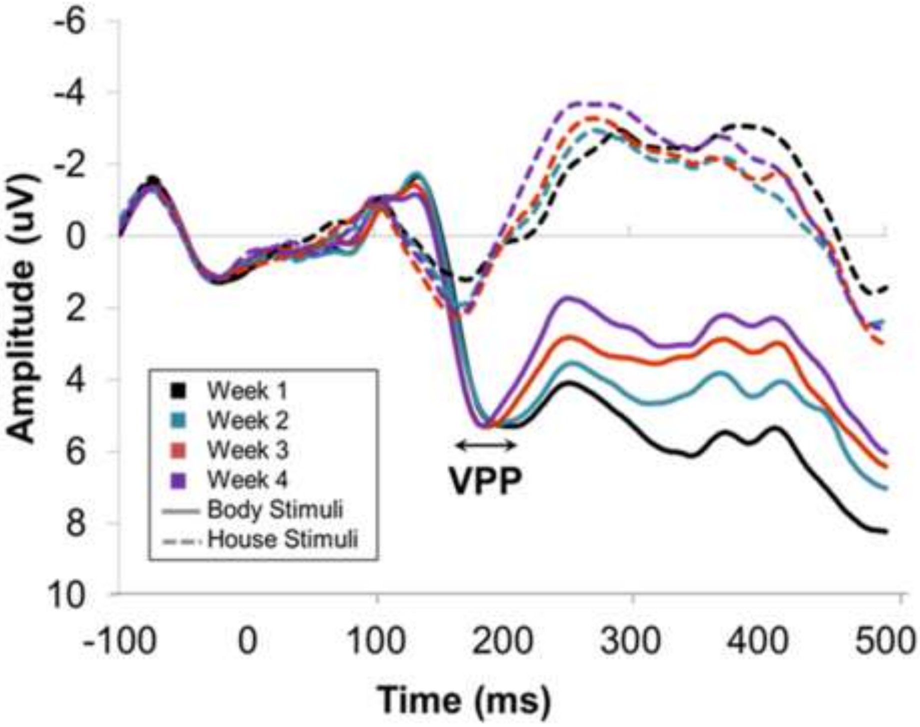

Figure 3.5. Grand averaged ERP responses during house and body viewing over the four weeks (bodies with solid lines, houses with dotted lines and week 1 to week 4 colour-coded as above) collapsed over electrodes F1/2, F3/4, FC1/2, FC3/4, C1/2, Fz, Fcz, Cz, CPz and Pz. A body-sensitive VPP response is evident each week, whilst amplitudes and latencies were not found to differ between weeks.

3.4.2.1.6 VPP peak latency

VPP latencies were found to be stable as ANOVA revealed no effect of week ($F(3, 33) = 2.639$, $p = .088$, $\eta_p^2 = .193$). A main effect of picture type was found ($F(1, 11) = 11.575$, $p = .006$, $\eta_p^2 = .513$), such that VPP responses were shorter to houses (169 ms) in comparison to bodies (186 ms) (see Figure 3.5). This effect was also stable as there was no interaction between picture type and week ($F(3, 33) = .503$, $p = .683$, $\eta_p^2 = .044$) (see Figure 3.5). A significant picture type by electrode interaction was found, however ($F(14, 154) = 7.243$, $p < .001$, $\eta_p^2 = .397$), with Bonferroni-adjusted follow-up comparisons revealing differences in VPP latency between bodies and houses at all electrodes ($F(1, 11) \geq 4.883$, $p \leq .049$, $\eta_p^2 \geq .307$) except Pz ($F(1, 11) = .304$, $p = .592$, $\eta_p^2 = .027$). This further suggests that body-sensitivity over VPP may occur at more anterior sites. In sum, there appears to be a distinction between bodies and other stimuli evident in VPP latencies, which, like VPP latency itself, is a seemingly stable finding.

3.4.2.1.7 Interim summary of reliability analyses

Amplitudes and latencies of early visual components over occipito-parietal (P1, N1) and fronto-central (VPP) sites appear to be stable over time. Body-sensitive effects measured here (for some electrodes over P1, most electrodes over VPP, and all electrodes over N1) also appear to be stable. As such, data were collapsed across weeks for analyses of own-body perception.

3.4.2.2 Assessing the robustness of early visual ERPs: The relationship between weeks at each electrode site

In order to further assess the reliability of early visual ERPs, amplitudes and latencies for each week were averaged across conditions at each electrode site that was used in P1, N1 and VPP analyses. Both amplitude and latency data for each week were then subjected to separate Pearson’s product-moment correlational analyses at each electrode. Six relationships between the weeks, representing each possible pairing of weeks, were therefore obtained at each electrode site separately for amplitude and latency data, and are summarised below (see Figure 3.6). As suggested by Figure 3.6, amplitude relationships between the weeks at each electrode were generally stronger and more frequently significant than latency relationships. These findings thus indicate that the latency of early visual components may be less stable than amplitude.

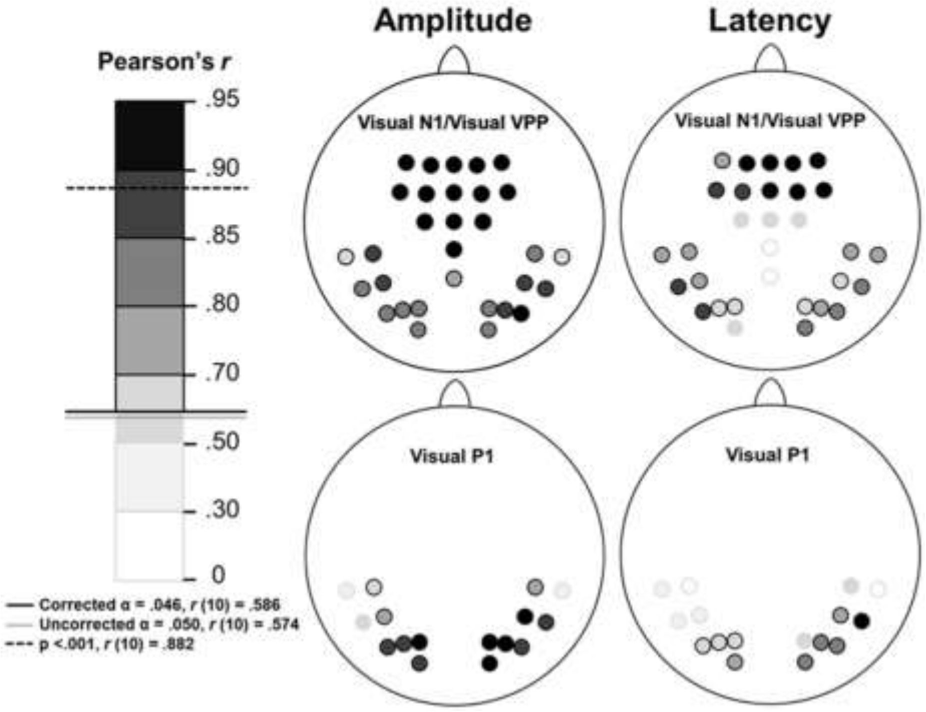

Figure 3.6. Visual ERP amplitude and latency correlations between the weeks at each analysed electrode site are depicted separately above. For each electrode site the weakest correlation (lowest Pearson's *r* value) is depicted out of the six possible combinations of the four weeks. Left panel shows the *r* value scale: darker colours indicate stronger relationships. Shades above the solid black line were significant after FDR correction (α = .046). Right panel shows scalp maps of analysed electrodes for each component (posterior electrodes for visual P1/N1 and anterior electrodes for visual VPP) for both amplitude and latency. Where all relationships between all weeks were significant the electrode is outlined in black. When at least one non-significant relationship was found between two of the weeks the electrode is outlined in grey.

For electrode sites that did not yield six significant relationships, the pairings are listed separately in Figure 3.7. Upon viewing this, it is clear that P1 amplitude and latency are less robust at lateral sites whilst VPP latency becomes less robust more posteriorly. At least for studies that utilise body stimuli, this suggests that anterior, rather than central or posterior, sites may be a more reliable indicator of the cortical activity reflected at VPP, whereas occipito-parietal, rather than more temporal, sites (particularly in the right hemisphere) may be a more reliable source of the P1-N1 complex.

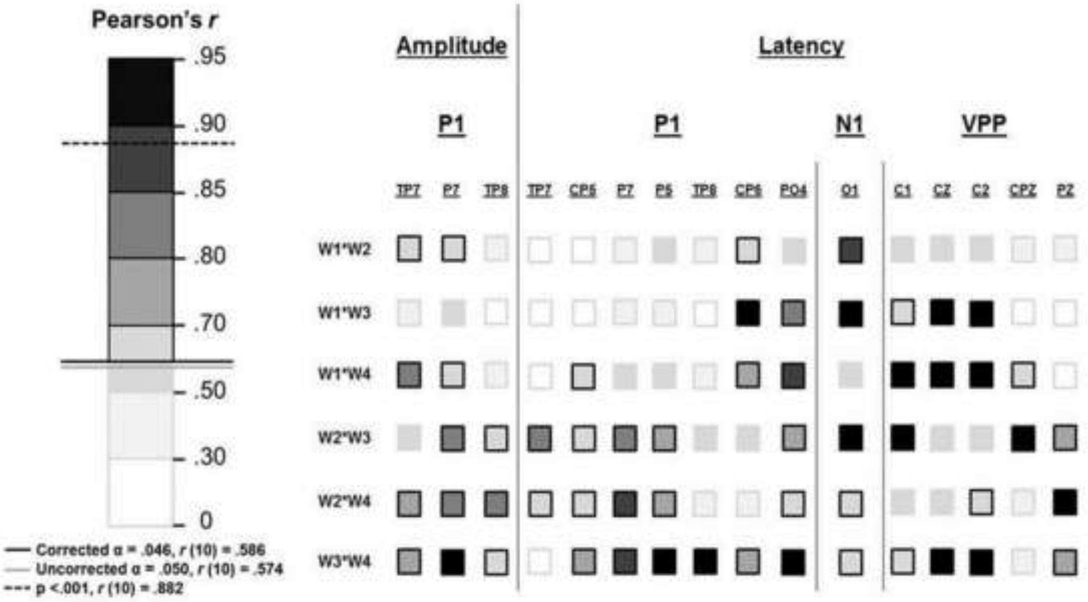

Figure 3.7. Visual ERP amplitude and latency correlations between weeks at electrode sites that did not yield six significant relationships. Left panel shows the scale pertaining to Pearson's *r* values, with darker colours indicative of a stronger relationship. Relationships indicated by a shade above the solid black line were significant after FDR correction (α = .046). Right panel shows separate week-to-week correlations at electrode sites where not all relationships were significant for P1 amplitude and P1, N1 and VPP latency. Non-significant relationships are outlined in grey; significant relationships are outlined in black.

3.4.2.3 Assessing own-body identity effects on body-sensitive components

Data were collapsed across weeks and subjected to a repeated measures ANOVA with body identity (own vs. other), part-whole (wholes vs. parts), hemisphere (left vs. right for P1/N1 analyses only) and electrode (as above) as within-subjects factors.

3.4.2.3.1 P1 mean amplitude

Body identity was not found to modulate P1 amplitudes ($F(1, 11) = .466$, $p = .509$, $\eta_p^2 = .041$) and there was also no effect of part-whole ($F(1, 11) = 2.741$, $p = .126$, $\eta_p^2 = .119$) (see Figure 3.8) but, as before, there was a trend towards larger P1 amplitudes in the right hemisphere (4.788 μV) compared to the left hemisphere (3.803 μV) ($F(1, 11) = 4.635$, $p = .054$, $\eta_p^2 = .296$). There were no additional main effects or interactions to report.

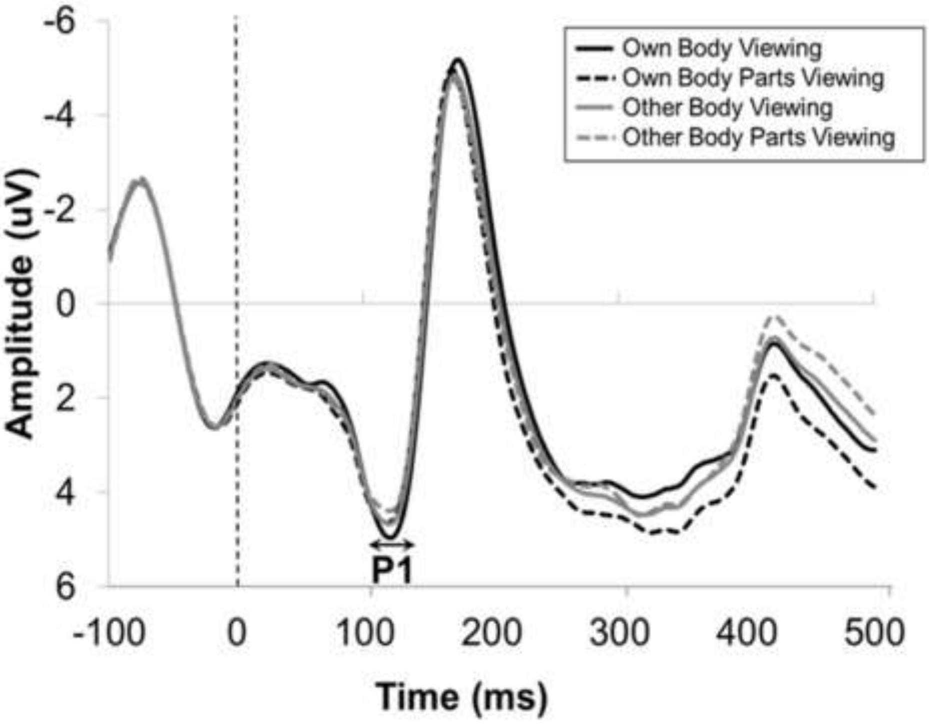

Figure 3.8. Grand averaged ERP waveforms in response to viewing whole (solid lines) or parts (dashed lines) of one's own body (black lines) and another body (grey lines), collapsed over electrodes P5/6, showing no effect of body identity or part-whole on P1 amplitudes.

3.4.2.3.2 N1 mean amplitude

A main effect of body identity was found ($F(1, 11) = 7.580$, $p = .019$, $\eta_p^2 = .408$), such that amplitudes were most negative in response to own-body stimuli (-5.047 μV) in comparison to other-body stimuli (-4.888 μV) (see Figure 3.9). There was no effect of part-whole ($F(1, 11) = .297$, $p = .597$, $\eta_p^2 = .026$) and this did not interact with body identity ($F(1, 11) = .177$, $p = .682$, $\eta_p^2 = .016$). There was however, a main effect of hemisphere ($F(1, 11) = 9.041$, $p = .012$, $\eta_p^2 = .451$) such that amplitudes were larger in the right hemisphere (-6.068 μV) compared to the left hemisphere (-3.868 μV). There were no additional main effects or interactions to report, which suggests that identity processing can occur in the N1 time range regardless of whether a whole body or body parts are viewed. Results also suggest that body processing elicits larger N1 amplitudes in the right hemisphere.

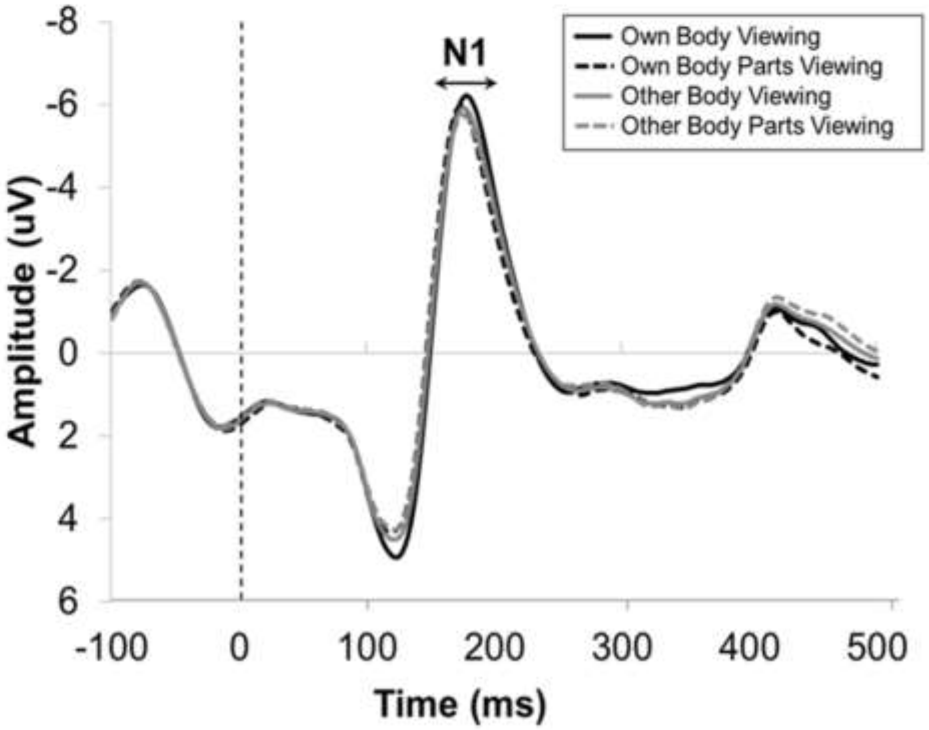

Figure 3.9. Grand averaged ERP waveforms in response to viewing whole (solid lines) or parts (dashed lines) of one’s own body (black lines) and another body (grey lines), collapsed over electrodes P7 and P8, showing larger N1 amplitudes to own-body stimuli in comparison to other-body stimuli irrespective of whether a whole body or parts of a body were shown.

3.4.2.3.3 VPP mean amplitude

Body identity was not found to modulate VPP amplitudes (*F*(1, 11) = 1.002, p =.338, η_p^2 = .083) and there was also no main effect of part-whole (*F*(1, 11) = .020, p =.889, η_p^2 = .002) (see Figure 3.10). There were no additional main effects or interactions to report suggesting that body-sensitive VPP amplitudes do not encode identity.

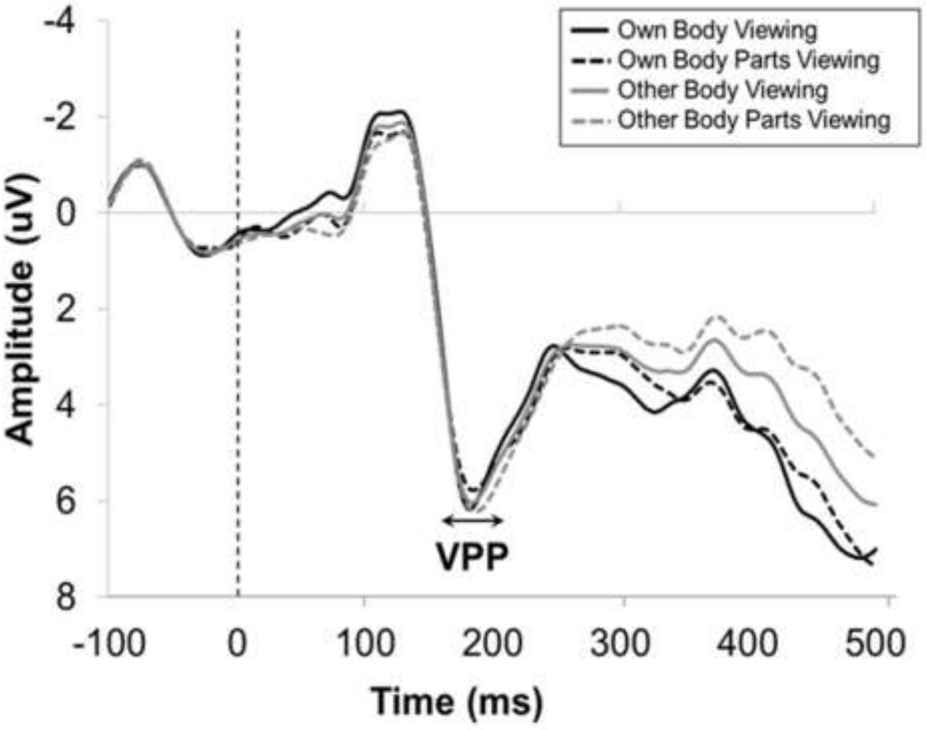

Figure 3.10. Grand averaged ERP waveforms in response to viewing whole (solid lines) or parts (dashed lines) of one's own body (black lines) and another body (grey lines), collapsed over electrodes F1 and F2, showing no effect of body identity or part-whole on VPP amplitudes.

3.4.2.3.4 Interim summary of own-body identity analyses

Body-sensitive N1 amplitudes seem to be modulated by own-body identity, as larger amplitudes were found in response to own-body stimuli in comparison to other-body stimuli. This pattern was not affected by whether a whole body or a body part was viewed. Own-body identity effects were not observed in body-sensitive P1 and VPP responses.

3.4.3 Correlations to assess whether the temporal dynamics of own-body identity perception is related to behaviour and how conscious the observer reported to be of their body

In order to discern whether own-body perception is related to how conscious the observer reported to be of their body, we correlated behavioural and ERP responses (whole bodies and body parts collapsed) with scores on the BICI. In order to reflect the identity effect observed over the N1, amplitudes to own-body stimuli were subtracted from amplitudes to other-body stimuli. A larger difference is therefore indicative of a larger component to own- versus other-body stimuli. The same process was not applied to behavioural data as no effects were observed. Thus, the 3 BCQ subscales; public body consciousness, private body consciousness, body competence, RT to own and other bodies, accuracy to own and other bodies and the N1 identity effect were all entered as variables for each analysis.

No relationships survived correction for multiple comparisons, suggesting that neural and behavioural recognition of one’s own body is not related to body consciousness.

3.4.4 Summary

In sum, amplitudes and latencies of early visual components over occipito-parietal (P1, N1) and fronto-central (VPP) sites appear to be stable over time. Body-sensitive effects measured here were also stable. In addition, body-sensitive N1 amplitudes appear to be sensitive to own-body identity as larger amplitudes were found in response to own-body stimuli as compared to other-body stimuli. This did not seem to be affected by whether a whole body or a body part was viewed, was similar in both hemispheres, and was not related to how conscious the observer reported to be of their body.

3.5 Discussion

The present study aimed to test the reliability, over time, of early visual ERPs and body-sensitive ERP effects, whilst assessing whether electrophysiological body-sensitivity is modulated by viewing own-body stimuli. We did so in order to inform the validity of research in the body processing field, especially with respect to whether these body-sensitive components have the potential to be trustworthy neural markers, and whether they are sensitive to own-body viewing.

Amplitude and latency of P1, N1 and VPP responses to body and house stimuli, recorded over a 4-week period in six men and six women, showed that early visual components, as well as body-sensitive effects, were reliable and stable over time. Moreover, correlational analyses between the weeks at each electrode site showed that amplitude may be more robust than latency. This is in line with similar findings from previous research on the reliability of other visual, auditory, face-sensitive and error-related components early-, late- and face-sensitive visual, auditory and error-related components (e.g. Gaspar et al., 2011; Huffmeijer et al., 2014; Walhovd & Fjell, 2002). Correlational analyses also indicated specific electrode sites that may yield more reliable reflections of body-related P1, N1 and VPP cortical activity, respectively. This included more parietal sites for P1 and more anterior sites for VPP. Excepting O1, all previously used electrode sites for N1 analyses of body selection were found to be reliable. Analyses probing own-body identity perception in this early time range also revealed an increase in N1 amplitude when participants viewed their own body in comparison to another person’s body. This privileged processing for own bodily information did not favour one hemisphere over the other, and was not modulated by the number of body parts shown. Furthermore, this was not reflected at the behavioural level, as participants responded no differently to their own and other bodies. Moreover, we found no evidence for a relationship between early cortical own-body processing and behaviour. This pattern of results suggest that any early own-body processing advantages might be diminished after further processing, perhaps due to the conflicts that can occur in explicit tasks between the memory of one’s own body and the actual appearance of one’s own body (see Candini et al., 2016). Alternatively, it is possible that behavioural tasks are not sensitive enough to identity differences that occur during early cortical processing. There is clearly an empirical question to be answered here.

The following sections will now proceed to discuss each of the ERP effects in turn.

3.5.1 Extending on the understanding of electrophysiological body-sensitive mechanisms

Consistent with previous research (see de Gelder et al., 2010; Minnebusch & Daum, 2009; Peelen & Downing, 2007 for reviews), an enhancement of electrophysiological activity over occipito-parietal and fronto-central sites was observed in the N1 and VPP time range. This adds to the literature which proposes that bodies, like faces, are processed by specialist populations of neurons (e.g. Brandman & Yovel, 2014; Meeren et al., 2013). With respect to body-sensitivity per se, these results support the notion that N1 and VPP responses are generated from the same neuronal sources and may therefore reflect the same process (e.g. Joyce & Rossion, 2005; Sadeh et al., 2011). However, our findings also revealed that N1 was amplified by own-body viewing compared to other-body viewing, whereas VPP was not. This finding differs from what has been reported in the face processing literature, whereby viewing one's own face leads to an enhancement of both N170 and VPP amplitudes relative to viewing the familiar or unfamiliar faces of others (Keyes, Brady, Reilly, & Foxe, 2010). Thus, our findings may be seen as further evidence for the distinctiveness of face and body processing mechanisms. Perhaps more importantly, our results suggest that, at least with regards to body processing, N1 and VPP components do not reflect the same process. Similar conclusions were drawn in other studies that also showed different body-sensitive N1 and body-sensitive VPP effects (Stekelenburg & de Gelder, 2004; van Heijnsbergen et al., 2007). As a consequence, we recommend that future research studies target the distinct roles that may be played by the body-related cortical mechanisms reflected at N1 and VPP. The present study found that self-related processing is an aspect of cortical analysis that appears to be associated specifically with N1.

We also observed relatively early temporal differences between body and house viewing over lateral occipito-temporal sites (TP7/8, CP5/6, P7/8, and P5/6) such that the P1 peaked earlier in response to bodies as compared to houses. Such rapid category-sensitive cortical activation has been shown for bodies in at least two other studies (Meeren, Hadjikhani, Ahlfors, Hämäläinen, & de Gelder, 2008; Thierry et al., 2006) but seems to be a relatively rare finding (see de Gelder et al., 2010 for review). As we did not observe this effect at all electrode sites, is possible that the sites over which effects are reported may be at least partly responsible for whether early category-specific activity is uncovered in studies of visual body perception. Moreover, we found body-sensitive P1 latency effects to be most robust over occipito-parietal sites (particularly in the right hemisphere), rather than temporal sites. As the effect in our study was seen specifically over lateral occipito-temporal sites, this too may help to explain why such rapid categorical distinctions are not always observed. Nonetheless, the present study contributes additional evidence for rapid distinctions between bodies and non-body stimuli during the early stages of visual analysis.

3.5.2 Early visual components, and early body-sensitive effects, are stable over time

Our findings show that early visual ERP components and the body-sensitive effects within their time ranges are stable over time within the same individuals, in line with what has been reported for auditory, face-sensitive and error-related ERP components (e.g. Fallgatter et al., 2001; Kuefner et al., 2010; Tello et al., 2010). Moreover, correlations between the weeks at each electrode site for each component showed that amplitude may be more reliable over time than latency. These correlational analyses also revealed that P1 amplitude and latency and VPP latency may be less robust at certain sites. Specifically, our results suggest that anterior (F1/2, F3/4, FC1/2, FC3/4, Fz and Fcz), rather than central or posterior (C1/2, CZ, CPZ, PZ), sites may be the most robust indicators of the cortical activity reflected at VPP. At the same time, occipito-parietal (O1/2, PO3/4, PO5/6, PO7/8, P7/8, P5/6), rather than more temporal (TP7/8, CP5/6), sites (particularly in the right hemisphere) may be the most robust source of cortical processes reflected at the P1-N1 complex. This is a finding of significance to the study of visual body perception as it strongly suggests that there are electrode sites whereby a more reliable indication of cortical activity may be obtained (i.e. electrode sites where all correlations were significant). We therefore suggest that our findings are considered as a potential guide for electrode selection in future studies of visual processing and in particular, visual processing of the human body form.

Previous research has suggested that visual ERPs and body-sensitive ERP effects may provide a potential bio-signature of disorders characterised by body image disturbance (e.g. Groves et al., 2017; Li et al., 2015; Mai et al., 2015). The implications of such claims advocate the use of neural markers to identify ‘at risk’ individuals, or to track the severity of symptoms and the efficacy of treatment over time. However, such possibilities rely on the inherent assumption that the ERPs and their associated effects are stable and reliable biological phenomena that are not subject to random changes within the same individual. For the first time, we provide explicit evidence in support of this assumption. In line with previous findings for other cortical (dys)functions (Ghosh Hajra et al., 2016; Williams et al., 2005), visual P1, N1 and VPP responses, as well as body-sensitive effects, appear to have potential as electrophysiological biomarkers.

3.5.3 Enhanced electrophysiological activity to own-body stimuli in the N1 time range

Enhanced body-sensitive N1 amplitudes were found in response to own-body stimuli compared to unfamiliar other-body stimuli, which did not differ between hemispheres or according to the sight of a whole body versus isolated body parts. This implies that the difference in stimuli is unlikely to account for the difference in findings between studies that employed manipulations of viewpoint (e.g. Chan et al., 2004; Saxe et al., 2006 2006) and those that compared own bodies with other bodies (e.g. Hodzic, Kaas, et al., 2009; Vocks et al., 2010a). Our findings are also unlike those of Taylor, Roberts, et al. (2010) who reported a linear increase in N1 activity as more of the body was visible. However, this linear increase in responsiveness has been questioned (e.g. Chan & Baker, 2011), which taken together with our findings, suggests that the N1 as an index of body-sensitive processing with EBA origins may not always be sensitive to part-whole differences.

In our study, body parts were shown from allocentric perspectives so that own-body recognition was free from spatial cues. Hence, our observed sensitivity to own-body identity over N1 might reflect own-body recognition in the early stages of visual body perception that is independent of viewpoint, similar to previous findings concerning EBA activity (e.g. Castellini et al., 2013; David et al., 2009; Hodzic, Muckli, et al., 2009). The absence of hemispheric differences in our reported identity effects suggests that own-body recognition at early processing stages may arise from both left and right EBA-related activity. In line with this, previous studies have found privileged processing for one’s own body either in right EBA (Vocks et al., 2010a) or in left EBA (Hodzic, Kaas, et al., 2009).

An enhancement of electrophysiological activity in response to own-body stimuli was not observed over P1 or VPP responses however. Body-sensitive VPP amplitudes, unlike body-sensitive N1 amplitudes, are reportedly increased in response to emotional stimuli such as fearful body postures (Stekelenburg & de Gelder, 2004; van Heijnsbergen et al., 2007). In light of this, our findings imply that the sight of one’s own body is unlikely to be a sufficiently emotionally salient event to evoke differential processing over VPP. This may differ for more emotional body postures, and in individuals with body image disturbances for whom bodies represent a source of anxiety. For example, as compared to controls, greater amygdala activity is found in anorexic participants when viewing photographs of their own body, (Vocks et al., 2010b), suggesting that their own body is an emotionally salient stimulus. Assuming that the body-sensitive VPP reflects a partially distinct, affective pathway for visual analysis of bodies, these individuals may thus also be more likely to show VPP enhancements for own-body viewing.

It appears then that own-body viewing affects only the structural encoding of body stimuli as reflected by enhanced body-selective N1 amplitudes. This mirrors the N170 effects of (self) identity recognition that have been reported for faces (e.g. Caharel, d’Arripe, Ramon, Jacques, & Rossion, 2009; Jacques, d'Arripe, & Rossion, 2007; Keyes et al., 2010; Kuehl, Brandt, Hahn, Dettling, & Neuhaus, 2013 Dettling, Neuhaus, 2013), and shows for the first time, that the (self) identity of bodies may be decoded at the same electrophysiological stage of processing. Although body processing mechanisms are understood as distinct from face processing mechanisms (see Downing & Peelen, 2016 for recent review), they are thought to be interrelated and similar in nature (e.g. Sadeh et al., 2011). Our findings of N1 enhancement for one’s own body support this notion. Given N1 origins in EBA activity (e.g. Sadeh et al., 2011), our study supports the findings of stronger EBA activation during own-hand than other-hand viewing conditions (Myers & Sowden, 2008), but are not in line with two other studies that found no evidence for identity distinction in EBA activity (Kable & Chatterjee, 2006; Taylor, Wiggett, & Downing, 2010).

It has been argued that identity effects like the above occur because participants find images of their own face or body more interesting or arousing, rather than reflecting the operation of early-stage visual own-body recognition mechanisms (Downing & Peelen, 2011). ERPs in the N1 time range are subject to top-down influences such as attention and arousal (e.g. Eimer, 2000a; Hillyard & Anllo-Vento, 1998; Soria Bauser et al., 2012; Stekelenburg & de Gelder, 2004; van Heijnsbergen et al., 2007). Particularly when identity perception is an explicit part of the task, which is typically the case (Hodzic, Kaas, et al., 2009; Ramsey & Hamilton, 2010; Sugiura et al., 2006; Vocks et al., 2010a), it is easily seen how attentional bias toward stimuli depicting one’s self might account for N1 enhancements, rather than the genuine encoding of a person’s identity (see Downing & Peelen, 2011). However, at least with regards to body processing, such attentional influences have been found to shift latencies at the same time as modulating amplitude (Soria Bauser et al., 2012; Stekelenburg & de Gelder, 2004; van Heijnsbergen et al., 2007). In our study, grand averaged ERPs did not indicate an N1 latency difference between own-body and other-body viewing, which suggests that top-down influences cannot solely explain our results. Moreover, research in the face literature suggests that the advantage seen for processing own-face stimuli is not due to attention (Keyes & Dlugokencka, 2014) and as such, the same might be true for bodies. Nevertheless, future studies should address this argument by assessing the effects of task and attention on bodily (self) identity processing directly.

It has also been argued that body-selective regions do not explicitly represent person perception beyond the encoding of body shape (Downing & Peelen, 2011). By extension, this suggests that the observed own-body enhancement of body-sensitive N1amplitudes may be an effect of shape recognition. Ramsey, van Schie, and Cross (2011) counter this position, stating that such a distinction is unnecessary because shape representation is still an important part of person perception. However, the distinction is relevant here as Downing and Peelen (2011) propose that body-sensitive responses should be heightened when viewing body parts with highly similar shape rather than for two different body parts from the same person. For this to be true, it is more likely that we would have found effects of part-whole rather than of own-body viewing; we did not. As a result, it seems that the body-sensitive N1 does not just encode shape but either encodes own-body identity explicitly, or is modulated by top-down processes related to own-body perception.

Whether or not body-sensitive components like N1 or VPP explicitly represent (own-body) identity perception beyond the structural encoding of body shape and posture or not (as argued for EBA/FBA in Downing & Peelen, 2011) is of great importance when considering the body-sensitive N1 as a potential biomarker of psychological or neuropsychiatric illnesses. For example, if the early neural correlates of body perception are sensitive to own-body recognition and not just shape, then this component also holds potential as a biomarker for disorders whereby visual self-recognition is destabilised (e.g. in schizophrenia, Irani et al., 2006; in depersonalization, Ketay et al., 2014; and in body image disturbance, Vocks et al., 2010b) or own-body identity perception is disturbed (e.g. in body integrity identity disorder, Blom et al., 2012; in heterotopagnosia, Felician & Romaiguère, 2008; and in somatoparaphrenia, Vallar & Ronchi, 2009). To our knowledge, these disorders have not yet been associated with body-sensitive ERPs and thus understanding whether the reported effects reflect identity processing or shape recognition seems fundamental to further research. With this in mind, we suggest that future studies employ either a task, or participants, which exhibit dissociation between body shape and body identity as in transgender individuals for example, or by the manipulation of own-body stimuli.

3.6 Conclusion

The results of this study indicate an early neural distinction between own and other-body viewing reflected in body-selective N1 amplitudes, with enhanced processing of own-body stimuli. While the underlying mechanisms remain unclear, these findings suggest that our own bodies hold a special status during structural encoding of the human form. We have also shown that early visual ERPs and body-sensitive effects are stable over time, with amplitudes relatively more stable than latencies. As a result, we confirm that P1, N1 and VPP responses, as well as their associated body-sensitive effects, are eligible candidates for research into bio-signatures of cognitive (dys)function related to body representation.

We propose that future research should seek to address whether the own-body modulations evident in the N1-time range are reflective of identity processing, shape processing or whether our own bodies are simply more interesting. This is of particular importance as the underlying mechanisms for the effect may be of clinical significance. In addition, the results of this investigation suggest that future studies of visual perception, and perhaps visual body perception in particular, should carefully consider the electrode sites from which data are analysed, as some sites appear to provide a more robust indication of relevant cortical activity than others.

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Chapter 4 Evidence for ERP biomarkers of eating disorder symptoms in women

4.1 Abstract

Growing evidence suggests that the brain processes bodies distinctively from other stimuli, but little research has addressed whether visual body perception is modulated by the observer's thoughts and feelings about their own body. The present study thus investigated the relationship between body image and electrophysiological signatures of body perception, with the aim of identifying potential biomarkers of body image disturbances. Occipito-parietal (P1 and N1) and fronto-central (VPP) processing of body and non-body stimuli were assessed in 29 weight-restored eating disordered (ED) women and compared to 27 healthy controls. Rapid early visual processing was seen in the ED group, as the entire P1-N1 complex unfolded significantly earlier compared to controls. ED women also showed a gender-sensitive response to other women's bodies over N1 and VPP components. Such gender-sensitivity was not evident in controls. Moreover, ERP effects correlated with scores on the Eating Disorder Inventory-II (EDI-2), indicating a close link between the observers' ED symptomatology, including body image, and the visual analysis of human bodies during very early stages of cortical processing. The temporal dynamics of visual body perception may therefore serve as potential neural markers for the identification of ED symptomatology in 'at risk' populations.

4.2 Introduction

Over the past 15 years there have been significant advances in identifying the neural correlates of visual body perception (see Downing & Peelen, 2016 for a recent review). In a pioneering study, Downing, Jiang, Shuman, and Kanwisher (2001) suggested a module for body processing in the extrastriate body area (EBA), a bilateral region of the lateral occipital cortex that responds selectively to images of the human body. Research has since revealed that this area is largely concerned with processing body parts and perhaps the shape of the body (see also Downing & Peelen, 2016). There is also evidence to suggest that EBA contains separate networks that distinguish between own body and other body recognition (Chan, Peelen, & Downing, 2004; Myers & Sowden, 2008; Saxe, Jamal, & Powell, 2006).

The EBA is complemented by a second body-selective region, the fusiform body area (FBA) (Schwarzlose, Baker, & Kanwisher, 2005), which may contribute functionally distinct representations of the human body to perception (Taylor, Wiggett, & Downing, 2007). While there is some debate about the relative contributions of EBA and FBA, and about how they integrate information (e.g. Chan & Baker, 2011; Hodzic, Muckli, Singer, & Stirn, 2009; Urgesi, Calvo-Merino, Haggard, & Aglioti, 2007), there seems to be very little doubt that these areas are selective for the visual perception of human bodies (Sadeh et al., 2011).

Source localisation techniques (Meeren, de Gelder, Ahlfors, Hämäläinen, & Hadjikhani, 2013; Thierry et al., 2006) as well as direct intracranial recordings (Pourtois, Peelen, Spinelli, Seeck, & Vuilleumier, 2007) have linked EBA activity with the enhancement of electrophysiological activity over occipito-temporal sites for bodies compared to non-body stimuli around 150-190 ms after stimulus onset (Pourtois et al., 2007; Thierry et al., 2006). The present study investigates the event-related visual component associated with this enhancement, which has been variably referred to as N170, N190 or simply N1 (see also Peelen & Downing, 2007 for review). We will refer to this component as the body-sensitive N1 throughout the present chapter. Inverting body stimuli has been found to modulate the body-sensitive N1 response (e.g. Bosbach, Knoblich, Reed, Cole, & Prinz, 2006; Minnebusch, Keune, Suchan, & Daum, 2010; Minnebusch, Suchan, & Daum, 2009). As a result, body-sensitivity in the N1 time range has been linked to late structural (de Gelder et al., 2010; Eimer, 2000c; Soldan, Mangels, & Cooper, 2006) and early configural encoding of bodies. This means that bodies, like faces, seem to be processed holistically according to the spatial relations between features, rather than the features themselves (Maurer, Le Grand, & Mondloch, 2002; Minnebusch & Daum, 2009).

Other early event-related potentials have also been linked to body selection. Thus, further to the N1, the present study will also investigate P1 responses and the vertex positive potential (VPP). P1 is the first positive deflection in the visual ERP waveform and is typically observed over occipito-parietal electrodes at around 80-120 ms after stimulus onset (see Luck, 2014, p72.).

A handful of studies have found evidence for body-sensitivity in this time range, especially when stimuli contain emotional cues, or bodies are the only stimuli presented (Meeren, van Heijnsbergen, & de Gelder, 2005; Righart & de Gelder, 2007; Thierry et al., 2006; van Heijnsbergen, Meeren, Grèzes, & de Gelder, 2007). VPP is found in time ranges similar to N1, but is a positive deflection occurring over fronto-central electrode sites, and has been implicated in the distinct visual processing of human bodies (Sadeh et al., 2011; Stekelenburg & de Gelder, 2004; van Heijnsbergen et al., 2007). In particular, evidence suggests that body-sensitive VPP responses are modulated by emotion (Stekelenburg & de Gelder, 2004; van Heijnsbergen et al., 2007). Despite some debate (e.g. Eimer, 2000b; Taylor, McCarthy, Saliba, & Degiovanni, 1999), the face processing literature indicates that VPP responses arise from the same cortical region as the N1, thus manifesting the same processes (Joyce & Rossion, 2005; Sadeh et al., 2011).

Visual body processing also includes the sight of our own bodies, which gives rise to two distinct constructs: ‘body schema’ and ‘body image’ (see Berlucchi & Aglioti, 2010 for short review). Body-schema has been described as the unconscious, physical representation of the body in space, sub-served and updated by bodily movements and the environment. Body-image on the other hand, should be understood as a conscious, mental representation of the body associated with perception and action (Berlucchi & Aglioti, 2010; Paillard, 1999). The relationship between body-related cortical processing and how observers experience their own body (body image) is of particular interest in the present study, as these introspective perceptions of one’s own body do not always reflect reality. Instead, they can manifest as body image distortions that are consistently identified as contributing factors to the complex dynamics that sustain some eating disorders (EDs) (American Psychiatric Association, 2013). Such disorders are characterised by a range of abnormal food- and body-related attitudes and behaviours, including an undue tendency to emphasise the importance of body weight and shape, which can lead to unhealthy eating habits such as binging, purging or fasting (see Skrzypek, Wehmeier, & Remschmidt, 2001).

Body image disturbances associated with EDs are multifaceted and are thought to arise from interrelated contributions from perception, cognition, affect and behaviour (see Cash, 2004). As such, their causes are still unclear (e.g. Stormer & Thompson, 1996). We were particularly interested in the perceptual facet of body image disturbance, as research is beginning to highlight how atypical functioning of the visual system might contribute to perceptual aspects of these distortions (see Suchan, Vocks, & Waldorf, 2015 for review). For example, it has been suggested that maladapted (Suchan et al., 2010) and underactive (Uher et al., 2005) EBA function, or at least disrupted communication between EBA and FBA, may underpin body image disturbance (Suchan et al., 2013). Despite evidence to suggest that early body-sensitive responses arise from EBA activity (e.g. Sadeh et al., 2011) little is known about the early stages of visual body-processing in EDs. Instead, studies to-date have focused on the relationship between stimulus salience and later, more conscious (see Sergent & Dehaene, 2004) stages of processing (e.g. Dodin & Nandrino, 2003; Gao et al., 2011; Horndasch, Heinrich, Kratz, & Moll, 2012; Mai et al., 2015). Therefore, the present study was designed to measure the latency and amplitude of body-sensitive P1, N1 and VPP components to shed light on the early cortical processing of male and female body stimuli in women with and without a history of EDs.

Previous ERP studies have shown that cortical alterations and pathologically related neurological differences (such as in response to food and body stimuli) are common in those with EDs, even after weight gain (e.g. Blechert, Ansorge, Beckmann, & Tuschen-Caffier, 2011; Hatch et al., 2010; Li et al., 2015; Mai et al., 2015; Otagaki, Tohoda, Osada, Horiguchi, & Yamawaki, 1998; Pollatos, Herbert, Schandry, & Gramann, 2008; Sfärlea et al., 2016). Specifically, Mai et al. (2015) found evidence for an attentional processing bias for overweight body stimuli in participants with Bulimia Nervosa, illustrated by larger P2 amplitudes and higher arousal ratings. Li et al. (2015) found evidence for abnormal face processing mechanisms in participants with anorexia nervosa, such that anorexics showed reduced P1 amplitudes and reduced and delayed N170 amplitudes relative to control participants. This was interpreted as reflecting reduced configural processing for face stimuli in these individuals. In addition, Sfärlea et al. (2016) suggest that reduced early posterior negativity (EPN) amplitudes in anorexic girls is potentially indicative of other peoples faces being perceived as less intrinsically relevant.

In sum, despite research clearly showing that it is possible to establish links between ED symptomatology and ERP responses (e.g. Li et al., 2015; Mai et al., 2015; Sfärlea et al., 2016), no ERP study to-date has investigated the early temporal dynamics of body processing in both anorexic and bulimic populations. This is of interest as the shared core pathology of anorexia and bulimia is the tendency to over-evaluate weight and shape (see Fairburn & Harrison, 2003 for review). Moreover, with reports stating that anorexia nervosa still has the highest death rate of all psychiatric conditions (e.g. Arcelus, Mitchell, Wales, & Nielsen, 2011; Papadopoulos, Ekbom, Brandt, & Ekselius, 2009), which prompted recent calls for more evidence-based treatment and early interventions (World Eating Disorders Action Day, 2016), the identification of objective, biological markers of ED symptoms would be timely. It is therefore important to investigate visual body processing not only in bulimia (Mai et al., 2015) but also in anorexia.

In addition, electrophysiological research on body representation suggests that the body-sensitive N1 is modulated by the gender of the body observed. This is because men (Hietanen & Nummenmaa, 2011) and women (Alho, Salminen, Sams, Hietanen, & Nummenmaa, 2015) have been found to elicit a larger body-sensitive N1 to female bodies in comparison to male bodies. Both Hietanen and Nummenmaa (2011) and Alho et al. (2015) proposed that the structural encoding of bodies may therefore trigger later attraction-related responses relevant for mating. For this argument to be convincing, however, one would expect these sensitive enhancements to hold across sexual orientations and gender (e.g. heterosexual women should show enhanced amplitudes to men, not women). Despite this, Alho et al. (2015) reasoned that the same-sex gender sensitivity seen over the N1 for their female participants may be because women display similar physiological and evaluative sexual responses toward both genders (see Rupp & Wallen, 2008 for review). However, if this is the case and N1 gender-sensitivity truly reflects an early sexual response, then women should show an absence of N1 gender-sensitivity, rather than enhanced responses to the sight of female bodies. It appears then, that an alternative explanation may be more fitting and consequently, the temporal dynamics of gender-sensitive body perception warrants further investigation.

