

Body Size Estimation: Multichannel or Opponent Process?

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Abstract

While body image distortion is a widespread issue both Australia and worldwide, little research has focussed solely on how humans visually encode body size. For example, it is not yet known whether body size is encoded through a multichannel (three or more neural channels) or an opponent process (where only two neural channels encode the stimulus). The present study aims to determine which of these processes encodes body size, through the use of visual aftereffects, which are defined as a change in appearance of a test stimulus after prolonged exposure to an adapting stimulus. Twenty participants viewed either expanded/‘fat’ bodies, or contracted/‘thin’ bodies at four separate levels of adaptor extremity. Following a baseline and a two-minute adaptation phase, participants were asked to select which of two distorted images (one expanded and one contracted by 3%) appeared more ‘normal’. Pre- to Post-Adaptation Scores (PPAS), or the change in aftereffect magnitude, was the main dependent variable across all levels (1-4) and group (expanded/contracted adaptors). Although the pattern of results was consistent with that of an opponent process in the expanded group only (aftereffect magnitude linearly increased as a function of adaptor extremity), no significant results in the contracted group were obtained. Limitations and reasons for non-significance are discussed, and plans to rectify these issues are outlined.

Body Size Estimation: Multichannel or Opponent Process?

1.1. Background Research

Although generally considered a definitive feature of eating disorders, body image concerns have become a prominent and widespread issue among many in the general, non-clinical population. This is exemplified by the finding that up to 70% of Australian adolescent females desire to be thinner, while a similar proportion of their male peers are also dissatisfied with their body shape, even when mean Body Mass Index (BMI) scores are within a healthy range (Mellor et al., 2014; Ricciardelli & McCabe, 2001). The high prevalence of body image dissatisfaction is particularly problematic when considering the negative consequences that have been associated with it, including increases in anxiety, depressive mood, disordered eating behaviours, and decreases in measures of self-esteem (Paxton, Neumark-Sztainer, Hannan, & Eisenberg, 2006; Stice, 2002). Furthermore, body image dissatisfaction and abnormalities in evaluation of body shape is often cited as a crucial contributing factor to the development of eating disorders (Fairburn & Harrison, 2003).

While it may be tempting to assume that low body satisfaction leads to eating pathology, the relationship between these two constructs is multifaceted and complex. One of the variables most attended to in recent times include societal pressures to obtain the ‘thin ideal’ often presented through the vehicle of western media. In a cluster of notable studies, Becker interviewed 63 adolescent females from Nadroga Island in Fiji, in which television had only been recently introduced. While none of the females interviewed met the inclusion criteria for body dissatisfaction or eating disturbances before the introduction of television, over 71% of an age-matched sample (thus controlling for age effects) displayed signs of disordered tendencies (including a jump from 0% to 11.3% of individuals reporting self-induced vomiting) after just three years of exposure to western media (Becker, 2004; Becker, Burwell, Herzog, Hamburg, & Gilman, 2002; Becker, Burwell, Navara, & Gilman, 2003).

This research was unique, as it provided a study sample almost completely naïve to western ideals at the onset of the study, in which longitudinal data collection through both questionnaires and semi-structured interviews could be obtained: a rarity in this field of research.

One of the common themes amongst Becker's participants included a desire for weight loss, and body size dissatisfaction. These discoveries mirror other experimental findings attributing exposure to a thin ideal (even for short periods of time) to an increased desire for thinness and decrease in body satisfaction (Glauert, Rhodes, Byrne, Fink, & Grammer, 2009; Groesz, Levine, & Murnen, 2002). A meta-analysis of studies empirically testing the short-term effects of media exposure suggests that not only do individuals tend to strive towards the presented ideal, but also tend to visually perceive themselves as larger after the presentation of experimental images (Groesz et al., 2002). Although the majority of the research has focused on the influence of a thin ideal on female body image and drive for thinness, recent findings suggest similar levels of body dissatisfaction in males after exposure to their own 'ideal' (Barlett, Vowels, & Saucier, 2008). While overall, females desired a smaller physique and males aspired to be larger, the main effect of experimental presentation of an 'ideal' was essentially the same for both groups. That is, exposure and attention to slim female and muscular male images influenced how participants estimated their own body size. For example, a larger form is generally idealised for males in western media, meaning that men are more likely to under-estimate their own body size after exposure, while the opposite is true for females.

The description of a presented stimulus influencing subsequent visual perception is reminiscent of the various visual aftereffects; changes in the appearance of a "test" stimulus following an extended period of exposure to an "adaptation" stimulus (Frisby & Mayhew, 1980). Recent research provides evidence for a real-world example of an adaptation effect, as

the relationship between media exposure and body perception may be mediated by perceptual changes in what is considered normal (Glauert et al., 2009; Hummel, Grabhorn, & Mohr, 2012; Hummel, Rudolf, Untch, Grabhorn, & Mohr, 2012; Winkler & Rhodes, 2005).

Furthermore, visual adaptation is considered an effective tool when studying the underlying neural structure responsible for encoding general sensory experiences.

1.2. Adaptation

While the neural organisation responsible for encoding higher-order visual stimuli such as an image of body size is still being investigated, low-level stimulus dimensions including colour, line orientation and motion have been extensively studied (Adams, 1834; Barlow & Hill, 1963; Frisby & Mayhew, 1980; Hurvich & Jameson, 1957). One of the most prominent methodologies utilises commonly observable aftereffects, for example motion aftereffects including the waterfall illusion. Adams is commonly credited with the famous description of this particular illusion, when he noted an enduring sensation of motion after watching a waterfall (Adams, 1834). The waterfall illusion itself is defined by the visual experience in which a static object appears to be moving upward after prolonged exposure to a downward moving stimulus (Frisby & Mayhew, 1980). In short, after a waterfall is viewed for an extended period of time, the viewing individual should perceive a stationary object, such as a rock on the opposite side of the lake, as slowly moving in the opposite direction (in this case upwards).

The waterfall illusion is a prime example of a visual adaptation aftereffect, which is defined as a change in the perception of a ‘test’ stimulus (in this case, the immobile rock) after consistently viewing the ‘adaptation’ stimulus (the waterfall). Sensory adaptations, such as visual aftereffects are a product of cells that code for the adapted stimulus property that fire rapidly at the onset of stimulus presentation, and in the case of the MAE, signal the direction of motion (Barlow & Hill, 1963). Gradually, these direction-sensitive cells decrease

in their rate of response, although still fire above spontaneous firing rate while the stimulus is still viewed. When the adapting stimulus is removed, the adapted cells fire below their baseline rate, while the neurons responsible for detecting the opposite direction still fires at baseline. This results in a level of activity encoded as the *opposite* of the adapting stimulus, since the adapted neurons firing rate is lower than that of the un-adapted cell.

1.2.1. Body Adaptation. While much of the literature focuses on how humans encode low-level stimuli such as motion, colour (Hurvich & Jameson, 1957) and orientation (Gibson & Radner, 1937), recent research has begun to explore higher-order stimuli such as facial features and bodies in terms of responsible neural mechanisms (Downing & Peelen, 2011; Hodzic, Kaas, Muckli, Stirn, & Singer, 2009; Hummel et al., 2013; Peelen & Downing, 2007). One of the many ways these can be explored is through the use of an adaptation paradigm. Thin and fat body shapes have received particular attention, with one study demonstrating that aftereffects are so strong that they can transfer across adaptor-test identity (Winkler & Rhodes, 2005), although this overlap is only partial (Brooks, Murley, Mond, & Stevenson, 2015). Body size aftereffects are demonstrated in Figure 1: After familiarisation with the ‘original’ image, focus solely on the ‘fat’ body for 1-2 minutes. Attending to the original image again after adaptation results in a perceptually slimmer ‘original’ image, despite it being the same size as prior to adaptation. Another important contribution of this research included uncovering the asymmetry in aftereffects for fat and proportionately thin adaptors, in that the adaptation effect was significantly stronger for thin bodies than fat (Winkler & Rhodes, 2005).