The aim of the present study therefore, was to investigate the early stages of visual body- and gender-sensitive processing in observers at risk of anorexia or bulimia, in order to identify potential biomarkers of ED symptoms. Body-sensitive P1 and N1 responses were sought over occipito-parietal electrodes, and body-sensitive VPP responses were sought over fronto-central regions, by comparing the brain's response to bodies and non-body stimuli (houses) in an oddball detection task (response to animals). This design was selected (similar to van Heijnsbergen et al., 2007) so that bodies were not the focus of the task, as evidence suggests attentional differences between ED participants and controls when viewing bodies (Blechert, Nickert, Caffier, & Tuschen-Caffier, 2009; Horndasch, Kratz, et al., 2012; Jansen, Nederkoorn, & Mulkens, 2005; Mahamedi & Heatherton, 1993; Shafran, Lee, Cooper, Palmer, & Fairburn, 2007; Vocks et al., 2010; Warschburger, Calvano, Richter, & Engbert, 2015), which could have influenced ERPs (Hillyard & Anllo-Vento, 1998). Both male and female bodies were shown in order to assess for any gender-sensitive effects over P1, N1 or VPP. Body stimuli were rated for valence and arousal, and the Eating Disorder Inventory-II (EDI-2) (Garner, 1991) was used as a measure of body image disturbances and characteristic traits of EDs in all participants.

We predicted that the early visual analysis of human bodies would differ between the groups, as reflected in P1, N1 and VPP responses. Although we did not specifically test for configural processing abnormalities, as Li et al. (2015) found altered early visual ERPs indicative of atypical configural face processing in anorexic participants, given that face and body processing mechanisms are reportedly similar (see de Gelder et al., 2010; Minnebusch & Daum, 2009 for review), there was a possibility of finding differences between the groups that might indicate atypical configural body processing in ED populations. We further expected that ED participants might feel differently about the body stimuli than controls, as Mai et al., (2015) found higher arousal ratings for overweight bodies in bulimic participants and Uher et al. (2005) found higher aversion ratings for body stimuli in anorexic participants. We also expected the ED group to display higher scores on all subscales of the EDI-2. Finally, valence and arousal ratings, as well as EDI-2 scores, were predicted to linearly relate to potential ERP effects, indicating that body-sensitive processing is modulated by the way the observer thinks and feels about their own body and those of others.

4.3 Method

4.3.1 Participants

4.3.1.1 Eating disordered participants

Thirty weight-restored female ED participants (15 anorexic, 15 bulimic) from North East Essex, UK, and the surrounding area, were recruited via email advertisements to University of Essex mailing lists, as well as posters placed on notice boards at the University of Essex and ‘The Gym’ Colchester. At the time of testing, five of these participants were medicated with fluoxetine or sertraline for symptoms of anxiety and/or depression, three reported undergoing counselling and two reported receiving both medication (as above) and counselling for their eating disorder. Four participants reported having had children, with the most recent pregnancy occurring five years before testing. Information regarding age, height, weight, Body Mass Index (BMI) and hours of weekly exercise is reported in Table 4.1.

We chose to recruit weight-restored anorexic participants so that any differences in ERPs would not be attributable to the effects of malnourishment (although despite weight gain, two of these participants did not consider themselves even partially recovered). Similarly, BN participants who considered themselves at least partially recovered were sought. All participants self-reported a previous medical diagnosis for their ED. We chose to recruit women who had not been diagnosed with more than one ED in their lifetime so that potential differences between disorders could be assessed.

Consequently, women who had been diagnosed with either anorexia only or bulimia only, and those who had no history of EDs, were recruited. No differences were evident between anorexic and bulimic participants with regards to demographic information, eating disorder symptomatology (with the exception of the bulimia subscale, see Table 4.4 in supplementary data section 4.8), valence and arousal ratings, or the amplitudes and latencies of early visual components (with the exception of a trend towards larger P1 amplitudes in anorexic participant’s, see Table 4.4 in supplementary data section 4.8). Therefore, data from these women were combined into one ED group (see also Horndasch, Kratz, et al., 2012).

4.3.1.2 Control participants

Twenty-nine females with no clinical history of EDs or body image disturbances were recruited from the University of Essex as control participants. Two participants reported having had children, with the most recent pregnancy occurring three years before testing. Information regarding age, height, weight, Body Mass Index (BMI) and hours of weekly exercise is reported in Table 4.1.

Table 4.1

Average demographic information for each group.

	ED group (N=29)	Control group (N=27)	T-test results
Age (years)	24.07 (8.34)	23.07 (5.35)	*t*(54) = 0.54, *p* =0.595
Height (m)	1.66 (.07)	1.68 (.04)	*t*(54) = 1.23 *p* =0.226
Weight (kg)	58.94 (9.33)	65.31 (12.39)	*t*(54) = 2.18, *p* =.036
BMI (kg/m^2)	21.38 (2.43)	23.11 (4.34)	*t*(54) = 1.86, *p* =.075
Weekly exercise (hrs)	5.81 (3.76)	2.91 (2.94)	*t*(54) = 3.20, *p* =.002
Total EDI-2 score	103.48 (48.05)	37.70 (25.05)	*t*(54) = 6.486, p < .001

Note. There were no differences between anorexic and bulimic participants on any of these measures, so the groups were combined to form one ED group. Standard deviation in parentheses.

4.3.1.3 Exclusion criteria

Individuals who had been diagnosed with more than one ED in their lifetime were not recruited. Those who had experienced a major psychiatric disorder, such as schizophrenia or bipolar disorder, were also not permitted to take part. Data from one ED participant (bulimic) and two control participants were not included due to excessive noise in the EEG recordings that made peak detection problematic.

4.3.2 Ethical declaration

The study was conducted in line with the 2008 Declaration of Helsinki, approved by the local Ethics Committee for the Psychology Department at the University of Essex, and endorsed by the Eating Disorders charity B-eat, whose advice was sought during the design phase.

4.3.3 Apparatus and stimuli

4.3.3.1 Eating Disorder Inventory-II (EDI-2)

The ‘Eating Disorder Inventory-II’ (EDI-2) (Garner, 1991) was used to measure the prevalence of any behavioural, cognitive and/or affective symptoms commonly associated with EDs. This explicit measure of unhealthy attitudes and behaviours towards one’s body is a widely used, reliable and valid research tool (e.g. Clausen, Rokkedal, & Rosenvinge, 2009; Eberenz & Gleaves, 1994; Nevonen & Broberg, 2001; Thiel & Paul, 2006). The measure assesses 11 dimensions of clinical relevance by means of 91 self-report statements, for example; ‘I think my hips are too big,’ to which participants respond; ‘Always,’ ‘Usually,’ Often,’ ‘Sometimes,’ ‘Rarely,’ or ‘Never.’

4.3.3.2 EEG stimuli

In order to obtain realistic body stimuli representative of the bodies that might be encountered in everyday life, 96 pictures of bodies (49 female, 47 male) and 99 pictures of houses were downloaded from the World Wide Web. To further simulate realistic viewing, both body and house stimuli were selected in order to depict an array of shapes and sizes. These were classified as obese, overweight, average, thin and very thin by a focus group of University of Essex students and then assessed by UK national eating disorder charity ‘B-eat’. Images of comparable background colour were selected (e.g. grey, beige, light blue) and then cropped and edited such that a similar amount of background space was evident across body shapes. All images were matched with regards to complexity (i.e. each showing only one body or one house, rather than scenes) as this has been shown to affect attentional processes (see Miller & Fillmore, 2010).

Whilst waiting for B-eat's assessment, control data was collected. Based on B-eat's advice, the ED group did not view stimuli that had been deemed potentially triggering (e.g. bodies with visible bones or those that B-eat considered morbidly obese). Therefore, only data from the stimuli that all participants viewed were analysed for this report. Body stimuli (half side facing, half front facing) were edited to exclude the head, and all showed the full trunk but varying amount of upper and lower limbs. Fifteen pictures of animals were also included as deviant target stimuli to which a response was required. All stimuli were 267 x 200 pixels and luminosity was adjusted to control for brightness across all images (see Figure 4.1 for examples).

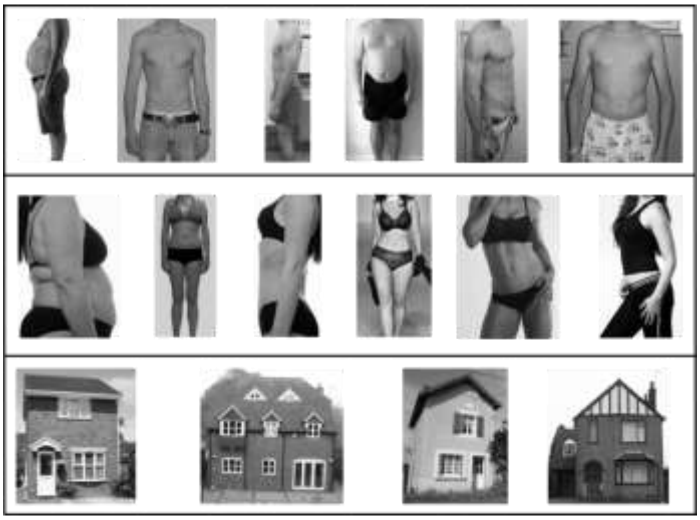

Figure 4.1. Example stimuli controlled for overall image brightness. (Top to bottom: male bodies, female bodies, houses).

4.3.3.3 Valence and arousal ratings of body stimuli

A computer-based task assessed responses of valence and arousal towards body stimuli. Two 9-point scales were used to represent ‘valence’ and ‘arousal’ dimensions, with adjective clusters to describe the extremes of the dimensions at either end. Scales were pictorial, using Self-Assessment Manikins (SAM) to illustrate the different points of the scale (Bradley & Lang, 1994). The centre was neutral. Each participant rated a random selection of 20 - 30 body stimuli pictures.

4.3.4 Procedure

A standardised overview of procedures was read, and written consent was obtained. The EDI-2 was completed during EEG preparation; an intermission of at least 45 minutes was ensured between questionnaire completion and the start of the task.

A computer-based oddball (animal) detection task (similar to van Heijnsbergen et al., 2007) was completed as EEG was recorded. Participants were asked to fixate on the centre of a grey screen (monitor resolution 1152 x 864 pixels). A cross was presented centrally except when it was replaced, for 250 ms on each trial, by a picture. After each 250 ms picture presentation there was a 1000 ms response interval and a random intertrial interval of between 300 ms and 700 ms. The picture was either a house, a male or female body, or occasionally an animal. Participants were instructed to press the space bar with both hands as quickly as possible whenever they saw an animal picture. For control participants, 195 images of bodies and houses were shown twice with the second presentation left-right reversed, and for ED participants 120 images of bodies and houses were shown three times each, with half of the total 360 presentations left-right reversed. Animals were shown twice to both ED participants and controls, with the second presentation left-right reversed. Thus, controls completed 420 trials (98 female bodies; 94 male bodies; 198 houses; 30 animals) and ED participants completed 390 trials (90 female bodies; 90 male bodies; 180 houses; 30 animals). Stimuli were shown in random order with a cumulative summary of animal detection times and errors displayed during inter-block intervals, timing of which was at the participant’s discretion. Participants remained at the computer to rate some of the previously seen body pictures for valence and arousal. Upon completion the EEG cap was removed.

Digital scales were used to weigh participants and a wall chart was used to measure height. Participants were not told their height or weight, and were then debriefed and paid.

4.3.5 EEG recording

4.3.5.1 EEG acquisition

Continuous EEG was sampled at a rate of 500 Hz from 64 Ag/AgCl electrodes placed according to the international 10-10 system (EASYCAP GmbH, Herrsching, Germany). Online, the signal was referenced to the left earlobe with impedances kept below 10 kΩ. Bipolar channels recorded vertical (VEOG) and horizontal (HEOG) electro-oculogram from above and below the midpoint of the right eye and beside the outer canthi of both eyes. Recording and offline analysis of EEG and EOG data was conducted with Neuroscan Synamps2 system and SCAN 4.5 software (Compumedics, Melbourne, Australia). Offline, EEG and EOG signal were digitally filtered using a 0.15Hz - 30Hz bandpass filter and re-referenced to the average of the two earlobes.

4.3.5.2 Segmentation

The data were divided into 600-ms epochs beginning 100 ms prior to stimulus onset and baseline corrected against the mean voltage during the 100-ms pre-stimulus period.

4.3.5.3 Artifact detection

Trials with horizontal eye movements (HEOG exceeding ± 40 µV relative to baseline), eye blinks or other artefacts (a voltage exceeding ± 80µV at any electrode relative to baseline) were rejected from further analysis. ERPs to target stimuli (animals) were also not included.

4.3.6 Statistical analyses

4.3.6.1 Demographics

Bonferroni-adjusted independent samples t-tests were conducted on demographic data in order to compare, age, height, weight, BMI and amount of weekly exercise between the groups. T-tests are reported unsigned.

4.3.6.2 EDI-2

Scores pertaining to the 11 subscales of the EDI-2 were calculated according to the manual (Garner, 1991) and then averaged for each group. Bonferroni-adjusted independent samples t-tests were conducted separately for each subscale in order to assess differences in ED symptomatology between the groups. T-tests are reported unsigned.

4.3.6.3 Valence and arousal ratings

Valence and arousal ratings given to body stimuli were subject to separate 2 x 2 mixed factorial analysis of variance (ANOVA) with gender (male body vs. female body) as the within subjects factor and group (ED vs. control) as the between-subjects factor. Greenhouse-Geisser adjustments to the degrees of freedom were applied when necessary and partial eta squared is reported as the measure of effect size. Follow-up pairwise comparisons of the estimated marginal means were Bonferroni corrected.

4.3.6.4 Electrophysiology

4.3.6.4.1 Electrode selection and ERP data extraction

In order to identify the electrodes on which ERP components should be measured, maximal P1 and N1 responses were assessed in each individual, at lateral posterior electrodes TP7/8, CP5/6, PO3/4, PO5/6, PO7/8, P3/4, P5/6, P7/8, O1/2, which are frequently implicated in body processing (e.g. Minnebusch et al., 2010; Minnebusch et al., 2009; Stekelenburg & de Gelder, 2004; Thierry et al., 2006; van Heijnsbergen et al., 2007). Discernible peaks for both the P1 and the N1 were seen in all participants only over electrodes P5/6, P7/8, PO5/6, PO7/8. P1 scalp topographies associated with the aggregated grand averaged waveforms (see Figure 4.2. in section 4.4.4.1.1) also indicated that this electrode selection captured the strongest P1 response in all groups of participants. We deemed N1 scalp topographies insufficiently informative, as the N1 remained in the positive range with a strong frontal negativity evident in the same time range. Instead, we computed P1 to N1 peak-to-peak amplitudes, and found that these, too, were most frequently maximal over P5/6, P7/8, PO5/6, PO7/8. To investigate body processing for both P1 and N1 time ranges, individual peak amplitudes and peak latencies were therefore extracted separately for male bodies, female bodies and houses at electrodes P5/6, P7/8, PO5/6, PO7/8. For the vast majority of P1 and N1 components, peak identification was straightforward within typical time windows based on the aggregated grand average waveform (P1: 70 ms - 140 ms; N1: 120 ms - 190 ms). However occasionally, for some participants, double peaks were observed for some components at some electrodes. The choice of which peak data to extract was informed by finding the same component peaks in surrounding electrodes in the same hemisphere or homologous electrodes on the opposite hemisphere. This approach was chosen over an automated approach because we noticed that latencies were very different from one person to the next and true component peaks would thus be missed by using a general time window.

To characterise the VPP, individual maximal positive peak amplitudes and latencies were assessed at fronto-central electrodes that have been implicated in previous VPP analyses (Ashley, Vuilleumier, & Swick, 2004; Eimer, 2000a; Luo, Feng, He, Wang, & Luo, 2010; Sadeh et al., 2011; Stekelenburg & de Gelder, 2004; van Heijnsbergen et al., 2007; Wheatley, Weinberg, Looser, Moran, & Hajcak, 2011). Strongest responses were seen at Fz, F1/2, and F3/4, with scalp topographies of the grand averaged origins of the VPP waveform for each group supporting this (see Figure 4.2. in section 4.4.4.1.1). Maximal peak amplitudes and peak latencies were therefore extracted separately for bodies and houses at electrodes Fz, F1/2, and F3/4. One ED participant (anorexic) did not show obvious VPP peaks to houses so their data was excluded from the body-sensitivity analysis. Again, to evaluate gender-sensitivity over the VPP, individual maximal peak amplitudes and latencies were extracted separately for male and female body trials at the same electrodes. The process to achieve this was identical to the process for the P1 and N1. Grand averaged VPP waveforms of all visual stimuli served as a guide for the timing of VPP deflections in each group (120 ms -190 ms for the ED group, 140 ms – 190 ms for controls). Manual identification and extraction of the VPP in each individual was then completed as previously described for P1 and N1.

4.3.6.4.2 ERP statistical analyses

To assess body-sensitivity, both amplitude and latency data for each component were subjected to separate mixed factorial ANOVA with group as the between-subjects factor (control vs. ED) and picture type (house vs. body), hemisphere (left vs. right, for P1/N1 analyses only) and electrode (4 electrodes for P1/N1 analyses or 5 electrodes for VPP analyses –as above) as the within-subjects factors. Gender-sensitivity was assessed similarly, with group as the between-subjects factor (control vs. ED) and picture type (male body vs. female body), hemisphere (left vs. right, for P1/N1 analyses only) and electrode (as above) as the within-subjects factors. For the sake of brevity, non-significant statistics are not reported, and hemisphere and electrode effects are only reported if they interacted meaningfully with picture type or group. Greenhouse-Geisser adjustments to the degrees of freedom were applied when necessary and partial eta squared is reported as the measure of effect size. Pairwise comparisons were Bonferroni corrected and t-tests are reported unsigned.

4.3.6.5 Correlational analyses

In order to investigate the links between lifestyle, cognition and electrophysiology, we planned to conduct a Pearson's *r* correlational analysis between the demographic factors, EDI-2 scores, valence and arousal ratings and ERP effects, which were found to differ between groups. Thus, relationships between sociodemographic factors and ERP effects were of interest as they would inform an understanding of group differences. As evidence suggests that eating disorder symptoms occur on a spectrum (Bienvenu et al., 2000; Shisslak, Crago, & Estes, 1995; Widiger & Samuel, 2005) the analysis was conducted across groups, synonymous with the methods of previous studies that have employed groups with different eating pathology (e.g. Eshkevari, Rieger, Longo, Haggard, & Treasure, 2012; Mai et al., 2015; Mitchison, Crino, & Hay, 2013). In line with this, data on figures have been colour coded such that ED and control data can be identified (see Figure 4.6 – Figure 4.19 in supplementary data section 4.8). The false discovery rate method of correction for multiple comparisons (Benjamini & Hochberg, 1995) was applied to correlation results, results that did not survive correction are not reported.

4.4 Results

4.4.1 Demographics

Bonferroni-adjusted independent sample t-tests assessing sociodemographic factors between the groups revealed no differences in age or height. However, ED participants were significantly lighter and performed more exercise on average per week than the controls ($t(54) \geq 2.182$, $p \leq .036$). There was also a trend towards a lower average BMI in the ED group ($t(54) = 1.861$, $p = .075$) although these were still in the healthy range (>18.5 kg/m^2; see Table 4.1; see Gallagher et al. (2000)).

4.4.2 EDI-2

Scores pertaining to the eleven subscales of the EDI-2 were calculated according to the manual (Garner, 1991) and then averaged for each group. Bonferroni-adjusted independent samples t-tests revealed that scores differed significantly between the groups on all subscales ($t(54) \geq 2.153$, $p \leq .037$) with ED participants scoring higher than controls (see Table 4.2).

Table 4.2

Mean scores and standard deviations for each group on the EDI-2 subscales

EDI-2 Subscale	ED Group Mean Score (SD)	Control Group Mean Score (SD)	*T-test results*
Drive for Thinness	11.93 (5.46)	3.26 (4.03)	*t*(54) = 6.72 p < .001
Bulimia	6.31 (5.99)	1.56 (2.61)	*t*(54) = 3.89, p < .001
Body Dissatisfaction	14.66 (7.05)	8.44 (8.85)	*t*(54) = 2.92, *p* =.005
Ineffectiveness	9.93 (7.89)	3.11 (4.15)	*t*(54) = 4.09, p < .001
Perfectionism	9.10 (4.43)	5.81 (4.44)	*t*(54) = 2.77, *p* =.008
Interpersonal Distrust	5.79 (4.50)	1.04 (1.68)	*t*(54) = 5.31, p < .001
Interoceptive Awareness	11.21 (7.56)	2.59 (4.19)	*t*(54) = 5.32, p < .001
Maturity Fears	8.10 (7.18)	4.78 (4.05)	*t*(54) = 2.15, *p* =.037
Ascetism	9.07 (4.09)	1.96 (1.93)	*t*(54) = 8.41, p < .001
Impulse Regulation	9.00 (6.89)	2.18 (3.29)	*t*(54) = 4.78, p < .001
Social Insecurity	8.38 (5.41)	2.96 (2.78)	*t*(54) = 4.66, p < .001

Note. SD=Standard Deviation

4.4.3 Valence and arousal ratings

A 2 x 2 mixed factorial ANOVA on valence ratings of body stimuli, with gender (male body vs. female body) as the within subjects factor and group (ED vs. control) as the between-subjects factor, revealed a significant main effect of gender ($F(1, 54) = 7.294$, $p = .009$, $\eta_p^2 = 0.119$). Follow-up comparisons showed that female bodies were rated more positively than male bodies ($F(1, 54) = 7.573$, $p = .008$, $\eta_p^2 = 0.123$, Table 4.3.). It should be noted nonetheless, that ratings for both male and female bodies were still rated around the neutral mark of ‘4.’ This effect did not interact with group ($F(1, 54) = 2.184$, $p = 0.145$, $\eta_p^2 = .039$) and the between-subjects main effect of group was also non-significant ($F(1, 54) = 0.232$, $p = 0.632$, $\eta_p^2 = .004$).

A 2 x 2 mixed factorial ANOVA on arousal ratings of body stimuli, with gender (male body vs. female body) as the within subjects factor and group (ED vs. control) as the between-subjects factor, did not yield any significant main effects or interactions.

Table 4.3

Mean ratings and standard deviations of valence and arousal towards male and female stimuli in both groups.

Scale	ED Group Mean Rating (SD)	Control Group Mean Rating (SD)
Valence to male bodies	4.66 (.84)	4.42 (1.04)
Valence to female bodies	4.78 (.73)	4.80 (1.00)
Arousal to male bodies	5.13 (1.13)	4.95 (1.20)
Arousal to female bodies	5.03 (1.07)	5.23 (1.28)

Note. SD=Standard Deviation

4.4.4 Electrophysiology

4.4.4.1 Assessing for body-sensitivity

ERPs to body and house stimuli were compared to assess for sensitivity to bodies over parietal-occipital (P1 and N1 components) and fronto-central (VPP component) electrodes. Body sensitivity in the amplitudes and latencies of these components was compared between ED and control groups. Latency and amplitude of all components were therefore subject to separate mixed factorial ANOVA with group as the between-subjects factor (control vs. ED) and picture type (house vs. body), hemisphere (left vs. right, for P1/N1 analyses only) and electrode (4 electrodes for P1/N1 analyses or 5 electrodes for VPP analyses – see method section) as the within-subjects factors.

4.4.4.1.1 P1 amplitude

As suggested in Figure 4.2 below, there were no significant main effects of picture type or group over the P1 amplitude. Still, there was a significant interaction between picture type, hemisphere and electrode (*F*(3, 162) = 4.002, *p* = .014, η_p^2 = .069). Follow-up comparisons of the estimated marginal means revealed that, despite a trend at electrode P5 showing marginally larger amplitudes to bodies ((7.369 μV vs. 4.914 μV) *F*(1, 54) = 3.288, *p* = .075, η_p^2 = .057), there were no amplitude differences between picture types at any of the electrodes. P1 amplitudes were, however, significantly larger to both bodies and houses in the right hemisphere at all electrodes (*F*(1, 54) ≥ 8.529, *p* ≤ .005, η_p^2 ≥ .136) except PO5/6 where the pattern was marginal (*F*(1, 54) = 3.529, *p* = .066, η_p^2 = .061). The between-subjects effect of group was non-significant and there were no significant interactions with group.

This suggests that P1 amplitudes are generally larger in the right hemisphere despite some electrode differences, but are not specifically sensitive to the human form and are unrelated to ED symptomatology.

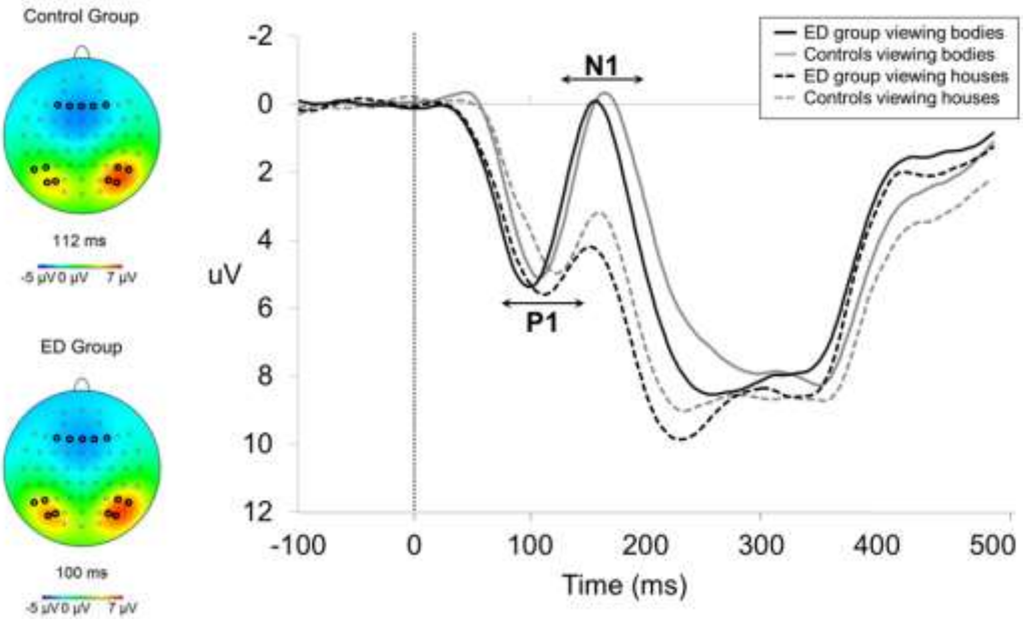

Figure 4.2. Left panel shows voltage maps for the time window of the visual P1 component (controls 112 ms, ED participants 100 ms), collapsed over viewing conditions. Visual N1/VPP, which P1-N1 peak-to-peak amplitudes indicated was maximal over similar regions, has not been illustrated because traces remained in the positive range throughout (120 ms – 190 ms; see right panel) with an additional strong frontal negativity that decreased the visibility of N1 topographies. Anterior electrodes analysed for VPP and posterior electrodes analysed for P1/N1 have been highlighted. The right panel shows grand averaged ERP responses during house and body viewing (ED participants in black, controls in grey) collapsed over electrodes P5/6, P7/8, PO5/6, PO7/8. A body-sensitive N1 response is evident in both groups and shorter P1 and N1 latencies to all stimuli can be seen in the ED group.

4.4.4.1.2 P1 latency

Figure 4.2 also suggests that P1 latencies differed between stimuli and again between the groups. This was confirmed by ANOVA showing a main effect of picture type such that bodies evoked quicker P1 responses than houses (102 ms vs. 110 ms) ($F(1, 54) = 24.217$, $p < .001$, $\eta_p^2 = 0.310$) across groups. This suggests that body-sensitive responses may already be seen in P1 time ranges. In addition, P1 latencies to all stimuli were shorter in ED participants compared to controls (100 ms vs. 112 ms) as illustrated by a significant between-subjects effect ($F(1, 54) = 7.549$, $p = .008$, $\eta_p^2 = 0.123$). This suggests that shortened P1 latencies during visual processing, regardless of stimulus type, may be related to ED symptomatology (P1 latency did not differ between anorexic and bulimic participants – see Table 4.4 in supplementary data section 4.8).

4.4.4.1.3 N1 amplitude

Observation of Figure 4.2 also suggests clear amplitude differences between viewing house and body stimuli in the N1 time range. ANOVA confirmed this, showing that bodies evoked larger negative amplitudes than houses (-1.471 μV vs. 2.030 μV) ($F(1, 54) = 88.288$, $p < .001$, $\eta_p^2 = 0.620$). This pattern did not differ between the groups, and neither did the overall component as the between-subjects factor group was not significant. These findings support the existing claim that the N1 is body-sensitive, and further suggests that body-sensitivity in the N1 time range does not differ in those with EDs.

4.4.4.1.4 N1 latency

With regards to the time course of the N1 in response to bodies and houses, ANOVA revealed a main effect of picture type ($F(1, 54) = 17.625$, $p < .001$, $\eta_p^2 = 0.246$) as houses evoked shorter N1 latencies than bodies (151 ms vs. 159 ms). This did not differ between groups but a significant between-subjects effect was found ($F(1, 54) = 5.115$, $p = .028$, $\eta_p^2 = .087$), as N1 responses in the ED group were significantly quicker overall in comparison to controls (150 ms vs. 160 ms). This suggests that the temporal dynamics of visual processing in both P1 and N1 time ranges may be related to ED symptomatology (N1 latency did not differ between anorexic and bulimic participants – see Table 4.4 in supplementary data section 4.8).

4.4.4.1.5 VPP amplitude

Figure 4.3 below suggests that, similar to the N1, there was also a body-sensitive effect over VPP in both groups. This was confirmed as a main effect of picture type in the ANOVA ($F(1, 52) = 7.441$, $p = .009$, $\eta_p^2 = 0.125$), such that bodies evoked larger VPP amplitudes than houses (1.293 μV vs. .434 μV). This pattern did not differ between the groups and neither did the overall component, as the between-subjects factor group was not significant. These findings support the idea that VPP body sensitivity might be a reflection of N1 body-sensitivity.

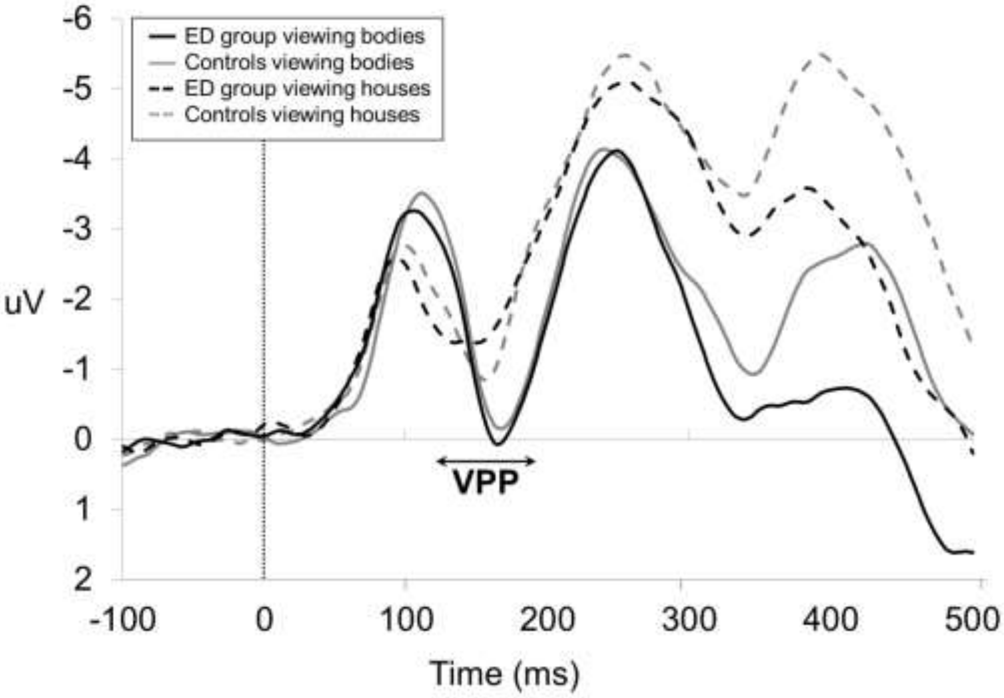

Figure 4.3. Grand averaged ERP responses depicting house and body viewing (ED group in black, controls in grey) collapsed over electrodes Fz, F1/2, F3/4, showing VPP latency differences between stimuli and higher VPP amplitudes to bodies in both groups.

4.4.4.1.6 VPP latency

Figure 4.3 suggests that VPP latencies to house stimuli may be shorter in both groups. ANOVA revealed a main effect of picture type (*F*(1, 52) = 52.966, *p* <.001, η_p^2 = 0.505) with follow-up comparisons showing faster responses to house stimuli (151 ms) than to body stimuli (168 ms). Unlike N1 latencies, average VPP latencies were not modulated by ED symptomatology, as there was no interaction with group.

4.4.4.2 Assessing for gender-sensitivity

ERPs to male and female body stimuli were compared to assess for sensitivity to gender over parietal-occipital (P1 and N1 components) and fronto-central (VPP component) electrodes. As houses do not have a gender, these stimuli were not included in the analyses. Gender-sensitivity in the amplitudes and latencies of these components was compared between ED and control groups. Latency and amplitude of all components were therefore subject to separate mixed factorial ANOVA with group as the between-subjects factor (control vs. ED) and picture type (male body vs. female body), hemisphere (left vs. right, for P1/N1 analyses only) and electrode (as above) as the within-subjects factors.

4.4.4.2.1 P1 amplitude

ANOVA found that P1 amplitudes were larger in the right hemisphere (7.842 μV vs. 5.598 μV) (*F*(1, 54) = 28.528, *p* <.001, η_p^2 = 0.346; see Figure 4.4. below). No other significant main effects or interactions were found. The between-subjects effect of group was non-significant. This suggests that P1 amplitudes to bodies in general, are larger in the right than in the left hemisphere but are not sensitive to gender or related to ED symptomatology.

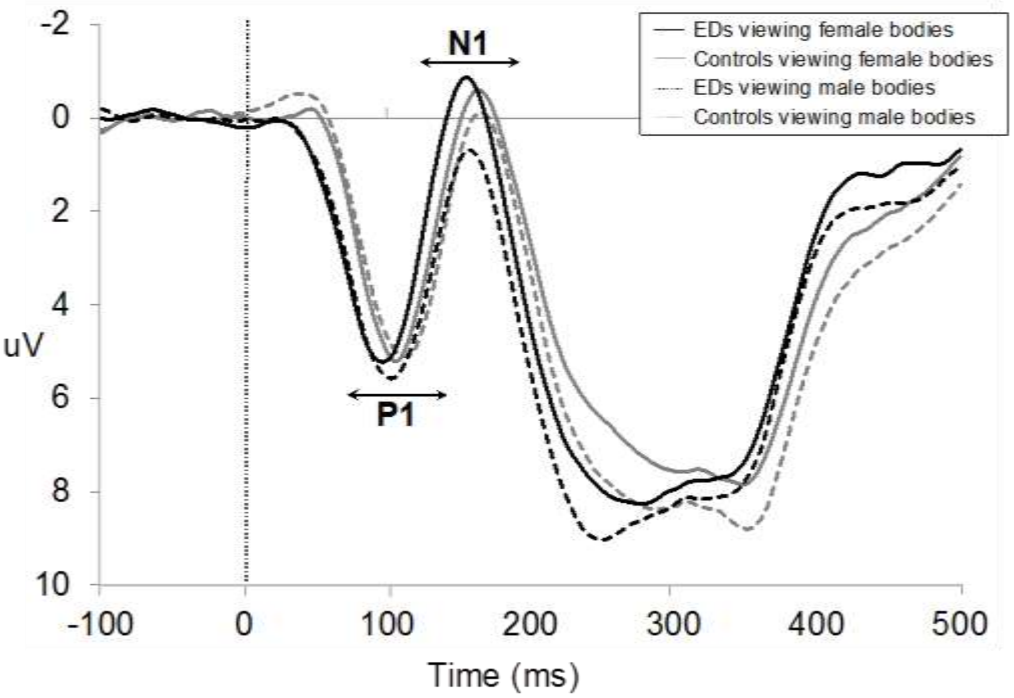

Figure 4.4. Grand averaged ERP responses depicting male and female body viewing separately (ED group in black, controls in grey) collapsed over electrodes P5/6, P7/8, PO5/6, PO7/8. An enhanced gender-sensitive effect in ED participants is evident in the ERP amplitudes in the N1 time range.

4.4.4.2.2 P1 latency

Figure 4.4 does suggest however, that P1 latencies differed according to whether participants viewed a male or female body. This was confirmed by ANOVA, finding P1 latencies to be shorter in response to female bodies as compared to male bodies (100 ms vs. 105 ms) ($F(1, 54) = 16.732$, $p < .001$, $\eta_p^2 = 0.237$) across groups. This suggests that gender-sensitive responses may be seen in P1 time ranges. As to be expected, a significant between-subjects effect showed that P1 latencies to all bodies were shorter in ED participants (96 ms vs. 109 ms) (*F*(1, 54) = 10.023, *p* = .003, η_p^2 = 0.157), again supporting the idea that shortened P1 latencies may be related to ED symptomatology.

4.4.4.2.3 N1 amplitude

Apparent differences in N1 amplitudes implicated in Figure 4.4 were confirmed by ANOVA. There was a main effect of picture type (*F*(1, 54) = 25.631, *p* < .001, η_p^2 = 0.322), describing larger N1 amplitudes to female bodies in comparison to male bodies (-1.051 μV vs. -2.092 μV). This interacted with group (*F*(1, 54) = 7.081, *p* = .010, η_p^2 = 0.116), and pairwise comparisons of the estimated marginal means showed larger amplitudes to female than to male bodies in the ED group (-2.470 μV vs. -.870 μV) (*F*(1, 54) = 30.151, *p* < .001, η_p^2 = 0.358), but no such differences in the control group (-1.232 μV vs. -1.715 μV) (*F*(1, 54) = 2.561, *p* = 0.151, η_p^2 = .045). Nevertheless, the average amplitude of the component appears to be the same as there was no significant main effect of the between-subjects factor group. Overall, these patterns suggest that enhanced gender sensitivity in body-sensitive N1 amplitudes is related to ED symptomatology in women (both anorexic and bulimic participants showed this effects; see Table 4.5 in supplementary data section 4.8).

4.4.4.2.4 N1 latency

As implicated in Figure 4.4, there were no differences in N1 latency when viewing male or female bodies, in either group. There was a significant between-subjects effect however, showing that overall, the N1 to bodies was faster in ED participants than in controls (154 ms vs. 165 ms) ($F(1, 54) = 8.330$, $p = .006$, $\eta_p^2 = 0.134$). This echoes previous suggestions that faster processing in both P1 and N1 time ranges may be related to ED symptomatology.

4.4.4.2.5 VPP amplitude

Figure 4.5 below suggests a similar gender-sensitive effect for the ED group as that which was observed over the body-sensitive N1; this was not apparent in controls. ANOVA found a main effect of picture type ($F(1, 53) = 6.549$, $p = .013$, $\eta_p^2 = 0.110$), showing that amplitudes to female body stimuli (1.657 μV) were significantly larger than amplitudes to male body stimuli (1.029 μV). A significant interaction with group was also found ($F(1, 53) = 4.596$, $p = .037$, $\eta_p^2 = .080$), with follow-up pairwise comparisons revealing the presence of this gender-sensitive effect in ED participants ($F(1, 53) = 11.075$, $p = .002$, $\eta_p^2 = 0.173$) but not in controls ($F(1, 53) = .069$, $p = 0.793$, $\eta_p^2 = .001$). This suggests that gender-sensitivity over the VPP is related to ED symptomatology (both anorexic and bulimic participants showed this effects; see Table 4.5 in supplementary data section 4.8).

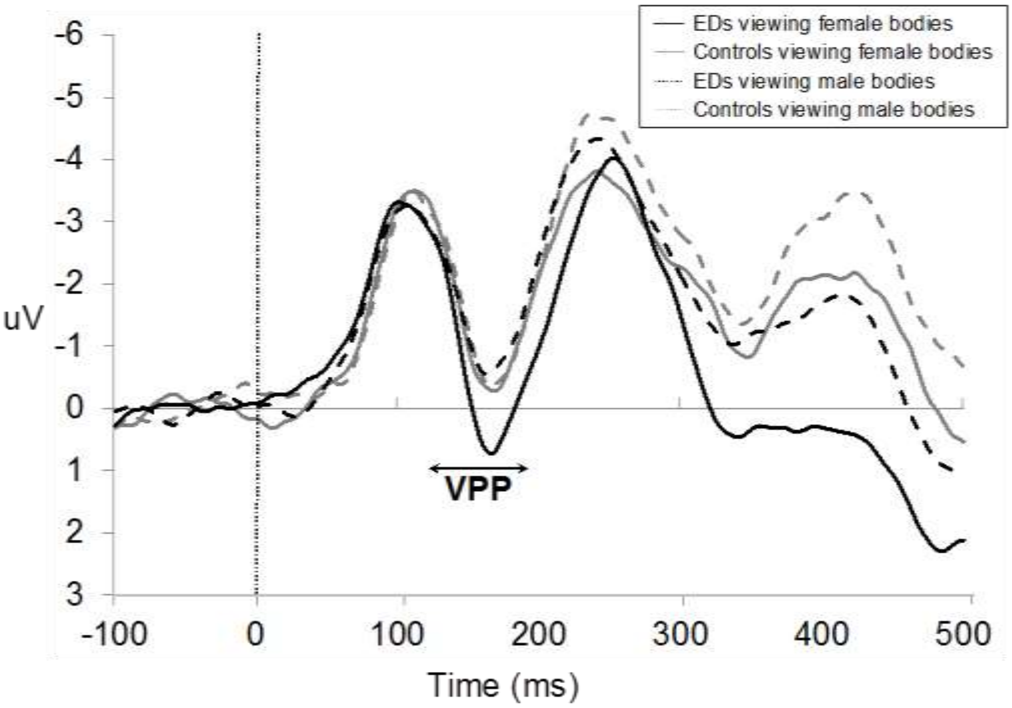

Figure 4.5. Grand averaged ERP responses depicting male and female body viewing separately (ED group in black, controls in grey) collapsed over electrodes Fz, F1/2, and F3/4. Increased gender selectivity in VPP amplitudes in the ED group is clear.

4.4.4.2.6 VPP latency

As suggested by Figure 4.5*,* ANOVA revealed no differences in VPP latency when viewing male or female bodies, in either of the groups. This suggests that the time course of body-sensitivity associated with this component is not modulated by gender or ED symptoms.

4.4.5 Correlations

4.4.5.1 Variables entered into Pearson's correlation

As there were significant differences between the groups on all eleven of the EDI-2 subscales, these scores were entered into the correlation as eleven variables (see also Eshkevari et al., 2012). Relationships between the subscales will not be reported because internal validity of the scale has been verified (e.g. Clausen et al., 2009; Eberenz & Gleaves, 1994; Nevonen & Broberg, 2001; Thiel & Paul, 2006). ANOVA results showed that early onset of visual P1 and N1 components might be characteristic of those who have experienced an ED. To quantify these effects, individual P1 and N1 peak latencies were averaged separately for body and house stimuli across electrodes P5/6, P7/8, PO5/6, PO7/8 and the resulting four variables entered into the correlation analysis. Gender-sensitive N1 and VPP peak amplitude differences were also implicated as characteristic of individuals who have experienced an ED. To reflect this, individual N1 and VPP peak amplitudes were averaged separately for male and female bodies across electrodes P5/6, P7/8, PO5/6, PO7/8 for the N1, and across electrodes Fz, F1/2, and F3/4 for the VPP. In both cases, amplitudes to male bodies were then subtracted from amplitudes to female bodies. For the N1, a more negative difference value is therefore indicative of gender-sensitivity towards higher N1 amplitudes in response to female bodies, whereas a more positive difference value is indicative of gender-sensitivity towards higher N1 amplitudes in response to male bodies. The opposite is true for the VPP. These difference values, representing gender-sensitivity for each component, were entered as two variables into the analysis. Weight and hours of weekly exercise also differed between the groups, thus, a total of 19 variables were included in the Pearson’s correlation.

4.4.5.2 EDI-2 subscale and ERP correlations

4.4.5.2.1 P1 latencies

A moderate, negative relationship between P1 latencies to houses and impulse regulation was found (*r*(54) = -.327, *p* =.014, see Figure 4.6 in supplementary data section 4.8). Moderate, negative correlations were also found between P1 latencies to bodies and scores on the drive for thinness, interoceptive awareness and impulse regulation subscales (*r*(54) ≥ -.312, p ≤ .019, see Figure 4.7– Figure 4.9 in supplementary data section 4.8). This indicates that as P1 latencies to bodies got shorter, participants showed higher levels of preoccupation with their weight, lower ability and trust in recognising internal affective and bodily states, and poorer abilities to regulate impulse behaviour. Shorter P1 latencies to houses were also associated with poorer abilities to regulate impulse behaviour.

4.4.5.2.2 N1 latencies

Similar to the relationships found between EDI-2 scores and responses in the P1 time range, a moderate, negative relationship was found between N1 latencies to bodies and impulse regulation (*r*(54) = -.319, *p* =.016, see Figure 4.10 in supplementary data section 4.8). This shows that as N1 latencies got shorter, self-reported abilities to regulate impulse behaviour got poorer.

4.4.5.2.3 N1 gender-sensitive effect

There were no significant correlations between N1 gender-sensitivity and EDI-2 measures.

4.4.5.2.4 VPP gender-sensitive effect

Moderate, positive relationships were found between the gender-sensitive effect over VPP amplitudes and nine of the eleven EDI subscales, including drive for thinness, body dissatisfaction, ineffectiveness, interpersonal distrust, interoceptive awareness, maturity fears, asceticism, impulse regulation and social insecurity (*r*(53) ≥ .329, p ≤ .022, *see* Figure 4.11– Figure 4.19 in supplementary data section 4.8)*.* This suggests that, as many of the cardinal symptoms of an ED increased, so did the difference between VPP amplitudes to males and females such that gender-sensitive responses were evident towards other women's bodies*.*

4.4.5.3 Correlations between sociodemographic variables and ERP effects

No significant relationships were found between weight and ERP effects or amount of weekly exercise and ERP effects. This suggests that sociodemographic group differences are not accountable for the ERP effects.

4.4.5.4 Correlations between ERPs

Latencies to all stimuli in the P1 time range were associated with the same changes in latency seen in the N1 time range. P1 latencies to house stimuli were strongly and positively associated with P1 latencies to body stimuli as well as N1 latencies to both body and house stimuli (*r*(54) ≥ .690, p <.001). It was also the case that P1 latencies to body stimuli were strongly and positively associated with N1 latencies to both house and body stimuli (*r*(54) ≥ .696, p <.001). There was also a strong, positive relationship between N1 latencies to body stimuli and N1 latencies to house stimuli (r(54) = 0.743, p<.001).