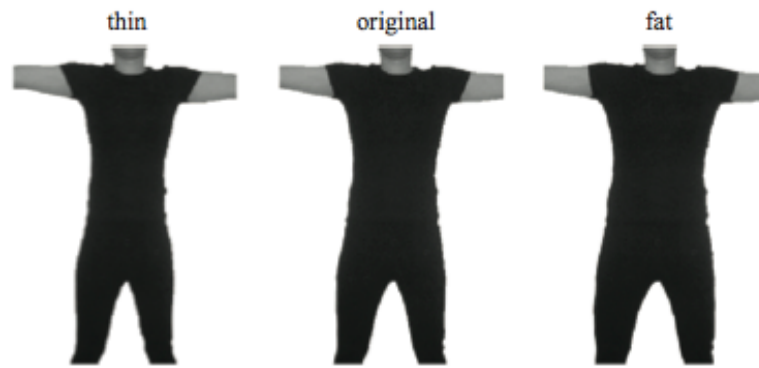


Figure 1: Aftereffect demonstration adapted from (Hummel, Grabhorn, et al., 2012). After adapting to the ‘thin’ image for 1-2 minutes, individuals tend to view the ‘original’ image as larger than prior to adaptation, and tend to rate slimmer images as more normal. This also occurs if exposed to the ‘fat’ image – except individuals view the ‘original’ image as thinner than pre-adaptation, and a larger individual is more likely to be seen as ‘normal’.

Similar adaptation aftereffects have been repeatedly demonstrated, although with slight variations. In the context of media exposure and body dissatisfaction, Glauert et al., (2009) replicated these findings computer-distorted images of the female body, that were more realistic than the previously favoured silhouette figures often displayed (Groesz et al., 2002; Sands, Maschette, & Armatas, 2004). Using the participants’ own body as both adaptor and test stimulus produces a similar aftereffect, as does using an unfamiliar identity for adaptation but images of their own figure for test (Hummel, Rudolf, et al., 2012). Although it seems that some overlap exists between neurons responsible for encoding own- and other- body shapes, transfer is significantly smaller for cross-identity adaptation than it would be if adaptor and test images were of the same-identity (Brooks et al., 2015). That is, adapting to an ‘other’ figure produces similar aftereffects in ‘self’ and vice versa, through a methodology known as contingent adaptation. As a whole, these findings coherently suggest

that neural mechanisms visually encoding representations of ‘self’ and ‘other’ somewhat overlap, although not completely.

1.2.2. Adaptation and Body Dissatisfaction. Since aftereffects have been demonstrated to transfer across identity, the suggestion that media images can contribute towards changes in perception due to aftereffects (as opposed to body schema or societal pressures) becomes increasingly plausible. Body image dissatisfaction can be defined as a discrepancy between what is considered ‘normal’ or ‘desirable’, and a perception of the self (which is susceptible to distortion through adaptation) (Gardner & Boice, 2004; Glauert et al., 2009; Skrzypek, Wehmeier, & Remschmidt, 2001). If skinny begins to look normal following adaptation, and these effects can transfer across identity onto the viewer, it becomes more plausible that the viewing individuals may begin to perceive themselves in a distorted manner which could then contribute towards an eventual decrease in body satisfaction (Glauert et al., 2009).

Some research has specifically focussed on how neural models relate to body dissatisfaction. It has been well documented that exposure to media ideals (usually thin for women and muscular for men) tends to increase body image dissatisfaction for both genders (Barlett et al., 2008; Groesz et al., 2002). Glauert and colleagues (2009) discovered that exposure to fat or thin bodies not only resulted in aforementioned adaptation effects, but also influenced perceived normality and body ideals, which in turn impact on body image satisfaction. Therefore, while western media itself cannot be blamed for reducing satisfaction, prolonged viewing of the presented ‘norm’ (which is often very slim) can incur aftereffects, which make one’s own regular-sized body appear larger than prior to adaptation. Suddenly perceiving oneself as fatter, especially in comparison to such slim images, can then widen the gap between perception of self and perception of normality, thus increasing dissatisfaction.

Another interesting finding from Glauert et al., (2009) includes the ‘blunted’ adaptation to fat bodies as dissatisfaction increased. However, it should be noted that all participants were female, and that they assumed dissatisfaction implied a desire to be slimmer. Therefore, the question of directionality of desirability and the relationship with adaptation susceptibility is still in question. Their findings suggest that dissatisfied participants are less susceptible to adaptation if direction of desire is opposing the direction of adaptation (i.e. desire to be slim adapting to fat bodies). Assessing direction of desirability, as well as testing both males and females will be performed in order to continue the findings relating to adaptation susceptibility.

Additionally, the relationship between accuracy of perceiving body size and body image satisfaction reveals interesting implications for adaptation. Prior research has demonstrated that body size overestimation could be predicted by measures including peer and media influences to be slimmer, as well as depression (McCabe, Ricciardelli, Sitaram, & Mikhail, 2006). Furthermore, in both non-clinical and disordered samples, those with lower body image satisfaction were less accurate in estimating their own body size, indicating that accuracy of perception may be somewhat influenced by satisfaction and desirability, although the directionality of this relationship is still unclear (Sand, Lask, Høie, & Stormark, 2011; Skrzypek et al., 2001). Additionally, women with lower satisfaction scores who desired thinness also chose slimmer ‘normal’ and ‘ideal’ body shapes than individuals satisfied with their figure (Glauert et al., 2009). Although it is difficult to determine whether these findings truly report a difference in perception rather than just the tendency to give socially desirable responses, fMRI studies have demonstrated differing neural responses to body pictures between those with Anorexia Nervosa (i.e. a highly dissatisfied group) and healthy controls (Castellini et al., 2013). These multiple differences demonstrate that the way in which

dissatisfied individuals perceive their own figures is truly different to those who are satisfied with their figures.

Although some research has attended to accuracy of estimation and the influences of adaptation on body satisfaction, reversing the relationship between these two constructs has received significantly less attention. In other words, only a few studies have demonstrated how body satisfaction scores can influence susceptibility to these adaptation effects. One interesting finding includes the effect that trait body dissatisfaction had on adaptation. As dissatisfaction increased, the exposure aftereffects for fat bodies decreased. However, this study did take into account the direction in which participants were dissatisfied with their figure. Furthermore, Glaert et al. (2009) used a rating scale to assess the perceived normality and preference of the bodies presented that may have been susceptible to social desirability effects, in that participants may have been responding in a way they thought was expected, rather than was actually perceived. Therefore, a peripheral aim of the present study is to further explore the relationship between body satisfaction and susceptibility to adaptation, as well as accuracy in body size perception prior to adaptation.

1.3. Two Types of Coding

While some of the mechanisms underlying the neural organisation and structure of the cells responsible for body stimuli are somewhat understood, many questions have still been left unanswered. One of the most pertinent questions that remains unexplored includes the number and organisation of neural channels involved in processing body size. It is generally well understood that there are two forms of coding in the human visual system (Valentine, 2001). These two functional mechanisms for encoding visual stimuli are known commonly as the opponent process and multichannel coding frameworks. The main difference between these two types of visual coding are the number of different channels assigned to each stimulus. Where stimuli processed using an opponent coding structure are encoded using only

two pools of neural channels, multichannel processing employs more than two neural channels to encode stimuli (Calder, Jenkins, Cassel, & Clifford, 2008; Storrs & Arnold, 2012).

1.3.1. Opponent Coding. Opponent coding, sometimes referred to as norm-based coding, entails a prototype that functions as a norm against which deviations can comparatively be coded. According to this framework, two broadly tuned neural channels are each maximally sensitive towards opposite extremes of a particular stimulus property. These broad neural tunings overlap, and are each responsible for encoding a opposite values of a single-dimensional stimulus (Pond et al., 2013). Depending on the relative activation of these two opposing channels, the stimulus is visually encoded in terms of deviation from the ‘average’ (Robbins, McKone, & Edwards, 2007). After prolonged exposure to a stimulus, the channel closest to the stimulus dimension becomes the most adapted. Since the channel most like the stimulus becomes more adapted than the other opponent channel, the point of subjective normality (PSN) – the level of distortion at which a stimulus is rated as ‘normal’ – is shifted towards the adapting stimulus.

One of the many higher-order visual traits consistent with the opponent coding framework is that of face gender (Pond et al., 2013). In terms of the model, one channel is maximally tuned to detect male faces, and the other female. In this way, an androgynous or neutral face would be represented by simultaneous and equal activation of both the male and female channels. As facial features deviate from neutral towards ‘maleness’, neural activation becomes more prominent in the ‘male’ channel. If an individual were to focus on a male face for a prolonged period of time, this channel would adapt more than the ‘female’ channel, consequently shifting perception of a subsequently presented neutral face towards maleness.