Amplitude effects did not correlate with the latencies of either component or each other.

4.5 Discussion

To the best of our knowledge, this is a novel study investigating the temporal dynamics of body- *and* gender- sensitive visual processing in observers at risk of body image disturbances, with the aim of identifying potential biomarkers of ED symptoms related to both anorexia and bulimia nervosa. P1, N1 and VPP responses to body and house stimuli over occipito-parietal and fronto-central sites were compared between women with ED history and healthy controls. This revealed that the entire P1-N1 complex was earlier in the ED group than in controls. Further comparisons were made between responses to male and female body stimuli in order to investigate gender sensitivity during body perception. A gender-sensitive effect was seen over N1 and VPP amplitudes in ED participants such that significantly larger component amplitudes were evident to female bodies in comparison to male bodies for the ED group but not controls. Findings were then correlated with scores on each of the EDI-2 subscales to assess the relationship with ED symptomatology. An earlier P1-N1 complex was associated with higher scores on several EDI-2 subscales, whilst gender selectivity in VPP amplitudes was related to all but two of the EDI-2 subscales. Ultimately, atypical ERP effects increased alongside the severity of ED symptoms and may therefore serve as potential neural markers of ED symptomatology.

Clear differences were also found between ED participants and controls with regards to how they felt about their own body. The ED group scored significantly higher on all EDI-2 subscales, indicating more unhealthy attitudes and behaviours towards their own body. There was no evidence that those with an ED and controls felt differently about other bodies however, as valence and arousal ratings in response to body stimuli did not differ between the groups. This contrasts with other findings that report higher arousal ratings for overweight body stimuli in bulimic individuals and higher aversion ratings for bodies in anorexic participants (Mai et al., 2015; Uher et al., 2005). However, Spring and Bulik (2014) found no differences in affective responses to body stimuli between recovered anorexic participants and controls. It is likely then, that as the majority of ED participants in our study reported partial recovery, this accounts for why body stimuli were not rated differently between the ED group and controls. This finding is of interest as it suggests that bodies are only abnormally salient during the acute stages of an ED. Further investigations would thus benefit from identifying when bodies begin to lose their emotional salience during recovery from an ED. With that in mind, it may also be of interest to identify at what point bodies begin to acquire emotional salience during the development of an ED.

The following sections will now proceed to discuss each of the ERP effects in turn, and to assess, where applicable, their potential as biomarkers for ED symptomatology.

4.5.1 Evidence for ERP body-sensitivity in ED participants and controls

In line with previous literature (see Peelen & Downing, 2007 for review), a body-sensitive N1 amplitude enhancement was found over occipito-parietal electrodes bilaterally. A body-sensitive VPP enhancement was also observed over fronto-central electrodes, supporting evidence that the N1 and the VPP may be generated from the same neural sources (cf. Eimer, 2000b; Joyce & Rossion, 2005; Sadeh et al., 2011; Taylor et al., 1999). We also found shorter P1 latencies in response to bodies compared to houses. This suggests that there may be an early distinction between bodies and other stimuli in the P1 time range. Early effects of face-sensitivity have also been seen over the P1 (Itier & Taylor, 2004, 2004b; Rossion et al., 1999; Rossion et al., 2000) so this finding in response to bodies is perhaps unsurprising. Our results indicate then, that the P1 effects may be a global response to bodies, reflecting the perception of a stimulus as a body, in a similar way to the process that has been proposed for faces (Itier & Taylor, 2004b).

N1 and VPP latencies on the other hand, were both longer to body stimuli in comparison to houses. Differences in N1 and VPP latency between bodies and other stimuli seem to be relatively undiscussed, although Stekelenburg and de Gelder (2004) describe the N1 to bodies as peaking earlier than the N1 to objects. The difference between findings might be attributed to the difference in stimuli as studies have consistently found longer N1 latencies to bodies without heads compared to bodies with heads (faces masked) (Alho et al., 2015; Minnebusch et al., 2010; Minnebusch et al., 2009). Further studies including both types of body stimuli and objects are therefore needed to verify the exact time course of body processing in the N1 time range.

4.5.2 Visual processing differences between ED women and controls

One of the most important findings to emerge from the present study was the difference in the temporal dynamics of the P1 and N1 between groups. To the best of our knowledge, this is the first study to find that the temporal dynamics of early visual processing are related to the severity of ED symptoms.

4.5.2.1 Early P1-N1 complex found in ED participants

In the ED group, P1 and N1 responses to all visual stimuli were significantly earlier than those elicited by the control group. While no previous ERP study has reported on the P1, our N1 latency shifts clearly differ from Mai et al. (2015), who report no N1 differences between bulimic and control participants whilst viewing overweight body stimuli. Our findings also differ from Li et al. (2015), who found longer N1 latencies to both faces and houses in anorexic participants compared to controls.

Unlike Li et al. (2015), the present study shows a clear relationship between P1 and N1 latency and several measures of ED symptoms (drive for thinness, interoceptive awareness and impulse regulation). Responses to both bodies and houses in the P1 time range were linearly associated with impulse regulation scores such that early responses were indicative of poorer abilities to regulate impulsive behaviour. This relationship remained only for body stimuli in the N1 time range. As P1 responses are thought to primarily reflect processing of the low-level visual properties of a stimulus (Latinus & Taylor, 2006; Rossion & Caharel, 2011), whereas the N1 is thought to primarily reflect structural encoding processes (Eimer, 2000c; Soldan et al., 2006), poor impulse regulation may therefore be associated with atypical low-level visual analysis of a stimulus but only with atypical structural encoding of bodies. Early P1 responses to bodies were also associated with a greater drive for thinness and less ability to recognise internal bodily states. Thus, the relationship between aberrant early visual processing of bodies and ED symptoms is more extensive than the relationship between aberrant early visual processing of houses and ED symptoms. This suggests that there may be general visual processing differences that are amplified for disorder-relevant stimuli in individuals who have experienced anorexia or bulimia nervosa.

As early P1 responses have been associated with the detection of fear in body stimuli (see Minnebusch & Daum, 2009 for review), it may be possible that the latency shifts we observed occurred because ED participants found the stimuli emotionally rousing. Two of our findings challenge this explanation however. First, valence and arousal ratings for body stimuli did not differ between the groups. Second, P1 and N1 responses to all stimuli were faster in those with EDs, not just those to bodies. In line with this, it may be posited that, due to the random nature of our stimulus presentation, ED participants were in a heightened state of arousal or attention throughout the EEG task, as they could not predict the occurrence of the more emotionally salient body pictures. This, and not the pictures themselves, may have evoked early visual responses, (see also Gazzaley, Cooney, McEvoy, Knight, & D'Esposito, 2005) explaining why the entire P1-N1 complex was early and not just responses to body stimuli. However, van Heijnsbergen et al. (2007) reported early P1 and early VPP responses to fear, whilst Stekelenburg and de Gelder (2004) also found early emotional modulations of VPP amplitude. So if a general state of arousal accounts for our results then we would also expect to see latency differences over the VPP for the ED group, which was not the case. Further investigations, perhaps employing a blocked design, are thus clearly necessary to determine the underlying mechanisms of these latency effects. Moreover, it is possible that explicit self-report ratings were not sensitive enough to detect differences in arousal and affect between the populations. Bodies are clearly salient stimuli for women with EDs and consequently, the threshold for arousal and valence are likely to be different in those who are partially recovered compared to controls. For example, a woman who has experienced an ED reporting feeling ‘slightly’ aroused to body stimuli might be the equivalent of women without an ED reporting to be ‘extremely’ aroused. This is because in comparison to how salient bodies are to individuals in the grips of the illness, they are likely to be less prominent after some recovery. As far as we know, this has not been investigated. Therefore, it may be beneficial to assess autonomic nervous system activity as an additional, more objective indication of emotional arousal to disorder-relevant stimuli when making comparisons between ED participants and controls, especially if those with EDs are not in the acute stages of illness. Nevertheless, the temporal dynamics of the P1-N1 complex appears to be a meaningful neural marker of ED symptoms.

4.5.2.2 No differences in body-sensitive amplitudes between ED participants and controls

As expected, body-sensitivity was observed in N1 and VPP amplitudes but not in P1 amplitudes. The extent of these effects did not differ between the groups and no general amplitude differences were found between the groups for any of the components. This suggests that the magnitudes of P1, N1 and

VPP responses, as well as that of body-sensitive effects, are not modulated by the experience of ED symptomatology.

Although not directly tested for, given the findings of Li et al. (2015), there was a possibility of observing amplitude differences between the groups that would perhaps indicate configural processing abnormalities in ED populations. Specifically, Li et al. (2015) argued that larger visual P1 amplitudes are indicative of more configural processing (Goffaux, Gauthier, & Rossion, 2003; Nakashima et al., 2008), and as anorexic participants in their study displayed reduced visual P1 and N170 amplitudes, this indicates a configural-processing deficit.

As no group differences in amplitude measures were found, does this imply that weight-restored ED participants do not have problems with configural processing? We believe such an interpretation should be drawn with caution. First and foremost, there is still debate as to whether bodies, especially those without head, recruit configural-processing mechanisms in a similar way to faces, or whether they are processed on a feature-by-feature basis similarly to objects (e.g. Itier & Taylor, 2004, 2004b; Rossion et al., 1999; Rossion et al., 2000). The difference between stimulus sets must therefore be considered as a possibility for the difference between findings. For example, if configural processing mechanisms are not elicited in response to (headless) bodies, or indeed if the processes are different, as has been suggested (e.g. Minnebusch & Daum, 2009; Minnebusch et al., 2009) then participants in this study would have been engaging in feature-based processing throughout. Thus, without a stimulus category such as faces to prompt configural processing, any configural processing deficit in ED participants would not have been measured in our study.

However, at least one study has found evidence for the configural processing of headless body stimuli over P1 (Minnebusch et al., 2010) as well as N1 amplitudes (Minnebusch et al., 2010; Soria Bauser & Suchan, 2013). In addition, if the bodies in our study were being processed like objects, we would expect to see no body-sensitive enhancements of the N1. As this was not the case, we may assume that headless bodies in our study were processed configurally. Thus, it is at least plausible that similar ERP effects of configural processing should be seen for bodies as are seen for faces, especially as body processing mechanisms are thought to arise from distinct but adjacent neural sources (Sadeh et al., 2011). We therefore propose that future studies should explicitly test for the neural correlates of configural processing deficits in EDs, such as by inverting or scrambling stimuli, before any firm conclusions can be drawn about potential configural processing deficits in these populations.

4.5.3 Evidence for ERP gender-sensitivity in ED participants but not controls

As far as we are aware, this is the only study to-date that investigated gender-sensitive visual body processing in EDs, and one of few studies to investigate gender-sensitive visual body processing in healthy women. As such, gender-sensitive effects were observed over N1 and VPP amplitudes in the ED group but not in the control group. This was reflected as a significant amplitude enhancement in response to viewing other women’s bodies compared to men’s bodies.

Observing no N1 gender-sensitivity in the control group supports what is reported by Hietanen and Nummenmaa (2011) but challenges results from Alho et al. (2015). Both papers argue that amplified N1 responses to nude female bodies are early affective responses that may be related to sexual drives and mating behaviours in men and women alike. Alho et al. (2015) elaborate by suggesting that the presence of any nude stimulus, irrespective of gender, might be enough to trigger sexual responses in women. Even if this were true, this does not explain why they found enhanced amplitudes to clothed female bodies in comparison to clothed male bodies. Irrespective, their explanation would predict similar N1, and by extension, VPP, responses to male and female body stimuli, which is exactly what our study has found for the healthy female control group.

Previous studies have not considered that female bodies might be salient stimuli for women in ways that are not driven by the primal urge to procreate. Findings from the present study thus suggest an alternative interpretation to that of Hietanen and Nummenmaa (2011) and Alho et al. (2015). In particular, the clear differences between N1 gender-sensitivity in the ED group and controls indicate that the effect is a potential biomarker of ED symptomatology in women. The mechanisms underpinning the effect are unclear, however, as N1 gender-sensitivity did not correlate with EDI-2 measures. Moreover, previous studies have consistently found the effect in men so any interpretation must take this into account.

We propose objectification of the female form as a possible explanation, because enhanced body-sensitive N1 amplitudes are associated with a switch from configural to feature-based processing mechanisms in ERP inversion studies (see Minnebusch & Daum, 2009 for review). Individuals showing enhanced amplitudes to female bodies relative to male bodies may therefore initially recruit configural processing mechanisms upon recognising the stimulus as a body, but then switch to feature-based processing when recognising the body as female. In other words, these individuals perceive women’s bodies like objects.

This is supported by western societal norms that encourage the objectification of female bodies (Jones, 2001), which is evident in men more so than women (Strelan & Hargreaves, 2005). Additionally, women without body image disturbance are not found to objectify women’s bodies more so than men’s bodies (Strelan & Hargreaves, 2005), perhaps explaining why controls do not show gender-sensitivity in the N1 time range. Furthermore, when women do objectify other women’s bodies, this is related to self-objectification and body dissatisfaction (Strelan & Hargreaves, 2005), both of which are ED traits (Calogero, Davis, & Thompson, 2005). By this reasoning, it is understandable that gender-sensitive N1 effects did not correlate with EDI-2 measures, as this questionnaire does not assess objectification. Future studies of gender-sensitive body processing should therefore include measures of objectification in order to test this potential explanation.

Alternatively, it is possible that top-down attentional processes may explain the effect, as women’s bodies may be particularly salient to those with EDs (e.g. Horndasch et al., 2015; Vocks et al., 2010). Although studies in the face processing literature often do not find effects of attention within the N1 time range (e.g. Carmel & Bentin, 2002; Lueschow et al., 2004), it is not altogether unheard of (Crist, Wu, Karp, & Woldorff, 2008; Sreenivasan, Goldstein, Lustig, Rivas, & Jha, 2009). Thus, despite our efforts to reduce attention effects with an oddball detection task, hypervigilance to relevant body information in EDs (Vitousek & Hollon, 1990), in this case the female form, could have resulted in a greater allocation of attentional processes to other women’s bodies than men’s bodies, leading to the observed N1 enhancement. This possibility should be addressed in future investigations.

We also observed a novel gender-sensitive effect in VPP amplitudes for the ED group, but not for the control group. This did not relate to gender-sensitive N1 amplitudes. The recruitment of extra neural resources over fronto-central sites whilst ED participants viewed same-sex stimuli may therefore represent processing mechanisms that are at least partly separable from those occurring more posteriorly. Importantly, the effect was positively associated with all but two of the EDI-2 subscales. This is a strong indication that VPP gender-sensitivity is a biomarker of ED symptomatology.

As it is argued that body-sensitive VPP amplitudes are modulated by fear (Stekelenburg & de Gelder, 2004; van Heijnsbergen et al., 2007), gender-sensitivity found over the VPP in the ED group might indicate that other women’s bodies are a source of anxiety for this population. Moreover, Stekelenburg and de Gelder (2004) found that fearful body expressions modulated VPP amplitudes but not N170 amplitudes. This indicates that the body-sensitive N1 is reflective of structural encoding processes whilst the body-sensitive VPP is (additionally) indicative of early emotion processing. As such, whilst N1 gender-sensitivity might be informative of the differences in structural encoding of gender body stimuli between controls and those with EDs, VPP gender-sensitivity could be an insight into the affective processes concerned with this. With that in mind, our results suggest that ED women may not only encode the structure of other women’s bodies differently to men’s bodies, but at a neural level, other women’s bodies are being recognised as emotionally salient.

It is possible that the foundations of such emotional responses could be rooted in social comparison behaviour. Evidence from Vocks et al. (2010) strongly supports this idea as enhanced limbic activity was found in anorexic participants during the viewing of other women's bodies. The authors suggest that this represents a stronger emotional response and perhaps more vigilance to other women's bodies that is likely due to social comparison processes. Corning, Krumm, and Smitham (2006) further support this, as women with ED symptoms evaluated their bodies more negatively during same-sex social comparisons than women without ED symptoms. Similarly, eye-tracking has shown that those with bulimia nervosa engage in upward comparisons whilst fixating for longer on bodies with a lower BMI, and reporting more body dissatisfaction after the comparison process (Blechert et al., 2009). Social-self concerns have also been linked to body dissatisfaction in bulimic individuals (Striegel-Moore, Silberstein, & Rodin, 1993) with such comparative processes reportedly inducing body-focused anxiety even in asymptomatic populations (Halliwell & Dittmar, 2004). However, as our design did not allow for, or indeed encourage, extensive rumination over body stimuli, it is unlikely that direct social comparison processes drive this effect. Instead, evaluative conditioning theory would dictate that female bodies might become affective stimuli if these anxiety-inducing comparisons are made frequently enough (Hofmann, De Houwer, Perugini, Baeyens, & Crombez, 2010). It is possible then, that the learned salience of other women's bodies, rather than direct social comparison, accounts for the gender-sensitive VPP effect observed in those with EDs. This may also explain why VPP and N1 responses both show gender-sensitivity without being related; essentially they are different mechanisms contributing to the same process.

4.6 Limitations

The interpretation of our findings must take into account some limitations. Firstly, participants were not clinically assessed for anorexia, bulimia, or other mental health issues. It is therefore possible that other mental health conditions were not disclosed during the recruitment procedure or that ED participants had not experienced the illness they claimed to. However, we were careful to advertise in such a way that potential participants did not know exact exclusion criteria and were thus encouraged to disclose everything. Furthermore, we did not advertise the amount of money participants would be reimbursed with, in order to discourage those who might apply solely for the monetary gain. The ED group also scored significantly higher than controls on all EDI-2 subscales, which suggests that those participants were drawn from an ED population. Nonetheless, future replications should aim to clinically assess participants for EDs and other mental health conditions.

Secondly, we chose to combine data from anorexic and bulimic participants into one overarching ED group, which it could be argued, might reduce disease-specific findings. However, whilst anorexia and bulimia should be understood as separate illnesses (American Psychiatric Association, 2013) there is also evidence for shared pathologies (see O'Brien & Vincent, 2003 for review). In our study, the absence of differences between anorexic and bulimic participants on sociodemographic factors (see Table 4.4. in supplementary data section 4.8) and ERP effects (see Table 4.5 in supplementary data section 4.8) justified combining their data (as in Eshkevari et al., 2012; Eshkevari, Rieger, Longo, Haggard, & Treasure, 2014; Horndasch, Kratz, et al., 2012 for example) .

A third limitation relates to the difference in protocol, as control participants completed 30 more trials than the ED group. It could therefore be argued that fatigue was responsible for the results rather than genuine group differences. However, as 30 trials would have taken less than a minute to complete, we feel that fatigue is an unlikely explanation for the difference between groups. Similarly, ED participants were presented stimuli three times whereas controls were only presented stimuli twice. Although not presented in succession, such repetition of stimuli could have led to a decrease in component amplitudes, known as repetition suppression (see e.g. Grill-Spector, Henson, & Martin, 2006 for review) and perhaps altered latencies (see the neural 'facilitation' model reviewed in Gotts, Chow, & Martin, 2012) for the ED group compared to the control group. There are several reasons why we do not think the extra repetition of stimuli for the ED group could explain our results. First and foremost, Henson (2012) argues that attenuated neural responses may be due to shorter duration of neural activity, and thus where latency differences have been observed due to repetition this is always accompanied by altered amplitudes (e.g. Itier & Taylor, 2004). Whilst latency differences were observed between the ED group and controls in this study, reduced components were not found. Moreover, these latency shifts were related to EDI-2 subscales, which would unlikely occur if they were an artefact of the task. Additionally, repetition only affects ERPs from 200 ms onwards if there is at least one item in between the repeated stimuli (see Grill-Spector et al., 2006 for review) and all effects reported here fall within the first 200ms post stimulus onset.

It should also be noted that control participants viewed stimuli that B-eat considered potentially triggering to those with an ED. Consequently, it could be argued that these stimuli are generally more arousing, which may have led to altered ERP effects between the groups. Arousal is usually found to modulate ERP amplitude, not latency (e.g. Junghöfer, Bradley, Elbert, & Lang, 2001; Kissler, Herbert, Winkler, & Junghofer, 2009; Olofsson & Polich, 2007; Rozenkrants, Olofsson, & Polich, 2008), with effects often evident on later, rather than earlier components (e.g. Kissler et al., 2009). As a result, it seems unlikely that the affective nature of the additional stimuli viewed by controls could be responsible for the latency shifts observed between groups. Moreover, if the gender-sensitive effects reported were a manifestation of such arousal then we might expect controls, not those with an ED, to elicit enhanced amplitudes to bodies (e.g. to female in comparison to male bodies). Further to this, there were no differences in body ratings indicative of a general increased state of arousal in controls. Therefore, whilst we suggest that future studies adhere to comparable protocol between groups, we are confident that the differences in protocol in this study could not account for the ERP differences observed between groups.

It is also important to take into account that we did not investigate whether sexual orientation was related to the gender-sensitive effects we observed in ED women. Hietanen and Nummenmaa (2011) suggest that the sexual preference of the observer effects gender-sensitive N1 responses, as they found that homosexual men did not elicit enhanced amplitudes to female bodies, whereas homosexual women did. However, they did not include heterosexual men or women in their analysis and as such, the effect of sexual orientation is not directly compared, it is only inferred. Moreover, sample sizes were very small; data from only four men and six women were analysed. It is therefore likely that statistical power was not sufficient to detect an effect in the male sample. In their later study (Alho et al., 2015), heterosexual men and women both elicited enhanced body-sensitive N1 responses to female bodies in comparison to male bodies. Here they argued that sexual orientation does not matter in the case of the women, as any sexual stimulus is likely salient to them. This not only directly contradicts claims from their first study but also does not hold as a theory because in fact, it suggests that no gender differences should be found in female observers' body-sensitive neural responses. As it is unlikely that we recruited 27 heterosexual controls and 29 homosexual ED participants (Feldman & Meyer, 2007), which would account for the observed differences in gender-sensitive processing, we are confident that sexual orientation cannot explain all of our gender-sensitive findings. Moreover, as evidence is mixed with regards to the relationship between sexual orientation and gender-sensitive body processing (Alho et al., 2015; Hietanen & Nummenmaa, 2011) a purely sex-related explanation of this effect seems unsatisfactory. Nonetheless, future studies should seek to investigate the relationship between ED symptomatology, sexual orientation and gender-sensitive body processing.

As a final limitation, we used an oddball detection task (similar to van Heijnsbergen et al., 2007) to reduce the attention paid to bodies, as studies have shown that those with EDs may visually analyse bodies differently to controls (e.g. Blechert et al., 2009; Horndasch, Kratz, et al., 2012; Jansen et al., 2005; Vocks et al., 2010) . It must be discussed then, that findings might differ when bodies are actively, rather than passively viewed.

Studies have shown that headless bodies evoke selective activity in lateral (EBA) and ventral (FBA) occipitotemporal cortex regardless of whether they are passively viewed (Downing et al., 2001; Morris, Pelphrey, & McCarthy, 2006; Saxe et al., 2006) or viewed in order to classify, discriminate or memorise them (see de Gelder et al., 2010 for an overview of tasks; Downing et al., 2001; Hodzic, Kaas, Muckli, Stirn, & Singer, 2009; Peelen & Downing, 2007; Schwarzlose et al., 2005; Taylor et al., 2007). ERP findings also suggest that regardless of the task, structural encoding of bodies typically occurs in the N1 time range (Minnebusch & Daum, 2009; Minnebusch et al., 2010; Stekelenburg & de Gelder, 2004). The same body-sensitive N1 component is affected by body distortion during passive viewing of headless bodies (Gliga & Dehaene-Lambertz, 2005) and during a discrimination task with similar, headless bodies (Soria Bauser & Suchan, 2013). Irrespective, fMRI or ERP studies have not addressed the possibility that bodies may be processed *more* selectively when they are task-relevant than when they are ignored or passively viewed. While future studies should directly compare the early cortical effects of attending and not attending to bodies on body-sensitive processes and on ED-related group differences, it seems unlikely that the task irrelevance of bodies in the present study would suffice to explain all of our findings.

4.7 Conclusions

This is the first study to demonstrate that the time course of visual processing in both anorexia and bulimia occurs earlier than in controls. Moreover, we found that amplified responses to female relative to male bodies are evident posteriorly in N1 time ranges, and reflected frontocentrally over VPP. Neuroimaging studies have already shown that the EBA is underactive and maladapted in those with EDs (Suchan et al., 2010; Suchan et al., 2015; Uher et al., 2005). It has also been shown that bulimic women display an attentional bias for processing overweight body stimuli (Mai et al., 2015) whereas those with anorexia and body dysmorphic disorder might engage in atypical visual processing of faces (Li et al., 2015). The present results therefore add to this body of literature, providing support for the hypothesis that visual body processing is modulated by body image. The evidence for this in the present study is particularly compelling as general posterior latency effects and anterior gender-sensitive amplitude effects systematically varied with ED symptomatology.

We propose that these differences in electrophysiological body processing may serve as potential biomarkers of EDs, offering an insight into disorder-relevant cognitive processes. These processes likely include social comparison and body surveillance behaviours that ultimately result in feature-based and anxious affective processing of bodies, and perhaps in giving other women's bodies an unusually salient status during structural analysis. Future studies should seek to replicate these findings with measures of social comparison tendencies and implicit anxiety (i.e. physiological arousal) in response to viewing body stimuli. Modulation of visual body processing in EDs should also be investigated in clinical and fully recovered populations, so as to profile whether these differences are characteristic of ED symptomatology or represent on-going maladaptation. Should it be the former, then such biomarkers hold the potential to identify 'at risk' individuals, whilst offering an insight into the efficacy of treatment for individuals in the acute stages of illness.

4.8 Supplementary data

Table 4.4

Average demographic information, EDI-2 scores, valence and arousal ratings and ERP latencies for anorexic and bulimic participants.

	Anorexic participants (N=15)	Bulimic participants (N=14)	T-test results
Age (years)	23.27 (8.71)	24.92 (8.16)	*t*(27) = .529, *p* =.601
Height (km)	1.65 (.05)	1.67 (.078)	*t*(27) = .523, *p* =.605
Weight (kg)	56.39 (8.95)	61.68 (9.25)	*t*(27) = 1.565, *p* =.129
BMI	20.60 (2.38)	22.21 (2.25)	*t*(27) = 1.868, *p* =.073
Weekly exercise (hrs)	6.00 (4.00)	5.61 (3.62)	*t*(27) = .277, *p* =.784
Drive for Thinness	10.87 (5.17)	13.07 (5.73)	*t*(27) = 1.090, *p* =.286
Bulimia	4.07 (4.13)	8.71 (6.85)	*t*(27) = 2.229, *p* =.034**
Body Dissatisfaction	14.33 (7.25)	15.00 (7.08)	*t*(27) = .250, *p* =.804
Ineffectiveness	9.60 (8.27)	10.29 (7.76)	*t*(27) = .230, *p* =.820
Perfectionism	9.80 (3.75)	8.36 (5.11)	*t*(27) = .872, *p* =.391
Interpersonal Distrust	6.13 (3.72)	5.43 (5.33)	*t*(27) = .415, *p* =.681
Interoceptive Awareness	12.27 (7.99)	10.07 (7.18)	*t*(27) = .776, *p* =.444
Maturity Fears	9.07 (7.27)	7.07 (7.21)	*t*(27) = .741, *p* =.465
Ascetism	9.87 (4.53)	8.21 (3.51)	*t*(27) = 1.091, *p* =.285
Impulse Regulation	10.67 (7.56)	7.21 (5.83)	*t*(27) = 1.370, *p* =.182
Social Insecurity	8.87 (4.91)	7.86 (6.05)	*t*(27) = .495, *p* =.625
Total EDI-2 score	105.53 (49.91)	101.29 (47.76)	*t*(27) = .234, *p* =.817
Valence to male bodies	4.62 (1.04)	4.72 (.59)	*t*(27) = .311, *p* =.758
Valence to female bodies	4.74 (.78)	4.82 (.75)	*t*(27) = .293, *p* =.771
Arousal to male bodies	5.00 (1.00)	5.28 (1.28)	*t*(27) = .649, *p* =.522
Arousal to female bodies	4.97 (1.18)	5.09 (.99)	*t*(27) = .299, *p* =.767
Visual P1 latency (ms)	100.21 (18.59)	99.92 (17.92)	*t*(27) = .042, *p* =.967
Visual N1 latency (ms)	147.99 (18.42)	152.13 (18.42)	*t*(27) = .604, *p* =.551
Visual VPP latency (ms)	150.37 (25.90)	161.71 (27.58)	*t*(26) = 1.122, *p* =.272
Visual P1 amplitude (μV)	8.32 (3.33)	6.06 (2.55)	*t*(27) = 2.039, *p* =.051
Visual N1 amplitude (μV)	1.06 (2.53)	-.25 (2.55)	*t*(27) = 1.378, *p* =.179
Visual VPP amplitude (μV)	.87 (3.30)	1.25 (3.68)	*t*(26) = .288, *p* =.755

Note. Standard deviation in parentheses. **significant at .05 level.

Table 4.5

Evidence for gender-sensitive ERP effects over N1 and VPP amplitudes (μV) in both anorexic and bulimic participants.

	Male Bodies		Female Bodies		Follow-up pairwise comparison results	
	N1	VPP	N1	VPP	N1	VPP
Anorexic participants (N=15)	.163 (1.01)	.562 (1.05)	-1.642 (.91)	1.886 (1.02)	*t*(14) = 4.090, p < .001**	*t*(14) = 2.622, *p* =.014**
Bulimic participants (N=14)	-1.977 (1.04)	1.381 (.97)	-3.357 (.96)	2.403 (.95)	*t*(13) = 3.026, *p* =.005**	*t*(13) = 2.174, *p* =.039**

Note. Standard deviation in parentheses and amplitudes given in μV. **significant at .05 level.

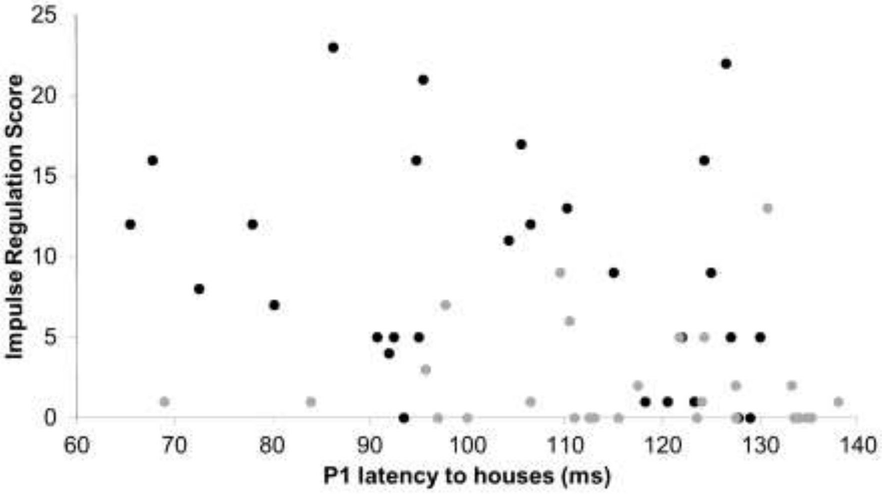

Figure 4.6. Moderate, negative relationship between P1 latency to house stimuli and impulse regulation score, *r*(54) = -.327, *p* =.014.

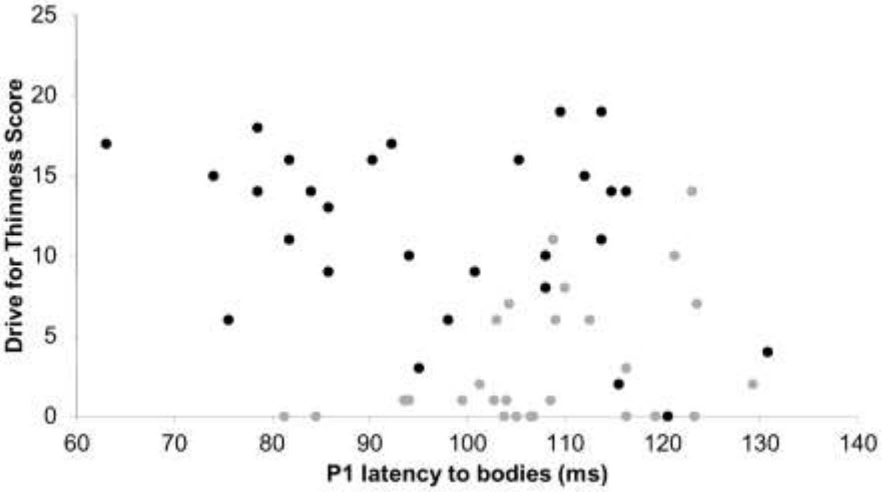

Figure 4.7. Moderate, negative relationship between P1 latency to body stimuli and drive for thinness score, *r*(54) = -.356, *p* =.007.

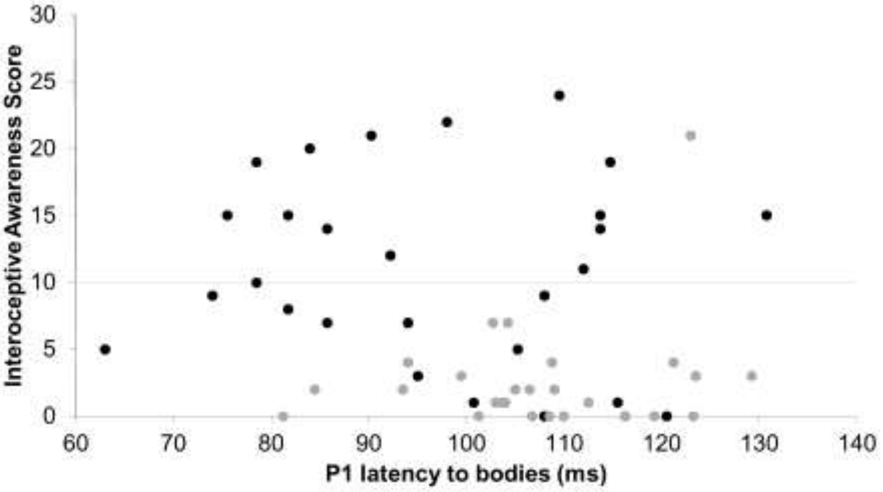

Figure 4.8. Moderate, negative relationship between P1 latency to body stimuli and interoceptive awareness score, *r*(54) = -.312, *p* =.019.

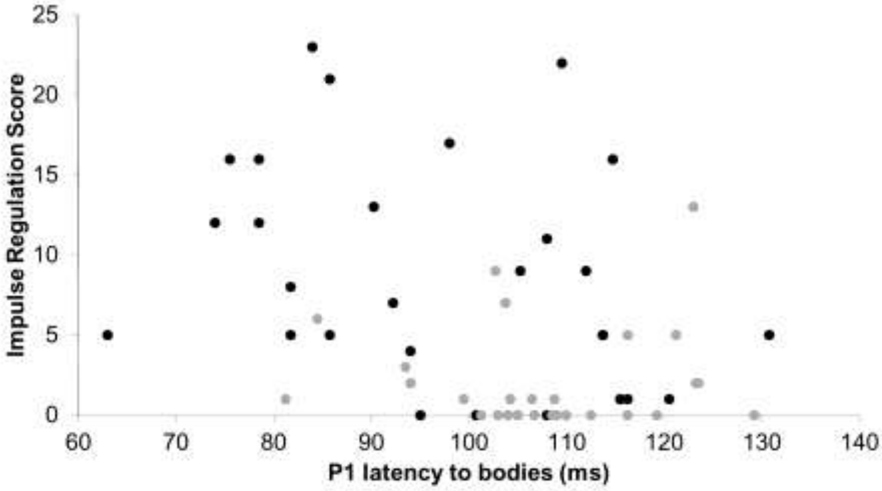

Figure 4.9. Moderate, negative relationship between P1 latency to body stimuli and impulse regulation score, *r*(54) = -.384, *p* =.003.

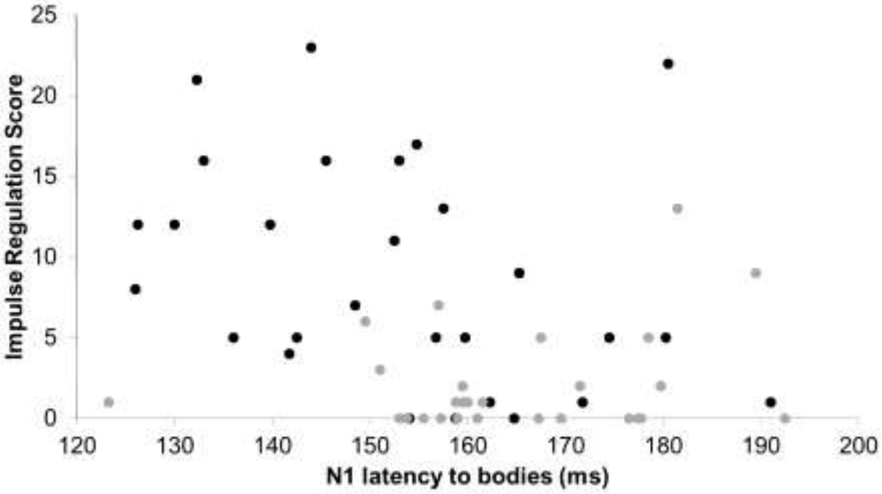

Figure 4.10. Moderate, negative relationship between N1 latency to body stimuli and impulse regulation score, *r*(54) = -.319, *p* =.016.

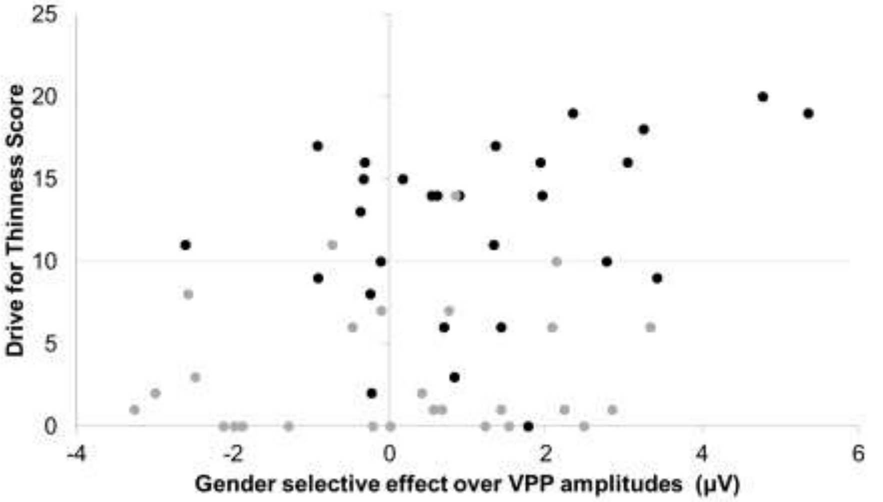

Figure 4.11. Moderate, positive relationship between the gender-sensitive effect over VPP amplitudes and drive for thinness score, *r*(53) = .371, *p* =.005.

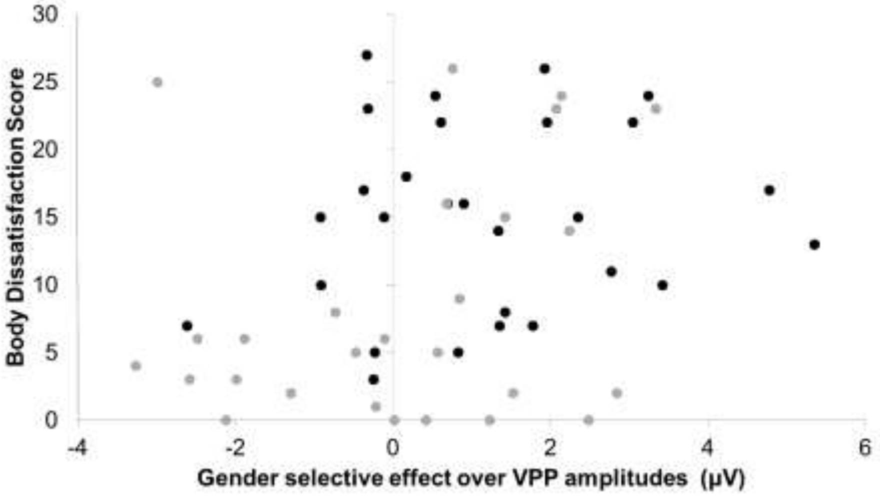

Figure 4.12. Moderate, positive relationship between the gender- sensitive effect over VPP amplitudes and body dissatisfaction score, $r(53) = .371$, $p = .022$.

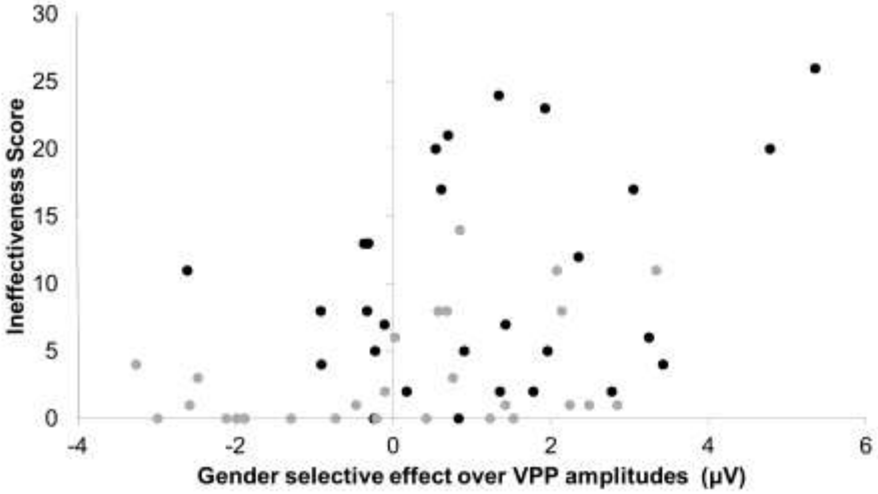

Figure 4.13. Moderate, positive relationship between the gender- sensitive effect over VPP amplitudes and ineffectiveness score, $r(53) = .404$, $p = .002$.

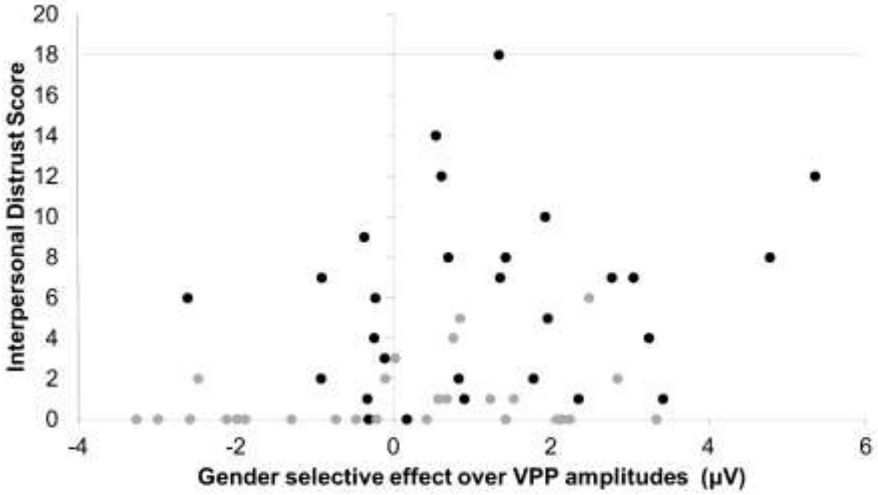

Figure 4.14. Moderate, positive relationship between the gender- sensitive effect over VPP amplitudes and interpersonal distrust score, $r(53) = .329$, $p = .014$.

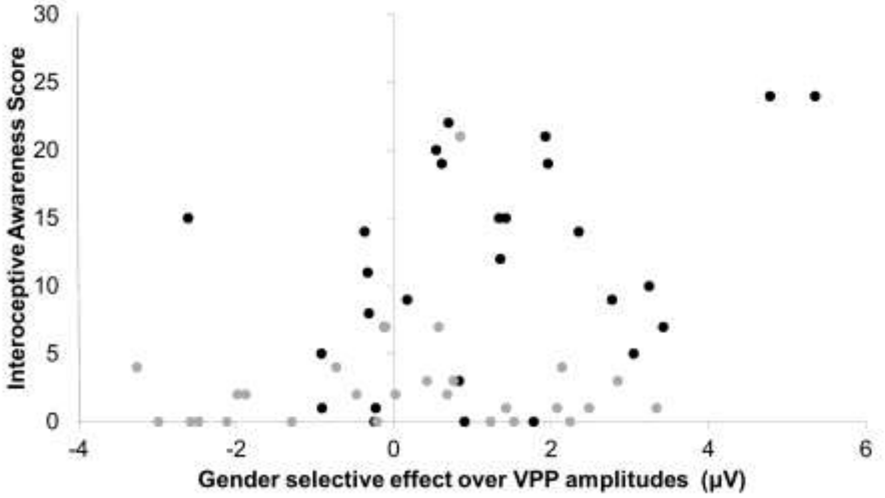

Figure 4.15. Moderate, positive relationship between the gender- sensitive effect over VPP amplitudes and interoceptive awareness score, *r*(53) = .375, *p* =.005.

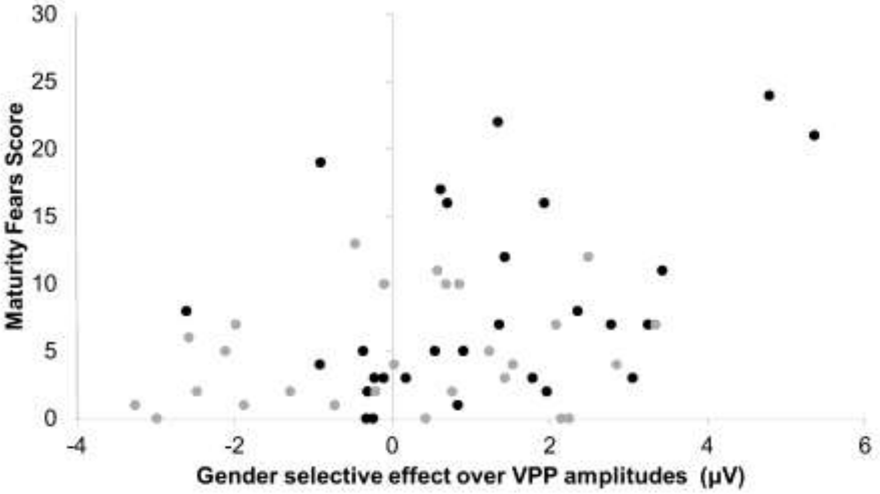

Figure 4.16. Moderate, positive relationship between the gender- sensitive effect over VPP amplitudes and maturity fears score, *r*(53) = .409, *p* =.002.