1.3.2. Multichannel Coding. Multichannel coding similarly relies on a particular pattern of activation of neural channels in order to perceptually encode a stimulus property,

and are also susceptible to adaptation aftereffects. While only two neural channels define an opponent process, stimuli encoded through the multichannel framework require more than two pools of neurons. For example, evidence suggests that eye gaze perception is encoded through three distinct channels (Calder et al., 2008). Through two adaptation experiments, Calder and colleagues (2008) identified that adapting to direct eye gaze produces a decreased tendency to categorise gaze angles of up to 10 degrees left and right as ‘direct’. This finding is consistent with multichannel processing, since adapting to a direct eye gaze would result in a higher amount of adaptation effect in the ‘direct’ gaze channel, relative to the left and right channels (Calder et al., 2008). That is, participants were found to be more sensitive when determining direct eye gaze, in that they rated a lower proportion of slightly averted eyes as ‘direct’ than prior to adaptation. As demonstrated in Figure 2 this contrasts with findings expected from the opponent model, which predicts no aftereffect following adaptation to direct eye gaze, since neither neural channel would fire strongly enough to neutral to produce the results described above. Their second experiment supported the multichannel model, as simultaneous adaptation to 25 degrees left and right resulted in an increased direct response, where opponent coding again predicts no aftereffect from such adaptation stimuli (as seen in figure 2b and e)

Figure 2 illustrates the main differences between multichannel and opponent processes, in terms of neural channel response rates. Each uniquely coloured line represents a different neural channel, with black signifies direct, blue signifies right and red signifies left. The shaded grey region represents the hypothesised number of perceived ‘neutral’ (in this case direct) responses. Diagrams (a) and (d) indicate firing rate of neural channels at baseline for each respective process. Adapting both left and right simultaneously decreases the response rate of both channels in both opponent coding and multichannel, however the multichannel framework predicts an increased proportion of ‘direct’ responses to slightly off-

centre angles (5-10 degrees). Furthermore, adaptation to direct eye gaze provides different predictions for each model, where multichannel predicts a narrower than baseline rate of ‘direct’ responses. This can be attributed to the adapted ‘neutral’ channel, whereas the left and right channels adapt equally to direct gaze in the opponent model.

It should be noted that this research was somewhat simplified in that the multichannel account assumed only three channels (left, right, direct gaze). However, multichannel does not necessarily imply a three-channel model, as it may any number of channels more than two.

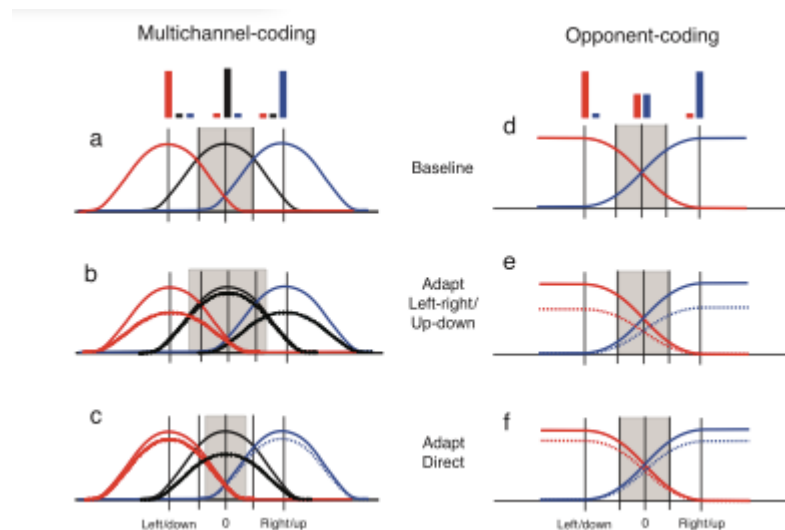


Figure 2: Diagram demonstrating the projected neural coding of both multichannel (three-channels a-c) and opponent processes (two-channels d-f), where the y-axis represents firing rate and y-axis represents stimulus direction and intensity (in this case, gaze direction).

Amended from (Calder et al., 2008), who were aiming to determine the means by which perception of gaze direction is encoded.

Although Calder et al.'s (2008) findings, which assumed a three-channel framework, provide a concise and meticulous set of predictions for a multichannel process, the

description becomes more complex when the precise number of channels is unknown. For example, one of the most extensively researched multichannel-encoded stimuli is that of line orientation. In the primary visual cortex lies a number of orientation columns - clusters of cells that are each maximally excited by specific visual stimuli of varying angles (Paradiso, 1988). Physiological research and neuroimaging studies on humans, primates and other mammals supports the suggest organisation and highly ordered structure of these clusters of neurons (Haynes & Rees, 2005). Although gaze direction and line orientation are both processed through a multichannel framework, it is important to note the distinction between the two visual dimensions: gaze direction is encoded through three channels according to electrophysiological and adaptation studies (Calder et al., 2008), while line orientation requires a larger number of neural channels. Furthermore, investigating adaptation aftereffects of orientation has uncovered findings that are consistent with the physiological structures previously discussed, though in a much less invasive manner.

However, unlike in gaze direction (Calder et al., 2008) and body orientation (Lawson, Clifford, & Calder, 2009), encoding line orientation cannot be explained by just three channels. In the case of many channels, the clusters closest to the adapting stimulus will be the most affected, which contrasts with an opponent model in which both neural channels are affected (Figure 3a). However, as shown in Figure 3, the channels responsible for encoding values of the stimuli very distant to that of the adapting stimulus will respond significantly less, and will therefore not adapt as much if at all (Gibson & Radner, 1937; Jeffery et al., 2011; Storrs & Arnold, 2012). In this way, perceptual aftereffects will only occur within the immediate realm of the adapting stimulus. For example, as shown below in column b, adapting to a perceptual value of 20 for a hypothetical stimulus dimension only lessens the response rate of the channels nearest to the adapting stimulus (in this case, between values of approximately -40 and +80. This contrasts with predictions made for the opponent model

(column a), where both neural channels are affected, albeit one significantly more than the other.

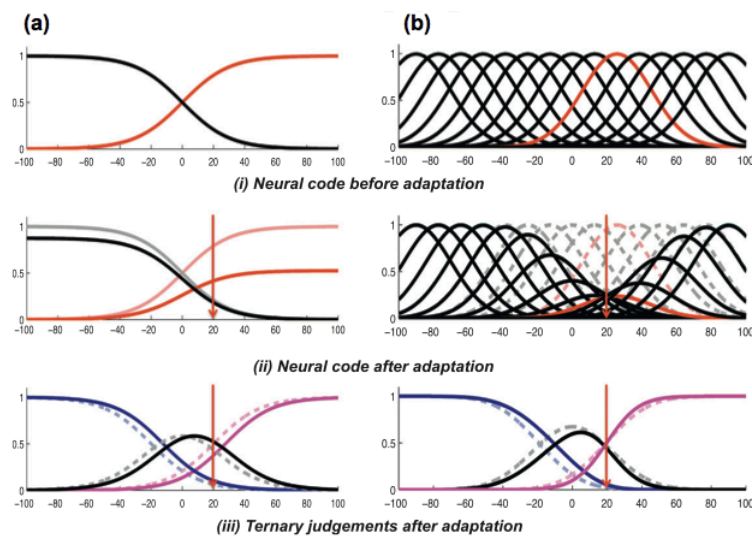


Figure 3: Depiction of adaptation channels for opponent (a) and multichannel (b) processes.

Dashed lines indicate un-adapted, baseline rate of neural firing. This shifts the perceptual judgements made after adaptation only in the surrounds of the adapting stimulus, as seen in (biii). Adapted from Storrs and Arnold (2012).

1.4. Application to Current Research

Although adaptation occurs in both multichannel and opponent processes, aftereffects for each model behave in slightly different ways, thus resulting in differing predictions. For multichannel, each neural channel is tuned toward a particular value, and the patterns of firing between these clusters determine how the stimulus is processed and therefore viewed. This method of encoding is distinct from the bipolar nature of the opponent processing framework, in which the separate pools of neurons are tuned to encode the most extreme values of a particular stimulus.

Since the two models represent body size in different ways, different predictions are produced for body size aftereffects. If body size is encoded using only two types of cells, as

in opponent coding, it would be likely that one channel of neurons would be dedicated towards detecting ‘fat’ or expanded figures, while the opposing pool would be responsible for encoding ‘thin’ or contracted bodies. Any body size and type will be encoded using a combination of the firing rate of both cells. However under multichannel processing, many of the narrowly tuned cells will often remain unaffected if the value of the stimulus is beyond the reach of the neural filter. Therefore, should body size be encoded through a multichannel process, any individual figure would excite neurons specifically tuned to detect that particular body size, as well as somewhat increase the firing rate of the surrounding neurons. However, the neuron clusters responsible for encoding body sizes dissimilar to the adapting stimulus will only be affected very slightly, if at all.