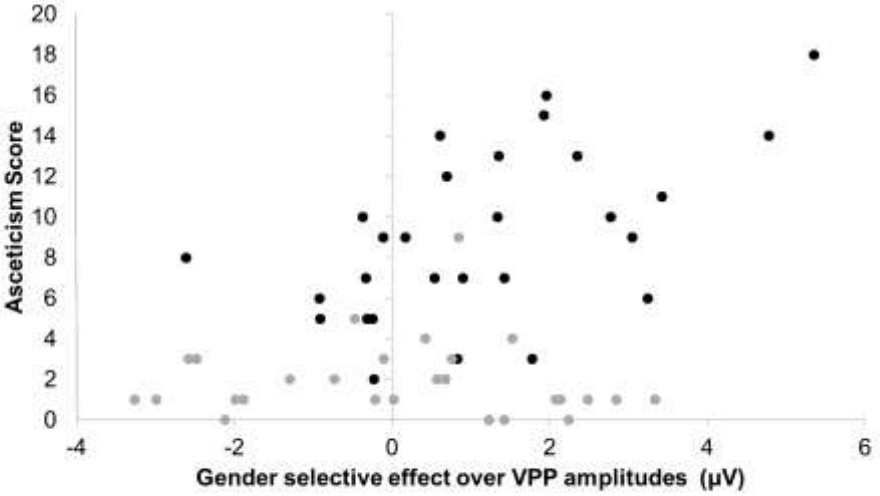

Figure 4.17. Moderate, positive relationship between the gender- sensitive effect over VPP amplitudes and asceticism score, *r*(53) = .435, *p* =.001.

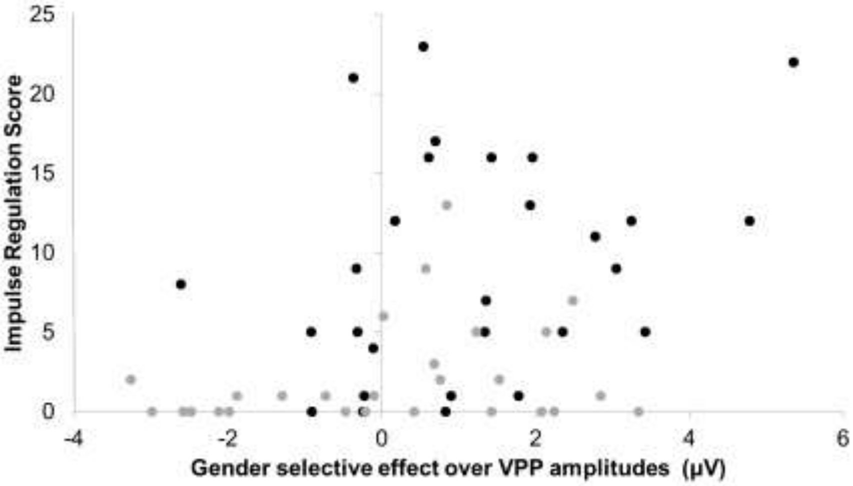

Figure 4.18. Moderate, positive relationship between the gender- sensitive effect over VPP amplitudes and impulse regulation score, r(53) = .373, *p* =.005.

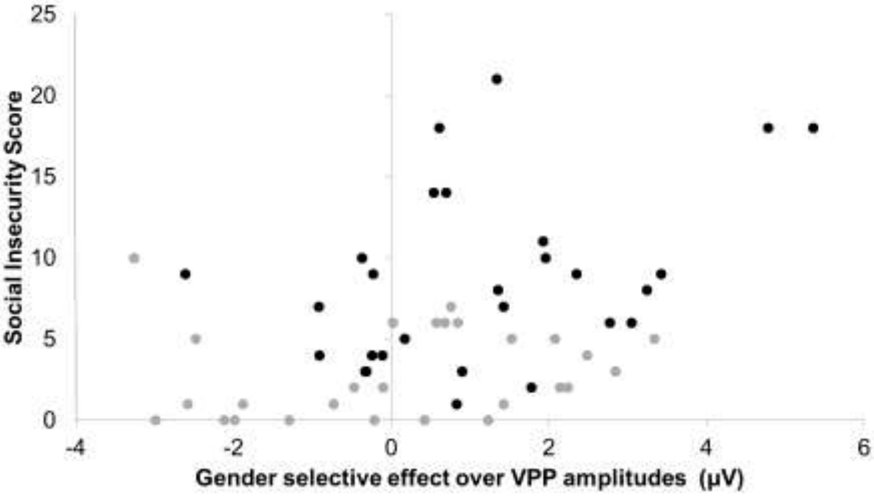

Figure 4.19. Moderate, positive relationship between the gender- sensitive effect over VPP amplitudes and social insecurity score, *r*(53) = .392, *p* =.003.

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Chapter 5 Atypical person perception in women with a history of body image disturbance: an ERP adaptation study

5.1 Abstract

The present study employed an ERP adaptation paradigm to investigate body-only person perception in 34 healthy controls and 35 weight-restored women with a history of eating or body dysmorphic disorders (BID group). Participants indicated whether successively presented upright or inverted male and female bodies, which were shown from either the same or different viewpoints (front and back), were of the same or different identity. Typical inversion effects, and gender-sensitivity to female bodies, were observed rapidly over occipito-parietal component P1. View-dependent adaptation effects were also evident within the P1 time range as reduced amplitudes to same compared to different person's bodies. Such identity processing was found to differ between controls and BIDs. Specifically, both groups encoded male body identity over P1 only when bodies were upright. However, this encoding was right-lateralised in controls, and was bilateral in BIDs. Female identity perception on the other hand, was widespread and tolerant to orientation in controls. In BIDs however, the encoding of female body identities was restricted to the right hemisphere. Due to these P1 effects, there were no meaningful patterns evident over N1 and VPP components. Additionally, irrespective of viewpoint, bilateral inversion effects and gender-sensitivity to female bodies were seen in N250 amplitudes, whilst familiarity effects were lateralised to the left-hemisphere. Our findings therefore indicate that body-only person perception begins rapidly over occipito-temporal cortex, but only when bodies are seen from the same view. The early stages of body-only person perception therefore appear to rely on information other than that provided by the outer contours of the body. A three-dimensional

representation of an individual’s body appears to be evident over left occipito-temporal cortex within later (N250) stages of processing. Furthermore, we provide evidence for ongoing, gender-dependent atypical representations of body identity in women who have experienced disorders characterised by body image disturbance. Effects are discussed in terms of gender-sensitive featural and configural processing mechanisms.

5.2 Introduction

There is an extensive literature documenting the importance of faces in person perception (see Young & Bruce, 2011 for review) with findings suggesting that faces, compared to bodies, are the preferred source of information when discriminating identities (Rice, Phillips, & O'Toole, 2013). Given that natural interactions with people often involve successful person perception in situations where face viewing is obscured (e.g. identifying someone in a crowd), investigating how bodily information contributes to person perception has been highlighted as an important step towards fully understanding this complex process (Young & Bruce, 2011). As such, a growing collection of behavioural studies have documented how body shape and motion are also important cues in person recognition (e.g. O’Toole et al., 2011; Rice, Phillips, Natu, An, & O’Toole, 2013; Robbins & Coltheart, 2012; Simhi & Yovel, 2016). Studies investigating the temporal dynamics of identity perception, however, still typically focus on the face. Findings from these studies have consistently established effects of identity processing in the late stages of visual encoding. In particular, the negative deflection that occurs over occipito-parietal sites approximately 250 ms (N250) after a face is seen is often enhanced to repeated presentations of an unfamiliar face, as well as to single presentations of familiar faces. This is thought to represent the activation of a short-term memory trace necessary for matching individuals to stored templates during identification (e.g. Amihai, Deouell, & Bentin, 2011; Caharel, d’Arripe, Ramon, Jacques, & Rossion, 2009; Gosling & Eimer, 2011; Jacques, d'Arripe, & Rossion, 2007; Nasr & Esteky, 2009; Schweinberger, Huddy, & Burton, 2004; Schweinberger, Pfütze, & Sommer, 1995; Schweinberger, Pickering, Jentzsch, Burton, & Kaufmann, 2002; Tacikowski, Jednoróg, Marchewka, & Nowicka, 2011; Tanaka, Curran, Porterfield, & Collins, 2006).

Nonetheless, evidence is beginning to show identity perception in the earliest stages of neural encoding (e.g. Caharel et al., 2009; Jacques et al., 2007; Keyes, Brady, Reilly, & Foxe, 2010; Lafontaine, Théoret, Gosselin, & Lippé, 2013; Parketny, Towler, & Eimer, 2015; Retter & Rossion, 2016), by exploiting adaptation responses (e.g. Amihai et al., 2011; Caharel et al., 2009; Jacques et al., 2007; Kovács et al., 2006; Kuehl, Brandt, Hahn, Dettling, & Neuhaus, 2013; Nemrodov & Itier, 2011; Retter & Rossion, 2016; Schinkel, Ivanova, Kurths, & Sommer, 2014). Also referred to as neural priming, repetition suppression, mnemonic filtering and decremented responses, adaptation can be understood as an attenuated neural response following the presentation of repeated stimuli, occurring even when retinal information is slightly different (see Grill-Spector, Henson, & Martin, 2006 for review). Thus, neural adaptation effects, indicative of identity processing, are evident when cortical activity or electrophysiological responses are reduced following the presentation of two identical faces in comparison to two different faces (see Henson, 2016 for review).

With regards to face recognition, ‘adaptation paradigms’ have also been employed in order to determine the neural time course of the ‘face inversion effect’ (FIE) (Yin, 1969), whereby recognition performance is reduced for inverted, compared to upright faces. The FIE is taken as evidence for the ‘configural processing’ of faces; a processing style that relies on first-order stored templates of relations between individual features (see Civile, McLaren, & McLaren, 2016). This holistic processing style is understood as distinct from featural processing mechanisms that are employed for object-recognition, whereby a stimulus is perceived on the basis of its individual parts and not the relations among them (Piepers & Robbins, 2012). As the templates underpinning configural representations are based on expected viewpoints, they are sensitive to changes in orientation and so inversion disrupts the coordinates of isolated parts in space whilst preserving spatial relations. As such, successful recognition of inverted faces requires a switch from configural processing to feature-based analysis, demanding more resources and resulting in slower, and often less accurate, behavioural responses, as well as enhanced and delayed face-sensitive electrophysiological responses (see Minnebusch & Daum, 2009 for review). Object recognition on the other hand, is typically unaffected by inversion since encoding is feature-based and therefore orientation-independent (Rossion & Gauthier, 2002).

Event-related potential (ERP) studies that employ adaptation paradigms are well-suited to identify the time course at which inversion disrupts identity recognition (e.g. Caharel et al., 2009; Jacques et al., 2007). Hence, adaptation effects (reduced ERP amplitudes) for upright but not inverted stimuli, are thought to be indicative of the point in time that neuronal responses identify identical upright stimuli as being the same, but not identical inverted stimuli as being the same (also see Brandman & Yovel, 2010). In other words, where adaptation is found for upright but not inverted stimuli, inversion has disrupted person recognition (e.g. Jacques et al., 2007). For faces, this has been shown to happen as early as 170 ms after stimulus onset (Jacques et al., 2007).

Although the neural mechanisms involved in visual body perception are understood as distinct from those of face processing (see de Gelder et al., 2010; Downing & Peelen, 2016; Minnebusch & Daum, 2009 for reviews) they share similar temporal dynamics as well as discrete but adjacent regions of the occipito-temporal cortex (e.g. Sadeh et al., 2011). It is hypothesised that this is likely an evolutionary adaptation as bodies and faces are rarely experienced in isolation (see Bernstein, Oron, Sadeh, & Yovel, 2014), which is supported by evidence of rapid information integration from bodies and faces (e.g. Meeren, van Heijnsbergen, & de Gelder, 2005). With this in mind, it is also of interest to investigate the cortical signatures of identity recognition when only bodily cues are available.

Neuroscientific studies of bodily identity processing have typically focused on the neural correlates of own vs. other body distinction (e.g. Chan, Peelen, & Downing, 2004; Devue et al., 2007; Hodzic, Kaas, Muckli, Stirn, & Singer, 2009; Hodzic, Muckli, Singer, & Stirn, 2009; Saxe, Jamal, & Powell, 2006; Vocks et al., 2010), with findings showing that body-selective regions in the occipito-temporal cortex might distinguish between own and other bodies (see Downing & Peelen, 2011 for review). However, identity processing involves more than simply determining whether a body is your own, especially as it is more likely that day-to-day social interactions will require distinguishing the identities of other people. Despite this, research describing the neural dynamics of unfamiliar other body recognition is sparse (specifically highlighted in the review by Downing & Peelen, 2011). This study was therefore interested in the temporal dynamics of unfamiliar other body recognition and when inversion disrupts this process.

ERP studies are particularly effective at delineating the temporal signatures of body perception, as research has shown a functional difference in early electrophysiological responses over occipito-parietal and fronto-central electrode sites when bodies are viewed in comparison to non-body stimuli (see Minnebusch & Daum, 2009 for review). As a result, we were predominantly interested in these early electrophysiological indices of body processing within the context of an adaptation paradigm. For example, body-related responses have been observed as early as 100 ms after stimulus onset in the first positive-going visual evoked potential (P1), especially when stimuli contain emotional cues, or bodies are the only stimuli presented

(Meeren et al., 2005; Righart & de Gelder, 2007; Thierry et al., 2006; van Heijnsbergen, Meeren, Grèzes, & de Gelder, 2007). This suggests that although the P1 component is primarily thought to reflect low-level visual processing mechanisms (e.g. Tarkiainen, Cornelissen, & Salmelin, 2002), in certain circumstances it may also reflect the categorical discrimination of bodies (Righart & de Gelder, 2007; Thierry et al., 2006) and some associated higher level processes such as emotion recognition (Meeren et al., 2005; van Heijnsbergen et al., 2007). However, the most consistent of body-related ERP responses is elicited as an enhanced negative deflection peaking at around 150 ms – 190 ms after body viewing (e.g. Minnebusch, Suchan, & Daum, 2009; Pourtois, Peelen, Spinelli, Seeck, & Vuilleumier, 2007; Taylor, Roberts, Downing, & Thierry, 2010; Thierry et al., 2006). Source localisation techniques (Meeren, de Gelder, Ahlfors, Hämäläinen, & Hadjikhani, 2013; Thierry et al., 2006), direct intracranial recordings (Pourtois et al., 2007), transcranial magnetic stimulation (TMS) (Sadeh et al., 2011), ERP investigations (Taylor et al., 2010) and magnetoencephalography (Ishizu, Amemiya, Yumoto, & Kojima, 2010) have all implicated a specific body-selective region in the lateral occipito-temporal cortex, the extrastriate body area activity (EBA, Downing, Jiang, Shuman, & Kanwisher, 2001), in the origins of this effect. The reported timing of this component has seen body-sensitive responses in this time range referred to variably as N1, N170 or N190 (see de Gelder et al., 2010; Downing & Peelen, 2016 for review). We will refer to this component as a body-sensitive N1 throughout this paper.

Inverting body stimuli has been found to modulate the body-sensitive N1 response (e.g. Bosbach, Knoblich, Reed, Cole, & Prinz, 2006; Minnebusch, Keune, Suchan, & Daum, 2010; Minnebusch et al., 2009) and as such, this component has been linked to the configural and late structural encoding of bodies (e.g. de Gelder et al., 2010; Soldan, Mangels, & Cooper, 2006). Interestingly, there have also been reports of N1 body-sensitivity being modulated by the gender of the body observed. For example, larger body-sensitive N1 amplitudes have been found to female bodies in comparison to male bodies in both men (Hietanen & Nummenmaa, 2011) and women (Alho, Salminen, Sams, Hietanen, & Nummenmaa, 2015). Both studies propose that such differences during the early stages of body processing may trigger later attraction-related responses that are relevant for mating. With this in mind, any evidence of identity processing in this early time range may be subsequently affected by the gender of the observed body and so both male and female bodies were included in the present study.

A body-sensitive enhancement of the vertex positive potential (VPP), evident over fronto-central sites, has also been reported when participants view bodies in comparison to non-body stimuli (Sadeh et al., 2011; Stekelenburg & de Gelder, 2004; van Heijnsbergen et al., 2007). Similarly to the body-sensitive N1, body-sensitive VPP effects are thought to arise from EBA activity, as TMS delivered to EBA has been found to increase VPP amplitudes to bodies but not to faces, whilst TMS delivered to the occipital face area (OFA) had the opposite effect (Sadeh et al., 2011). Studies have shown that this component is particularly sensitive to the emotion that bodies convey, as larger VPP amplitudes are typically found in response to fearful bodies (Stekelenburg & de Gelder, 2004; van Heijnsbergen et al., 2007). In order to delineate the temporal dynamics of body-only person perception, the present study employed an adaptation design in order to assess the amplitude and latency of body-sensitive P1, N1 and VPP components, as well as the amplitude of the N250 component.

Given that evidence suggests bodies, like faces, are processed configurally (Minnebusch & Daum, 2009) inverted body stimuli were also included in this study so as to assess the disruptive effects on person perception. In particular, inverting bodies has been found to result in slower and less accurate behavioural responses, as well as enhanced and delayed early body-sensitive ERP responses (e.g. Minnebusch et al., 2010; Minnebusch et al., 2009; Reed, Stone, Bozova, & Tanaka, 2003; Reed, Stone, Grubb, & McGoldrick, 2006). However, there is debate about whether headless bodies are perceived on a configural basis as findings from inversion studies with these stimuli have been less consistent. For example, Minnebusch et al. (2009) report reverse electrophysiological and no behavioural inversion effects for headless body stimuli whilst Brandman and Yovel (2010) suggest that configural body-processing is mediated by the presence of the head. Robbins and Coltheart (2012) on the other hand, argue that the absence of behavioural inversion effects for headless stimuli may be due to confounds that encouraged focus on non-body aspects of the stimuli, such as clothing. Moreover, Brandman and Yovel (2014) conclude that the neural representation of a body (even if it is headless) is based on first-order configurations and thus, bodies are represented as wholes rather than as a sum of their parts in body-selective brain regions. Given that the evidence is conflicting, inverted headless body stimuli were presented in order to assess for behavioural and electrophysiological inversion effects and the point at which they interfere with person recognition (Jacques et al., 2007).

Body inversion effects have been found to differ in those with body image disturbance; a multifaceted distortion to the conscious experience of the body (Berlucchi & Aglioti, 2010; Paillard, 1999), arising from interrelated contributions from perception, cognition, affect and behaviour (see Cash, 2004). We were particularly interested in the perceptual aspect of these disturbances, as evidence suggests that those with anorexia nervosa have a selective deficit for processing configural body information due to a reduction in their ability to discriminate upright body stimuli compared to controls (Urgesi et al., 2014), whilst showing an improved ability to discriminate detail-based bodily information (Urgesi et al., 2012). Moreover, studies have demonstrated that those with body dysmorphic disorder (BDD) (Feusner, Moller, et al., 2010), as well as non-clinical students with high body image concern (BIC; Mundy & Sadusky, 2014), show reduced inversion effects for bodies and faces. In other words, even non-clinical individuals with high BIC appear to treat bodies like objects, suggesting that this is a trait rather than state characteristic of those with body image disturbance. As a result, it has been suggested that such feature-based processing of appearance-related stimuli might underpin the fixations with perceived flaws in appearance and ‘fat’ body parts (see Lang, Lopez, Stahl, Tchanturia, & Treasure, 2014;

Madsen, Bohon, & Feusner, 2013 for reviews) that are frequently seen in people with eating disorders (EDs) and BDD (American Psychiatric Association, 2013).

In addition, early visual ERP components (Groves, Kennett, & Gillmeister, 2017; Li, Lai, Bohon, et al., 2015; Li, Lai, Loo, et al., 2015) and later body-sensitive ERP responses (Mai et al., 2015) have been implicated as potential biomarkers of ED symptomatology. In keeping with this, studies have found reduced activity, volume and connectivity in brain structures that are specialised for the visual perception of human bodies, in women with EDs (see Suchan, Vocks, & Waldorf, 2015 for review). In particular, it has been found that the EBA is maladapted (Suchan et al., 2010) and underactive (Uher et al., 2005) in women with anorexia. Moreover, at least one study has shown that EBA functions via links with brain regions that have been implicated in body image, in particular, the ventral premotor cortex (VMPC; Kitada, Johnsrude, Kochiyama, & Lederman, 2009). This suggests that not only is it possible to establish links between ERPs and ED symptomatology, but that there are clear alterations to the structures involved in body perception and body image in those who experience body image disturbances. Similarly, there is evidence to suggest that the neural underpinnings of person perception differ in those who experience clinical levels of body image disturbance, such as in EDs and BDD (see Esposito, Cieri, Giannantonio, & Tartaro, 2016; Kaplan, Rossell, Enticott, & Castle, 2013 for reviews). For example, Castellini et al. (2013) found that patterns of brain activation were the same in anorexic participants and controls when processing other-body pictures. However, during own-body viewing, anorexic participants showed reduced activation in several areas, including the occipital cortex. However, it is yet to be investigated whether unfamiliar other person perception differs in those with body image disturbance compared to controls. This is of particular interest given that body-sensitive N1 amplitudes are reportedly enhanced to the female body form, with proposed mechanisms of the effect linked to mate choice and sexual behaviour (Alho et al., 2015; Hietanen & Nummenmaa, 2011). However, Groves et al. (2017) revealed that these same-sex gender modulations of early body-sensitive visual responses in women are associated with ED symptomatology. They hypothesise that this might be related to excessive objectification of the female form (see Calogero, 2012; Calogero, Davis, & Thompson, 2005) rather than sexual processes. Therefore, it is possible that the neural correlates of person perception, particularly identification of the female from, might differ between those who experience body image disturbance and controls.

Thus, whilst the overarching aim of this study was to delineate the temporal dynamics of body-only person perception and when this is disrupted by inversion, fundamental to this question was whether those with body image disturbance show altered effects. Consequently, women with a history of body image disturbance (BID group) and control women were recruited. Body-sensitive P1, N1 and N250 responses were recorded over occipito-parietal sites, and body-sensitive VPP responses were sought over fronto-central regions, during an adaptation paradigm with upright and inverted male and female bodies (based on method in Jacques et al., 2007). Bodies were shown from the front and the back in order to assess whether identity effects were subject to substantial changes in viewpoint (similar to what has been proposed for face-sensitive mechanisms; Caharel et al., 2009). The Body Image Concern Inventory (BICI; Littleton, Axsom, & Pury, 2005) was administered as a measure of dysmorphic appearance concerns and the self-objectification questionnaire (SOQ; Fredrickson, Roberts, Noll, Quinn, & Twenge, 1998; Noll & Fredrickson, 1998) was administered as an assessment of the extent to which participants thought of their own body like an object (based on objectification theory; Fredrickson & Roberts, 1997).

As behavioural studies have shown that the body is an important cue in person perception (e.g. Rice, Phillips, Natu, et al., 2013; Robbins & Coltheart, 2012; Simhi & Yovel, 2016), we predicted that adaptation effects indicative of body-only identity processing would be evident in early visual ERPs (as has been found for faces, e.g. Caharel et al., 2009; Jacques et al., 2007; Parketny et al., 2015) and familiarity effects as a result of repetition, also indicative of identity processing, would be evident in N250 amplitudes (as has been found for faces, e.g. Gosling & Eimer, 2011; Schweinberger et al., 1995; Tanaka et al., 2006). Further to this, we expected that inversion would disrupt bodily identity processing during early time ranges (as has been found for faces, e.g. Caharel et al., 2009; Jacques et al., 2007; Parketny et al., 2015) and that identity processing might differ according to the gender of the body viewed (Alho et al., 2015; Groves et al., 2017; Hietanen & Nummenmaa, 2011). With that in mind, we predicted that the temporal dynamics of person perception

(Esposito et al., 2016; Feusner, Bystritsky, Hellemann, & Bookheimer, 2010) might differ between the BID group and control group. Specifically, we thought it possible that inversion effects might be reduced in this population (Feusner, Moller, et al., 2010; Mundy & Sadusky, 2014; Urgesi et al., 2014). Finally, we predicted that any differences, especially with regards to inversion effects (see Beilharz, Atkins, Duncum, & Mundy, 2016), would systematically relate to self-objectification and scores on the BICI.

5.3 Method

5.3.1 Participants

5.3.1.1 Body image disturbance (BID) participants

Thirty-five women with a history of EDs and/or BDD were recruited from North East Essex and the surrounding area via email advertisements sent to University of Essex mailing lists, as well as posters placed on notice boards at the University of Essex and ‘The Gym,’ Colchester, UK. Data from two of these women was not included due to excessive noise in the EEG recordings that would have made peak detection problematic.

Weight-restored anorexic participants were recruited so that any differences in ERPs would not be attributable to the effects of malnourishment. Similarly, those with other ED/BDD diagnoses were at least partially recovered at the time of testing. Diagnostic and treatment information relating to the thirty-three women in the body image disturbance (BID) group has been summarised in Table 5.1 Treatment referred to was current at the time of testing and the average age of the group was 24 years (SD: 5 years).

Table 5.1

Body image disturbance (BID) group diagnostic and treatment information.

	Total	Recovered	Partially recovered	Unrecovered	Medicated	Counselled
AN	14	7	7	0	1	1
BN	7	4	1	2	0	1
AN & BN	5	1	4	0	1	0
BDD	1	0	1	0	0	0
AN & BDD	4	0	4	0	1	0
BN & BDD	1	0	1	0	0	1
AN & EDNOS	1	1	0	0	0	0

Note. Anorexia Nervosa (AN), Bulimia Nervosa (BN), Body Dysmorphic Disorder (BDD), Eating Disorder Not Otherwise Specified (EDNOS). Treatment referred to was current at time of testing. One anorexic participant was medicated with oestrogen as an aid to induce the menstrual cycle, one participant with co-morbid anorexia and bulimia was medicated to increase potassium levels and aid depression whilst one participant with co-morbid anorexia and body dysmorphic disorder was also medicated to aid depression.

5.3.1.2 Control participants

Thirty-four women with no clinical history of EDs, BDD or body image disturbances were recruited from the University of Essex as control participants. Data from one participant was excluded due to excessive noise in the EEG data that would have made peak detection impossible. The average age of the group was 23 years (SD 5 years).

5.3.1.3 Exclusion criteria

Individuals under the age of 18 and those who had experienced a major psychiatric disorder, such as schizophrenia or bipolar disorder, were not permitted to take part. Pregnant women or those who had given birth 6 months prior to testing were also not recruited, as the experience of pregnancy may have altered body image.

5.3.2 Ethical declaration

The study was conducted in line with the 2008 Declaration of Helsinki, approved by the local Ethics Committee for the Psychology Department at the University of Essex. We also followed advice from eating disorder charity B-eat, and did not show stimuli that may be potentially triggering (e.g. emaciated or obese bodies).

5.3.3 Apparatus and stimuli

5.3.3.1 Questionnaires

The Body Image Concern Inventory (BICI; Littleton et al., 2005) is a 19 item self-report measure used to explicitly assess dysmorphic appearance concern. This includes intense concern and dissatisfaction with a perceived or exaggerated flaw in appearance, camouflaging and checking behaviours, reassurance seeking and appearance-related comparisons (Littleton & Breitkopf, 2008; Littleton et al., 2005). With the previous week in mind, respondents are required to use a 5-point Likert scale (1= ‘never,’ 5 =

'always') to indicate how closely they identify with statements such as, 'I am ashamed of some part of my body.' Scores are obtained by summing all items and thus, a score may range from 19-95, with higher scores indicative of a higher level of dysmorphic concern.

Whilst dysmorphic appearance concern is the well-known hallmark symptom of body dysmorphic disorders (American Psychiatric Association, 2013; Jorgensen, Castle, Roberts, & Groth-Marnat, 2001), such concern is also reportedly prevalent in ED symptomatology (Cororve & Gleaves, 2001; Dingemans, van Rood, de Groot, & van Furth, 2012; Grant & Phillips, 2004; Hartmann, Greenberg, & Wilhelm, 2013; Hartmann et al., 2015; Jolanta & Tomasz, 2000; Mazzeo, 1999; Rosen & Ramirez, 1998; Ruffolo, Phillips, Menard, Fay, & Weisberg, 2006). The BICI is therefore a suitable tool for measuring abnormal BIC in both EDs and BDD. It has also been validated multi-ethnically (Littleton & Breitkopf, 2008) and it a recommended reliable tool for clinical practice and research (e.g. Dingemans et al., 2012; Ghadakzadeh, Ghazipour, Khajeddin, Karimian, & Borhani, 2011; Littleton & Breitkopf, 2008; Littleton et al., 2005).

Whilst dysmorphic concern and the behaviours associated with it have been found to reduce quality of life in EDs (e.g. Latner, Mond, Vallance, Gleaves, & Buckett, 2012; Ríos & Lobera, 2011), the disturbance to psycho-social functioning is a clinical criterion for diagnosis of BDD (American Psychiatric Association, 2013). As a result, two items were included that aimed to assess the extent to which perceived flaws interfered with work life and social life. These were posed as questions such as; ‘How much has your perceived flaw interfered with your social life?’ which were completed after the BICI. Responses were given on a 5-point Likert scale (1 = ‘never,’ 5 = ‘very often’) and each item was treated separately. Thus, the maximum score of 5 was indicative of more interference with either work life or social life.

Based on objectification theory (Fredrickson & Roberts, 1997) the self-objectification questionnaire (SOQ; Fredrickson et al., 1998; Noll & Fredrickson, 1998) measures the extent to which an individual thinks of their body in terms of what it looks like (observable appearance) rather than in terms of what it can do (non-observable competence). With their own physical self-concept in mind, the SOQ requires respondents to rank order a list of 10 bodily attributes from 0 (least important) to 9 (most important). Of those 10 items, 5 relate to bodily appearance (physical attractiveness, weight, sex appeal, measurements and muscle tone) and 5 relate to bodily competence (strength, health, energy level, physical fitness and physical coordination). A trait self-objectification score is obtained when the sum of the 5 competence items are subtracted from the sum of the 5 appearance items. This difference value, ranging from -25 to +25, thus represents the relative emphasis given to the dimensions such that a positive score is indicative of more focus on how the body looks over what the body can do, whereas a negative score indicates the reverse. A positive score would therefore suggest self-objectification (Fredrickson et al., 1998). The SOQ has been validated against measures of body shame, body dissatisfaction, appearance anxiety, negative affect and neuroticism (Miner-Rubino, Twenge, & Fredrickson, 2002; Noll & Fredrickson, 1998) as well across cultures, life styles, age and psychiatric illnesses (see Calogero, 2012). As a result, it was an appropriate tool to use in order to assess self-objectification in controls as well as individuals with body image disturbance.

5.3.3.2 EEG stimuli

Digital images of 15 bodies (head cropped, 7 men, 8 women) were taken from a stimuli base that was created in our lab. Both upright and inverted front and back views of each body were included, resulting in a stimuli set of 60 body pictures. All bodies (140 x 340 pixels, 2.5 cm x 8.0 cm) were set against a black background (1024 x 768 pixels, screen size 32.5 cm x 24.5 cm) clothed in a neutral white vest and briefs in order to minimize cues from clothing that might affect results (Robbins & Coltheart, 2012). Luminosity was adjusted to control for brightness across all images but bodies were unretouched so as to depict an array of natural shapes and sizes (see Figure 5.1).

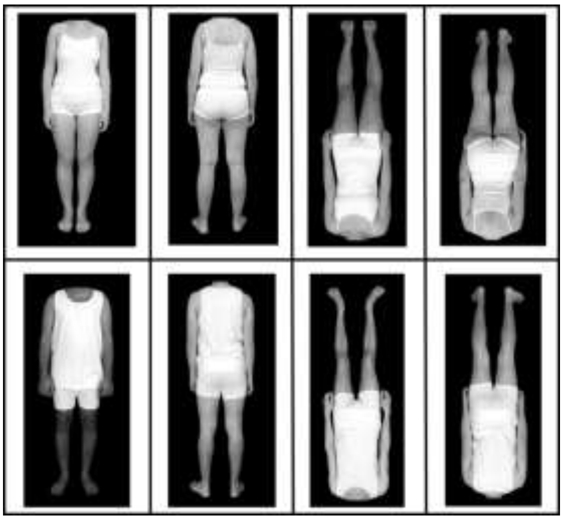

Figure 5.1. Example stimuli controlled for overall image brightness. Female body stimuli can be seen in the top panel and male body stimuli in the bottom panel. The first panel from the left shows upright body stimuli from a front view, the second panel shows upright body stimuli from a back view, the third panel shows inverted body stimuli from a front view, and the last panel on the right shows inverted body stimuli from a back view.

5.3.4 Procedure

A standardised summary of procedures was emailed to participants prior to participation, which was presented again at the start of the test session. Written consent was obtained once the procedures were understood. Questionnaires were completed prior to EEG preparation to ensure participant privacy, although the experimenter remained nearby to answer potential questions.

Participants were instructed to complete a speeded identity matching task during EEG recording, whereby they were instructed to press ‘1’ on the keyboard if the serially presented bodies were the same and ‘2’ if they were different. Emphasis was placed on speed and accuracy.

Stimuli were displayed on a black background with screen resolution of 1920 x 1200 pixels (screen size 32.5 cm x 24.5 cm) at approximately 70 cm viewing distance (26° 8' 0.32'' visual angle). Each trial began with a central fixation cross presented for 200 ms, followed by a black delay screen for 200 ms. A body (adapting stimulus) then appeared centrally for approximately 3,000 ms (2,800 ms - 3,100 ms) followed by an inter-stimulus interval of 100-300 ms. A second centrally located body (test stimulus) was then presented for 200 ms. The offset of the second body was followed by a 1,100 ms - 1,300 ms response interval, which terminated once a response was given (see Figure 5.2). ERPs were time-locked to the second body picture (test image). In order to reduce ERP effects as a result of adaptation to low-level visual features, the size of the test body was increased by 5% relative to the adapting body.

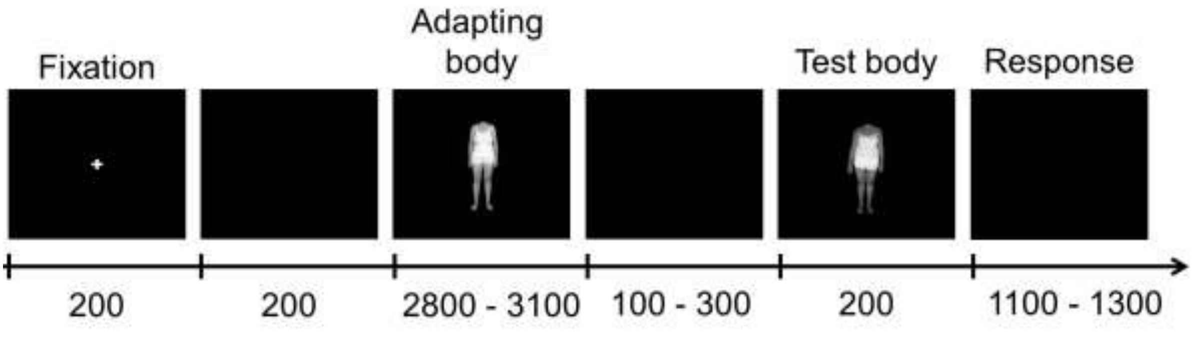

Figure 5.2. Timeline of one trial and stimulus sequence (timings in ms).

In total, 480 trials were presented, with half of those being sequential pairs of different views (e.g. front view of adapting body, back view of test body) and half being sequential pairs of the same view (e.g. front view of adapting body, front view of test body). Of those 240 same-view trials (128 female, 112 male), and likewise for different view trials (again, 128 female, 112 male), 120 were inverted (64 female, 56 male). Gender was always matched between the adapting body and the test body, and the same body was shown in half of all trials. Different body trials did not always show the same body but a selection of 6 (for men) or 7 (for women) different bodies.

A cumulative summary of RTs and errors was given at 40-trial intervals to promote performance improvement and to provide a break. The break was terminated by pressing the space bar. Task duration was between 40 minutes - 50 minutes, throughout which participants were asked to refrain from excessive movement and minimise blinking. Medical history was sought upon task completion and a full debrief was given.

5.3.5 EEG recording

5.3.5.1 EEG acquisition

Continuous scalp EEG was sampled at a rate of 500 Hz from 64 Ag/AgCl electrodes that were placed according to the international 10-10 system (EASYCAP GmbH, Herrsching, Germany). Online, EEG was band pass filtered at 0.01 – 100 Hz and referenced to the left earlobe. Electrode impedances were kept below 10Ω. Bipolar channels recorded vertical (VEOG) and horizontal (HEOG) electro-oculogram from above and below the midpoint of the right eye and beside the outer canthi of both eyes. An additional channel was also placed on the right earlobe. Both recording and offline analysis of EEG and EOG data were conducted with Neuroscan Synamps2 system and SCAN 4.5 software (Compumedics, Melbourne, Australia). Offline, EEG and EOG signal were digitally filtered using a 30Hz 12 dB low-pass filter and re-referenced to the average of both earlobes.

5.3.5.2 Segmentation

Data were divided into 500-ms epochs beginning 100 ms prior to test stimulus onset and baseline corrected against the mean voltage during the 100-ms pre-stimulus period.

5.3.5.3 Artifact detection

Trials containing eye blinks or other artefacts exceeding a voltage of ±100 µV at any electrode relative to baseline were excluded from analysis. HEOG exceeding ±40 µV and ERPs to incorrect responses were also excluded.

5.3.6 Statistical analyses

5.3.6.1 Demographics

Independent samples t-tests were conducted to assess any difference in age between the groups.

5.3.6.2 Body Image Concern Inventory (BICI)

Individual dysmorphic concern scores were calculated by summing all 19 responses (see Littleton & Breitkopf, 2008; Littleton et al., 2005), which were then averaged across groups. A Bonferroni-adjusted independent samples t-test was conducted to assess for differences between the groups.

5.3.6.3 Assessing the impact of perceived flaws on psychosocial functioning

Work life interference scores and social life interference scores were summed separately and averaged for each group. Average scores were then subjected to two separate Bonferroni-adjusted independent samples t-tests.

5.3.6.4 Self-objectification questionnaire (SOQ)

Individual self-objectification scores were obtained by subtracting the sum of the 5 competence items from the sum of the 5 appearance items (Fredrickson et al., 1998). Group averages were then subjected to a Bonferroni-adjusted independent samples t-test to assess differences between the groups.

5.3.6.5 Assessing behavioural performance

Inversion effects can be reflected in RT and errors, so given that analyses in this study were extensive, for the sake of brevity a single combination of the two was used in order to assess performance. Similar to previous studies of body inversion effects (e.g. Rivolta, Lawson, & Palermo, 2016; Susilo, Yovel, Barton, & Duchaine, 2013), the inverse efficiency measure (Townsend & Ashby, 1978, 1983) was used by dividing RT by the proportion of correct trials. Inverse efficiency is therefore measured in units of time (ms) with smaller inverse efficiency scores indicative of more efficient performance. Inverse efficiency for same and different view conditions was subjected to separate 2 (adaptation; same vs. different) x 2 (orientation; upright vs. inverted) x 2 (gender; female body vs. male body) x 2 (group; controls vs. BIDs) mixed factorial ANOVA. It should be noted that although efficiency results are presented, these closely matched the results of separate analyses of RT and error data.

5.3.6.6 Electrophysiology

5.3.6.6.1 Electrode selection and ERP data extraction

In order to identify the electrodes on which ERP components should be measured, maximal P1, N1 and VPP responses were assessed at electrode sites frequently implicated in body processing. For the P1 and N1 this included lateral posterior sites TP7/8, CP5/6, PO3/4, PO5/6, PO7/8, P3/4, P5/6, P7/8, O1/2 (e.g. Minnebusch et al., 2010; Minnebusch et al., 2009; Stekelenburg & de Gelder, 2004; Thierry et al., 2006; van Heijnsbergen et al., 2007), whilst for the VPP this included fronto-central sites F1/2, F3/4, FC1/2, FC3/4, C1/2, Fz, Fcz, Cz, CPz and Pz (Ashley, Vuilleumier, & Swick, 2004; Eimer, 2000; Luo, Feng, He, Wang, & Luo, 2010; Sadeh et al., 2011; Stekelenburg & de Gelder, 2004; van Heijnsbergen et al., 2007; Wheatley, Weinberg, Looser, Moran, & Hajcak, 2011). VPP peaks were not evident and thus no VPP analyses were conducted. Discernible peaks for both the P1 and the N1 were seen over seven pairs of bilateral electrodes; PO3/4, PO5/6, PO7/8, P3/4, P5/6, P7/8 and O1/2. P1 scalp topographies associated with the aggregated grand averaged waveforms (see Figure 5.3.) also revealed the most prominent P1 activity over these electrode sites.

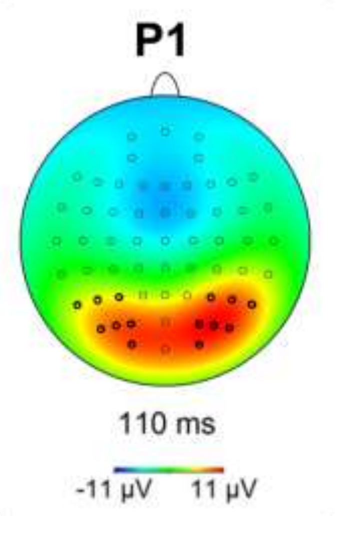

Figure 5.3. Voltage maps for the time window of the visual P1 component peak (110 ms), collapsed over viewing conditions, confirming areas of strongest activation. Electrodes analysed, which were also selected based on previous literature, have been highlighted.

N1 scalp topographies were not informative however, as strong frontal negativity and more positive posterior activity was evident. Instead, P1 to N1 peak-to-peak amplitudes were computed on all occipito-parietal electrodes and these too suggested maximal activity over sites PO3/4, PO5/6, PO7/8, P3/4, P5/6, P7/8 and O1/2. ERP waveforms were averaged across viewing conditions in each participant. This included adaptation (same body vs. different body), orientation (upright vs. inverted bodies), gender (male body vs. female body) and view (same view vs. different view) for each participant. Inspection of the grand average waveforms revealed that inversion and adaptation effects that were expected in the N1 time range were evident in the P1 time range (see Figure 5.4.), likely a result of vertical asymmetries in local contrast present in upright vs. inverted bodies (e.g. Itier & Taylor, 2004). A consequence of reduced P1 amplitude through adaptation and enhanced P1 amplitude through inversion was that effects in the N1 time range were reversed (e.g. enhanced amplitudes to upright rather than inverted as well as same rather than different bodies). In order to avoid producing misleading results we decided not to analyse waveform differences in the N1 time range. Thus, ERP peak amplitude and latency data were extracted for the visual P1 (maximal at approximately 110 ms) evoked in response to the second body presented in the trial sequence (test body) during a time window 30 ms either side of the maximal aggregate grand average peak (80 ms – 140 ms post stimulus onset).

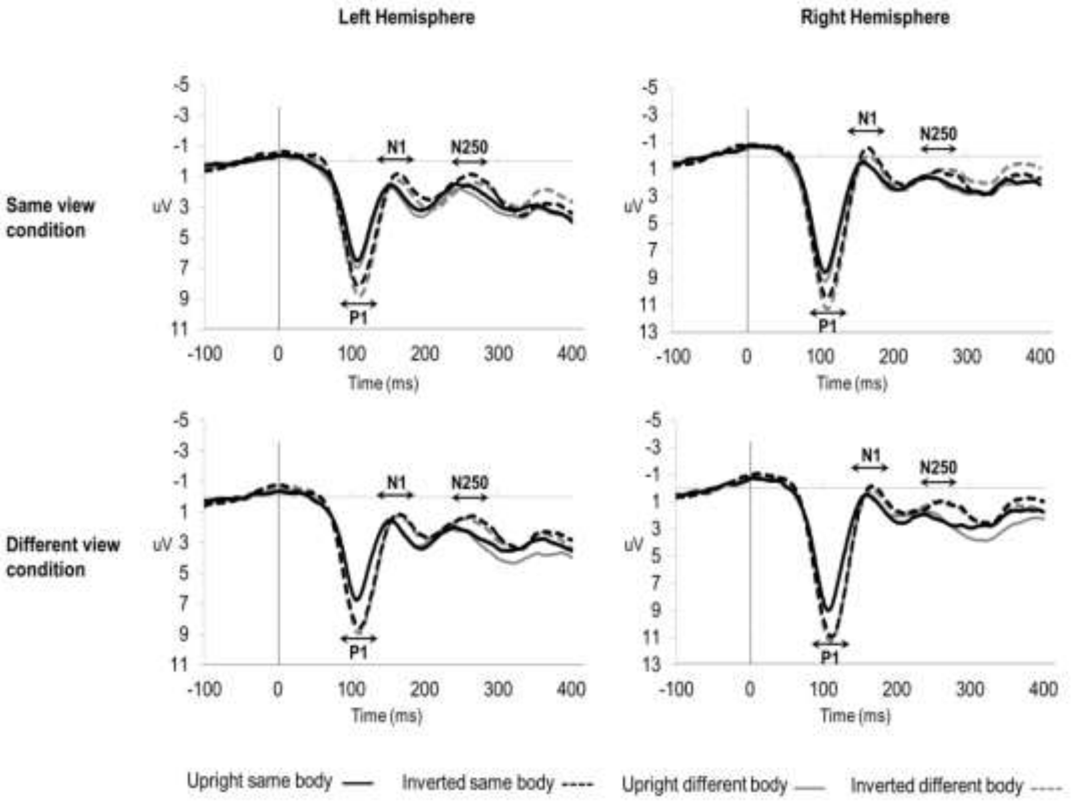

Figure 5.4. Grand averaged ERP responses depicting upright and inverted same and different body viewing separately in each hemisphere, for both the same view and different view conditions (upright depicted with solid lines, inverted depicted with dashed lines, same body depicted in black and different body depicted in grey) collapsed over electrodes PO3/4, PO5/6, PO7/8, P3/4, P5/6, P7/8 and O1/2. Inversion and adaptation effects that were expected in the N1 time range are evident in the P1 time range; as a consequence, effects in the N1 time range are reversed.

In order to assess N250 responses, mean amplitude data, rather than peak data, were extracted in this time range as the latter would be unsuitable due to the sustained nature of the N250 component and the associated difficulty involved with finding individual peaks (see also Nasr & Esteky, 2009; Neumann, Mohamed, & Schweinberger, 2011; Parketny et al., 2015; Pierce et al., 2011). Mean voltages for each condition were extracted within a 50 ms time window (230 ms – 280 ms post stimulus onset) centred on the maximal aggregated grand average peak latency at a pair of bilateral electrodes (P7/8) previously identified as the site of maximal N250 activity (Gosling & Eimer, 2011) and thus frequently analysed (e.g. Nasr & Esteky, 2009; Parketny et al., 2015; Schweinberger et al., 2004; Summerfield, Wyart, Johnen, & de Gardelle, 2011).

5.3.6.6.2 ERP statistical analyses

P1 amplitude and latency data were collapsed over electrode in each hemisphere and subjected to separate mixed factorial analysis of variance (ANOVA) with group as the between-subjects factor (control vs. ED) and adaptation (same body vs. different body), orientation (upright vs. inverted), gender (male body vs. female body) and hemisphere (left vs. right) as within-subjects factors. Separate but identical models were applied for same view and different view conditions.