The core difference between the two encoding frameworks is reflected in their respective patterns of adaptation, that in turn result in observable and measurable differences in aftereffects. Stimuli encoded via an opponent process should result in aftereffects that increase relative to adaptor extremity, while the multichannel framework is characterised by an initial increase, then decrease in aftereffect size as adaptor extremity increases (Pond et al., 2013). Therefore, the opponent model predicts that extremely fat/thin bodies should result in a larger aftereffect than somewhat fat/thin bodies, while the multichannel framework proposes an increase in adaptation aftereffects for somewhat fat/thin bodies, but then a decrease as body shape becomes more extreme. These prospective differences in aftereffects will be harnessed in order achieve the main aims of the study, which is to uncover whether body size is encoded through a multichannel or opponent process.

1.5. Other Neural Models of Body Perception

Before the neural mechanisms underpinning the unknown of human body perception are investigated, some prior research on body perception should be discussed. Although relatively unexplored, some adaptation research reveals aftereffects for body attributes

including gender (Palumbo, Laeng, & Tommasi, 2013), shape (Hummel, Grabhorn, et al., 2012) and identity (Hummel, Rudolf, et al., 2012; Rhodes, Jeffery, Boeing, & Calder, 2013). Importantly, aftereffects of higher-order stimulus properties, such as body identity and gender, have been shown to transfer across changes in stimulus size and orientation (Lawson et al., 2009), indicating that they cannot be attributed to low-level visual properties and aftereffects. These findings are congruent with functional imaging research, which suggests that bodies are visually encoded in areas of the brain such as the mid-fusiform gyrus (Downing & Peelen, 2011; Hummel et al., 2013; Peelen & Downing, 2005). This lies in contrast with low-level stimuli, which tend to be processed retinotopically, meaning that adaptor and test stimuli would need to fall on the same area of the retina in order for an aftereffect to occur (Gollisch & Meister, 2010).

1.6. Links to Face Perception Research

One area of interest that has arguably been the most influential to the development of experimental practices for exploring the neural mechanisms underlying visual body perception is rooted in the more extensively explored face perception research. For example, Rhodes et al., (2013) describe a model that can be likened to the ‘face space’ metaphor, whereby an individual face is encoded along a series of dimensions that serve to visually discriminate faces, such as face width (Robbins et al., 2007). According to this framework, known as the Multidimensional Space Framework (MSF) a ‘norm’ face occupies the center space, and the more a face deviates from this, the further away from this midpoint (Leopold, O'Toole, Vetter, & Blanz, 2001; Valentine, 2001). Each face lies upon an ‘identity trajectory’, where the more atypical a face the further away from the central ‘norm’ identity, into the periphery. Adaptation to atypical or distinctive facial features shifts the norm in terms of its specific identity trajectory. By plotting a face in the MSF along an identity trajectory, not only can the relationship between the identity and average be evaluated, for

which the inverse is known as the ‘anti-face’. For instance, if Jim’s face featured smaller eyes and lips than the norm, anti-Jim would sport eyes and lips proportionately larger than the norm. Following adaptation to anti-Jim, a neutral stimulus should subsequently be perceived as Jim-like.

These findings were more recently replicated with body identities, using bodies with opposing characteristics (Rhodes et al., 2013). The researchers developed two target figures – Rose and Elle – which were then manipulated along the trajectory of the MSF to create their anti-identity figures (Fig. 4). Paralleling Leopold et al.’s (2001) findings, adaptation to anti-Rose influenced the subsequently presented norm to appear more like Rose. Critically, the size of this aftereffect increased with adaptor extremity, indicating that body identity is encoded through an opponent process. These findings suggest that both body identity and face identity are likely to be encoded through a two-channel model (Rhodes et al., 2013; Robbins et al., 2007).