N250 mean amplitude data were subject to a mixed factorial ANOVA with group as the between-subjects factor (control vs. ED) and adaptation (same body vs. different body), orientation (upright vs. inverted), gender (female body vs. male body) and hemisphere (left vs. right) as within-subjects factors separately for same view and different view trials.

For the sake of brevity, non-significant statistics are not reported unless informative with respect to the hypotheses and hemisphere interactions are only reported where meaningful to hypotheses. Partial eta squared is reported as the measure of effect size and Greenhouse-Geisser adjustments to the degrees of freedom were applied when necessary. Bonferroni corrections were applied to follow-up pairwise comparisons and t-tests are reported unsigned.

5.3.6.7 Correlational analyses

In order to investigate the links between electrophysiology, behaviour and attitudes towards one's own body (dysmorphic concern and self-objectification), Pearson's *r* correlational analyses were planned between main effects found in ERP responses and those found in behavioural responses, as well as ERP effects that interacted with group and questionnaire scores. Relationships between ERP effects and between behavioural effects are not reported as this was not relevant to the hypothesis. Relationships between questionnaire measures will be reported as to our knowledge no study to date has investigated the links between self-objectification and dysmorphic body concern.

The correlational analysis was conducted across groups, synonymous with the methods of previous studies (e.g. Eshkevari, Rieger, Longo, Haggard, & Treasure, 2012; Mai et al., 2015; Mitchison, Crino, & Hay, 2013), as evidence suggests that ED symptoms, inclusive of body image disturbance, occur on a spectrum (Beilharz et al., 2016; Bienvenu et al., 2000; Shisslak, Crago, & Estes, 1995; Widiger & Samuel, 2005) .

The false discovery rate method of correction for multiple comparisons (Benjamini & Hochberg, 1995) was applied to correlation results. Results that did not survive correction are not reported.

5.4 Results

5.4.1 Age and questionnaire results

An independent sample t-test found no difference in age between the control group and the BID group. Differences were found on all questionnaire measures, with BIDs demonstrating moderate self-objectification whilst controls did not ($t(64) = 3.425$, $p = .001$, see Table 5.2). BIDs also showed significantly higher levels of BIC than controls ($t(64) = 7.796$, $p < .001$), with these concerns having a significantly greater interference with both their social life ($t(64) = 4.943$, $p < .001$) and their work life ($t(64) = 3.733$, $p < .001$, see Table 5.2).

Table 5.2

Average age and questionnaire scores for each group.

	BID group (N = 33)	Control Group (N = 33)
Age (years)	23.70 (5.28)	23.45 (5.38)
Self-Objectification Score*****	6.94 (11.43)	-3.24 (12.67)
Body Image Concern Score*****	66.15 (11.67)	44.15 (11.25)
Social life interference Score*****	3.03 (1.05)	1.97 (.77)
Work life interference Score*****	2.03 (1.08)	1.24 (.56)

Note. Asterisk indicates measures that differed significantly between groups. Standard deviation in parentheses.

5.4.2 Analyses of trials when test body shown from the same view as adapting body

5.4.2.1 Performance analyses

Significant within-subjects effects of adaptation (*F*(1, 64) = 16.238, *p* < .001, η_p^2 = .202) and orientation (*F*(1, 64) = 24.463, *p* < .001, η_p^2 = .277) were found, revealing that participants' responses were more efficient to test stimuli that were the same as adapting stimuli (485 ms for same vs. 587 ms for different bodies) and to test stimuli in upright orientations (525 ms for upright vs. 547 ms for inverted bodies). There were no other main effects or interactions to report as although BIDs (530 ms) appeared to be more efficient than controls (541 ms) overall, the between-subjects main effect of group was not significant ($F(1, 64) = .098$, $p = .755$, $\eta_p^2 = .002$, see Figure 5.5).

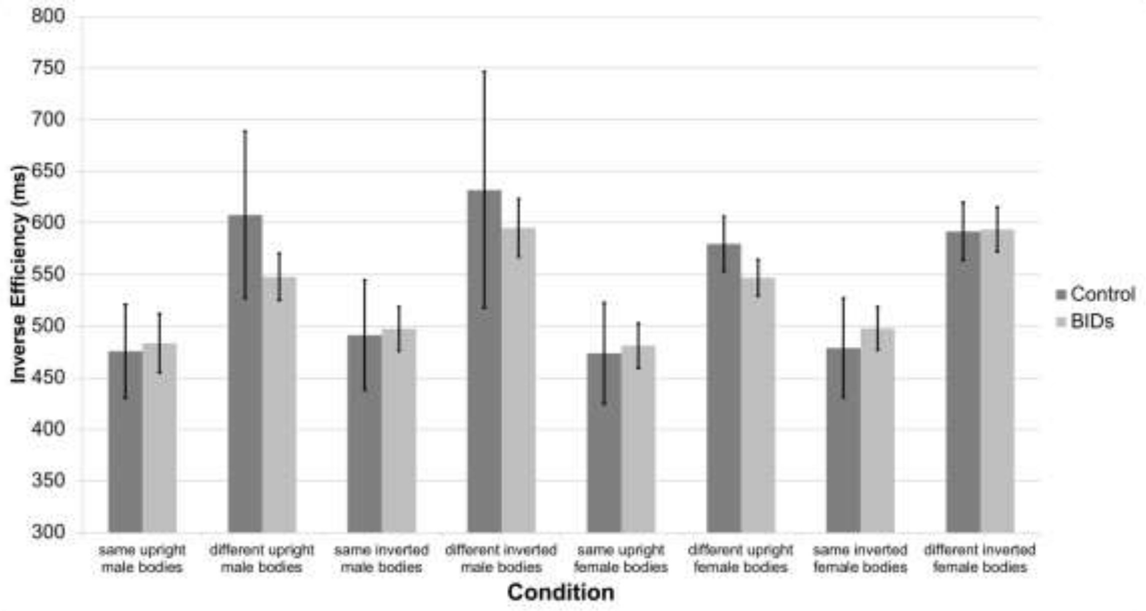

Figure 5.5. Inverse efficiency data from trials whereby adapting bodies and test bodies were shown from the same view. Smaller numbers are indicative of more efficient performance. Control responses are shown in dark grey whereas BID responses are shown in light grey.

5.4.2.2 ERP analyses

P1 data were collapsed over electrode and subject to separate 2 (adaptation; same vs. different) x 2 (orientation; upright vs. inverted) x 2 (gender; female body vs. male body), x 2 (hemisphere; left vs. right) x 2 (group; controls vs. BIDs) mixed factorial ANOVA for both amplitude and latency. The same model was applied to N250 mean amplitude data.

5.4.2.2.1 P1 peak amplitude

ANOVA revealed significant within-subjects effects of adaptation (*F*(1, 64) = 40.552, $p < .001$, η_p^2 = .388), orientation (*F*(1, 64) = 84.287, $p < .001$, η_p^2 = .568), gender (*F*(1, 64) = 13.512, $p < .001$, η_p^2 = .174) and hemisphere (*F*(1, 64) = 48.330, $p < .001$, η_p^2 = .430). Thus, P1 amplitudes were larger to different as compared to same bodies (10.106 µV vs. 9.225 µV), larger to inverted as compared to upright bodies (10.548 µV vs. 8.782), larger to female as compared to male bodies (9.937 µV vs. 9.394 µV) and also larger in the right hemisphere than the left hemisphere (10.901 µV vs. 8.429 µV). A significant interaction between orientation, gender and group was observed (*F*(1, 64) = 6.506, $p < .013$, η_p^2 = .092) with follow-up comparisons revealing that there was a significant difference in P1 amplitudes to male and female bodies for upright stimuli in BIDS (*t*(64) = 2.152, *p* =.035, 9.872 µV vs. 9.276 µV) and for inverted stimuli in controls (*t*(64) = 4.153, p<.001, 10.395 µV vs. 9.257 µV), such that amplitudes were larger for female bodies overall. A five-way interaction was also found between all factors (*F*(1, 64) = 4.836, *p* = .031, η_p^2 = .070; see Figure 5.6). Follow-up comparisons revealed that in the left hemisphere, controls adapted to upright (*t*(64) = 2.330, *p* =.023, 6.251 µV for same vs. 7.041 µV for different bodies) and inverted female bodies (*t*(64) = 4.021, p < .001, 8.048 µV vs. 9.563 µV), whereas BIDs adapted only to upright male bodies (*t*(64) = 4.654, p < .001, 7.381 µV vs. 8.941 µV). In the right hemisphere, there was adaptation to upright male bodies in both controls (*t*(64) =2.339, *p* =.023, 8.601 µV for same vs. 9.561 µV for different bodies) and BIDs (*t*(64) = 2.812, *p* =.007, 9.814 µV vs. 10.968 µV) but there was no adaptation to inverted male bodies (controls; *t*(64) = .496, *p* =.621, 10.564 μV vs. 10.764 μV; BIDs; *t*(64) = 1.821, *p* =.073, 11.689 μV vs. 12.423 μV). With regards to female bodies in the right hemisphere, controls did not adapt to upright stimuli (*t*(64) = 1.398, *p* =. 671, 9.159 μV vs. 9.784 μV) but did adapt to inverted stimuli (*t*(64) = 3.521, *p* =.001, 11.241 μV vs. 12.727 μV). In contrast, BIDs adapted to upright female bodies (*t*(64) = 2.568, *p* =.013, 8.939 μV for different vs. 11.653 μV for same bodies) but not reliably to inverted female bodies (*t*(64) = 1.986, *p* =.052, 10.725 μV vs. 12.904 μV). As suggested by Figure 5.6, this indicates that control participants encode the identity of upright male bodies in the right hemisphere but not in the left hemisphere, while the identity of inverted men is not encoded at all (i.e. Inverted men are not perceived as individual persons). Controls also encode the identity of both upright and inverted female bodies in the left hemisphere, as well as inverted female bodies in the right hemisphere. Similar to controls, BIDs encoded the identity of male bodies only when they were upright and not when they were inverted. Unlike controls however, this was not confined to the right hemisphere but was present bilaterally. They further encoded the identity of upright female bodies in the right hemisphere, unlike controls, for whom this encoding was left-lateralised, whilst they did not encode female body identity for inverted stimuli (Figure 5.6). A main effect of group was also evident (*F*(1, 64) = 4.280, *p* = .043, η_p^2 = .063), as BIDs elicited a larger overall visual P1 than controls (10.422 μV vs. 8.908 μV).

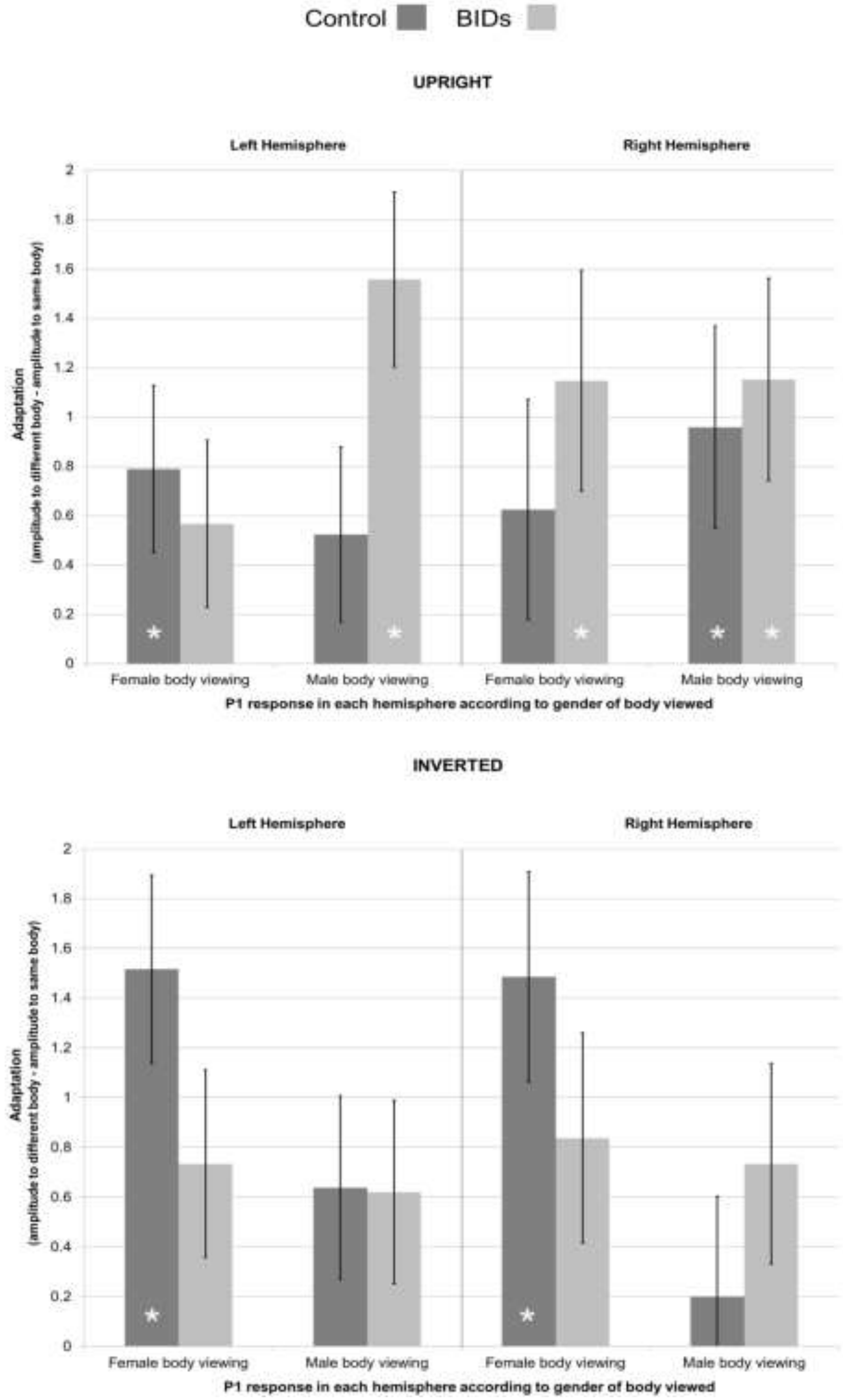

Figure 5.6. Grand average P1 adaptation response (amplitude to different body – amplitude to same body) recorded from electrodes PO3/4, PO5/6, PO7/8, P3/4, P5/6, P7/8 and O1/2. Top panel shows adaptation to upright male and female bodies, bottom panel shows adaptation to inverted male and female bodies. Control responses are shown in dark grey whereas BID responses are shown in light grey. Asterisks indicate significant adaptation effects.

5.4.2.2.2 P1 peak latency

Significant within-subjects effects of orientation (*F*(1, 64) = 29.312, *p* <.001, η_p^2 = .314) and gender (*F*(1, 64) = 48.854, *p* < .001, η_p^2 = .433) were seen over P1 latency as the component peaked later to inverted than upright stimuli (111 ms vs. 108 ms) and to female than male bodies (110 ms vs. 108 ms). The between-subjects factor of group was not significant (*F*(1, 64) = .007, *p* = .934, η_p^2 < .001) and there were no other main effects or interactions to report.

5.4.2.2.3 N250 mean amplitude

ANOVA revealed significant within-subjects effects of adaptation (*F*(1, 64) = 71.777, *p* < .001, η_p^2 = .185), orientation (*F*(1, 64) = 20.163, *p* < .001, η_p^2 = .240), gender (*F*(1, 64) = 18.357, *p* < .001, η_p^2 = .223) and hemisphere (*F*(1, 64) = 5.492, *p* = .022, η_p^2 = .079) over the N250. Thus, a larger negative deflection was found in response to same bodies compared to different bodies (-2.304 µV vs. -1.782 µV), to inverted compared to upright stimuli (-2.494 µV vs. -1.592 µV), to female compared to male bodies (-2.331 µV vs. -1.755 µV) and also in the right hemisphere compared to the left hemisphere (-2.467 µV vs. -1.619 µV). There was also a significant interaction between adaptation and hemisphere (*F*(1, 64) = 15.512, *p* < .001, η_p^2 = .195), with follow-up comparisons revealing larger N250 amplitudes to same bodies in comparison to different bodies in the left hemisphere (*t*(64) = 5.402, p < .001, -2.076 µV vs. -1.163 µV) but not in the right hemisphere (*t*(64) = .769, *p*

=.443, -2.532 μV vs. -2.402 μV). To the best of our knowledge, this suggests for the first time that the effects of familiarity with repeated bodies are lateralised to the left hemisphere. There were no other main effects or interactions to report and the between-subjects effect of group was not significant ($F(1, 64) = 2.064$, $p = .156$, $\eta_p^2 = .031$).

5.4.2.2.4 Interim summary of results: Test body shown from the same view as adapting body

A brief summary of results can be viewed in Table 5.3.

Table 5.3

Summary of results when test body shown from same view as adapting body.

	Group	Orientation	Adaptation	Gender	Hemisphere	Interaction
Performance	-	✓	✓	-	-	-
P1 amplitude	✓	✓	✓	✓	✓	✓ 5-way
P1 latency	-	✓	-	✓	-	-
N250 amplitude	-	✓	✓	✓	✓	✓ Adapt*Hem

Note. Main effects indicated on left side of vertical divider and interactions on the right side.

When the test body and adapting body were shown from the same view, participants’ responses were more efficient to the same than different bodies and to upright than inverted bodies, showing adaptation and inversion effects in behaviour. There were no differences according to the stimulus gender or group.

Effects of adaptation were evident over P1 amplitudes and left-hemisphere N250 amplitudes. Inversion effects were seen over P1 amplitudes and latencies, as well as over N250 amplitudes. In addition, female body viewing enhanced and delayed the P1 response and also enhanced the N250 response. In the P1 time range, these effects interacted and differed between the groups in a way that suggests female body identity might be encoded atypically in those with body image disturbance. Specifically, control participants encoded upright male bodies in the right hemisphere only and did not encode the identity of inverted male bodies in either hemisphere. Controls seemed to encode female body identity more extensively by comparison, as adaptation was evident to both upright and inverted bodies in the left hemisphere, as well as to inverted bodies in the right hemisphere. Similar to controls, the BID group encoded male body identity only for upright and not inverted bodies, although this was evident bilaterally. They further encoded the identity of upright female bodies in the right hemisphere, unlike controls. Strikingly, this group showed no encoding of female identity for inverted bodies and no evidence for female body person perception was seen in the left hemisphere. Thus, female identity perception was widespread and tolerant to orientation in controls, but restricted in BIDs.

5.4.3 Analyses of trials when test body shown from a different view to adapting body

5.4.3.1 Performance analyses

Significant within-subjects effects of orientation (*F*(1, 64) = 49.126, *p* < .001, η_p^2 = .434) and gender (*F*(1, 64) = 17.753, *p* < .001, η_p^2 = .217) were found, revealing that participants were more efficient to respond to upright compared to inverted stimuli (639 ms vs. 698 ms) and to female compared to male bodies (637 ms vs. 699 ms). A significant interaction was observed between orientation and adaptation (*F*(1, 64) = 11.875, *p* = .001, η_p^2 = .157). Follow-up comparisons revealed a significant reverse adaptation effect for inverted stimuli (*t*(64) = 2.230, *p* = .029, 734 ms for same vs. 661 ms for different bodies) but no effect of adaptation for upright stimuli (*t*(64) = .196, *p* = .845, 641 ms for same vs. 636 ms for different bodies). There were no other main effects or interactions to report and as before, the between-subjects effect of group was not significant (*F*(1, 64) = .004, *p* =.949, η_p^2 < .001) indicating that BIDs and controls completed the task with similar efficiency (669 ms vs. 667 ms, see Figure 5.7).

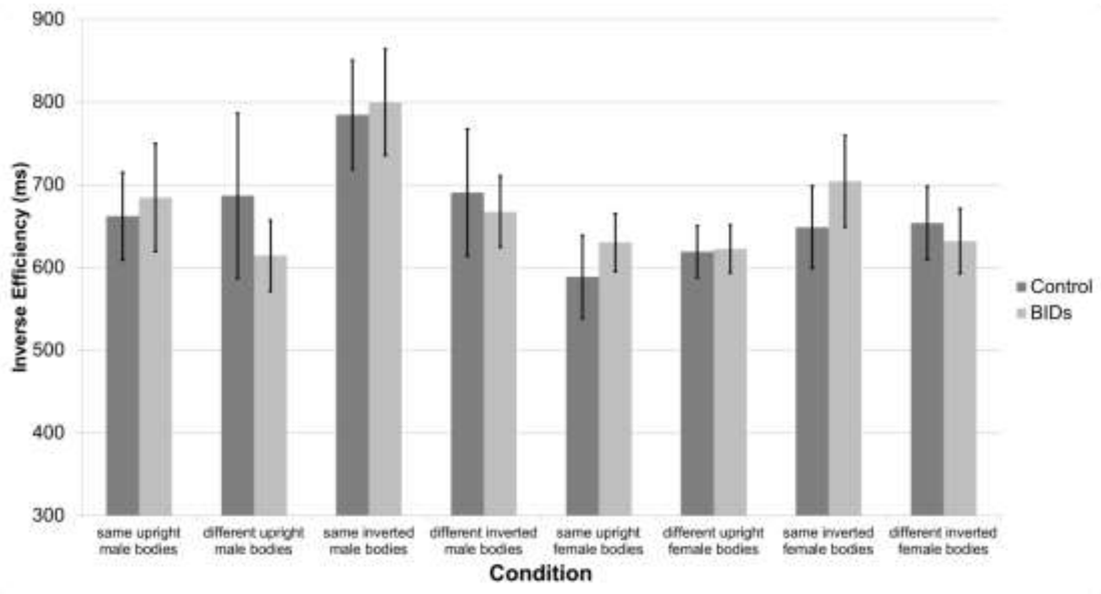

Figure 5.7. Inverse efficiency data from trials whereby adapting bodies and test bodies shown from a different view. Control responses are shown in dark grey whereas BID responses are shown in light grey.

5.4.3.2 ERP analyses

As for the previous analyses for same-view trials, P1 data were collapsed over electrode and subject to separate 2 (adaptation; same vs. different) x 2 (orientation; upright vs. inverted) x 2 (gender; female body vs. male body), x 2 (hemisphere; left vs. right) x 2 (group; controls vs. BIDs) mixed factorial ANOVAs for both amplitude and latency. The same model was applied to N250 mean amplitude data.

5.4.3.2.1 P1 peak amplitude

Significant within-subjects effects of orientation ($F(1, 64) = 110.914$, $p < .001$, $\eta_p^2 = .634$), gender ($F(1, 64) = 14.215$, $p < .001$, $\eta_p^2 = .182$) and hemisphere

($F(1, 64) = 45.208$, $p < .001$, $\eta_p^2 = .414$) were seen over P1 amplitudes as the component was larger to inverted than upright bodies (10.935 μV vs. 8.930 μV), to female than male bodies (10.236 μV vs. 9.629 μV) and over the right than over the hemisphere (11.180 μV vs. 8.685 μV). There were no other main effects or interactions to report and the between-subjects factor of group was not significant ($F(1, 64) = 2.568$, $p = .114$, $\eta_p^2 = .039$).

5.4.3.2.2 P1 peak latency

ANOVA found that P1 latencies were longer to inverted stimuli (110 ms) in comparison to upright stimuli (108 ms) ($F(1, 64) = 15.430$, $p < .001$, $\eta_p^2 = .194$) as well as to female bodies (110 ms) in comparison to male bodies (108 ms) ($F(1, 64) = 44.467$, $p < .001$, $\eta_p^2 = .410$). This suggests that when the viewpoint of the body (front vs. back) is altered from adapting to test stimulus, inversion effects and gender sensitivity still ensue, similar to the way they did in the same-view analyses. A significant interaction was found between orientation and gender ($F(1, 64) = 6.920$, $p = .011$, $\eta_p^2 = .098$) with follow-up comparisons revealing that inversion effects were more significant in response to female bodies ($t(64) = 5.197$, $p < .001$, 112 ms vs. 109 ms) compared to male bodies ($t(64) =2.021$, $p = .048$, 109 ms vs. 107 ms). A significant interaction between adaptation and gender was also seen ($F(1, 64) = 13.676$, $p < .001$, $\eta_p^2 = .176$), which was superseded by an adaptation by gender by group interaction ($F(1, 64) = 5.809$, $p = .019$, $\eta_p^2 = .083$). Follow-up comparisons revealed that BIDs displayed no differences in P1 latency to same and different bodies but controls showed adaptation effects to male bodies regardless of orientation (*t*(64) =2.764, *p* = .007, 107 ms vs. 109 ms) and reverse adaption to female bodies regardless of orientation (*t*(64) = 3.055, *p* = .003, 111 ms vs. 109 ms). The contrast with same-view analyses suggests that BIDs are not generating a view-point invariant 3D view of the body during the encoding of bodily identities. The findings for controls further exemplify gender differences in the structural encoding of the human body. The latency of the P1 component did not differ between the groups as the between-subjects factor of group was not significant (*F*(1, 64) = .077, *p* = .782, η_p^2 = .001).

5.4.3.2.3 N250 mean amplitude

As in the same view condition, ANOVA revealed significant within-subjects effects of orientation (*F*(1, 64) = 46.363, *p* < .001, η_p^2 = .420), gender (*F*(1, 64) = 22.418, *p* < .001, η_p^2 = .259) and hemisphere (*F*(1, 64) = 9.332, *p* = .003, η_p^2 = .127), such that the N250 was largest in response to inverted stimuli (-2.516 µV vs. -1.109 µV), female bodies (-2.153 µV vs. -1.743 µV) and also in the right hemisphere (-2.295 µV vs. -1.231 µV). The main effect of gender interacted with group (*F*(1, 64) = 6.778, *p* = .011, η_p^2 = .096), with follow-up comparisons showing that gender-sensitive effects over N250 were only evident in BIDs (*t*(64) = 5.192, p < .001, -3.106 µV vs. -2.052 µV), not controls (*t*(64) = 1.507, *p* =137, -1.200 µV vs. -.894 µV). There was also a significant interaction between adaptation and hemisphere (*F*(1, 64) = 4.451, *p* = .039,

η_p^2 = .065), revealing larger N250 amplitudes to same bodies in comparison to different bodies only in the left hemisphere (*t*(64) = .217, *p* =.015, -1.410 μV vs. -1.051 μV). This suggests that effects of familiarity with bodies are lateralised to the left hemisphere irrespective of viewpoint changes between adapting and test body. There were no other main effects or meaningful interactions to report and the between-subjects effect of group was not significant (*F*(1, 64) = 3.557, *p* = .064, η_p^2 = .053).

5.4.3.2.4 Interim summary of results: Test body shown from a different view to adapting body

A brief summary of results can be viewed in Table 5.4.

Table 5.4

Summary of results when test body shown from different view to adapting body.

	Group	Orientation	Adaptation	Gender	Hemisphere	Interaction
Performance	-	✓	-	✓	-	✓ orient*adapt
P1 amplitude	-	✓	-	✓	✓	-
P1 latency	-	✓	-	✓	-	-
N250 amplitude	-	✓	-	✓	✓	✓ Adapt*Hem/ Gender*Group

Note. Main effects indicated on left side of vertical divider and interactions on the right side.

When the test body and adapting body were shown from a different view, participants were more efficient at responding to upright than inverted bodies and to female than male bodies. Contrary to performance in the same view condition, no adaptation was seen for upright bodies and reverse adaptation was evident for inverted bodies, such that participants were more efficient to identify different bodies, rather than to identify the same body, when its viewpoint changed from adapting to test stimulus presentations. None of these effects differed according to group.

Similar inversion effects as in the same-view condition were seen in the P1 time range for both amplitude and latency as well as in N250 amplitudes. Gender differences were also still evident, such that female bodies enhanced and delayed P1 responses as well as enhanced the N250 response. Unlike in same-view trials, there were no adaptation effects in the early stages of visual processing for BIDS. In controls, P1 latency was modulated by adaptation such that different male bodies evoked longer P1 latencies than same male bodies, whereas different female bodies evoked shorter P1 latencies than same female bodies. Familiarity effects were still seen in left hemisphere N250 amplitudes.

Altogether this suggests that inversion effects and gender effects occur irrespective of viewpoint and thus rely on the shape (outer contours) of the body rather than on the features that define the front or the back of the body form. Early adaptation effects on the other hand, appear to be somewhat viewpoint-dependent, especially in those with body image disturbances. This suggests that the processing of body identity relies on more than the shape of the body in such a way that a three-dimensional body representation of individual person's identities may not be constructed until later stages of processing.

5.4.4 Correlational analyses

5.4.4.1 Variables analysed

In order to assess relationships between brain and behaviour, Pearson's *r* correlational analyses were conducted between main effects found in ERP responses and main effects found in behavioural responses. Effects were quantified as the difference between conditions (collapsed over hemisphere in the case of ERPs) such that responses to same body stimuli were subtracted from different body stimuli, responses to upright stimuli were subtracted from responses to inverted stimuli and responses to male bodies were subtracted from those to female bodies. Performance variables were therefore reflective of adaptation and inversion effects in same view condition as well as inversion and gender effects in the different view condition. ERP variables were computed to reflect effects of adaptation, orientation and gender on P1 peak amplitude as well as effects of orientation and gender on P1 peak latency in the same view condition. Similarly, effects of orientation and gender on P1 peak amplitude and latency were computed with regards to the different view condition. Effects of orientation and gender in both the same view and different view conditions were computed for N250 mean amplitudes.

Adaptation effects were only seen in the left hemisphere during the N250 time range, as such, variables reflecting the effects of adaptation on left hemisphere N250 mean amplitude in both the same and different view conditions were computed.

Relationships between body image disturbance, ERP effects and behaviour were also of interest, and so Pearson's *r* correlational analyses were conducted between ERP effects that interacted with group, main effects of behaviour and questionnaire scores in both same view and different view conditions. As a result, the total BICI score, self-objectification score, WLI score and SLI score were all entered as separate variables into the analysis. The three-way interaction between orientation, gender and group over P1 peak amplitudes in the same view condition was represented by variables computed to reflect gender effects to upright stimuli and inverted stimuli separately. As the five-way interaction found over P1 peak amplitudes in the same view condition (orientation*adaptation*gender*hemisphere*group) revealed differences in the way male and female body identity was processed between the groups, this was represented by variables computed to reflect adaptation effects separately for upright and inverted stimuli, for male and female bodies in each hemisphere (as shown in Figure 5.6). As the overall size of P1 peak amplitudes differed between the groups in the same view condition, data from these trials were collapsed across all conditions to represent the size of the visual P1 component and this was entered into the analysis. A three-way interaction between adaptation, gender and group was also observed in the different view condition in P1 latencies. In order to reflect this, adaptation effects were computed separately for male and female bodies and these variables were also included in the analysis.

As a result, 41 variables were entered into the Pearson's *r* correlational analysis.

5.4.4.2 Relationships between ERP effects, behaviour and questionnaire scores

No correlations between ERP effects, behavioural responses, and questionnaire scores survived correction for multiple comparisons.

5.4.4.3 Relationships between questionnaire measures

Self-objectification score was moderately and positively related to BICI score $r(64) = .538$, $p<.001$ meaning that participants who self-objectified more also had more body concerns. BICI score also positively correlated with SLI score $r(64) = .774$, $p<.001$ as well as with WLI score $r(64) = .659$, $p<.001$, meaning that the more body concerns participants reported, the more they felt these concerns interfered with both work- and social- life. Perhaps unsurprisingly, SLI score and WLI score were strongly and positively related $r(64) = .714$, $p<.001$, meaning that the more participants felt body concerns interfered with social life, the more they also interfered with work life. These results therefore suggest a close relationship between BIC, self-objectification and the impact this has on psycho-social functioning.

5.5 Discussion

The overarching aim of this study was to delineate the temporal dynamics of body-only person perception and to assess whether this differs in women with body image disturbance. To this end, we measured visual ERPs in an adaptation paradigm, in which bodies were also shown from both the front and the back in order to investigate whether bodily identity perception is based on overall body shape (outer contours). If so, adaptation to an individual person's body may extend to substantial changes in viewpoint (similar to what has been proposed for face-sensitive mechanisms; Caharel et al., 2009).

We predicted that identity processing for bodies would be evident in early visual ERPs (similar to face-only identity processing, e.g. Jacques et al., 2007), and that it might be disrupted by inversion (cf. Minnebusch et al., 2010; Minnebusch et al., 2009). As there is evidence to suggest that the visual processing of bodies differs according to the gender of the body viewed (e.g. Alho et al., 2015; Groves et al., 2017) we also hypothesised that these effects may differ for male and female bodies. Furthermore, we expected that the temporal dynamics of identity perception (see Esposito et al., 2016) and the effects of inversion (e.g. Mundy & Sadusky, 2014) might differ between the BID group and control group. In such instances, we hypothesised that altered effects would linearly relate to self-objectification, dysmorphic body concerns and associated interference with psycho-social functioning (Beilharz et al., 2016).

Effects of adaptation that were expected to occur over the body-sensitive N1 component were found within the P1 time range. Accordingly, when the test body and adapting body were shown from the same view, the P1 response was attenuated to the sight of the same body relative to a different body. To the best of our knowledge, this provides the first evidence for the rapid processing of bodily identity. Moreover, adaptation was largely absent when the test body and adapting body were shown from different viewpoints. This shows that bodily identity is not encoded solely on the basis of the outer contours of an individual’s body during the early stages of processing, but includes internal bodily features such as those that differ between a person’s front and back. We also found the typical effects of inversion that were expected to occur over N1 within the P1 time range. Specifically, P1 peak amplitude and latency were enhanced and delayed, respectively, to inverted stimuli. Inversion effects occurred despite the absence of the head, and even when the test body and adapting body were shown from different viewpoints. Similarly, and again irrespective of viewpoint, female (compared to male) body viewing enhanced and delayed the P1 response rather than the N1 response.

In the same-view condition, these P1 adaptation effects interacted and differed between the groups in ways suggesting that person perception in women, and its lateralisation, strongly depends on the gender of the viewed person and on the presence of a history of body image disturbance. Adaptation effects indicated that male bodies were individuated only when they were presented in upright orientations by both control and BID groups.

This signifies that the recognition of individual male identities at this processing stage may depend upon the configural processing of presented body form. Groups differed only in terms of the spread of this adaptation. While controls showed adaptation over the right hemisphere only, adaptation was bilateral for BIDs. Dependence upon configural processing for individuating female bodies was not seen for controls. Instead, adaptation was present for both upright bodies (left-lateralised) and inverted bodies (bilaterally) in controls. In BIDs, however, adaptation was constrained to upright bodies in the right hemisphere, with no equivalent evidence for configural encoding of female bodily identities in the left. Female person perception by healthy women was thus more pervasive and tolerant of changes in orientation than male person perception. In contrast, women with a history of disorders characterised by body image disturbance showed far more restricted evidence for individuating female bodies. Moreover, P1 amplitudes were generally enhanced in the BID group compared to the control group, perhaps indicative of low-level processing differences between the groups (e.g. Li, Lai, Bohon, et al., 2015). As this did not relate to self-objectification or BIC, future studies should seek to directly address the potential mechanisms underlying this difference.

While the patterns of adaptation, inversion and gender mean that there were no meaningful effects over N1 and VPP, we found that N250 amplitudes were enhanced to same compared to different bodies in the left hemisphere, to female compared to male bodies and to inverted compared to upright bodies in both the same-view and different-view conditions. This indicates that configural body perception is an ongoing process, whilst a three-dimensional representation of the body is likely constructed during later stages of processing.

Behavioural performance for all participants was more efficient in trials presenting the same compared to different bodies and upright compared to inverted bodies, showing the expected adaptation and inversion effects in the same-view condition. In the different-view condition, participants were not only more efficient to process upright compared to inverted bodies but also female compared to male bodies, showing the expected inversion effects as well as a same-gender advantage. Similar to what has been found for face processing (Jacques et al., 2007) behavioural effects therefore mirrored electrophysiological effects occuring roughly 400 ms earlier. Unlike the same-view condition, adaptation effects were not evident to upright stimuli in the different-view condition, again mirroring the pattern of adaptation effects in P1 amplitudes. Instead, participants were more efficient at responding to different rather than the same inverted stimuli. It is possible that a lack of, or reverse adaptation, in the different-view condition reflect a difference in task demands. When stimuli are shown from the same view participants have access to the same featural (e.g. appearance of knees or toes) and global (e.g. size/shape) information. As a result, making a ‘same’ judgment is likely to be easier than a ‘different’ judgment. However, in the different view condition, featural information changes while global information remains the same. If identity perception is not based on global information alone, which our findings suggest, then there is likely to be conflict between featural differences prompting ‘different’ judgments and shape or size information prompting ‘same’ judgments. This may lead to an overall lack of behavioural adaptation effects, or even to reverse adaptation in the case of inverted bodies, which are specifically conducive to feature-based processing (Minnebusch & Daum, 2009; Robbins & Coltheart, 2015) and thus may prime ‘different’ judgments more.

ERP and behavioural effects were not correlated and neither related to any of the questionnaire measures. This suggests that behavioural effects, although showing similar patterns of adaptation, inversion and gender effects as early visual ERPs (see also Jacques et al., 2007) are not directly related to them. It also suggests that the effects of body image on the perception of (individual) bodies may be limited to group effects rather than vary systematically across the population of women, with body image disturbance at one extreme. However, self-objectification and dysmorphic body concerns were, as expected, associated in such a way that the more the participants self-objectified the more concerns they had about their bodies. Moreover, these dysmorphic concerns were related to psycho-social functioning such that the more concerns participants had, the more they reported interference in their work and social lives. In all, this suggests that the body image measures themselves were sound and thus unlikely to be responsible for the lack of correlation with behavioural or ERP effects.

On all measures, despite partial recovery, BIDs scored more highly than controls such that body concerns were elevated and they self-objectified to a greater extent, although on average BID BICI scores were still at subclinical levels (see Littleton et al., 2005 for clinical cut-off point). This may be of clinical interest as it suggests that dysmorphic appearance concerns may not return to a completely healthy level with treatment. Future research may thus benefit from addressing whether this is still the case in fully recovered individuals. If so, body concerns and self-objectification may well be ongoing symptoms that persist despite the return of healthy body-related behaviours.

5.5.1 Rapid visual processing of the human form

Primarily, P1 has been thought of as an early indicator of low-level visual perception (e.g. Tarkiainen et al., 2002) sensitive only to spatial processing (see Mangun, 1995 for review). However, it has increasingly been shown that P1 amplitude and latency can be modulated by top-down processes such as task demands and stimulus salience (see Taylor, 2002 for review). As such, previous studies have reported body-sensitive responses in the P1 time range (Righart & de Gelder, 2007; Thierry et al., 2006), especially when stimuli contain emotional cues, or when bodies are the only stimuli presented (Meeren et al., 2005; Righart & de Gelder, 2007; Thierry et al., 2006; van Heijnsbergen et al., 2007).

In this study, body-sensitive effects usually evident in the N1 time range (e.g. inversion effects, Minnebusch et al., 2009) were observed instead in P1 responses. In particular, P1 was enhanced and delayed, irrespective of viewpoint, to both inverted bodies and female bodies. When the test body was shown from the same view as the adapting body, adaptation effects were also evident such that P1 was enhanced to same as compared to different stimuli. This suggests that the visual system can rapidly encode a configural body representation that distinguishes gender and identity. But why should these processes occur so rapidly in the P1 time range, rather than in the expected N1 time range?

As P1 is thought to originate from extrastriate regions, which are particularly sensitive to the low-level visual properties of a stimulus (e.g. V1, V2, Di Russo, Martínez, Sereno, Pitzalis, & Hillyard, 2002), it is likely that the observed shift in effects was due to the low-level visual differences evident between upright and inverted body stimuli. For example, our stimuli were presented on a black background and more often than not, models assumed a neutral, relaxed posture with arms rested by the side and legs slightly separated. Hence, there were strong asymmetries in the local contrasts present in upper and lower visual fields, with upright stimuli containing more contrast in the lower visual field than in the upper visual field for example (see Figure 5.1). These asymmetries may account for the shift in effects to P1 time ranges. This explanation is in line with accounts of early (P1) face processing effects (e.g. Jacques et al., 2007), for which it is argued that such local contrasts define the configuration of an image and are therefore not low-level (e.g. Itier & Taylor, 2004; Itier & Taylor, 2004b). This is of interest to the body processing literature in the sense that it suggests that body-sensitive effects are not tied to a specific ERP component or time-range, but can be accelerated by including or enhancing the low-level visual features and asymmetries that define the human body form.

Alternatively, as attention has been found to modulate early visual ERPs (e.g. Hillyard & Anllo-Vento, 1998) it could be that attention was heightened due to task demands or because bodies were the only stimuli presented (see Meeren et al., 2005). In order to assess this, future studies should consider replicating our task but presenting only the trunk of the body where the arms are held at the side, or body stimuli with a closed (although somewhat unnatural) stance. Under such circumstances, if the difference in local contrasts between upright and inverted bodies explains the shift in effects observed in this study, then we predict effects would shift back into the expected N1 time range. Alternatively, if attentional processes due to task demands, or perhaps another unknown mechanism, are accountable for these rapid body-related effects, we would expect the effects to remain in the P1 time range.

Irrespective of the specific underlying mechanisms, our findings add to the body of literature suggesting that under certain circumstances the P1 component can reflect higher level processes associated with the visual analysis of the human body (e.g. Meeren et al., 2005; van Heijnsbergen et al., 2007).

5.5.2 Evidence for view-dependent body-only person perception

As adaptation effects were evident in behaviour when the test body and adapting body were shown from the same view, our findings support previous work, which has proposed that the body plays an important role in distinguishing identity (e.g. Rice, Phillips, Natu, et al., 2013; Simhi & Yovel, 2016). In line with this, adaptation effects were seen in P1 amplitudes for the same-view condition, showing rapid encoding of bodily identity for the first time. Unlike for faces (e.g. Caharel et al., 2009), and in line with functional magnetic resonance imaging (fMRI) studies of EBA and FBA (see Downing & Peelen, 2011 for review), adaptation effects for bodies were somewhat view-dependent as there was no difference in efficiency or P1 response between same and different bodies when adapting and test stimuli were shown from different viewpoints (unless the body was inverted in the case of behaviour, discussed above, and in P1 latencies for controls depending on the gender of the viewed body). This suggests that whilst person perception is evident in these early time ranges as has been shown for faces (e.g. Caharel et al., 2009; Jacques et al., 2007; Parketny et al., 2015), the extent of this in both brain and behaviour depends on viewing the body from the same side (front vs. back). It does not mean, however, that bodily identity perception is intolerant to more subtle changes in perspective, such as the changes in viewing angle typically used in face perception research to show viewpoint invariance (Caharel et al., 2009). Future studies should therefore seek to address whether electrophysiological body adaptation effects are evident when less extreme orientations or the body are contrasted. This may also help to identify what aspects of bodily information are required in order for rapid person perception to occur as fMRI studies show a release from adaptation at about 45° (see Downing & Peelen, 2011 for review).

The reason for presenting bodies from the back in the present study was to assess the role of body shape in identity processing. It has been argued that identity processing in the occipitotemporal cortex is simply a result of shape processing rather than explicit person perception (Downing & Peelen, 2011). However, the pattern of results observed in this study suggests otherwise, as information other than that which can be gleaned from the outer contours of the body was needed in order for adaptation to occur. As a result, it seems that body-only person perception relies on more than just the outer shape of the body (cf. Downing & Peelen, 2011). With that in mind, it seems that a three-dimensional representation of another person’s body does not get generated during early stages of visual processing.

A three-dimensional neural representation of the body did appear to be evident however within 250 ms of body viewing. This was reflected as enhanced left-hemisphere N250 amplitudes in response to the same stimuli, irrespective of viewpoint. This is a novel finding, and given that the N250 component is thought to reflect the activation of a stored structure of a face in memory (see Caharel, Fiori, Bernard, Lalonde, & Rebai, 2006), this suggests that structural body templates are lateralised to the left hemisphere. Body-only person perception might therefore begin with bilateral structural encoding during the early stages of visual perception, but then continue into later stages of processing as a lateralised stored template. This explanation is however largely speculative as, to our knowledge, no literature exists that has investigated this. As such, future studies should seek to address why the structural representation of body identity might be lateralised in memory.

Nonetheless, effects observed in this study were largely similar to the effects of adaptation in visual face processing (e.g. Caharel et al., 2009; Jacques et al., 2007; Keyes et al., 2010; Lafontaine et al., 2013; Parketny et al., 2015; Retter & Rossion, 2016). Given that specialist body- and face- brain regions are reportedly adjacent and likely interconnected (Minnebusch & Daum, 2009), this supports the proposition that information from both bodies and faces are employed for person perception (e.g. O'Toole et al., 2011; Rice, Phillips, Natu, et al., 2013; Robbins & Coltheart, 2012; Simhi & Yovel, 2016). In particular, our findings suggest that such processes can occur rapidly.

5.5.3 Evidence for configural body processing despite the absence of the head

Regardless of viewpoint changes, typical inversion effects were observed in the P1 response (enhanced and delayed amplitudes to inverted as compared to upright bodies) and in behaviour (slower and less accurate responses to inverted as compared to upright bodies). In line with previous research (e.g. Brandman & Yovel, 2014; Robbins & Coltheart, 2012), this indicates that the absence of the head does not disrupt first-order relations to the extent that configural processing is abolished for headless bodies as has been suggested (Minnebusch & Daum, 2009; Minnebusch et al., 2009). As bodies in this study were neutrally clothed with all jewellery and unique features (e.g. tattoos) removed, this supports the idea that the absence of typical inversion effects for headless bodies (see Minnebusch et al., 2009) may be due to attention being drawn to non-body cues, such as clothing (Robbins & Coltheart, 2012). This is further supported as inversion effects were present regardless of whether the test body and adapting body were shown from the same or different viewpoint, suggesting that the outer contours of the body (the configural whole), rather than the observable internal features, are the primary drivers of inversion effects. As such, inversion effects appear to occur for bodies independently of the view they are observed from.

The effects of body inversion were seen to persist into later stages of processing as N250 amplitudes were enhanced to inverted, compared to upright bodies. This is different from what has been reported in studies of face adaptation, as the N250 has been found to be enhanced to upright rather than inverted faces following typical inversion effects over N1 (e.g. Jacques et al., 2007; Schweinberger, Kaufmann, Moratti, Keil, & Burton, 2007). This suggests that the structural encoding of an (individual) body might be a longer process than the structural encoding of an (individual) face. With that in mind, the body-sensitive N250 might therefore reflect processes other than just familiarity.

In sum, the pattern of findings in this study suggests that headless bodies are processed configurally at both the behavioural and neural level. Moreover, this process appears to persist for longer in response to bodies than for faces. Nonetheless, when investigating body perception with headless stimuli, extraneous factors that might interfere with configural processing mechanisms, such as clothing, should be controlled.

5.5.4 Evidence for same-sex gender processing

Previous research has demonstrated that body-sensitive N1 amplitudes are enhanced to the female form (compared to the male form) in heterosexual men (Hietanen & Nummenmaa, 2011) and heterosexual women (Alho et al., 2015), as well as in women with EDs (Groves et al., 2017). Here, we found evidence to suggest that such effects can occur even earlier, as enhanced and delayed P1 responses were evident to female bodies in comparison to male bodies, irrespective of viewpoint. For the first time, we also show that gender-sensitivity continues into later stages of processing as N250 amplitudes were enhanced to female, as compared to male, bodies. Perhaps unsurprisingly, this may indicate that other female bodies are more familiar to a female observer than male bodies. As such, it is important for future studies to assess the temporal dynamics of gender-sensitive processes in men as with a familiarity hypothesis in mind, enhanced N250 amplitudes would be expected in response to other male bodies rather than female bodies.

Given that gender-sensitive P1 effects appear to mirror inversion effects, it is possible that female bodies compared to male bodies might disrupt processing in a similar way to inversion. This is supported by evidence to suggest that female bodies are objectified more than male bodies (e.g. Heflick & Goldenberg, 2014; Vaes, Paladino, & Puvia, 2011) and that this objectification is associated with local processing of female features, rather than with configural processing of the female form (e.g. Gervais, Vescio, Förster, Maass, & Suitner, 2012). With that in mind, assuming that feature-based visual processing mechanisms predominate over the usual configural mechanisms during female body viewing, enhanced and delayed P1 amplitudes might reflect the associated switch in processing style. To a certain extent the behavioural findings support this as participants were less accurate when discriminating women's bodies than they were when discriminating men's bodies. As this effect did not differ between the groups and did not correlate with self-objectification score, it seems that objectifying oneself and objectifying others are distinct processes. Future studies should therefore measure the extent to which other bodies are objectified in comparison to self-objectification, and assess the relationship with behavioural and electrophysiological configural gender perception. Furthermore, it would be insightful to investigate the effects in men, as for this to be true, female gender-sensitivity might be reflected in early visual ERPs (as in Alho et al., 2015; Hietanen & Nummenmaa, 2011 for example) whilst N250 amplitudes might be enhanced to other men's bodies due to familiarity.

5.5.5 Electrophysiological evidence for altered person perception in women who have experienced body image disturbance

In the same-view condition, we found that identity perception in the P1 time range (indexed by the presence of adaptation effects) was modulated according to hemisphere, the gender of the body viewed and whether it was presented upright or inverted, as well as whether the observer had experienced an ED or BDD.

In particular, controls adapted to upright male body identity in the right but not in the left hemisphere, while inverted men were not adapted to at all. Both upright and inverted female bodies were adapted to in the left hemisphere, whilst inverted female bodies were also adapted to in the right hemisphere. This suggests that perceiving bodily identity of the same gender is more widespread and less susceptible to the effects of inversion, whilst perceiving bodily identity of the opposite gender is more constrained. This would need to be substantiated by investigating the effects in a sample of men.

Similar to controls, BIDs adapted to male body identity only when bodies were upright but not when they were inverted. In contrast to controls however, this was not confined to the right hemisphere but was evident bilaterally. Moreover, this group did not adapt to female bodies (upright or inverted) in the left hemisphere as did controls, instead adaptation was evident only to upright female bodies in the right hemisphere. Altogether then, female identity perception was widespread and tolerant to orientation in controls, but more restricted in BIDs.

Strikingly, this pattern of findings suggests that BIDs do not perceive female body identity in the left hemisphere but instead, process female body identity in the right hemisphere. This is in line with previous research which shows that visual body processing networks in the left hemisphere are disrupted in those with body image disturbance. For example, reduced connectivity between left FBA and EBA has been seen in anorexia, which was directly related to body image distortion (Suchan et al., 2013). Furthermore EBA, thought to be the source of body-sensitive early visual ERP components (Pourtois et al., 2007; Sadeh et al., 2011; Thierry et al., 2006) and also linked to identity perception (Downing & Peelen, 2011; Downing & Peelen, 2016), is reportedly underactive (Uher et al., 2005) and maladapted (Suchan et al., 2010) in those with anorexia. It may be the case then, that maladapted and altered activity in the left-lateralised body processing network extends to those who are recovering from disorders characterised by body image disturbance, not just anorexia, and may be specific to the processing of female bodies.

Given that a proportion of participants in the BID group did not suffer from anorexia, this further suggests that the observed alterations are unlikely to reflect effects of malnourishment through starvation. It should also be noted that differences in cortical activity may not necessarily precede the onset of illness. This would therefore be of interest to investigate in those ‘at risk’ of body image disturbance, perhaps in twin studies, whereby one twin has been diagnosed with an ED or BDD whilst the other twin is considered healthy.

This is not the first time that those with body image disturbance show evidence of visually analysing bodies in a different way to controls (e.g. Groves et al., 2017; Jansen, Nederkoorn, & Mulkens, 2005). However, previous behavioural research has indicated that those with high levels of body image disturbance process appearance-related stimuli, such as bodies, in a piecemeal way (Beilharz et al., 2016; Feusner, Moller, et al., 2010; Mundy & Sadusky, 2014; Urgesi et al., 2014). In line with this, we expected to find inversion effects in the control group but not in the BID group. Moreover, whilst right hemisphere adaptation to inverted female bodies in the BID group only just missed significance, it could be argued that adaptation to both upright and inverted bodies should be expected in BIDs if inversion is not thought to disrupt how this population process bodies (Mundy & Sadusky, 2014; Urgesi et al., 2014). However, participants in this sample were at least partially recovered, which may account for the differences. For example, it is possible that body-related treatment processes may encourage a sort of ‘training’ in body recognition that results in expertise (as has been shown for 'Greebles', Gauthier & Tarr, 1997; and houses, Husk, Bennett, & Sekuler, 2007) rather than objectification. As such, it may be the case that clinical participants would show similar, but perhaps stronger, adaptation effects to inverted female bodies as controls. Alternatively, BID effects observed might reflect a return to baseline for those who have recovered, as Duncum, Atkins, Beilharz, and Mundy (2016) found evidence for increased levels of configural body processing in undiagnosed participants with high levels of BIC.

Nonetheless, ERP findings in this study did not relate to self-objectification scores, which could mean that objectification is not associated with the effects. On the other hand, this is likely further indication that self-objectification might not necessarily reflect the objectification of others. Future research should therefore seek to address whether these early visual processing differences reflect an objectification of female bodies as compared to male bodies in controls and right-lateralised expert processing in those recovered from disorders characterised by body image disturbance. Irrespective of the underlying mechanisms accountable for the observed differences, it is clear that despite partial recovery, there are ongoing alterations in the temporal dynamics of body-only person perception in those who have experienced disorders characterised by body image disturbance.

5.6 Conclusions

Findings from this study provide evidence for rapid body-only person perception, configural body processing despite the absence of the head and gender-sensitive electrophysiological responses. Importantly, we also provide evidence to suggest that bodily identity is encoded differently in those who have experienced disorders characterised by body image disturbance. Specifically, female identity perception was widespread and unaffected by orientation in controls, but appeared to be more restricted in BIDs as only upright female body identities were reliably encoded over right occipito-temporal cortex. Female identity perception was also conspicuously absent over left occipito-temporal cortex in the BID group. These differences might reflect female body objectification, expert female identity recognition or perhaps a return to baseline visual processing mechanisms in those who have experienced EDs and/or BDD (see Duncum et al., 2016). Irrespective of the underlying mechanisms, body-only identity perception appears to be altered, despite recovery, in those with high levels of BIC and self-objectification.

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Chapter 6 Evidence for disturbed configural body processing before and after the onset of disorders characterised by body image disturbance and self-objectification

6.1 Abstract

Previous research has suggested that those experiencing disorders such as anorexia nervosa or body dysmorphic disorder (BDD) might visually analyse bodies and faces on the basis of their features, rather than as a configural whole. Moreover, it has been suggested that such configural processing deficits might be markers of body image concern (BIC) in these populations. We conducted two studies to assess whether appearance-related configural processing is disturbed in populations at risk of developing disorders characterised by body image disturbance. By means of inversion, Experiment 1 assessed the visual processing mechanisms associated with body, face and house viewing in adolescents, as adolescence is thought to be a vulnerable period with regards to the onset of eating disorders (EDs) and BDD. BIC was measured using the Body Image Concern Inventory (Littleton, Axsom, & Pury, 2005) and self-objectification was measured using the Self-Objectification Questionnaire (Fredrickson, Roberts, Noll, Quinn, & Twenge, 1998). Experiment 2 then applied the same protocol in order to assess appearance-related configural processing and the relationship with BIC and self-objectification in high risk adolescent girls, low risk adolescent girls and those in recovery from EDs and BDD. Experiment 1 found evidence for typical configural face- and body- processing, although adolescent girls reported higher levels of BIC and self-objectified to a greater extent than adolescent boys. In Experiment 2, configural body processing was found to be disrupted in women recovering from EDs/BDD as well as in high risk adolescents, whilst typical body inversion effects were seen in the low risk group. Women in recovery were also quicker to respond to all stimuli, whilst high risk girls took

longer to respond to bodies than both other groups. Configural face processing was not disrupted in any group and the effects did not systematically relate to BIC or self-objectification. These findings suggest that feature-based processing of the human form may precede the onset of EDs/BDD and continue into recovery. This has direct clinical implications for early interventions and treatment.

6.2 Introduction

Body image is described as a multi-dimensional construct that reflects the malleable, conscious representation a person has of their bodily self, including subjective emotions and cognitions relating to appearance satisfaction (Cash, 2004; Cash, 2012). As such, body image exists on a spectrum of body image concern (BIC; Callaghan, Lopez, Wong, Northcross, & Anderson, 2011), which can be understood as the amount of concern an individual has about their physical appearance, ranging from healthy or 'positive' to unhealthy (Mundy & Sadusky, 2014). At the extreme negative end of the spectrum, these concerns manifest as body image distortions, which are reported to the point of delusion in some psychiatric conditions (Phillips, Kim, & Hudson, 1995). In particular, perceived flaws in appearance, that are often unnoticeable or considered to be minor by others, are characteristic of mental illnesses such as anorexia nervosa, bulimia nervosa and body dysmorphic disorder (BDD) (American Psychiatric Association, 2013). However, the DSM-5 classifies anorexia and bulimia under 'feeding and eating disorders,' whilst BDD is referred to on the obsessive-compulsive spectrum (American Psychiatric Association, 2013). This is due to subtle symptomatic differences between the conditions, as those with anorexia and/or bulimia tend to overemphasise the importance of body weight and shape, focusing on their own ‘fat’ and/or ‘ugly’ body parts but directing attention to others’ ‘beautiful’ body parts (Jansen, Nederkoorn, & Mulkens, 2005). In contrast, although bodily concerns may be present, those with BDD are more likely to find themselves preoccupied with facial-, skin- or hair-related appearance concerns (see Feusner, Neziroglu, Wilhelm, Mancusi, & Bohon, 2010). Nevertheless, it has been argued that these conditions might be better understood as interrelated body image disorders (Cororve & Gleaves, 2001) due to shared symptomatology such as body image disturbance, severe psychological distress and reduced psychosocial functioning (Harris & Barraclough, 1997; Mitchison, Crino, & Hay, 2013). Moreover, BDD is often distinctly comorbid in EDs (Dingemans, van Rood, de Groot, & van Furth, 2012; Jolanta & Tomasz, 2000). As reports show the highest mortality rate of all psychiatric illnesses in anorexia (Arcelus, Mitchell, Wales, & Nielsen, 2011; Papadopoulos, Ekbom, Brandt, & Ekselius, 2009; Sullivan, 1995) as well as high levels of suicide ideation and suicide attempts in BDD (Phillips et al., 2005), there is an earnest need to understand the aetiology of such disorders so that objective symptom markers can be identified.

Whilst evidence is currently limited, research has attempted to elucidate some of the factors that may contribute to the development and maintenance of the symptomatology associated with disorders characterised by body image disturbance (see Buchanan, Rossell, & Castle, 2011; Feusner, Neziroglu, et al., 2010; Suchan, Vocks, & Waldorf, 2015 for reviews). Given that body image is supposedly underpinned by interrelated contributions from perception, cognition, affect and behaviour (see Cash, 2004; Cash, 2012) and given the elevated level of dysmorphic appearance concerns seen in EDs and BDD, disturbances to visual perception have been proposed as a possible factor in the maintenance and development of body image disturbance. In particular, it has been suggested that preoccupations with specific body areas or flaws in appearance seen in those with EDs and BDD, might reflect a bias for processing local over global information (see Feusner, Neziroglu, et al., 2010; Lang, Lopez, Stahl, Tchanturia, & Treasure, 2014 for review). Specifically, weak central coherence (WCC), whereby detail-based, local processing is employed instead of global processing, has been observed across EDs (Lang et al., 2014) as well as in recovered ED participants (Lopez, Tchanturia, Stahl, & Treasure, 2009). This suggests that local processing bias might be a trait characteristic of those who have experienced EDs, perhaps predisposing, or helping to maintain body image disturbance pathologies (Lopez et al., 2009). WCC is understudied in BDD, although there is evidence to suggest global processing disturbances and local processing bias also exists in this population (Feusner, Neziroglu, et al., 2010; Kerwin, Hovav, Helleman, & Feusner, 2014). Thus, as ED and BDD symptoms are highly comorbid (Mitchison et al., 2013) it is possible that such perceptual disturbances might underpin the high level of attention-to-detail required for the development and maintenance of body image disturbance. Studies investigating face- and body- processing in populations with high BIC have addressed this directly and report disturbances indicative of a focus on the features of appearance-related stimuli (e.g. Beilharz, Atkins, Duncum, & Mundy, 2016; Duncum, Atkins, Beilharz, & Mundy, 2016; Feusner, Moller, et al., 2010; Mundy & Sadusky, 2014; Urgesi et al., 2014; Urgesi et al., 2012).

It has been extensively documented that the visual processing mechanisms employed for face perception differ from those recruited for object perception. In particular, faces are processed configurally, in a top-down global manner, whilst objects are recognised in a bottom-up style on the basis of their local features (see Minnebusch & Daum, 2009). Maurer, Le Grand, and Mondloch (2002) explain that configural processing is driven by three underlying mechanisms, which include first- and second- order relational information as well as holistic processing. Face detection is therefore based on first-order information, referring to the configuration of a face (e.g. two eyes appear above a nose). It is thought that this information is then processed holistically, meaning the face is perceived as a whole rather than on the basis of individual facial features (see Piepers & Robbins, 2012, for review of definition). Identity discrimination then relies on second-order information, which refers to the spatial distances between features as well as the individual differences between features themselves (Maurer et al., 2002).

The most robust evidence for configural processing is found by observing the effects that occur when stimuli are inverted or when stimulus features are scrambled. The face inversion effect (FIE) (Yin, 1969) for example, describes reduced recognition performance for inverted compared to upright faces. The effect is thought to occur for faces but not objects because first-order templates underpinning configural representations are based on canonical viewpoints. As such, they are sensitive to changes in orientation. Thus, face processing is disturbed by inversion because although spatial relations between features are preserved, the coordinates of facial features in space are disrupted. Configural processing mechanisms are therefore unsuccessful and a switch to feature-based processing is thought to be required for successful recognition (Piepers & Robbins, 2012). The ‘costs’ associated with this (the FIE) are reflected as slower and often less accurate behavioural responses, as well as enhanced and delayed face-sensitive electrophysiological responses (see Minnebusch & Daum, 2009 for review). Object recognition on the other hand, is typically unaffected by inversion since encoding is feature-based and therefore orientation-independent (Rossion & Gauthier, 2002).

Similarly, there is also evidence of a body inversion effect (BIE) (e.g. Minnebusch, Keune, Suchan, & Daum, 2010; Minnebusch, Suchan, & Daum, 2009; Reed, Stone, Bozova, & Tanaka, 2003; Reed, Stone, Grubb, & McGoldrick, 2006) as akin to faces, inverting body stimuli has been found to result in slower and less accurate behavioural responses (e.g. Reed et al., 2003; Reed et al., 2006), as well as enhanced and delayed electrophysiological responses (see Minnebusch & Daum, 2009 for review). Although such evidence is indicative of configural body processing, findings are less straightforward than for face processing. For example, it has been suggested that configural body posture recognition is mediated by the presence of the head (Brandman & Yovel, 2010) as research has shown that even contextual cues indicating the presence of the face might trigger face processing mechanisms (Cox, Meyers, & Sinha, 2004; Morris, Pelphrey, & McCarthy, 2006). In line with this, Minnebusch et al. (2009) found reverse electrophysiological inversion effects and no behavioural inversion effects for headless body stimuli. On the contrary, Reed et al. (2006) claim that configural body recognition relies on the structural hierarchy of the body, not on a complete template match. This suggests that the absence of the head may not be accountable for the lack of BIE in Minnebusch et al. (2009). In line with this, Robbins and Coltheart (2012) found behavioural BIE for headless stimuli, and as a result, argue that stimuli in studies reporting an absence of the BIE may have led participants to focus on non-body aspects, such as clothing. Similarly, even headless bodies appear to be represented as wholes, rather than as a sum of their parts, in body-selective brain regions (Brandman & Yovel, 2014). It is therefore largely accepted that body recognition, like face recognition, reflects a configural process (see de Gelder et al., 2010, for an older review of debate).

In line with the argument that global, configural processing is disrupted in those with body image disturbance (see Feusner, Neziroglu, et al., 2010; Lang et al., 2014 for review), it has been proposed that FIE and BIE might be reduced or altered in EDs (Urgesi et al., 2014; Urgesi et al., 2012) and BDD (Beilharz et al., 2016; Duncum et al., 2016; Feusner, Moller, et al., 2010; Mundy & Sadusky, 2014). It is therefore possible that in these disorders, appearance-related corporeal stimuli might not be processed in the typical configural manner but on the basis of their features. For example, Feusner, Moller, et al. (2010) found that under certain circumstances, inverting face stimuli did not affect how quickly BDD participants recognised a face, whilst control participants' responses were slower for inverted than upright faces. In addition, Mundy and Sadusky (2014) found weaker inversion effects for faces and bodies in healthy participants with high BIC compared to those with low BIC. This was reflected by faster responses to inverted face and body stimuli compared to upright, plus more accurate responses to inverted bodies as compared to upright. Findings from these studies therefore imply that the appearance-related scrutiny associated with body image disturbance may be associated with the predominance of feature-based processing mechanisms, which are perhaps present before the onset of illness.

Beilharz et al. (2016) specifically addressed whether local visual processing bias could be a potential marker of body image disturbance by assessing face- and body- inversion effects across a continuum of participants with BIC. They found evidence for a graded local processing bias alongside increases in BIC and concluded that local processing bias may therefore be an objective marker of BDD. However, Duncum et al. (2016) found that irrespective of stimulus type (bodies, faces, scenes and objects) participants with non-clinical, high levels of BIC displayed increased inversion effects compared to participants with low levels of BIC. This indicates that the relationship between disturbed visual processing mechanisms and disorders characterised by body image disturbance might not be as straightforward as previously thought. The authors suggest that the findings might be an artefact of their study design, or perhaps indicative of a global processing deficit in high BIC participants. Specifically, they argue that as stimuli were shown for a short duration (500 ms), this might not have been enough time for those with high BIC to switch to their preferred, slower local-processing strategy. As a result, they were reliant on defective global processing mechanisms, causing them to be less accurate than low BIC participants who were still able to use attenuated configural processing in the inverted condition. Duncum et al. (2016) also suggest stimuli presentation may account for the difference in findings as presenting stimuli successively, not simultaneously as in previous studies (Feusner, Moller, et al., 2010; Mundy & Sadusky, 2014), may result in visual working memory effects that would interfere with the effects of inversion. Nonetheless, as effects were not consistent between the low and high BIC groups, this is still indicative of atypical visual processing mechanisms in those with high BIC.

Similarly, given evidence for local processing bias in EDs (Lang et al., 2014; Lopez et al., 2009), research has investigated how this might translate to appearance-related stimuli. Urgesi et al. (2012) addressed precisely whether body form or body action recognition were altered in women with anorexia, and found that detail-based form recognition, but not action recognition, was enhanced in anorexic participants. As such, anorexic participants were not generally superior at visually analysing human stimuli, but showed a specific enhancement in the ability to recognise body morphology. Consequently, the authors reasoned that this might reflect detail-based body processing that is perhaps associated with the tendency to routinely explore body parts. In a second study, Urgesi et al. (2014) directly assessed configural body processing by means of a matching-to-sample task whereby anorexic and control participants were asked to discriminate upright and inverted body, face and motorcycle stimuli. Typical inversion effects were observed for faces in both groups, but the anorexic group did not display inversion effects for bodies, suggesting that bodies were being processed like objects, in a feature-based manner. However, findings from both studies did not identify whether impairments in configural body processing are specific to anorexic symptomology or related to body image disturbance more generally.

Findings from neuroimaging studies also support the idea of a visual body processing deficit in populations with body image disturbance, as evidence suggests atypical structure, function and connectivity in brain regions associated with distinct body processing (Suchan et al., 2015). In addition, findings from electroencephalogy (EGG) studies provide evidence for aberrant face processing mechanisms in anorexia and BDD (Li, Lai, Bohon, et al., 2015; Li, Lai, Loo, et al., 2015). Moreover, it has been shown that during face viewing, brain regions associated with detail-based processing are more active in BDD compared to controls, suggesting that participants with body image disturbance visually perceive faces in a piecemeal fashion (see Feusner, Neziroglu, et al., 2010 for review).

With those studies in mind, it is clear that research has focused on configural face- and body- processing in anorexia and BDD, largely neglecting how BIC relates to visual processing in other disorders such as bulimia. As far as we are aware, only one study has investigated visual body processing in bulimic participants, finding evidence for a cognitive processing bias towards overweight stimuli (Mai et al., 2015). This suggests that visual body processing may also be disturbed in other disorders characterised by body image disturbance. Furthermore, despite claims that local processing bias for face and body stimuli might be markers of BDD (Beilharz et al., 2016), no study has investigated whether disturbed configural face- and body-processing might be characteristic of other disorders perpetuated by body image disturbance, such as in EDs other than anorexia (e.g. Urgesi et al., 2014; Urgesi et al., 2012). We were therefore interested in whether disturbed configural processing of appearance-related stimuli can precede the onset of illnesses symptomatic of body image disturbance, and/or continues into recovery. As such, we conducted two studies to address this question.

It is understood that adolescence is a particularly vulnerable period of time within which young people are most ‘at risk’ of developing BDD (Bjornsson et al., 2013) or an ED characterised by body image disturbance (Striegel-Moore & Bulik, 2007; Striegel-Moore et al., 2003). Interestingly, there is also evidence to suggest a slow maturation of configural face processing mechanisms throughout adolescence into adulthood (e.g. Blakemore & Mills, 2014; Mondloch, Le Grand, & Maurer, 2002; Steinberg, 2005; Taylor, Edmonds, McCarthy, & Allison, 2001). Thus, in Experiment 1, we recruited participants within this ‘at risk’ age bracket in order to assess general face- and body- configural processing mechanisms in adolescence. As it has been proposed that the single greatest risk factor for developing EDs such as anorexia and bulimia is simply being female (see Striegel-Moore & Bulik, 2007 for review), we were particularly interested in assessing differences in configural processing mechanisms between adolescent girls and adolescent boys. With that in mind, the self-objectification questionnaire (SOQ; Fredrickson et al., 1998; Noll & Fredrickson, 1998) was administered as a measure of the extent to which the body is thought of in terms of observable appearance, rather than competence (based on objectification theory; Fredrickson & Roberts, 1997), as this has not been considered with regards to configural processing. The Body Image Concern Inventory (BICI; Littleton et al., 2005) was also administered in order to assess dysmorphic appearance concerns.

Experiment 2 was designed to compare appearance-related configural processing mechanisms between high risk and low risk adolescent girls, as well as women who had partially recovered from EDs and BDD. ‘High risk’ was determined on the basis of BIC and self-objectification, as self-objectification and body dissatisfaction (Strelan & Hargreaves, 2005) are known traits of disorders such as anorexia, bulimia (Calogero, Davis, & Thompson, 2005) and BDD (Lambrou, Veale, & Wilson, 2011). Furthermore, self-objectification has been identified as a contributing factor to body image disturbance (see Riva, Gaudio, & Dakanalis, 2015 for review).

In both of our studies, participants were asked to discriminate between upright and inverted bodies, faces and houses in a matching-to-sample task (modelled on Urgesi et al., 2014; Urgesi et al., 2012). Houses were used as control stimuli because similarly to bodies and faces, houses often portray distinct first-order information (e.g. door beside and often below windows) and despite some evidence to the contrary (Eimer, 2000; Husk, Bennett, & Sekuler, 2007; Prince & Heathcote, 2009; Wiese, 2013) they are less susceptible to the effects of inversion. Reaction time (RT) and accuracy measures were recorded in order for findings to be comparable to previous literature (e.g. Beilharz et al., 2016; Duncum et al., 2016; Feusner, Moller, et al., 2010; Mundy & Sadusky, 2014; Urgesi et al., 2014; Urgesi et al., 2012).

Given that western societal norms encourage the objectification of female bodies (Jones, 2001) and as women are reportedly more likely to experience body image disturbance than men (Striegel-Moore & Bulik, 2007), we thought that adolescent girls in Experiment 1 might report more BIC and self-objectification than adolescent boys. As a result, whilst we expected that adolescents would show normative configural processing for faces and bodies, indexed by slower RT and reduced accuracy to inverted compared to upright face and body stimuli, we thought these effects might be reduced or altered in girls compared to boys (Duncum et al., 2016; Mundy & Sadusky, 2014).

In light of previous research (e.g. Mundy & Sadusky, 2014) we also thought that high risk adolescents in Experiment 2 would perform comparably to the body image disturbance (BID) group, showing evidence for reduced configural face- and body- processing. In addition, we expected these altered effects to correlate with scores on the BICI and SOQ (as in Beilharz et al., 2016) such that higher BIC and greater levels of self-objectification would be associated with increased altered effects.

6.3 Experiment 1: Assessing configural processing in those within the 'at risk' age bracket for developing EDs and BDD

Configural processing disturbances have been reported in both anorexia (Urgesi et al., 2014) and BDD (Feusner, Moller, et al., 2010), and have also been linked with BIC even in non-clinical populations (Beilharz et al., 2016; Duncum et al., 2016; Mundy & Sadusky, 2014). Experiment 1 therefore aimed to investigate configural processing mechanisms in adolescents, as this is considered a particularly vulnerable developmental stage for the onset of EDs (Striegel-Moore & Bulik, 2007; Striegel-Moore et al., 2003) and BDD (Bjornsson et al., 2013). As a result, participants were asked to discriminate between upright and inverted body-, face- and house stimuli in a matching-to-sample task whilst RT and accuracy was recorded. Scores on the BICI and SOQ were also assessed.

6.3.1 Method

6.3.1.1 Participants

As a result of email advertisements sent to University of Essex mailing lists and the University of Essex Outreach team, 226 participants (58 male) between the ages of 16 and 23 were recruited from schools and colleges in and around North East Essex. Participation was on a voluntary basis and often during an optional workshop that was included as part of a University of Essex campus visit. Behavioural data failed to record for one participant and seven of those recruited reported an eating disorder (ED) diagnosis. As a result, data from 218 participants (58 male) were analysed. Age data and questionnaire scores have been summarised in Table 6.1 (section 6.3.2.1).

6.3.1.2 Ethical declaration

The study was conducted in line with the 2008 Declaration of Helsinki and approved by the local Ethics Committee for the Psychology Department at the University of Essex.

6.3.1.3 Apparatus and stimuli

6.3.1.3.1 Questionnaires

The Body Image Concern Inventory (BICI; Littleton et al., 2005) is a 19-item self-report measure designed to explicitly assess dysmorphic appearance concern. The questionnaire assesses the level of concern and dissatisfaction with either perceived or exaggerated flaws in appearance, as well as associated behaviours (e.g. camouflaging and checking, reassurance seeking and appearance-related comparisons, Littleton & Breitkopf, 2008; Littleton et al., 2005). Respondents are required to use a 5-point Likert scale (1= ‘never,’ 5 = ‘always’) to indicate, with regards to the last week, how closely they identify with statements such as, ‘I examine flaws in my appearance.’ The measure is scored by summing all items, meaning scores can range from 19 to 95 with higher scores indicative of more dysmorphic concerns. High scores on the BICI may be indicative of BIC in both EDs and BDD as dysmorphic appearance concern is not only the hallmark symptom of BDD (American Psychiatric Association, 2013; Jorgensen, Castle, Roberts, & Groth-Marnat, 2001), but is also prevalent in ED symptomatology (Cororve & Gleaves, 2001; Dingemans et al., 2012; Grant & Phillips, 2004; Hartmann, Greenberg, & Wilhelm, 2013; Hartmann et al., 2015; Jolanta & Tomasz, 2000; Mazzeo, 1999; Rosen & Ramirez, 1998; Ruffolo, Phillips, Menard, Fay, & Weisberg, 2006).

The BICI has been validated multi-ethnically (Littleton & Breitkopf, 2008) and deemed a recommended reliable tool for both clinical practice and research (e.g. Dingemans et al., 2012; Ghadakzadeh, Ghazipour, Khajeddin, Karimian, & Borhani, 2011; Littleton & Breitkopf, 2008; Littleton et al., 2005).

The self-objectification questionnaire (SOQ; Fredrickson et al., 1998; Noll & Fredrickson, 1998) is a 10-item self-report measure based on objectification theory (Fredrickson & Roberts, 1997). The measure is designed to assess the extent to which an individual thinks of their body in terms of what it looks like (observable appearance) rather than in terms of its ability (non-observable competence). Respondents are required to think about their physical self-concept and rank order a list of 10 bodily attributes from 0 (least important) to 9 (most important). Five items relate to bodily appearance. These are physical attractiveness, weight, sex appeal, measurements and muscle tone. The other five items relate to bodily competence. These are strength, health, energy level, physical fitness and physical coordination. A trait ‘self-objectification score’ is obtained by subtracting the sum of the five competence items from the sum of the five appearance items. The difference value obtained, ranging from -25 to +25, represents the relative emphasis given to appearance and competence. A positive score is therefore indicative of more focus on how the body looks over what the body can do, whereas a negative score indicates the reverse (Fredrickson et al., 1998).

The SOQ has been validated against measures of body shame, body dissatisfaction, appearance anxiety, negative affect and neuroticism (Miner-Rubino, Twenge, & Fredrickson, 2002; Noll & Fredrickson, 1998) as well across cultures, life styles, ages and psychiatric illnesses (see Calogero, 2012). It is therefore an appropriate research tool.

6.3.1.3.2 Body, face and house stimuli

The stimulus set was comprised of 10 digital photographs of houses (300 x 340 pixels, 3.5 cm x 4.3 cm) downloaded from the World Wide Web, 10 front-facing digital photographs of bodies (five men) (200 x 350 pixels, 2.5 cm x 4.5

cm) taken from a stimulus set created for use in our lab, and 10 digital photographs of neutral faces (five men) (210 x 330 pixels, 2.5 cm x 4.8 cm) downloaded from the MacBrain NimStim face stimulus set (Tottenham et al., 2009) (available to the scientific community at http://www.macbrain.org/resources.htm see Figure 6.1 for examples). Body stimuli depicted the upper thighs and torso, did not include the head and were clothed in a neutral white vest and briefs so as to minimize cues from clothing that might alter inversion effects (Robbins & Coltheart, 2012). Faces were resized and cropped so that facial features fit into a standard oval. Luminosity was adjusted to control for brightness across all images, and stimuli were presented greyscale on a black background (512 x 384 pixels).

Figure 6.1. Example stimuli controlled for overall image brightness and presented greyscale on a black background. On the left, a neutral, male face, in the middle, a female body and on the right, a house.

6.3.1.4 Procedure

A standardised summary of procedures was explained to participants prior to task completion. Written consent was obtained once the experimenters were sure procedures had been understood, and questionnaires were then administered.

Following this, participants were instructed to complete a delayed matching-to-sample task as in Urgesi et al. (2014). Stimuli were displayed on a black background with screen resolution of 1920 x 1200 pixels (screen size 47.3 cm x 26.8 cm) at approximately 70 cm viewing distance (37° 20' 0.15" visual angle). Each trial started with a central fixation cross presented for 500 ms, followed by a sample stimulus presented centrally for 250 ms (consistent with Minnebusch et al., 2009; Reed et al., 2006; Urgesi et al., 2014; Yovel, Pelc, & Lubetzky, 2010). Image retention was reduced by presenting a mask for 500 ms, which was obtained by shifting each horizontal row of pixels of the sample stimulus by a random amount. Directly after the mask, the two probe stimuli appeared, one left of centre and one right of centre, until a response was given (see Figure 6.2). Participants were asked to respond as quickly and accurately as possible using their dominant hand, by pressing the left or right mouse button in order to indicate which probe matched the sample stimulus.

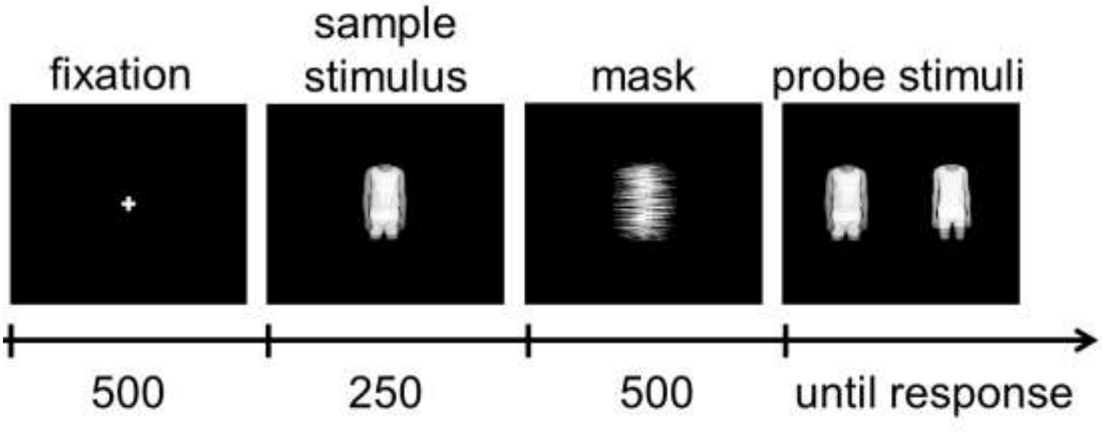

Figure 6.2. Stimulus sequence and timeline (in milliseconds) of one upright body trial. Sequence and timing was the same for all upright and inverted body, face and house trials.

Body, face and house stimuli were presented four times each (twice upright, twice inverted, with the ‘different’ probe altered each time) in discrete, randomised, 40-trial blocks. In each stimulus block, the matching probe appeared on the left for 20 trials (10 upright and 10 inverted) and on the right for 20 trials (10 upright and 10 inverted). Genders were consistent between sample and probe stimuli for both body and face trials, and body, face and house blocks were separated by self-paced breaks. During the break, participants were given a summary of their performance, including the amount of correct trials and an average RT.

Medical history was sought upon task completion and a full debrief was given.

6.3.2 Results

6.3.2.1 Assessing the differences between adolescent boys and girls

Three separate independent sample t-tests were conducted to assess whether boys and girls differed with regards to age, self-objectification and BIC. T-tests are reported unsigned.

Independent sample t-tests revealed that the age of boys and girls in the sample did not differ ($t(216) = .329$, $p = .742$), but that as a group, girls gave a relative emphasis to appearance over competence, whilst boys gave a relative emphasis to competence over appearance ($t(203) = 4.664$, $p < .001$). Additionally, girls reported a higher level of BIC than boys ($t(216) = 7.828$, $p < .001$, see Table 6.1).

Table 6.1

Average age and questionnaire scores of boys (n = 58) and girls (n = 160) in the sample. Four boys and seven girls did not complete the SOQ correctly so their data were discarded for that measure.

	Age (years)	BICI Score	Self-Objectification Score
Girls	17.36 (1.63)	56.35 (13.53)	1.51 (13.15)
Boys	17.26 (2.59)	43.03 (10.07)	-8.13 (12.36)

Note: Standard deviation in parentheses.

6.3.2.2 Behavioural performance

The proportion of correct responses (accuracy) and mean RTs to correct responses were calculated for each stimulus and orientation in each participant (as in Feusner, Moller, et al., 2010; Mundy & Sadusky, 2014; Urgesi et al., 2014). Trials with an RT higher than 5000 ms were identified and discarded (as in Urgesi et al., 2014). Both RTs and accuracy were then averaged across participants and subjected to separate 2 x 3 x 2 between-subjects analysis of variance (ANOVA), with orientation (upright vs. inverted) and stimulus (bodies vs. faces vs. houses) as within-subjects factors and gender (boys vs. girls) as a between-subjects factor. Follow-up comparisons of the estimated marginal means were Bonferroni-corrected and Greenhouse-Geisser adjustments to degrees of freedom were applied where necessary. Where applicable, t-tests are reported unsigned.

6.3.2.2.1 Behavioural performance: RTs

The ANOVA on RTs revealed a main effect of orientation (*F*(1, 216) = 142.532, *p* < .001, η_p^2 = .398) and a main effect of stimulus (*F*(2, 432) = 306.086, *p* < .001, η_p^2 = .586), which was qualified by a significant two-way interaction between them (*F*(2, 432) = 31.547, *p* < .001, η_p^2 = .127). Comparisons of the estimated marginal means revealed that participants were slower to respond to inverted compared to upright faces (*t*(217) = 11.866, *p* <.001), bodies (*t*(217) = 5.228, *p* <.001) and houses (*t*(217) = 3.946, *p* <.001), although such inversion effects were most prominent for faces (mean difference = 174 ms), followed by bodies (mean difference = 75 ms) and least prominent for houses (mean difference = 37 ms, see Figure 6.3). The between-subjects effect of gender was not significant (*F*(1, 216) = .117, *p* = .732, η_p^2 = .001), and did not interact with either of the within-subjects factors (*F*(2, 432) ≤ 1.102, *p* ≥ .331, η_p^2 ≤ .005).

6.3.2.2.2 Behavioural performance: Accuracy

ANOVA on accuracy data (see Figure 6.3) revealed a main effect of orientation (*F*(1, 216) = 109.430, *p* < .001, η_p^2 = .336) and of stimulus (*F*(2, 432) = 102.102, *p* < .001, η_p^2 = .321), which was qualified by a significant two-way interaction between them (*F*(2, 432) = 37.127, *p* < .001, η_p^2 = .147). Pairwise comparisons revealed that participants were more accurate to upright than inverted bodies (*t*(217) = 3.1375, *p* = .008, mean difference = 2.7%) and faces (*t*(217) = 10.600, *p* <.001, mean difference = 10.6%), but accuracy did not differ between upright and inverted houses (*t*(217) = 2.000, *p* = .051, mean difference = 1.2%). The between-subjects effect of gender was significant (*F*(1, 216) = 3.978, *p* = .047, η_p^2 = .018) as girls were more accurate than boys (76.0% vs. 72.1%), but gender did not interact with either of the within-subjects factors (*F*(2, 432) ≤ 1.270, *p* ≥ .281, η_p^2 ≤ .000).

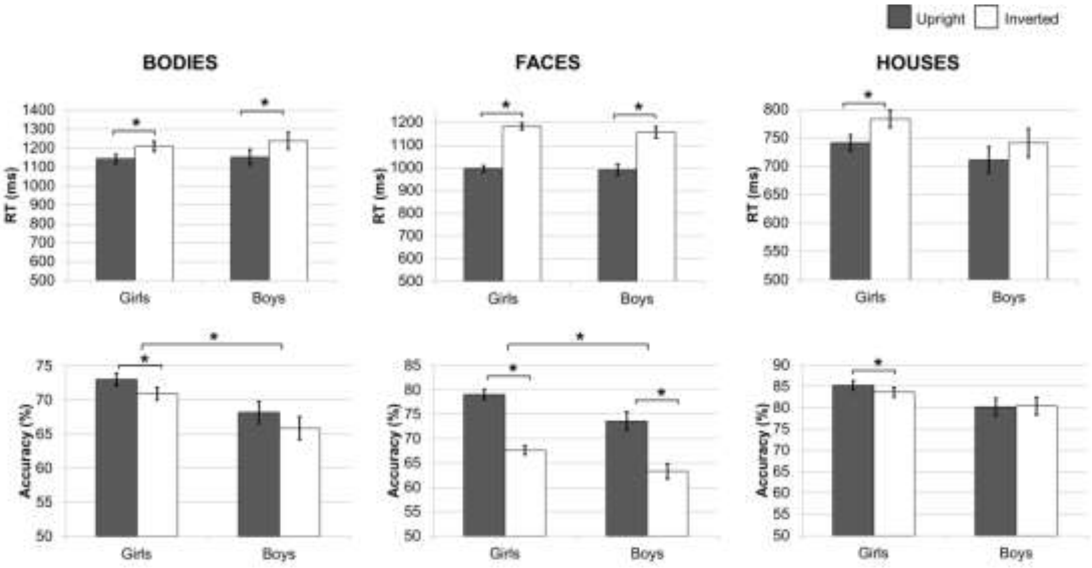

Figure 6.3. Top panel shows RT (ms), bottom panel shows accuracy (%) reported for boys and girls. RT and accuracy to bodies in the left panel, faces in the middle panel and houses in the right panel. Responses to upright stimuli are depicted in grey and responses to inverted stimuli are depicted in white. Error bars depict standard error of the means and asterisks indicate significant pairwise comparisons.

6.3.2.3 Correlational analyses

A Pearson's *r* correlational analysis was conducted in order to assess the association between self-objectification and BIC, as well as to investigate the relationship between each construct and behavioural performance. Therefore, scores on the SOQ and the BICI, as well as RTs and accuracy to both upright and inverted bodies, faces and houses, were entered into the analysis. The false discovery rate method of correction for multiple comparisons (Benjamini & Hochberg, 1995) was applied to correlation results, and results that did not survive correction are not reported. Figures have been colour coded so that male and female participants' data can be identified separately.

SOQ score was moderately and positively related to BICI score, *r*(205) = .411, *p* < .001, such that the more participants self-objectified the more body concerns they had (see Figure 6.4). There were no other relationships to report as neither self-objectification nor BIC relates to RTs or accuracy for upright or inverted stimuli.

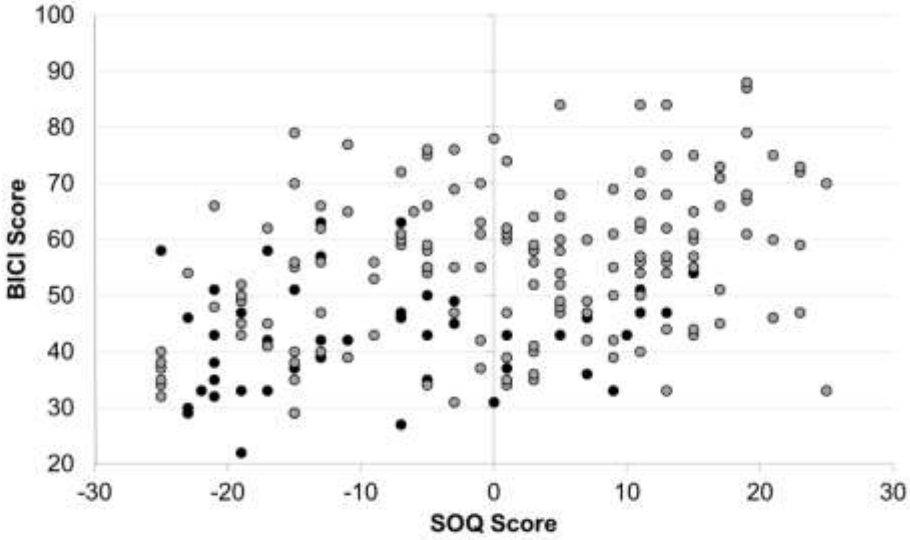

Figure 6.4. Moderate positive relationship between SOQ score and BICI score, *r*(205) = .411, p < .001, with boys' data in black, and girls' data in grey.

6.3.3 Experiment 1: Interim summary of results

As a group, teenage girls gave more relative emphasis to bodily appearance over competence and reported greater levels of BIC than teenage boys. In line with expectations, we also found that self-objectification and BIC were positively related. As expected, inversion effects were observed for faces and bodies in both RTs and accuracy data, meaning participants were less accurate and slower at identifying the correct probe stimulus during inverted trials. Inverting house stimuli also resulted in slower identification of the correct stimulus probe, but did not affect accuracy. These effects were the same for both boys and girls. Inversion effects for bodies or faces did not show a systematic relationship with self-objectification or BIC concern in adolescents, perhaps due to relatively low levels of BIC overall and little evidence of extreme self-objectification.

6.4 Experiment 2: Comparing configural processing in high- and low- risk adolescent girls, and women with EDs/BDD

The aim of Experiment 2 was to assess appearance-related configural processing mechanisms in adolescent girls considered to be at either high- or low- risk of developing disorders characterised by body image disturbance, as well as women who had partially recovered from EDs and/or BDD. Thus, the same matching-to-sample task as in Experiment 1 was completed by women who reported a history of disorders characterised by body image disturbance and performance was compared with a selection of adolescent girls from Experiment 1 who were considered high- or low- risk according to their scores on the BICI and SOQ.

6.4.1 Method

6.4.1.1 Participants

6.4.1.1.1 Body image disturbance (BID) participants

In response to email advertisements sent to University of Essex mailing lists, we recruited 45 women, aged 16 years – 43 years, who had experienced an ED or BDD (see Table 6.2 for diagnostic and treatment information). Weight-restored anorexic participants were sought and similarly, those with other ED/BDD diagnoses were non-clinical at the time of testing. All participants reported a previous medical diagnosis for their condition and the average age of the sample was 22 years (SD: 6 years). A monetary incentive was offered as time reimbursement.

Table 6.2.

Body image disturbance (BID) group diagnostic and treatment information.

	Total	Recovered	Partially recovered	Unrecovered	Medicated	Counselled
AN	22	8	14	0	1	0
BN	9	4	3	2	0	0
BDD	3	0	1	2	0	0
AN & BN	5	1	4	0	1	1
AN & BDD	3	0	3	0	1	0
BN & BDD	1	-	1	-	0	0
AN & EDNOS	1	1	-	-	0	0
BDD & EDNOS	1	1	-	-	0	0

Note. Anorexia Nervosa (AN), Bulimia Nervosa (BN), Body Dysmorphic Disorder (BDD), Eating Disorder Not Otherwise Specified (EDNOS). Treatment referred to was current at time of testing. One anorexic participant was medicated with oestrogen as an aid to induce the menstrual cycle, one participant with co-morbid anorexia and bulimia was medicated to increase potassium levels and aid depression whilst one participant with co-morbid anorexia and BDD was also medicated to aid depression.

6.4.1.1.2 High- and low- risk participants

We selected 45 adolescent girls from Experiment 1 in order to create a ‘high risk’ group that matched the BID group on scores of both self-objectification and body concern; on average, both groups scored within the BICI subclinical range (Littleton et al., 2005). A ‘low risk’ group was created by selecting 45 girls who scored significantly lower than both the high risk and BID group on both the SOQ and the BICI (see Figure 6.5). The average age of the high risk group was 17 years old (SD 2 years), whilst the average age of the low risk group was 18 years old (SD 2 years).

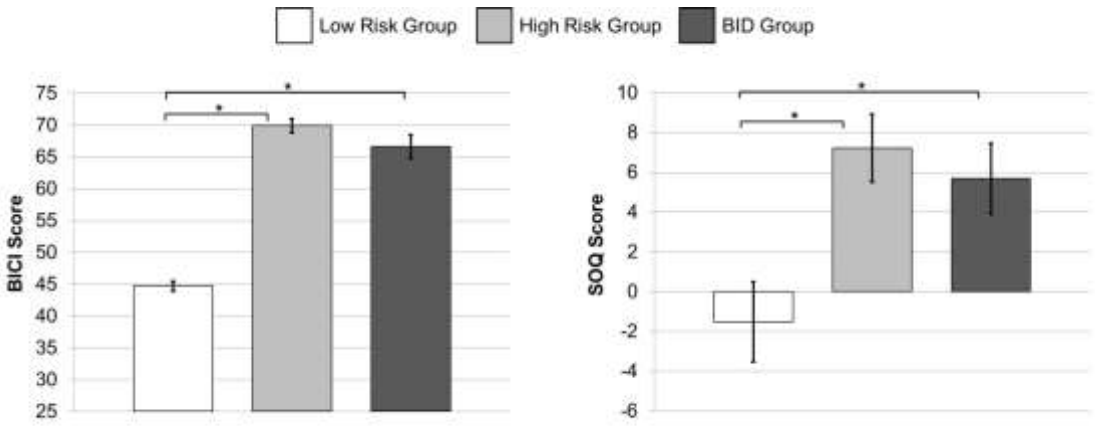

Figure 6.5. Left panel shows BICI scores and right panel shows SOQ scores. The low risk group is depicted in white, the high risk group in light grey and the BID group in dark grey. The high risk group was matched to the BID group for both BICI score ($t(88) = 1.745$, $p = .249$) and SOQ score ($t(88) = .579$, $p = 1.000$). The low risk group scored significantly lower than both the high risk and BID group on the BICI ($t(88) \geq 11.636$, $p < .001$) and the SOQ ($t(88) \geq 2.730$, $p \leq .022$).

6.4.1.2 Ethical declaration

The study was conducted in line with the 2008 Declaration of Helsinki and approved by the local Ethics Committee for the Psychology Department at the University of Essex. We also followed advice from eating disorder charity B-eat, and did not show stimuli that may be potentially triggering (e.g. emaciated or obese bodies).

6.4.1.3 Apparatus and stimuli

Apparatus and stimuli were exactly the same as in Experiment 1.

6.4.1.4 Procedure

The procedure was exactly the same as in Experiment 1, although as BID participants were not recruited as part of campus visits and in order to ensure confidentiality and anonymity, testing was completed individually.

6.4.2 Results

6.4.2.1 Behavioural performance

As in Experiment 1, accuracy and mean RTs to correct responses were calculated for each stimulus category and orientation in each participant. Again, trials with an RT higher than 5000 ms were identified and discarded. Both RT and accuracy data were then subjected to separate 2 x 3 x 3 mixed-subjects ANOVA, with orientation (upright vs. inverted) and stimulus (bodies vs. faces vs. houses) as within-subjects factors and group (low-risk vs. high-risk vs. BID) as a between-subjects factor. Given that configural face- and body-processing is reportedly disturbed in populations with high body image disturbance (Feusner, Moller, et al., 2010; Mundy & Sadusky, 2014; Urgesi et al., 2014), we planned follow-up comparisons for the three-way interaction orientation x stimulus x group. All follow-up comparisons of the estimated marginal means were Bonferroni-corrected and Greenhouse-Geisser adjustments to degrees of freedom were applied where necessary. Where applicable, t-tests are reported unsigned.

6.4.2.1.1 Behavioural performance: RTs

The ANOVA on RTs (see Figure 6.6) revealed a main effect of orientation (*F*(1, 132) = 115.108, *p* < .001, η_p^2 = .466) and of stimulus (*F*(2, 264) = 253.196, *p* < .001, η_p^2 = .657), which was qualified by a significant two-way interaction between them (*F*(2, 264) = 20.706, *p* < .001, η_p^2 = .136). As in Experiment 1, comparisons of the estimated marginal means revealed that participants were slower to respond to inverted compared to upright, faces (*t*(134) = 6.264, *p* <.001), bodies (*t*(134) = 4.008, *p* <.001) and houses (*t*(134) = 5.268, *p* <.001), although as in Experiment 1, inversion effects were most prominent for faces (mean difference = 150 ms), least prominent for houses (mean difference = 43 ms) and bodies fell in between (mean difference = 55 ms). A significant group x stimulus interaction was also found (*F*(4, 264) = 2.969, *p* = .022, η_p^2 = .043). Follow-up comparisons revealed that there were no differences between RTs to bodies and faces in the low risk group (*t*(44) = .969, *p* = 1.000) or BIDs (*t*(44) = 1.182, *p* = .717), but that responses to bodies were significantly slower than to faces in the high risk group (*t*(44) = 4.041, *p* < .001). Orientation did not reliably interact with group (*F*(2, 132) = 2.478, *p* = .088, η_p^2 = .036) and the three-way interaction between orientation, stimulus and group was non-significant (*F*(4, 264) = 1.145, *p* = .335, η_p^2 = .017). However, we were justified to look into this interaction further for three reasons. Most importantly, separate follow-up comparisons for each group were planned a priori. Secondly, three-way interaction effects are not often found due to reduced power (McClelland & Judd, 1993), which makes it difficult to obtain statistical justification for follow-up comparisons even in studies with large sample sizes such as the present one. Finally, (Howell, 2010) argues that significant interactions in the omnibus ANOVA are unnecessary when specific simple effects are predicted by the study's hypothesis (p.372-373). Thus, Bonferroni-corrected follow-up comparisons revealed that whilst inversion effects were present for faces ($t(44) \geq 3.467$, $p \leq .001$) and houses ($t(44) \geq 2.252$, $p \leq .026$) in all groups, despite being close to significance, no inversion effect was evident for bodies in the BID group ($t(44) = 1.964$, $p = .053$). In comparison, inversion effects for bodies were seen in both low risk ($t(44) = 2.934$, $p = .004$) and high risk groups ($t(44) = 2.054$, $p = .042$), although they were reduced in the high risk group.

The between-subjects effect of group was also significant ($F(1, 132) = 8.497$, $p < .001$, $\eta_p^2 = .114$), as the BID group responded faster than both the low risk group ($t(88) = 3.388$, $p =.003$) and the high risk group ($t(88) = 3.728$, $p =.001$), whilst high risk and low risk groups responded similarly ($t(88) = .329$, $p = 1.000$).

6.4.2.1.2 Behavioural performance: Accuracy

ANOVA on accuracy data (see Figure 6.6) revealed a main effect of orientation ($F(1, 132) = 96.024$, $p < .001$, $\eta_p^2 = .421$) and of stimulus ($F(2, 264) = 116.176$, $p < .001$, $\eta_p^2 = .468$), which was qualified by a significant two-way interaction between them ($F(2, 264) = 33.262$, $p < .001$, $\eta_p^2 = .201$). As before, follow-up comparisons revealed that participants were more accurate when responding to upright compared to inverted, faces ($t(134) =$

10.727, *p* <.001), bodies (*t*(134) = 3.000, *p* = .004) and houses (*t*(134) = 2.714, *p* = .005), although again, inversion effects were most prominent for faces (mean difference = 11.8%), least prominent for houses (mean difference = 1.9%) and bodies fell in between (mean difference = 3.0%). The group x stimulus interaction was significant (*F*(4, 264) = 3.499, *p* = .010, η_p^2 = .050), with follow-up comparisons revealing no differences between the groups for face or body stimuli (*t*(88) ≤ 1.556, p ≥ .381), but that BIDs were more accurate in response to house stimuli than both the low risk group (*t*(88) = 2.600, *p* = .033) and the high risk group (*t*(88) = 3.800, *p* = .001). Orientation did not interact with group (*F*(2, 132) = .547, *p* = .580, η_p^2 = .008) and the three-way interaction between orientation, stimulus and group was non-significant (*F*(4, 264) = .603, *p* = .656, η_p^2 = .009). Nevertheless, as argued above, we were justified to look into this interaction. Bonferroni corrected follow-up comparisons revealed that whilst inversion effects were present for faces in all groups (*t*(44) ≥ 5.350, *p* < .001), inversion effects were evident for bodies in the low risk group (*t*(44) = 2.056, *p* = .039) but not in the high risk group (*t*(44) = 1.833, *p* = .061) or in the BID group (*t*(44) = 1.111, *p* = .258). Additionally, inversion effects for houses were not evident in the low risk group (*t*(44) = .091, *p* = .923) but were present for both high risk (*t*(44) = 2.545, *p* = .017) and BID (*t*(44) = 2.727, *p* = .010) groups.

The between-subjects effect of group was also significant (*F*(1, 132) = 3.660, *p* = .028, η_p^2 = .114), as the BID group responded more accurately overall compared to the high risk group (*t*(88) = 2.667, *p* =.024) but not compared to the low risk group (*t*(88) = 1.542, *p* =.352), whilst high risk and low risk groups responded similarly (*t*(88) = 1.083, *p* = .799).

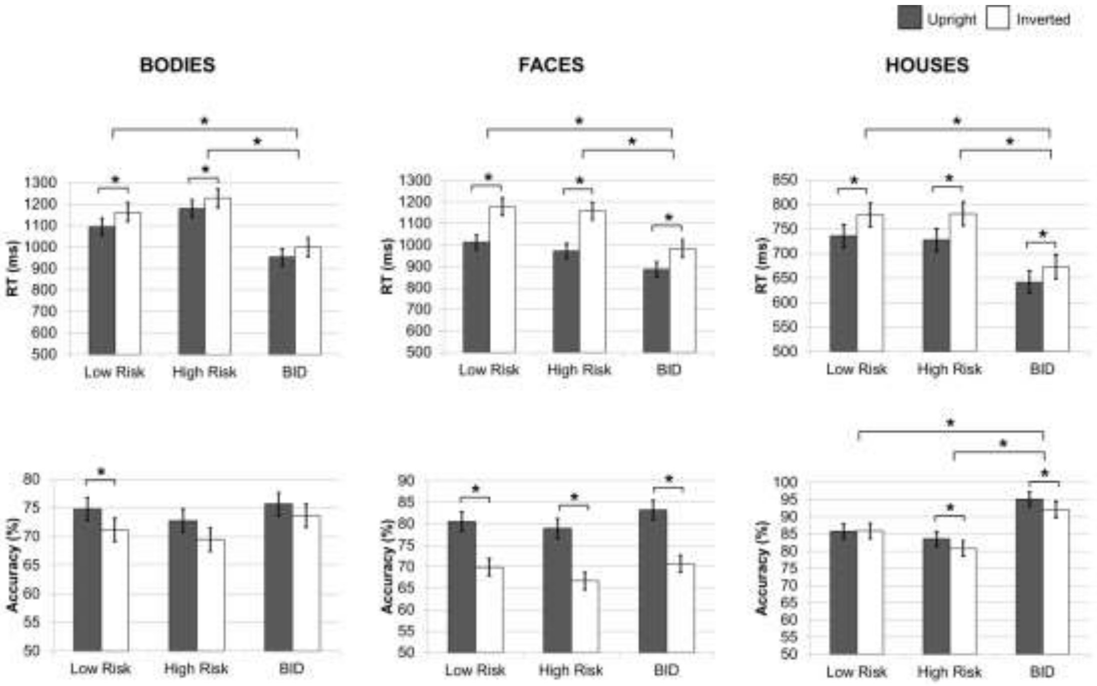

Figure 6.6. Top panel shows RT (ms), bottom panel shows accuracy (%) reported for low risk, high risk and BID groups. RT and accuracy to bodies in the left panel, faces in the middle panel and houses in the right panel. Upright stimuli are depicted in grey and inverted stimuli are depicted in white. Error bars depict standard error and asterisks indicate significant pairwise comparisons.

6.4.2.2 Correlational analyses

As in Experiment 1, a Pearson's *r* correlational analysis was planned in order to assess the relationship between self-objectification and BIC, as well as to investigate associations between the aforementioned constructs and behavioural performance. In line with this, scores on both questionnaires, as well as RT and accuracy data to upright and inverted bodies, faces and houses, were entered into the analysis. The false discovery rate method of correction for multiple comparisons (Benjamini & Hochberg, 1995) was applied, results that did not survive correction are not reported. Figures have been colour coded so that data corresponding to each group can be identified separately.

Findings from Experiment 1 were replicated, as SOQ score was moderately and positively related to BICI score, $r(133) = .374$, $p < .001$ (Figure 6.7) meaning that the more participants self-objectified the more body concerns they reported. No other relationships can be reported as again, self-objectification and body concern did not relate to RTs or accuracy for upright or inverted stimuli.

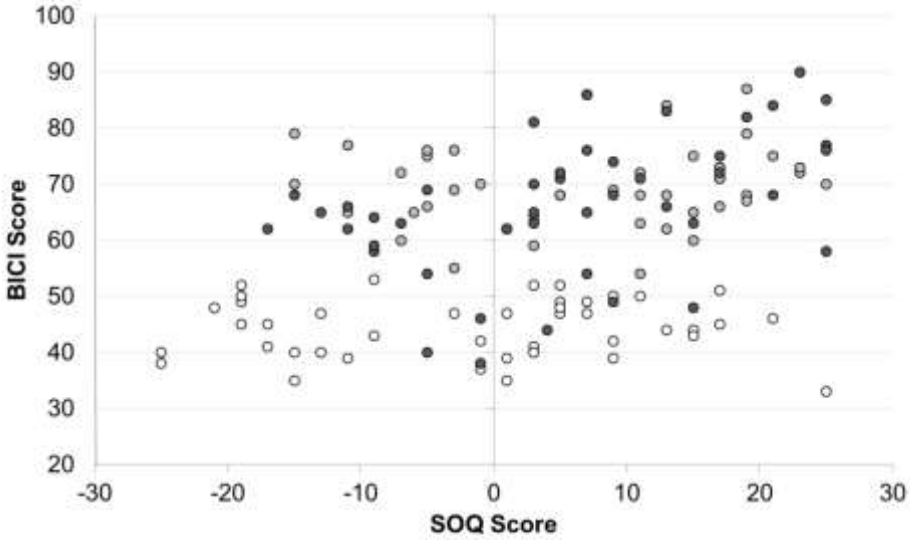

Figure 6.7. Moderate positive relationship between SOQ score and BICI score, *r*(133) = .374, p < .001, with data from the low risk group depicted in white, data from the high risk group depicted in light grey, and data from the BID group depicted in dark grey.

6.4.3 Experiment 2: Interim summary of results

Inverting body stimuli did not disrupt processing for the BID group as they were able to discriminate probe stimuli with the same level of accuracy and within a similar time frame, irrespective of whether bodies were upright or inverted. Similarly, inverting bodies did not affect the accuracy of identifying the correct probe stimulus in the high risk group, although it did increase RT. In comparison, the low risk group displayed typical inversion effects for bodies in both RTs and accuracy. Inversion effects in both RTs and accuracy were seen in all groups for faces and houses. In addition, the BID group were quicker to respond overall and were also more accurate in their responses to houses than both other groups. Participants in the high risk group were generally slower to respond to bodies than those in low risk and BID groups.

Furthermore, as in Experiment 1, BICI score was positively related to SOQ score.

6.5 Discussion

Two studies were conducted in order to investigate whether appearance-related configural processing deficits may precede the potential onset of illnesses characterised by body image disturbance, and/or continue into recovery. In Experiment 1, configural processing mechanisms were investigated in adolescent girls and boys, as adolescence has been identified as a particularly vulnerable time for the development of EDs (Striegel-Moore & Bulik, 2007) and BDD (Bjornsson et al., 2013), and may thus also be an at-risk stage of development for body image disturbances. Moreover, the single most predicative risk factor for the development of body image disturbance is thought to be gender (Striegel-Moore & Bulik, 2007). As a result, we predicted that girls would report higher levels of BIC and a greater extent of self-objectification, which might be associated with altered appearance-related configural processing (Duncum et al., 2016; Mundy & Sadusky, 2014). In Experiment 2, we directly compared high risk adolescent girls (risk defined by high BIC and self-objectification), low risk adolescent girls and women who were partially recovered from EDs and/or BDD. We predicted that appearance-related configural processing might be similar in the high risk and BID group, and that it would differ to the low risk group (Feusner, Moller, et al., 2010; Mundy & Sadusky, 2014; Urgesi et al., 2014).

In Experiment 1, we found higher levels of BIC and greater self-objectification in girls compared to boys, supporting our hypothesis. However, although questionnaire measures were positively related, they were not associated with behavioural performance. Moreover, comparable effects of body- and face- inversion were found between the genders. This suggests that, as a group, both adolescent girls and adolescent boys show typical inversion effects for appearance-related and unrelated stimuli. Furthermore, this suggests that although there is evidence for a slow maturation of configural face processing mechanisms throughout adolescence into adulthood (e.g. Blakemore & Mills, 2014; Mondloch et al., 2002; Steinberg, 2005; Taylor et al., 2001), configural processing of appearance-related stimuli appears to be evident by 17 years of age. In Experiment 2, we found that the BID group showed no inversion effects for body stimuli, as RTs and accuracy were comparable for upright and inverted body discrimination. This group were also significantly quicker to respond overall and were also more accurate when discriminating houses than both the low risk and high risk groups of adolescent girls. Configural body processing also appeared to be disrupted in the high risk group, as there were no inversion effects in the accuracy of discriminating bodies. Moreover, participants in the high risk group were generally slower to respond to bodies than both other groups. This suggests that atypical configural body representation is not only present in women with anorexia (Urgesi et al., 2014) and (subclinical) dysmorphic concern (Mundy & Sadusky, 2014), but extends to both women recovering from disorders marked by body image disturbance and to adolescent girls with high levels of self-objectification and dysmorphic concern. Typical inversion effects were seen for faces and houses in all groups and those in the low risk group also displayed typical BIEs in both RT and accuracy. As in Experiment 1, BIC and self-objectification did not relate to behavioural performance but were positively related to each other.

Given that evidence for configural body processing was found in both adolescent participants, as well as the low risk group, this supports previous findings that suggest headless bodies are processed configurally (e.g. Brandman & Yovel, 2014; Robbins & Coltheart, 2012). As we chose to present greyscale bodies, with neutral and uniform clothing, this supports the idea that a lack of BIE observed in other studies (e.g. Minnebusch et al., 2009) may be due to aspects of the stimuli that encouraged focus on non-body properties, such as clothing (Robbins & Coltheart, 2012). Consequently, studies investigating configural body processing with headless stimuli should consider controlling extraneous factors that might draw attention to non-corporeal details and thus interfere with configural processing mechanisms.

However, as inversion effects were also found for houses, it could be argued that bodies and faces are not processed by distinct visual mechanisms but as a result of expertise (e.g. Husk et al., 2007), especially as this finding is not the first (Eimer, 2000; Husk et al., 2007; Itier, Latinus, & Taylor, 2006; Meeren, Hadjikhani, Ahlfors, Hämäläinen, & de Gelder, 2008; Persike, Meinhardt-Injac, & Meinhardt, 2014; Prince & Heathcote, 2009; Rosburg et al., 2010; Wiese, 2013). We find this unlikely however, as our study design did not encourage expert processing (cf. Husk et al., 2007) whilst both BID group and high risk group in Experiment 2 displayed inversion effects for houses and faces, but not for bodies. Alternatively, houses viewed in the context of faces (e.g. Meeren et al., 2008) might induce face-pareidolia; the illusion of a face-like pattern in a random image (Liu et al., 2014). This is supported by research showing that facial expression is attributable to house facades (Chalup, Hong, & Ostwald, 2010), whilst face-like objects have been shown to elicit similar MEG responses to faces (Hadjikhani, Kveraga, Naik, & Ahlfors, 2009). Moreover, using random-noise stimuli, it has been shown that such illusory perception of a face activates face-specific brain regions (Liu et al., 2014), which are thought to be at least partly responsible for the processes involved with face perception (e.g. Busigny & Rossion, 2010; Eimer & McCarthy, 1999). With that in mind, if houses induce face pareidolia, then perhaps the activation of face-selective brain regions results in houses being somewhat processed like faces (see also Bentin & Golland, 2002). Future research would benefit from investigating pareidolia (as in Liu et al., 2014 for example) with the addition of house stimuli. Thus, it is likely that configural face processing is not best investigated with stimuli that might be perceived as faces (Chalup et al., 2010). Nevertheless, the majority of evidence suggests that bodies and faces recruit functionally specialised visual processing mechanisms that are not employed for houses (e.g. Downing & Peelen, 2016; Haxby et al., 1999; Minnebusch & Daum, 2009; Reed et al., 2003; Reed et al., 2006). As our house inversion effects were greatly reduced in comparison to body and face inversion effects, the current findings support this position.

In both studies, we also found that self-objectification and BIC were linearly related. This is perhaps unsurprising, as body dissatisfaction and self-objectification have both been reported as traits in both EDs (Calogero et al., 2005) and BDD (Lambrou et al., 2011). However, relatively little emphasis is given to the interaction between these two constructs, which may be of interest for diagnosis and treatment. Future research should hence consider BIC in the context of self-objectification in order to further work towards an understanding of ED and BDD aetiology. We will now proceed to discuss specific findings from each study in turn.

6.5.1 Appearance-related configural processing in adolescence

As expected, adolescent girls showed higher BIC and greater emphasis on bodily appearance compared to bodily competence than adolescent boys, which is in line with findings from previous research (e.g. Abbott & Barber, 2010; Furnham, Badmin, & Sneade, 2002; Muth & Cash, 1997). It has been proposed that this difference may occur, at least in part, as a result of the cultural definitions assigned to what a male and female body *should* be; typically, male bodies are thought of as active and agentic, whereas the function of the female body is to be attractive and sexually pleasing (see Smolak, 2004 for review). In our study, not only did girls report higher levels of BIC but they also self-objectified to a greater extent than boys. As we also found that BIC and self-objectification were linearly related, our results therefore support the idea that body dissatisfaction in women might be motivated by the belief that the primary function of a female body is to look good. Additionally, reports show that these culturally defined bodily understandings are propagated by the media, family and peers from a young age (see Smolak, 2004 for review), which in turn affects girls more than boys (Hargreaves & Tiggemann, 2004). Our results suggest that such social messages may have impacted girls' body image differently from boys' by the age of 16, whilst at least one study has shown that girls as young as 6 years old self-objectify to a similar extent to adult women (Jongenelis, Byrne, & Pettigrew, 2014). Having said that, it should be noted that despite the differences between girls and boys, there was essentially no evidence for particularly strong self-objectification in adolescent girls given they scored an average of 1.51 on the SOQ, whilst a score of 25 indicates the most extreme level of self-objectification. Furthermore, there was a clear spread of scores on both the BICI and SOQ (see Figure 6.4, in section 6.3.2.3) with some girls falling within the range of lower scores. Thus, further research should address how and why some adolescent girls seem to be protected from such culturally defined body understandings as self-objectification, whilst others appear to be more susceptible to their influence.

Despite the difference in questionnaire scores found between groups, evidence for appearance-related configural processing mechanisms was comparable between genders, whereas previous research has found altered configural processing in those with higher levels of BIC (e.g. Duncum et al., 2016; Mundy & Sadusky, 2014). It is possible that these differences did not occur in our sample because overall levels of BIC were within the normal range (see Littleton et al., 2005 for clinical cut-off point). This suggests that there may be a threshold of BIC that is to be reached before altered configural processing is evident, which supports Beilharz et al. (2016). With that in mind, our findings suggest that appearance-related configural processing mechanisms present typically during adolescence and as such, it is unlikely that configural processing deficits or local processing biases are underlying factors contributing towards the elevated risk for individuals in this age group in the most general of terms. However, as we found that girls were more self-objectifying than boys, whilst also reporting higher levels of BIC, this may help to explain why girls are at greater risk of developing disorders characterised by body image disturbance (Striegel-Moore & Bulik, 2007). Future research would therefore benefit from addressing when this difference develops and why it does so, in order for early interventions to be instigated that would reduce BIC and encourage all adolescents to focus more on their abilities rather than on their appearance.

6.5.2 Configural body processing is altered in high risk adolescent girls and women recovering from disorders characterised by body image disturbance

Configural body processing was disrupted in the BID group, as inversion effects were not apparent in either RT or accuracy. Unlike other studies (e.g. Beilharz et al., 2016; Feusner, Moller, et al., 2010; Mundy & Sadusky, 2014), the present study also observed evidence for typical configural face processing. It is possible that this difference occurred because a large proportion of the BID group had suffered from EDs, rather than BDD, as evidence suggests that configural body processing is disturbed in women with anorexia (Urgesi et al., 2014; Urgesi et al., 2012), whilst configural face processing is intact in anorexia (Urgesi et al., 2014) but disturbed in those with BDD (e.g. Feusner, Moller, et al., 2010). If this is the case, it suggests that appearance-related configural processing deficits in those with subclinical BIC, as in Mundy and Sadusky (2014) for example, become disorder-specific as an illness progresses. Understanding this is particularly important for determining the aetiology of such illnesses, which is relevant for early interventions and treatment. As a result, future research should seek to assess appearance-related configural processing mechanisms in those specifically ‘at risk’ of EDs or BDD and compare them to distinct ED/BDD groups. Nonetheless, our findings suggest a selective deficit in body-related visual processing in women who are recovering from disorders characterised by body image disturbance and self-objectification. This is in line with research that has previously shown a selective deficit in configural body processing might be characteristic of women with anorexia (Urgesi et al., 2014; Urgesi et al., 2012). Furthermore, it has been suggested that the feature-based analysis of the human body, which predominates when configural representation is disrupted, may underpin, and perhaps help to maintain, fixations with perceived deficits, fat body parts and flaws in appearance that are typically seen in anorexia and BDD (Mundy & Sadusky, 2014; Urgesi et al., 2014). For the first time, we have found that this appears to generalise across eating and body dysmorphic disorders. As research investigating visual processing in EDs other than anorexia is scarce, this finding is of particular importance because it suggests that disturbed appearance-related configural processing should be considered as an underlying mechanism for body image disturbance more generally. This, therefore, has implications for both treatment and recovery.

In addition, we have also shown for the first time, that despite moving into recovery and reporting subclinical levels of BIC on average (see Littleton et al., 2005 for clinical cut-off point), women who have experienced an ED or BDD still appear to visually analyse the body in a piecemeal way. Hence, atypical visual analysis of the human form might be an ongoing symptom of EDs and BDD, which could be of particular interest with regards to treatment and relapse-prevention. For example, if local processing bias contributes to the underlying mechanisms of body image disturbance pathology, then sufferers may benefit from a form of training that promotes configural processing (as has been done for fingerprints, Busey & Vanderkolk, 2005; Greebles, Gauthier & Tarr, 1997; and houses, Husk et al., 2007). As a result, it is possible that focus would shift from perceived flaws or minor defects in appearance due to the body being perceived as a whole. The BID group were also quicker and more accurate at discriminating houses than both other groups. Given that houses are supposedly processed in a feature-based manner, the superior performance of those in the BID group is thus further evidence of local-processing bias. This is further supported as we found that the BID group were generally faster to respond than both other groups (see also Beilharz et al., 2016), although this must be taken with some caution as it is also possible that faster responses in this group were due to greater maturity. Nevertheless, this finding is of particular interest given that Groves, Kennett, and Gillmeister (2017) report rapid neural encoding of visual stimuli in those with an ED compared to controls. It seems therefore, that the differences in RT observed in this study, might mirror the reported electroencephalographic effects. Furthermore, as Groves et al. (2017) suggest that such rapid encoding of visual stimuli might be a potential marker for ED symptomatology, future research should seek to address whether quicker RTs to visual stimuli truly are the behavioural manifestation of this. As a result, it might then be possible to suggest objective markers of ED symptomology in both brain and behaviour.

Another novel and important finding to emerge from this study is that configural body processing was also disrupted in the high risk group. As in previous research, (Duncum et al., 2016; Urgesi et al., 2014), performance differences from inversion were only seen for accuracy data, not for RTs. Similarly, Beilharz et al. (2016) found a correlation between BIC and accuracy rates to inverted stimuli, not RTs. At present, there is little understanding about why accuracy rather than RT might be affected in high BIC populations (see Duncum et al., 2016), especially as other studies have found RT differences between low BIC, high BIC and BDD (Mundy & Sadusky, 2014), sometimes at the expense of accuracy (Feusner, Moller, et al., 2010). Given that our BID group displayed evidence of a configural body processing deficit in RTs, it could be that participants in studies that report RT differences (e.g. Mundy & Sadusky, 2014) are clinical but undiagnosed (a point also argued by Duncum et al., 2016). With that in mind, it seems that configural processing deficits manifest in accuracy before they do so in RTs. Future studies may therefore benefit from addressing why this might be the case.

Nonetheless, contrary to other studies of non-clinical participants with elevated levels of BIC (e.g. Mundy & Sadusky, 2014), we found evidence of typical configural face processing in the high risk group. It is possible that the difference occurred because we also accounted for elevated levels of self-objectification. It has been shown specifically, that self-objectification appears to be linked to body image disturbance in anorexia (see Riva et al., 2015 for review). Perhaps then, elevated levels of self-objectification coupled with high BIC is indicative of those at risk of developing EDs, rather than BDD. This is supported by the observation that the BID group was largely populated by women who had experienced EDs, and they too showed disturbances in the visual processing of only body stimuli. Future research should aim to address this by comparing the extent of self-objectification in EDs and BDD, whilst considering how this relates to body image disturbance. In doing do, it may help to distinctly identify those at risk of EDs and those at risk of BDD.

Participants in the high risk group were also slower to respond to bodies than both other groups. Although not directly tested, this finding could reflect an attentional bias for disorder-relevant stimuli, as for example, Gotlib, Krasnoperova, Yue, and Joormann (2004) found that depressed participants spent more time attending to sad faces. Moreover, Horndasch et al. (2012) found that adolescent girls with EDs showed an attentional bias towards unclothed body parts, proposing that this was a behavioural manifestation of the tendency to over-evaluate the importance of body weight and shape. They proceed to suggest that shifting attentional processes away from body shape may therefore help to alleviate some BIC when idealised media images are viewed. As such, it could be argued that longer RTs to bodies in our high risk group reflect a tendency to over evaluate the importance of body weight and shape in subclinical populations. Such attentional bias may therefore initiate and help to maintain BIC (in the same way that vigilance has been proposed to initiate and maintain anxiety, see Koster, Crombez, Verschuere, & De Houwer, 2004), especially as those who rate their body as unattractive have been found to focus on their own ‘unattractive’ body parts whilst focusing on others’ ‘attractive’ body parts (Roefs et al., 2008) as has been found in EDs (Jansen et al., 2005). This idea of vigilance towards other bodies in those with high BIC and self-objectification is supported by neuroimaging evidence. For example, Vocks et al. (2010) found enhanced limbic activity in anorexic participants compared to controls, as they viewed other women’s bodies. They specifically suggest that this may reflect a stronger emotional response and more vigilance to other women’s bodies. The suggestion to shift attentional processes away from body shape (Horndasch et al., 2012) may therefore be of particular interest for early interventions in adolescent girls who show elevated levels of BIC and self-objectification. As the BID group did not show this effect, this would suggest that such vigilance to other women’s bodies dissipates with recovery.

On the other hand, it has been proposed that longer RTs do not necessarily reflect an attentional bias, but difficulty with disengaging from a stimulus (e.g. Amir, Elias, Klumpp, & Przeworski, 2003; Bindemann, Burton, Hooge, Jenkins, & de Haan, 2005; Fox, Russo, Bowles, & Dutton, 2001; Koster et al., 2004; Koster, De Raedt, Goeleven, Franck, & Crombez, 2005). In particular, it has been proposed that threat stimuli affect attentional dwell time, such that attention is held and participants struggle to locate target stimuli (Fox et al., 2001). Given that longer response latencies were only evident when high risk participants were discriminating body stimuli, this indicates that bodies might have been perceived as a threat. This interpretation is supported by Amir et al. (2003), who found that those with social phobia struggled to disengage attention from socially threatening stimuli (e.g. a social threat word, such as humiliated), which was reflected in longer RTs. Moreover, studies have found that those with EDs rate body stimuli more highly with regards to arousal (Mai et al., 2015) and aversion (Uher et al., 2005).

It is possible that the observation of other bodies promotes a threat response due to social comparison. For example, Corning, Krumm, and Smitham (2006) found that own-body evaluations were more negative in women with ED symptoms during same-sex body comparisons, whilst women without ED symptoms were unaffected. Furthermore, eye-tracking studies have shown bulimic individuals report more body dissatisfaction after comparing their bodies to those of others (Blechert, Nickert, Caffier, & Tuschen-Caffier, 2009). BIC in bulimia has also been linked to social-self concerns (Striegel-Moore, Silberstein, & Rodin, 1993), whilst self-other corporeal comparisons reportedly provoke body-focused anxiety even in asymptomatic populations (Halliwell & Dittmar, 2004). Consequently, similar to the anxiety induced by social threat words in Amir et al. (2003), bodies may induce anxiety in adolescents with elevated levels of BIC and self-objectification. Longer RTs to bodies in the high risk population may therefore be a behavioural manifestation of threat response. Again, as BID participants did not show such an effect, this would suggest that other women’s bodies are not threatening during recovery from a disorder characterised by body image disturbance and self-objectification.

In future, studies should seek to directly address whether these results in subclinical populations reflect an attentional bias towards body stimuli, or difficulty disengaging from body stimuli. This is particularly important in order to understand the underlying mechanisms of the effect, such that early interventions may appropriately address either an over evaluation of body weight and shape, or the perception of a body as a threat. Nonetheless, as there were no differences between response times to bodies and other stimuli in the BID group, this suggests that the underlying mechanism for the effect is likely to be reduced once sufferers begin to recover. Bodies therefore, either no longer pose a threat perhaps because comparison behaviours have reduced, or bodies no longer disproportionately capture attention perhaps because body weight and shape is no longer unduly emphasised. Given that RT to bodies was found to increase alongside BIC in Beilharz et al. (2016), the attentional processes involved with body observation may particularly characterise those who are ‘at risk’ of developing EDs or BDD, rather than those who have suffered from such an illness. The response speed profile to bodies may thus be a useful tool for charting recovery and perhaps even predicting relapse.

Beilharz et al. (2016) proposed that local processing bias might be an objective marker of BIC as accuracy rates for face and body stimuli were positively associated with BIC. We found no such relationships, which appears to put into question Beilharz et al.'s proposal. However, the difference between our findings could be due to the use of different questionnaire measures of dysmorphic concern. Beilharz et al. (2016) measured BIC with the Dysmorphic Concern Questionnaire (DCQ; Mancuso, Knoesen, & Castle, 2010), whilst we used the BICI (Littleton et al., 2005). By comparison, the DCQ is a diagnostic tool used in order to screen for BDD, whilst the BICI claims to address BIC in both EDs and BDD (e.g. Ghadakzadeh et al., 2011; Littleton et al., 2005). It is possible then, that local processing bias might be a marker for BIC in BDD but not in EDs. Further to this, Beilharz et al. (2016) did not apply any correction for multiple comparisons to their correlational results and as relationships between behavioural measures and questionnaire scores were not highly significant, perhaps interpretations are drawn beyond the power of the data. As a result, more work seeking to assess the relationship between BIC and behavioural measures of local processing bias needs to be completed before an objective marker of general BIC can be confirmed.

6.6 Conclusions

Given that configural processing for bodies and faces in adolescent boys and girls was found to be intact and unrelated to self-reported levels of BIC and self-objectification, it is unlikely that a general atypicality to visual processing mechanisms contributes to the increased vulnerability toward developing EDs and BDD that young people experience. However, BIC and self-objectification were found to be higher in girls compared to boys, which may help to explain why being female increases the risk of developing an ED or BDD (Striegel-Moore & Bulik, 2007).

For the first time, we report evidence for a selective deficit in configural body processing in women recovering from disorders characterised by body image disturbance and self-objectification, as typical BIEs (lower and less accurate responses to inverted body stimuli compared to upright) were not observed in the BID group. Given that these women were generally quicker to respond, and also more accurate when discriminating houses, it is likely that a local processing bias underpins the deficit, although it also suggests that such a perceptual bias is not completely specific to illness-relevant stimuli (i.e., bodies) in this population. Adolescent girls in the high risk group also showed selectively deficient configural body processing as their discrimination accuracy was no higher for upright than inverted bodies. Therefore, not only does it seem that feature-based body processing is an ongoing maladaptation evident in women recovering from disorders characterised by high BIC and self-objectification, but that this altered processing style may also be evident in non-clinical individuals with high BIC and self-objectification, who are thus potentially at risk of developing illnesses such as BDD or EDs (Calogero et al., 2005; Lambrou et al., 2011; Strelan & Hargreaves, 2005). Further to this, high risk adolescent girls took longer when discriminating body stimuli, suggestive of attentional differences that may reflect either a threat response to bodies, or an over evaluation of body weight and shape. As such, these findings have direct clinical relevance for identifying at-risk individuals and for monitoring and predicting successful recovery in those already affected. It is important for future research to address the underlying mechanisms associated with attentional differences to body stimuli in at-risk and clinical populations. While this study documented differences at the group level, behavioural performance (inversion effects) did not systematically relate with BIC or self-objectification, however. It is not possible at this time therefore, to conclude that altered visual perception of the human body is a marker for BIC or self-objectification.

6.7 References

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Chapter 7 General Discussion

Body image disturbance, such as that experienced in EDs and BDD, is a multi-sensory distortion to the conscious experience of the body (see Cash, 2004; Cash, 2012). The causes of such distortions remain unclear however, as they are underpinned and maintained by a complex network of interrelated contributions from perception, cognition, affect and behaviour, (e.g. Feusner, Neziroglu, Wilhelm, Mancusi, & Bohon, 2010; Stormer & Thompson, 1996; Striegel-Moore & Bulik, 2007). Nonetheless, as an increasing amount of evidence suggests that the perceptual aspects of body image disturbance (e.g. fixations on ‘fat’ or ‘ugly’ body parts) might be related to maladapted visual processing mechanisms (see Lang, Lopez, Stahl, Tchanturia, & Treasure, 2014; Suchan, Vocks, & Waldorf, 2015b for review), the primary aim of this thesis was to assess the relationship between body image and visual body perception specifically. Ultimately, the intention was to assess potential electroencephalographic and behavioural symptom markers associated with body image disturbance, given that severe psychological distress and reduced psychosocial functioning are common symptoms of EDs and BDD (Harris & Barraclough, 1997), whilst reports show that the highest mortality rate of all psychiatric illnesses occurs in anorexia (e.g. Arcelus, Mitchell, Wales, & Nielsen, 2011; Papadopoulos, Ekbom, Brandt, & Ekselius, 2009; Sullivan, 1995). Thus, a series of studies were designed to investigate appearance-related visual perception and the early cortical signatures of visual body processing in women who had experienced disorders characterised by body image disturbance.

7.1 Summary of findings

The first study in this thesis, presented in Chapter 2, was comprised of two investigations, conducted in order to inform our choice of stimuli in future studies of visual body perception. Specifically, we aimed to determine whether headless bodies evoke affective responses that might confound electrophysiological findings (see Minnebusch & Daum, 2009; Minnebusch, Suchan, & Daum, 2009). Implicit and explicit affective responses to headless body stimuli and bodies with masked faces were therefore assessed using an online rating task (ratings given on the basis of disgust, fear, naturalness, valence and arousal) and a free word association task. We found no differences in responses to bodies without heads and bodies with masked faces; although it seemed female bodies were thought of more positively than male bodies. Given that even contextual cues of the face have been found to elicit face processing mechanisms (e.g. Cox, Meyers, & Sinha, 2004; Morris, Pelphrey, & McCarthy, 2006), we therefore decided that headless bodies were the preferable stimuli for investigating body perception processes. Moreover, we thought it important to consider the gender of the stimulus observed, especially as this has been found to modulate the early temporal dynamics of body perception (Alho, Salminen, Sams, Hietanen, & Nummenmaa, 2015; Hietanen & Nummenmaa, 2011).

In the second study, presented in Chapter 3, the question of ERP reliability and own-body perception was addressed in order to inform the validity of research in the body processing field, whilst addressing whether early components have the potential to be trustworthy neural markers. Thus, the stability of early visual P1, N1 and VPP components, as well as body-sensitive responses, were assessed over a 4-week period during a task that investigated the effects of own- and other-body viewing. An enhanced body-sensitive N1 response was observed during own-body viewing compared to other-body viewing, and we found that amplitude and latency of early visual components and their associated body-sensitive effects were stable. Correlational analyses also suggested that amplitude might be more reliable than latency and specific electrode sites might be more robust indicators of body-selective cortical activity than others. Our findings indicate then, that own-body viewing holds a special status during the structural encoding of the human form and that visual P1, N1 and VPP responses, alongside body-sensitive N1/VPP effects, are robust indications of neuronal activity. As a result, we thought it appropriate for these components to be investigated as potential electrophysiological biomarkers of body image disturbance.

In the third study, presented in Chapter 4, an EEG investigation was conducted in order to assess the relationship between body image and the early temporal dynamics of body-sensitive processing in women with anorexia and bulimia compared to control women. The overarching aim was to identify potential biomarkers of ED symptoms, such as body image disturbance. Visual P1, N1 and VPP components were recorded in response to male- and female bodies, as well as houses, then correlated with responses on the EDI-2 (Garner, 1991) in order to assess the relationship with ED symptomatology. In those with EDs we found evidence for rapid early visual processing as the entire P1-N1 complex unfolded significantly earlier than in controls. In addition, ED participants elicited a gender-sensitive response to other women's bodies over N1 and VPP components, which was not evident in controls. Rapid visual processing and gender-sensitive VPP effects were associated with scores on the EDI-2. We therefore concluded that the temporal dynamics of visual body perception might hold potential as neural markers for the identification of ED symptomatology.

As mentioned in Chapter 1, investigations to assess the temporal dynamics of body-only identity perception have been largely neglected in favour of face identity perception (e.g. Caharel, d'Arripe, Ramon, Jacques, & Rossion, 2009; Jacques, d'Arripe, & Rossion, 2007). Moreover, studies of bodily identity perception typically focus on 'own' body processing or familiar other body processing (see Downing & Peelen, 2011 for review). In addition, research assessing person perception in those with body image disturbance has not addressed unfamiliar-other person perception (see Esposito, Cieri, Giannantonio, & Tartaro, 2016; Kaplan, Rossell, Enticott, & Castle, 2013 for reviews). As a consequence, the fourth study, presented in Chapter 5, aimed to delineate the cortical signatures of body-only, unfamiliar other-person perception and assess whether these processes were atypical in women with body image disturbance (BID group). Participants were therefore required to discriminate between upright and inverted male and female bodies, which were shown from both the same and different view (front or back), during an ERP adaptation paradigm. Occipito-parietal (P1, N1 and N250) and fronto-central (VPP) processing of body stimuli was assessed and effects were observed rapidly over P1. In contrast to what was expected (e.g. Alho et al., 2015; Mai et al., 2015; Minnebusch et al., 2009; Thierry et al., 2006) a reversal of effects was evident within the N1 time range, reflective of a return to baseline after the P1 response. VPP responses were not evident. Inversion effects (enhanced and delayed amplitudes in response to inverted as compared to upright bodies) and gender-sensitivity (enhanced and delayed amplitudes in response to female as compared to male bodies) were thus found over P1, irrespective of viewpoint. Adaptation effects (enhanced P1 amplitude to same as compared to different bodies), taken as evidence for rapid identity perception (e.g. Caharel et al., 2009; Jacques et al., 2007), were only seen when the test body was shown from the same view as the adapting body. Results were therefore indicative of a rapid configural representation of the human form irrespective of viewpoint. As early stages of identity perception were viewpoint dependent however, this suggests that person perception is not solely based on information gleaned from the outer contours of the body, but also depends on internal features that differ between front and back. A three-dimensional body representation does not appear to be evident until later stages of processing.

As discussed in Chapter 5, the point at which adaptation effects are observed for upright but not inverted stimuli, is thought to be the point in time at which inversion disrupts identity processing (e.g. Jacques et al., 2007). In keeping with that, we also found that gender-specific body-only person perception differed between women who had experienced disorders characterised by body image disturbance and controls. Specifically, both groups showed evidence of encoding male body identity over P1 only when bodies were upright. However, this encoding was right-lateralised in controls, and was bilateral in BIDs. In comparison, female identity perception was widespread and tolerant to orientation in controls. In BIDs however, the processing of female body identity appeared to be restricted to the right hemisphere. Consequently, findings from this study provide further indication of ongoing atypical representations of the human body in women who have experienced disorders characterised by body image disturbance.

In the fifth and final study, presented in Chapter 6, two experiments were conducted in order to directly address whether disrupted appearance-related configural processing (e.g. Beilharz, Atkins, Duncum, & Mundy, 2016; Mundy & Sadusky, 2014; Urgesi et al., 2014) is present in those ‘at risk’ of developing disorders characterised by body image disturbance and/or remain as ongoing symptoms during recovery. In the first experiment, a matching-to-sample task that included inverted stimuli was employed in order to assess the visual processing mechanisms associated with body, face and house viewing in adolescents. This was done as adolescence is thought to be a vulnerable period with regards to the onset of EDs (Striegel-Moore & Bulik, 2007; Striegel-Moore et al., 2003) and BDD (Bjornsson et al., 2013). Body image concern (BIC) was assessed by the Body Image Concern Inventory (BICI; Littleton, Axsom, & Pury, 2005) and self-objectification was measured using the self-objectification questionnaire (SOQ; Fredrickson, Roberts, Noll, Quinn, & Twenge, 1998). Evidence for typical configural face- and body-processing was found, although adolescent girls reported higher levels of BIC and self-objectified more than adolescent boys. Having said that, it should be noted that levels of self-objectification in the girls varied and as a group, whilst their average score was not indicative of particularly strong self-objectification (score of 1.51, with maximum possible score being 25). In Experiment 2, RTs and accuracy were again recorded during the same matching-to-sample task whereby upright and inverted face, body and house stimuli were presented to high risk teenagers, low risk teenagers and women who had experienced EDs and BDD (BID group). Risk was determined on the basis of BIC and self-objectification with those who were high risk matched to the BID group and those who were low risk scoring significantly lower than those in the high risk and BID groups. Here, we found evidence for disrupted configural body processing in women recovering from EDs/BDD as well as in high risk adolescents. In contrast, typical body inversion effects were seen in the low risk group. The BID group were also generally quicker to respond, whilst high risk girls took longer to respond to bodies than both other groups. Configural face processing appeared typical in all groups and altered body processing effects did not systematically relate to BIC or self-objectification. With direct clinical implications, especially for early interventions and treatment, we concluded that the pattern of results from both experiments suggest that appearance-related visual processing mechanisms are typical (adult-like) during developmental periods vulnerable for the onset of EDs and BDD. At the same time, a predominance of feature-based processing of the human form may be present specifically in ‘at risk’ adolescent girls, in EDs/BDD and also continue into post- recovery stages.

The next sections will continue to discuss the present thesis' main progressions in our understanding of visual body processing, as well as visual body processing in those who have experienced disorders such as BDD and EDs.

7.2 Main progressions in our understanding of visual body perception

7.2.1 Evidence for configural body processing when stimuli are presented headless

Previous research has proposed that bodies presented without the head are perceived on the basis of their features rather than as a configural whole because inversion effects are sometimes absent (e.g. Minnebusch et al., 2009; Yovel, Pelc, & Lubetzky, 2010) or in the case of ERPs, reversed (e.g. Minnebusch et al., 2009). In line with this, it has been argued that headless body stimuli do not match stored templates of the body because a key element of the template is missing (Minnebusch et al., 2009). This is a clear concern for the field of visual body perception as it implies that headless body stimuli are substandard for investigating both the behavioural and neural mechanisms that underpin body processing. However, as previously mentioned, presenting bodies with the head intact might elicit face processing mechanisms (e.g. Cox et al., 2004; Morris et al., 2006). As a result, it has been suggested that the presence of the head mediates observed effects of configural body processing (e.g. Reed, Stone, Bozova, & Tanaka, 2003) due to the activation of specialist brain regions dedicated to the visual analysis of human faces (e.g. Brandman & Yovel, 2010).

Counter to this position, behavioural evidence suggests that altered or absent body inversion effects might be due to fixation on non-body aspects of the stimuli such as clothing, rather than the body itself (Robbins & Coltheart, 2012). However, this had not been investigated in ERPs. Findings from our investigations, presented in Chapters 5 and 6, support the idea that non-body aspects of the stimulus might have been responsible for altered configural body processing effects in other studies (e.g. Minnebusch et al., 2009; Yovel et al., 2010). Using neutrally clothed (e.g. no embellishments, logos, designs or colour variation), emotionally neutral stimuli, we observed electrophysiological and behavioural inversion effects for headless bodies when stimuli were presented in an adaptation paradigm that required sequential discrimination (similar to the sequential discrimination required to complete the task in Minnebusch et al., 2009) and in a matching-to-sample task. As the same style of headless body stimuli were presented in each task, which included neutral, uniform clothing and no unique defining features (e.g. jewellery or tattoos), this suggests that configural body processing is consistent across task demands when stimuli do not encourage a focus on non-body features. Nonetheless, evident from our findings in Chapter 6, configural body processing appears to be less prominent than configural face processing. It is likely that this is because bodies do not have such a strong canonical representation as faces. For example, we see our own bodies as almost inverted when gazing down, and it is not uncommon to see other bodies from different orientations such as when swimming, dancing or sleeping. In addition, it has been proposed that configural body representations develop later than configural face representations (Slaughter, Heron-Delaney, & Christie, 2011). Thus, whilst stored templates may represent first-order information for bodies (e.g. two arms attached to a torso, above two legs) this might not be as deeply encoded as it is for faces given the different orientations bodies are often observed from, as well as the difference in developmental trajectory. Nonetheless, one of the main findings from the series of investigations presented in this thesis is that headless bodies do appear to recruit configural processing mechanisms, which are evident not only in behaviour but also within the early temporal dynamics of human body perception (supporting Minnebusch, Keune, Suchan, & Daum, 2010; Soria Bauser & Suchan, 2013). Future studies should carefully consider controlling extraneous factors such as clothing, jewellery and tattoos for example, when compiling headless body stimuli, especially if investigating configural processing mechanisms.

7.2.2 Evidence for gender-sensitive body processing in ERPs, and the potential predominance of feature-based processing of the female form

Previous research has suggested that the gender of the body observed modulates the early temporal signatures of body perception (Alho et al., 2015; Hietanen & Nummenmaa, 2011). Consistently throughout this thesis, we provide evidence to support this as our findings suggest that the gender of the body should be considered when investigating the temporal dynamics of visual body perception. Specifically, in Chapter 2, female bodies were rated more positively than male bodies. Given that top-down processing has been shown to affect the speed and magnitude of neuronal processing (Gazzaley, Cooney, McEvoy, Knight, & D'Esposito, 2005; Hillyard & Anllo-Vento, 1998), differences between observing male and female bodies is likely an important consideration for electrophysiological investigations. Furthermore, in Chapter 4, those with EDs elicited N1/VPP amplitudes enhanced to the female from, whilst in Chapter 5 all participants elicited similar gender-sensitive P1 effects. Identity perception also appeared to be lateralised according to the gender of the body observed (although BIDs seemed to encode configural male body identity bilaterally). Assessing gender modulations on early electrophysiological responses therefore seems to be especially important when participants have a history of EDs/BDD, given that some gender ERP effects were different between those with body image disturbance and controls in both Chapter 4 and Chapter 5. This suggests that whilst our findings support previous research (e.g. Alho et al., 2015; Hietanen & Nummenmaa, 2011), they do not support the interpretation that early neural gender-sensitivity reflects mechanisms for mate choice and sexual behaviour. Instead, it is likely that an enhancement of N1/VPP amplitudes in response to female compared to male bodies might be a potential biomarker of ED symptomatology in women, especially as gender-sensitivity in VPP amplitudes was positively associated with scores on EDI-2 (Garner, 1991). This will be discussed further in the next section.

Findings from Chapters 4 and 5 also suggest that women's bodies might be perceived more on the basis of individual features rather than a configural whole, given that the gender-sensitive effects observed present similarly to inversion effects, for which featural processing is assumed. In particular, gender-sensitivity in Chapter 5 was elicited as an enhanced and delayed P1 response to female as compared to male bodies. Moreover, controls in this study appeared to encode female body identity primarily on the basis of features, as adaptation effects were evident to both upright and inverted female bodies, but only to upright male bodies. Given that reports suggest Western societal norms encourage the objectification of female bodies (Fredrickson & Roberts, 1997; Jones, 2001; Miner-Rubino, Twenge, & Fredrickson, 2002), it is possible that these top-down processes are influencing the earliest stages of visual body perception. This might account for the occasional inconsistencies in findings between studies (e.g. Meeren, Hadjikhani, Ahlfors, Hämäläinen, & de Gelder, 2008; Minnebusch et al., 2009) and is even more reason to consider the gender of the body when conducting research in the field of body processing.

7.2.3 Evidence for body-only identity processing within the early stages of visual body perception

Previous research addressing body-only identity processing has largely focused on neural activation, whilst somewhat neglecting the temporal dynamics of these processes (Downing & Peelen, 2011). In particular, the early temporal signatures of own-body processing and unfamiliar other body processing have not been investigated. Chapters 3 and 5 of this thesis aimed to explore this gap in the literature and in both studies, evidence for early, if not rapid, identity processing was found. Specifically, findings from Chapter 3 indicate that own-body processing holds a special status within the early stages of visual analysis, as body-sensitive N1 responses were enhanced during own-body viewing irrespective of whether the whole body or parts of the body were viewed. In Chapter 5, P1 adaptation revealed that identity processing was somewhat lateralised according to gender and strongly view-dependent. Previously, it has been argued that explicit identity processing does not occur in occipito-temporal cortex but that only body shape is recognised (Downing & Peelen, 2011). As adaptation was not evident when bodies were seen from different viewpoints in Chapter 5, this suggests that information other than that which can be gleaned from the outer contours of the body was needed in order for an individual person to be recognised. Thus, our investigations indicate that unique features, which would be unavailable when viewpoint alters, might account for the identity effects evident in early occipito-temporal neural activity. We therefore propose that top-down processes such as identity perception are evident within the early stages of visual body perception.

7.3 Main progressions in our understanding of visual body perception in disorders characterised by body image disturbance

First and foremost, it is important to acknowledge that the majority of literature which has addressed visual body processing in EDs has done so with anorexic participants (e.g. Suchan, Vocks, & Waldorf, 2015a). For the first time, the series of investigations presented in this thesis show that disturbances to visual body processing are not reserved for anorexia. Instead, we have shown that atypical visual body processing seems to occur in a heterogeneous sample of individuals who have suffered from EDs and BDD, but who share the core pathology of body image disturbance. As a result, our findings could be taken as support for the idea that EDs and BDD might be better understood as interrelated body image disorders (Cororve & Gleaves, 2001; Mitchison, Crino, & Hay, 2013). Furthermore, this suggests that alterations of perceptual mechanisms and maladaptation to visual body processing might not be due to the effects of malnourishment that occur alongside starvation. Importantly, our pattern of results also highlight that it is necessary and beneficial to study the links between body image disturbance and visual body perception in understudied EDs, such as bulimia for example. With that in mind, we feel that this thesis makes three major contributions to the understanding of visual body processing in disorders characterised by body image disturbance. These include the possibility of an early P1-N1 complex and gender-sensitive VPP amplitudes as potential biomarkers of ED symptomatology, the consistent finding that visual analysis of the female form might specifically be atypical, and also that configural body processing is disrupted in those at risk of disorders characterised by body image disturbance, including those in recovery. The remainder of this section will reflect on these findings in turn.

7.3.1 Early P1-N1 complex might be potential biomarker of ED symptomatology

In Chapter 4, latency differences were found between ED participants and controls as the entire P1-N1 complex was observed significantly earlier. As this effect was related to three EDI-2 subscales, including drive for thinness, interoceptive awareness and impulse regulation, we concluded that this might be a potential biomarker of ED symptomatology. However, in Chapter 5, such latency differences were not observed between BIDs and controls.

In Chapter 4, we discuss the possibility of heightened arousal due to the random presentation of stimuli as an alternative explanation for latency differences and argue that employing a blocked design might help to address this as a potential mechanism for the effect. Given that bodies were the only stimuli presented in Chapter 5 and latency effects were not observed, it might therefore be argued that participants in Chapter 4 were indeed subject to a heightened state of attention and/or arousal waiting for the presentation of salient body stimuli amongst images of houses and animals. It is possible then, although somewhat unlikely, that those scoring more highly on the drive for thinness, interoceptive awareness and impulse regulation subscales were more susceptible to the effects of attention and/or arousal. In other words, the relationship between the latency shift and EDI-2 might be mediated by attention and/or arousal.

However, task demands differed substantially between studies, especially as participants in Chapter 4 were required to passively view bodies whilst those in Chapter 5 were engaged in active encoding of stimulus identities. Similarly, results from Chapter 5 showed that body-related effects expected within the N1 time range were observed early in P1 responses. As discussed within that chapter, low level visual differences as a consequence of the vertical asymmetries caused by inverting body stimuli might have resulted in early effects (e.g. Itier & Taylor, 2004). Subsequently, as differences between the tasks and affected components were quite substantial, this makes a comparison between findings from these studies difficult. As a result, we cannot conclude at this time, that the latency effects observed in Chapter 4 were due to a heightened state of attention or arousal. Furthermore, and perhaps most importantly, the participants themselves differed substantially as those in Chapter 4 suffered from either anorexia or bulimia, whilst those in Chapter 5 suffered from numerous conditions characterised by body image disturbance. It is quite possible then, that atypically rapid visual processing occurs in pure anorexia and bulimia, but not in other body image disorders.

Interestingly however, the BID group in Chapter 6 were found to respond significantly earlier to all stimuli, compared to both high- and low- risk adolescents. It appears then, that ERP findings in Chapter 4 were somewhat mirrored in the behavioural findings of Chapter 6. As participants in Chapter 6 were drawn from a population that reported several ED diagnoses, as well as BDD, this suggests that the rapid neural encoding of visual stimuli found in Chapter 4 might also be evident in those who have experienced disorders other than pure anorexia and pure bulimia. Future research should therefore investigate whether the rapid P1-N1 complex observed in those with EDs manifests as quicker RTs to visual stimuli. As a result, it might then be possible to suggest objective markers of ED symptomology in both brain and behaviour.

Such behavioural group differences were not found in Chapter 5 however. This further suggests that differences in sample characteristics might account for the differences between findings as more of the participants in Chapter 5 were recovered compared to those in Chapter 4 and Chapter 6. Given that latency shifts observed in Chapter 4 were positively associated with some subscales of the EDI-2, it is possible that such latency effects were not observed due to recovery. Further to this, the same stimuli were not shown in Chapters 4 and 5, and although stimuli always adhered to the guidelines provided by B-eat so as not to present potentially triggering images, bodies presented in Chapter 5 were less like bodies that would be viewed in everyday situations. It is possible that this might contribute to the timing differences evident in ERP responses.

It is therefore clear that further investigations with comparable protocol and comparable participants, but with blocked designs, are required in order to determine the underlying mechanisms of the latency shifts evident in Chapter 4. This is important in order to define whether rapid visual processing, as indexed by the P1-N1 complex, can be considered a reliable biomarker of ED symptomatology. It might also be wise to include measures on a diagnostic tool, such as EDI-2, as although BICI and SOQ revealed group differences, they did not systematically relate to any behavioural or electrophysiological effects in Chapter 5 or 6. Nonetheless, the evidence provided in this thesis currently suggests that these latency shifts are systematically associated with ED symptomatology, including at least one aspect of body image disturbance (drive for thinness).

7.3.2 Women who have experienced EDs/BDD show not only atypical body perception but atypical visual analysis of the female body form

As discussed in several chapters of this thesis, previous findings have indicated that maladapted visual processing mechanisms might be related to the perceptual aspects (i.e. distortion to the way the body looks or feels) of body image disturbance (see Lang et al., 2014; Madsen, Bohon, & Feusner, 2013; Suchan et al., 2015b for review) . Further to this, reduced connectivity has been reported between functional brain regions selective for the visual analysis of the human body in women with anorexia (Suchan et al., 2013), whilst EBA has been found to be underactive (Uher et al., 2005) and maladapted (Suchan et al., 2010) in such women. Findings from the investigations presented in this thesis support such literature, as visual body processing in both ERPs and behaviour was found to present atypically in women with EDs, whilst body-only identity perception seems to be atypical in women who have experienced disorders characterised by body image disturbance. Further to this, throughout this thesis we have demonstrated that ED and BID participants elicit different gender-sensitive electrophysiological responses in comparison to controls. Specifically, in Chapter 5, the encoding of female body identity was widespread and tolerant to orientation in controls whilst such processing appeared to be restricted to the right-hemisphere in those recovering from disorders characterised by body image disturbance. This conspicuously absent left occipito-temporal encoding of female body identity in the BID group is of particular interest given that reduced connectivity between left EBA and FBA have been directly linked to body image disturbance in anorexia (Suchan et al., 2013). Moreover, findings from Chapter 4 indicate that gender-sensitive VPP amplitudes are potential biomarkers of ED symptoms in women, suggesting that the female form might hold a particularly salient status during the structural encoding of human bodies in these populations. This is in keeping with previous reports that claim differences between electrophysiological responses in EDs and controls when disorder-specific stimuli, such as overweight bodies, are viewed (Mai et al., 2015).

Furthermore, it is argued in Chapter 4 that those with an ED such as anorexia or bulimia might encode female bodies on the basis of their features due to objectification. This was thought given that the difference in gender-sensitive N1 responses to male and female bodies somewhat mirrored body-sensitive N1 inversion effects (larger amplitudes to inverted as compared to upright stimuli). Thus, we hypothesised that female body viewing might induce a switch from configural processing mechanisms to feature based processing mechanisms as inverted bodies appear to do in comparison to upright. This hypothesis was supported by findings in Chapter 5 as gender-sensitive effects mirrored inversion effects such that like inverted body viewing, female body viewing elicited enhanced and delayed P1 amplitudes irrespective of viewpoint. It is therefore possible that women's bodies might be processed in an objectified manner compared to male bodies, which is in line with claims that Western societal norms encourage the sexual objectification of female bodies (e.g. Heflick & Goldenberg, 2014; Miner-Rubino et al., 2002).

However, unlike in Chapter 4, in Chapter 5 such gender-sensitivity was evident in both the BID group and controls. There are several possible reasons for this difference. For example, given that upright and inverted stimuli were presented as part of the task in Chapter 5 but not in Chapter 4, this might have primed switching between processing mechanisms, perhaps encouraging and enhancing any underlying inclination to analyse female bodies according to features in the control group. A second explanation might relate to the differences between participants in each sample, in particular, more participants in the BID sample in Chapter 5 reported a full recovery than those in the ED sample in Chapter 4. Hence, the lack of group differences with regards to ERP gender-sensitivity might reflect 'training' in body recognition (as has been shown for 'Greebles', Gauthier & Tarr, 1997; and houses, Husk, Bennett, & Sekuler, 2007) that results in a level of expertise for all bodies that mirrors that of controls, which might still include some objectification of the female form. Moreover, the specific gender-sensitive effects observed for the ED group in Chapter 4 could be evident only in anorexia and/or bulimia, but not in those individuals who have received multiple ED diagnoses within their lifetime. In order to assess the relevance of such explanations, it might be of interest to repeat the study in Chapter 5 with the inclusion of measures that specifically assess the extent to which other female bodies are objectified, as well the EDI-2 and a diagnostic tool for BDD. Nevertheless, irrespective of the slight difference in findings between the studies presented in chapters four and five, a fitting conclusion appears to be that female bodies in particular, give rise to altered electrophysiological processes compared to controls. Moreover, early atypical visual ERP responses to the female form may serve as potential biomarkers for ED symptomatology as measured by the EDI-2.

7.3.3 Configural body processing is disturbed in women who have experienced EDs and/or BDD in the past and in those ‘at risk’ of developing disorders characterised by body image disturbance

Previous research has found that those with a clinical diagnosis of anorexia (e.g. Urgesi et al., 2014; Urgesi et al., 2012) and BDD (e.g. Feusner, Moller, et al., 2010), as well as those with clinically high levels of BIC (e.g. Beilharz et al., 2016; Mundy & Sadusky, 2014), show reduced levels of appearance-related configural processing. In other words, it seems that bodies and faces are processed predominantly according to their features rather than as a configural whole. In contrast, at least one other study has found that configural body processing appears to be increased in those with subclinical levels of BIC (e.g. Duncum, Atkins, Beilharz, & Mundy, 2016). Findings from the studies presented in this thesis support and extend this literature.

Particularly, in Chapter 6, we found behavioural evidence to suggest that women recovering from disorders characterised by body image disturbance do not process the human body configurally, as inversion effects were not apparent in RT data or accuracy. In addition, we found that adolescent girls matched to the BID group on the basis of BIC and self-objectification did not show accuracy inversion effects in response to body stimuli. It therefore appears that configural body processing disturbances are not only present in those ‘at risk’ of developing disorders characterised by body image disturbance (e.g. Mundy & Sadusky, 2014), but also in those who are recovering. However, evidence for disturbed configural processing in behavioural performance (i.e. reduced or absent inversion effects, perhaps specifically for body stimuli) was not found in the BID group data presented in Chapter 5. In general, BID participants in Chapter 5 were reportedly further along in their recovery than BID participants in Chapter 6. Thus, further to the argument outlined in section 7.3.1 above, this supports the idea that sample characteristics might explain the differences in atypical configural processing across studies. This is perhaps unsurprising as Beilharz et al. (2016) propose local processing bias as a marker of BDD. Accordingly, disturbances in configural processing might transition from a deficit to an advantage (i.e. reflecting poor configural processing, to enhanced configural processing) and perhaps vice versa according to levels of risk and recovery. Accordingly, this suggests that these processes are perhaps somewhat malleable in those who have experienced body image disturbance, a notion supported by research that also suggests body ownership plasticity in these populations (Eshkevari, Rieger, Longo, Haggard, & Treasure, 2012; Mussap & Salton, 2006).

Alternatively, timing of stimulus presentation might be responsible for the difference in findings. For example, Feusner, Moller, et al. (2010) found that behavioural inversion effects to faces were reduced in BDD participants compared to controls when stimuli were shown for long duration (5000 ms) but not when they were shown for a short duration (500 ms). However, the differences we observed for body stimuli occurred in the opposite direction to those observed for faces in Feusner, Moller, et al. (2010). In Chapter 5, where inversion effects did not differ between BIDs and controls, stimuli were presented for 3000 ms. In contrast, stimuli were shown for 250 ms in Chapter 6, whereby BID participants did not show inversion effects to bodies. Irrespective of the precise direction, this highlights that it is possible for the duration of stimulus presentation to alter effects, which should be considered in future studies. The opposite direction of differences might be understood on the basis that inversion effects to faces were typical in BID participants in both of our studies, and that the majority of our participants were recovering from various EDs not BDD (unlike in Feusner, Moller, et al., 2010, whereby clinical BDD participants were tested). It is therefore possible that when stimuli are shown for longer durations, such as 3000 ms, this allows time for configural processing mechanisms to perhaps replace the initial tendency to process by features, which cannot occur when stimuli are only shown for 250 ms. This might be especially true for those further along in recovery.

Despite the differences between findings, on the basis of the evidence revealed as a result of the studies presented within this thesis, it is fair to say that configural body processing is atypical in those who have experienced a disorder characterised by body image disturbance and self-objectification. The underlying mechanisms relating to how and exactly when these differences develop, as well as why these processes might alter according to levels of risk and recovery, are questions that remain to be answered by future research.

7.4 Limitations

Neuroscientific research can be a challenging task that is not without limitations, especially when studying specialist populations. The interpretation of the findings presented in this thesis must therefore take into account some limitations.

Recruiting and studying visual body perception in men who had experienced disorders characterised by body image disorders was beyond the scope of this thesis. Whilst this does not invalidate or diminish the findings, perhaps one of the most obvious limitations is that it might not be possible to generalise the interpretation of findings beyond ED/BID symptomatology in women. This is because as mentioned in the introduction, although rates of BIC are thought to be comparable between men and women (e.g. Dakanalis & Riva, 2013; Woodside et al., 2001), aetiology and presentation is thought to be qualitatively different (Dakanalis & Riva, 2013). With that in mind, questionnaire measures of symptomatology are often criticised for not capturing BIC (e.g. Dakanalis & Riva, 2013) or objectification (e.g. Daniel & Bridges, 2010) adequately in men. Given that we did not explicitly consider whether our measures were suitable for assessing symptomatology in men, it does not seem appropriate to infer by extension, that gender-sensitive N1/VPP effects or an early P1-N1 complex might be associated with similar aspects of ED symptomatology in men. Moreover, given that we argue objectification and social comparison processes as a possible explanation for gender-sensitive ERP effects, these might present as enhanced to male bodies if a population of men with ED/BDD symptomatology were to be tested. However, whilst the possibility of generalising electrophysiological findings might be limited, it might be possible to generalise our behavioural findings to men. For example, no gender differences were found between the visual processing mechanisms employed for appearance-related stimuli in adolescents, whilst previous research has found disturbed appearance-related configural processing in high BIC samples of mixed gender (e.g. Beilharz et al., 2016; Mundy & Sadusky, 2014). As a result, it seems fair to suggest that disturbed appearance-related configural processing mechanisms might also be found in men with EDs and/or BDD. Nonetheless, mere extrapolation of these interpretations to men who have experienced disorders characterised by body image disturbance without further validating research should be done with caution.

We also noticed that questionnaires might not specifically assess what we would like them to. As a result, it is possible that the effects we observed in ERPs and behaviour are associated with constructs that were not measured. For example, although the EDI-2 is a diagnostic tool, only three subscales were related to body image disturbance; they were, drive for thinness, bulimia and body dissatisfaction. However, we felt that these subscales did not quite tap into body image disturbance as we wanted to do because, for example, camouflaging and checking behaviours were not assessed. We also felt that questions such as, ‘I exaggerate the importance of weight,’ might not best reflect the feelings of those with an ED because they do not, in their mind, exaggerate the importance of weight, it really is as important as they think it is. Furthermore, the EDI-2 is not suitable for the assessment of body image disturbance as it might present in BDD, because it is specifically tailored to EDs (Garner, 1991). In turn, whilst the BICI (Littleton et al., 2005) addresses such issues that we felt were missing from the EDI-2 and also claims to have the ability to clinically distinguish between EDs and BDD, it is not used as a diagnostic tool. As such, this might account for why we did not find correlations between BICI scores and the effects observed in Chapters 5 and 6. Moreover, self-objectification is completely omitted from EDI-2 assessment and might not be adequately reflected in all populations by the SOQ (e.g.

Daniel & Bridges, 2010). Interestingly, this highlights the need for objective symptoms markers, which was one of the aims of the thesis. Nonetheless, we feel that the interpretations of effects are limited because each questionnaire used does not fully capture ED/BDD symptomatology and/or reflect diagnostic criteria. Thus, future studies should perhaps administer several questionnaire measures to ensure all aspects of ED/BDD symptomatology are reliably and comprehensively assessed. Additionally, it might be beneficial to seek professional, clinical assessment of participants as it is likely that symptomatology do not present as neatly and distinctly as questionnaires would suggest.

With that in mind, it must also be noted that participants were not clinically assessed for the disorders they reported to have a history of, nor were they clinically assessed for other mental health issues. It is possible then, that ED and BID participants in Chapters 4, 5 and 6, had not experienced the reported illnesses, or that other mental health issues were not disclosed. However, the advertising for each study was done very carefully so that exclusion criteria and monetary compensation could not be guessed (as discussed in Chapter 4). In all chapters the ED and BID groups scored significantly higher than controls on the EDI-2 and BICI, and also reported higher levels of self-objectification. This suggests that participants were drawn from a population with a history of disorders such as EDs and BDD (see Garner, 1991; Littleton et al., 2005), especially as in Chapter 4, bulimic participants scored selectively and significantly higher on the bulimia subscale of the EDI-2 than the anorexic participants. Moreover, in Chapter 6, despite being matched to the high risk group on measures of BIC and self-objectification, the BID group elicited a different pattern of effects. If these groups were not drawn from different populations (i.e. one that had experienced EDs/BDD and one simply with high BIC and self-objectification) then results would be less likely to differ. Furthermore, as effects observed in the BID group were in line with what was expected from a population with EDs and/or BDD, this indicates that self-reported diagnosis was trustworthy. That being said, future studies, extending those described in this thesis, should seek to clinically assess participants for EDs/BDD and other mental health conditions where possible.

The fact that we combined data from anorexic and bulimic participants in Chapter 4 and then progressed to investigating women who had been diagnosed with more than one ED and/or BDD in chapters five and six, could be considered a limitation of this thesis. It might be argued for example, that assessing disorders heterogeneously in this way, reduces disease-specific findings. Whilst such argument appears logical and fair, it leads to studying these illnesses as distinct constructs. In turn, this could lead to potentially unrealistic findings, or findings that are only minimally generalisable given that pathologies are shared between anorexia and bulimia (see O'Brien & Vincent, 2003 for review) and comorbidity of EDs and BDD is common due to shared clinical features such body image disturbance (Mitchison et al., 2013). Future studies might therefore choose to study these disorders distinctly, but we were justified in combining data (similar to Eshkevari et al., 2012; Eshkevari, Rieger, Longo, Haggard, & Treasure, 2014; Horndasch et al., 2012 for example) because the aim was to investigate these conditions as interrelated body image disorders (Cororve & Gleaves, 2001) occurring on a spectrum of BIC (see Callaghan, Lopez, Wong, Northcross, & Anderson, 2011).

The interpretation of findings from this thesis might also be limited because stimuli deemed potentially triggering by B-eat (e.g. morbidly obese or emaciated bodies) were not shown to participants in any of the studies (other than control participants in Chapter 4, which has been discussed as a specific limitation within that chapter). It could be argued that such stimuli are arousing and as arousal has been found to modulate ERP amplitudes (e.g. Junghöfer, Bradley, Elbert, & Lang, 2001; Kissler, Herbert, Winkler, & Junghofer, 2009; Olofsson & Polich, 2007; Rozenkrants, Olofsson, & Polich, 2008), the differences in ERP effects between EDs/BIDs and controls presented in this thesis might be altered further if extreme body shapes had been observed. The observed effects therefore, might be a conservative estimate of differences present in reality.

Given that triggering body shapes are likely to be encountered on a daily basis, especially with the increasing prevalence of obesity (Finucane et al., 2011), this is an important point to consider when interpreting our findings. Having said that however, effects of arousal are often found on later components, rather than the earlier components investigated in this thesis (e.g. Kissler et al., 2009). It may very well be the case then, that the effects on early visual body processing as we present them would be unchanged in response to extreme body shapes. Furthermore, in Chapter 4, no differences in body ratings indicative of a general increased state of arousal were found between EDs and controls. Nonetheless, it may be of interest for future studies to include triggering bodies in their stimulus battery in order to more closely reflect the bodies that might be encountered on a day-to-day basis.

Finally, it is important to note that we did not investigate whether sexual orientation was related to the effects presented in this thesis. In particular, Hietanen and Nummenmaa (2011) propose that the observers’ sexual preference effects gender-sensitive N1 amplitudes as homosexual women elicited enhanced gender-sensitive N1 amplitudes to other female bodies, whilst homosexual men did not. Following that line of argument, sexual orientation might have modulated our gender-sensitive ERP effects. However, it seems unlikely that we recruited a majority homosexual ED sample and a majority heterosexual control sample in Chapter 4 (Feldman & Meyer, 2007), alongside a majority homosexual sample in Chapter 5. Furthermore, as argued in Chapter 4, Hietanen and Nummenmaa (2011) only infer the effect of sexual orientation as a direct comparison between gender-sensitive ERP effects in heterosexual and homosexual participants was not conducted. Moreover, data from only four men and six women were analysed meaning it is likely that statistical power was not sufficient enough to detect gender-sensitivity in the male sample. This is supported by findings from their later study (Alho et al., 2015), whereby enhanced body-sensitive N1 responses to female bodies in comparison to male bodies were found in both heterosexual men and women. As a result, they argue that sexual orientation is irrelevant to finding the effect in women, as any sexual stimulus is likely salient to them.

First and foremost, this directly contradicts the interpretations outlined in their first study, whilst it does not hold as a theory because if all sexual stimuli are salient in women then no gender differences should be found in female observers' body-sensitive neural responses. We are therefore confident that sexual orientation cannot explain all of our gender-sensitive findings, especially as BIDs appeared to encode female body identity differently to controls in Chapter 5 and sample sizes were large in all studies. In accordance with the findings outlined in this thesis, we propose that the neural correlates of gender-sensitivity in women are likely related to how the observer thinks and feels about their own body as effects were positively associated with scores on the EDI-2. Nonetheless, further investigation should work towards explicitly understanding the relationship between body image disturbance, sexual orientation and gender-sensitive visual body processing, including person perception.

7.5 Clinical implications and future directions

As previously mentioned, alterations to the temporal dynamics of visual body perception and configural body processing disturbances appear to be ongoing in women who have experienced EDs and BDD given that participants in all investigations outlined in this thesis were at least partially recovered. This has direct clinical implications and inspires several other questions, including when and how these alterations to visual body processing develop, whether they are evident at the individual level and what this means for those with EDs/BDD, as well as those 'at risk' of developing such disorders. The discussion of results presented throughout this thesis go some way in trying to address such questions but ultimately, future research is important as it will be the key to understanding the full implications of the findings we outline here.

The most obvious line of future research perhaps, is to investigate these effects in clinical samples. We found that latency shifts of the P1-N1 complex and gender-sensitive VPP amplitudes were associated with ED symptomatology in such a way that suggests the visual P1-N1 complex might possibly occur even earlier during the acute stages of an ED, whilst the relative difference found between VPP amplitudes to male and female bodies might be even larger. Having said that, it is well understood that the brain can reorganise itself in response to injury or learning, even in the later stages of adulthood (Duffau, 2006). Thus, we cannot rule out the possibility that these effects are all consequences of having had an ED, or that they are related to the duration of illness. A simple *Google* search for ‘thinspiration’ for example, results in thousands of pages whereby individuals discuss and actively encourage each other to feel their own bones (e.g. Owens, 2011) or to look at pictures of thin models (e.g. Erin, 2011) as fasting inspiration. These images often depict young women’s body parts rather than the body as a whole (e.g. I'llGetThereSomeDay, 2014), which has led to the discussion of thinspiration as a form of body objectification (Ghaznavi & Taylor, 2015). This is exemplified by the tagline in Figure 7.1, which was found on a thinspiration blog (skinnyisthedream, 2014).

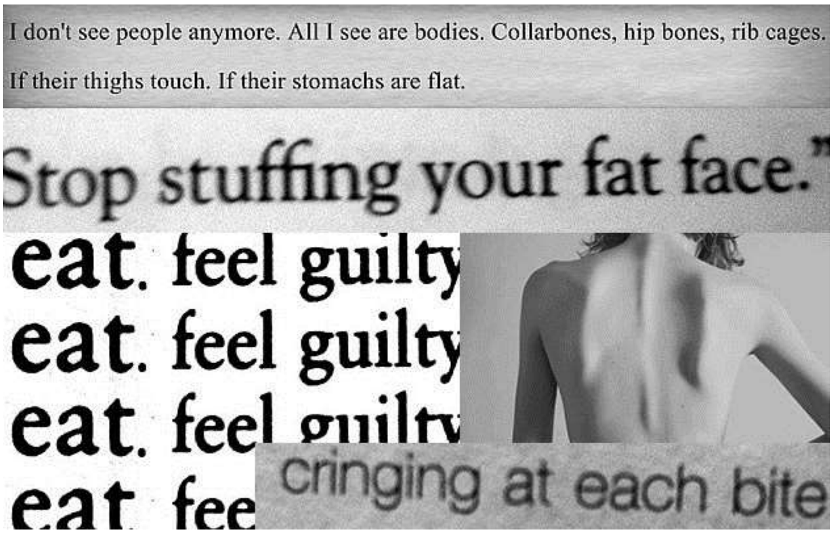

Figure 7.1. Image found on thinspiration blog as part of an ED website, which exemplifies that this sufferer feels that they no longer see the body as a whole person, but as individual parts.

Alterations in neuronal activity such as those which are presented in this thesis might therefore reflect years of essentially ‘learning’ to treat, and think about, the body differently to controls, in particular, to observe the female body form as an object. It is possible then, that effects on the temporal dynamics of the P1-N1 complex and gender-sensitive processing might present differently to our initial predictions in clinical women and perhaps instead, would only appear marginally different to controls at the onset of these disorders. Furthermore, the extent of these effects might relate to the duration of illness or the intent that is placed on treating the body like an object. Thus, an earlier P1-N1 complex and enhanced gender-sensitivity might be found to a greater extent in those who have been engaging in unhealthy behaviours for longer.

Alternatively, those who engage in such behaviours might be predisposed to do so, perhaps by genetics (Bulik & Tozzi, 2004), and as a result, actively seek out such thinspiration. It is possible then, that alterations to visual body processing exist as a vulnerability trait, which alongside other risk factors (Feusner, Neziroglu, et al., 2010; Striegel-Moore & Bulik, 2007) and yet to be identified vulnerability traits, would put at individual at an increased risk of developing disorders such as EDs/BDD. There are clearly many questions to be answered. Assessing the possibilities associated with such answers would further document the potential of these ERP effects as biomarkers of ED symptomatology. Moreover, such investigations should be conducted in those with BDD in order to ascertain whether these effects are potential biomarkers of EDs specifically, or of body image disturbance more generally. Given that BDD fixations are often centred on the face according to the DSM-5 (American Psychiatric Association, 2013), it could be the case that altered effects present when face stimuli, rather than body stimuli, are observed (e.g. Li et al., 2015). However, to our knowledge, no study to date has investigated the temporal dynamics of visual body processing directly in BDD.

As we have also argued that the processes associated with visual body perception and configural recognition might be somewhat malleable in those with body image disturbance, it would be of interest to assess the cortical and behavioural differences found in those with EDs/BDD alongside treatment procedures. For example, similar to the use of EEG to characterise epileptiform seizures (e.g. Smith, 2005), with further research, an enhancement of gender-sensitive N1/VPP amplitudes to female bodies compared to male bodies, and perhaps an early P1-N1 complex, could be used as a diagnostic marker for body image disturbance and ED symptomatology. This may be particularly useful with regards to evaluating the efficacy of treatment systems as not only are ED treatments vast, but no one superior treatment has been successfully identified (e.g. Kass, Kolko, & Wilfley, 2013). Similarly, the efficacy of BDD therapies is also largely questioned (Prazeres, Nascimento, & Fontenelle, 2013). With claims that transdiagnostic treatments might be more effective given that they address shared pathologies (Kass et al., 2013), the use of objective biomarkers would help to identify to what extent treatments and therapies are working with regards to body image symptoms. In line with this, and also with further research, it might be possible to monitor such markers in those ‘at risk’ of developing disorders characterised by body image disturbances and therefore answer calls for early interventions as well as more evidence-based treatments (World Eating Disorders Action Day, 2016).

Ultimately, what this suggests is that ED/BDD symptomatology might exist on a continuum, with these disorders at one extreme end. The opposite end of the spectrum might reflect an obsessive fixation with being fit and healthy. For example, recent research has shown that the antagonist to thinspiration, ‘fitspiration,’ whereby individuals strive for strong, lean bodies and actively shun the ideal of being ‘skinny’ in favour of being healthy, has been shown to have negative consequences on body image (Tiggemann & Zaccardo, 2015) and also appears to be related to maladapted eating and exercise behaviours (Holland & Tiggemann, 2017). This is supported by claims for the existence of orthorexia nervosa, a currently unclassified ED that manifests as a pathological obsession for healthy, biologically pure food (see Sánchez & Rial, 2005). Thus, an obsessive drive to be fit and healthy, instead of skinny, also seems to have a detrimental relationship with mental health. Understanding these disorders as occurring on a spectrum of symptomatology might further aid early intervention, diagnosis and successful treatment.

Neurostimulation techniques such as repetitive transcranial magnetic stimulation (rTMS) and transcranial direct-current stimulation (tDCS) have been found to increase functional connectivity (e.g. Kunze, Hunold, Haueisen, Jirsa, & Spiegler, 2016; Okabe et al., 2003), reduce disorder-specific symptoms (e.g. Kalu, Sexton, Loo, & Ebmeier, 2012; Sokhadze, El-Baz, Sears, Opris, & Casanova, 2014) and modulate ERPs in such a way that implies more efficient processing (e.g. Sokhadze et al., 2014) in neurological and psychiatric disorders such as autism (D'Urso et al., 2014), depression (e.g. Kalu et al., 2012) and schizophrenia (e.g. Vercammen, Knegtering, Liemburg, Boer, & Aleman, 2010). With the subject of treatment efficacy in mind then, future research might aspire to addressing the possibilities of using neuromodulation in a clinical setting for the treatment of body image disturbance in EDs and BDD. There has recently been discussion with regards to addressing the food- and weight-related abnormalities in behaviour and cognition associated with EDs (see Val-Laillet et al., 2015), but as yet, this does not seem to have been applied to the potential of addressing body image disturbance symptomatology.

Based on the findings presented here, alongside research that suggests maladaptation (Suchan et al., 2010), underactivity (Uher et al., 2005) and reduced connectivity between brain areas selective for visual body processing (Suchan et al., 2013) in those with anorexia, it seems that investigating the effects of neuromodulation on body-related attitudes and visual body processing mechanisms would be an insightful endeavour. For example, Suchan et al. (2013) postulate that body shape misjudgements seen in anorexia might be explained, at least partly, by alterations in the functional connectivity between left FBA and left EBA. This is especially interesting as loss of the right FBA appears to have no impact on body perception (Susilo, Yang, Potter, Robbins, & Duchaine, 2015), which could be taken as evidence for left-dominant body perception processes. The question to be addressed then, is whether stimulating connections between left hemisphere FBA and EBA would go some way in alleviating symptoms of body image disturbance in anorexia?

Alternatively, normal body perception despite the loss of the right fusiform gyrus (Susilo et al., 2015) could be a result of left hemisphere compensation. With regards to this potential plasticity, it would be of interest to assess whether stimulation of body-selective regions in the right hemisphere would encourage a functional lateralisation that might help to account for maladaptation in the left hemisphere found in those with anorexia. Further to this, it would be beneficial to assess whether any functional alterations are associated with improvements to body image disturbance symptomatology and perhaps alterations to early body-sensitive ERPs. This would help to assess the role of neurostimulation as a treatment intervention as well as the suitability of ERPs as symptom biomarkers. In addition, there is evidence for aberrant functional connectivity in the occipito-temporal face networks that process configural and holistic information in those with BDD (Moody et al., 2015). Thus, future studies might seek to assess whether this can be normalised through neurostimulation. Similarly to the proposed investigations in anorexia, it would then be of interest to document whether changes are associated with improvements to body image disturbance symptomatology and perhaps alterations to early face-sensitive ERPs. As a result of studies such as this, neurostimulation might be able to help towards enhancing treatment efficacy as has been shown for other disorders (e.g. Kass et al., 2013; Prazeres et al., 2013). This might also encourage a move towards a more personalised, and perhaps more successful, approach to treatment that is thought to be required in order to combat these disorders (see Val-Laillet et al., 2015). However, at the moment this line of research is clearly limited to anorexia and BDD. This further highlights the need to investigate the neural correlates of body image disturbance in understudied disorders.

Another question evoked by the studies presented in this thesis corresponds to the visual analysis of female bodies. As discussed, we provide evidence to suggest that female bodies might be processed and identified more on the basis of their features rather than as a configural whole. However, it is not clear whether this is more prevalent in EDs/BDD, thus leading to gender-sensitive ERP effects as observed in Chapter 4, or whether this type of visual analysis is evident in healthy controls, as suggested by the gender-identity

ERP effects observed in Chapter 5. A future line of investigation therefore, might be to replicate the behavioural study presented in Chapter 6 whilst accounting for stimulus gender and recording occipito-parietal (P1, N1) and fronto-central (VPP) ERPs in response to body and face stimuli. In addition, responses on diagnostic tools, such as the EDI-2 and the dysmorphic concern questionnaire (DCQ; Jorgensen, Castle, Roberts, & Groth-Marnat, 2001) should be collected for correlational analyses. The primary aim therefore, would be to assess the relationship between gender-sensitive ERP and behavioural inversion effects, in light of ED/BDD symptomatology. Furthermore, including a sample of clinical men, whilst controlling for sexual orientation, would help towards understanding the mechanisms that drive gender-sensitivity in body-sensitive ERPs.

As a result, the potential held by findings from such an investigation would not only inform the current understanding of visual processing in general, as well as of processing disturbances in EDs/BDD, but might also be useful for treatment. For example, if those with body image disturbance specifically focus on the features of those they are comparing themselves to (i.e. women focus on other women’s features, men focus on other men’s features) as suggested by thinspiration blogs, specific training could be undertaken alongside other conventional therapies (see Kass et al., 2013; Prazeres et al., 2013) in order to encourage configural, rather than feature-based, processing of target stimuli. In turn, this might reduce the tendency to fixate on others ‘beautiful’ body parts compared to own ‘fat’ or ‘ugly’ body parts (Jansen, Nederkoorn, & Mulkens, 2005). Moreover, for those who are potentially at risk of developing EDs/BDD, such as adolescents displaying several characteristic vulnerability traits (Feusner, Neziroglu, et al., 2010; Striegel-Moore & Bulik, 2007), learning to both think about and view the body as an agent in the world, rather than as an object, might help as a form of early intervention to prevent such fixations.

Interventions such as the suggested behavioural training could be included in the school curriculum for example, whereby students could also be educated about the dangers of fitspiration and thinspiration (see Ghaznavi & Taylor, 2015). This would encourage young people to discuss the unrealistic images that they see online in a safe and non-judgemental environment, whilst considering their bodies on the basis of ability and function rather than the appearance of certain body parts. Additionally, configural processing training might encourage the configural encoding of bodies at a neural level due to homeostatic plasticity previously discussed (also see Duffau, 2006).

Preventative efforts to reduce mental health conditions seem to be effective with regards to other mental health conditions such as depression and anxiety (e.g. Cuijpers, Van Straten, & Smit, 2005) and although not all students would clinically benefit from such education programmes, there is no reason to believe it would do them harm. Given that there is an estimated £1.6-billion per-year strain on the NHS for diagnosis and treatment of EDs (Henderson, 2012) whilst many individuals are suffering in silence, there are however, many reasons to argue that with more research, such interventions would be useful and are highly necessary. Moreover, this would address three of the nine goals set out by World Eating Disorders Action Day (2016), as it speaks to the point of creating a readily available community treatment support programme, also to the call for research-based interventions to be delivered in schools and also to the point of educating the public so as to reduce the stigma surrounding these disorders, which would encourage people to seek help.

The final line of future research proposed as a result of the investigations presented in this thesis, refers to that of own-body perception. In Chapter 3, we found evidence to suggest that own-body viewing enhances the early temporal signatures of visual body perception. Given that specific findings show altered patterns of brain activation, including in occipital cortex, when anorexic participants view own-body stimuli compared to controls (Castellini et al., 2013), it may therefore be of interest to assess the temporal dynamics of own-body perception in those with body image disturbance. Specifically, considering the tendency to fixate on perceived flaws or ‘fat’ body parts (American Psychiatric Association, 2013) or to picture and experience body parts as larger than they are (see Smeets, 1997), those with EDs/BDD might show ERP modulations according to whether the whole body, or body parts are viewed. In addition, given that reduced activation of occipital cortex has been observed in those with anorexia during own-body viewing (Castellini et al., 2013), the sight of one’s own body might attenuate, rather than enhance (as found in Chapter 3), body-sensitive ERP amplitudes in those with EDs/BDD. Should such evidence be found, this might also hold the potential to serve as a neurological marker of the symptomatology associated with disorders characterised by body image disturbance.

7.6 Conclusions of thesis

This thesis aimed to investigate the relationship between body image disturbance and visual body perception, with the intention of exposing evidence for potential electroencephalographic and behavioural symptom markers of disorders such as anorexia and bulimia. Early on, we found evidence for the stability of early visual ERP responses and associated body-sensitive effects. In light of literature which suggests EBA, a region from where early body-related electrophysiological activity is thought to arise (e.g. Sadeh et al., 2011; Thierry et al., 2006), appears to be atypical in anorexic women (see Suchan et al., 2015a for review), visual P1, N1 and VPP components were thus deemed eligible for examination as potential biomarkers. With that, further investigation revealed several differences between the cortical signatures associated with visual body perception in those who have experienced body image disturbance compared to controls. Specifically, ED participants, not controls, elicited a significantly earlier P1-N1 complex and gender-sensitive N1/VPP responses to other women's bodies. These effects were deemed potential neural markers for the identification of ED symptomatology in 'at risk' populations given their relationship with scores on the EDI-2. Further to this, gender-sensitive body-only person perception presented atypically in EDs/BDD, whilst evidence for disturbed configural body processing mechanisms was found in those recovering from EDs and

BDD, as well as those ‘at risk’ of developing such disorders. However, these effects did not relate systematically with questionnaire measures of BIC and self-objectification. Thus, the conclusion of this thesis is that the temporal dynamics of visual body perception, as well as configural body processing mechanisms, are atypical in those who have experienced a disorder characterised by body image disturbance. Moreover, the early temporal signatures of visual perception, as well as early gender-sensitive ERP effects, appear to be potential neural markers of ED symptomatology.

7.7 References

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