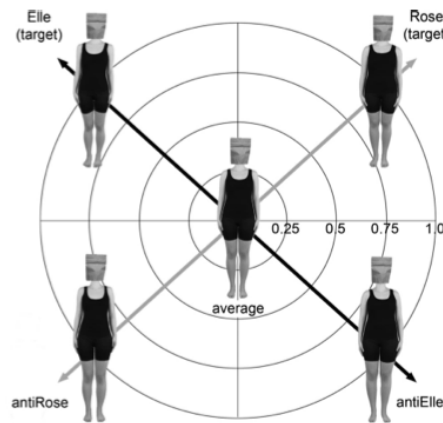


Figure 4: Illustration of a simple MSF with two body identities, Rose and Elle. The average body lies at the center, with anti-Rose and anti-Elle occupying the opposite location relative to the norm. The anti-identities have proportionately opposite properties to the original identity. For example, Elle has slightly narrow hips, and anti-Elle has slightly wider hips than the average. Adapted from (Rhodes et al., 2013)

While body identity may be encoded via an opponent mechanism, not all body-related properties are processed by norm-based mechanisms, such as body orientation (Lawson et al., 2009). Since face direction and orientation is also likely encoded through a multichannel process (Lawson, Clifford, & Calder, 2011), it could be said that stimulus dimensions are processed through similar numbers of neural channels in both faces and bodies, for at least some visual properties.

Since some stimulus properties are applicable to both faces and bodies, such as orientation, gender and identity, appear to be encoded in similar ways, it is imperative to investigate the face literature most similarly related to the aims of the present study. One study in particular employed not only an adaptation paradigm, but also the measurement of electrophysiological substrates (including an event-related potential correlate known as the P250 measured using an electroencephalogram) in order to determine whether face expansion

and compression is encoded through an opponent or multichannel process (Burkhardt et al., 2010). Burkhardt and colleagues (2010) discovered that the relationship between adaptor extremity and aftereffect magnitude were consistent with the opponent process for the stimulus property of facial feature organisation, spanning from compressed to expanded. The aforementioned argument assessing parallels between face and body research would indicate that this particular research somewhat suggests opponent coding for body size. This comparison must also be made tentatively, as the ways in which the expanded and contracted images were distorted are different to the methods used in the present study, as seen in Figure 5. While the study did expand and contract the facial features, the face shape itself remained unchanged, whereas the current study will be distorting the entire body shape of each image, rather than just particular structures within the silhouette. Due to these major differences in experimental adaptor, one must approach applying this particular face research to the current study on body size tentatively.



Figure 5: An example of how the expansion/contraction differs between Burkhardt and colleagues (2010) in (a), and the images being used in the present study (b)

1.7. Research Aims and Hypotheses

In order to maximally contribute toward the recently expanding body perception literature, the present study aims to address the neural organisation representing body size. Essentially, the main aim of this study is to determine whether body size is visually encoded through an opponent or multichannel process. This experiment will try to equalise the asymmetry between ‘thinness’ (or contraction of image) and ‘fatness’ (expansion of image) of adaptors through the use of a pilot study assessing the perceived size of the stimuli. Furthermore, the relationship between body dissatisfaction, baseline accuracy, and susceptibility to adaptation effects will also be explored. However, it should be noted that unlike Calder et al. (2009), the present study does not aim to determine the exact number of neural channels responsible for encoding body size, should it be encoded through a multichannel process. While Calder and colleagues hypothesised either two or three channels, the present study will categorise opponent process as ‘two-channel’ and multichannel as ‘more than two channels’. The dependent variable of the main study was the difference in percentage of times a slightly expanded (rather than slightly contracted) image was chosen between baseline and post-adaptation test (i.e. % expanded chosen in baseline test minus % expanded chosen in post-adaptation test). From this point forward, the dependent variable will be referred to as the Pre- to Post- Adaptation Score (PPAS).

1.7.1. Hypothesis 1. The aims of the main experiment are to determine whether body size is encoded through an opponent or multichannel process, a question that will be further explored through the use of a simple adaptation paradigm. Since body size has no definitive ‘neutral’ value, it is predicted that it will be processed via an opponent mechanism. This is mainly due to stimulus properties processed under a multichannel framework exhibiting a relatively perceptible neutral, for example direct eye gaze for gaze perception or face-forward head orientation (Calder et al., 2008; Lawson et al., 2011; Storrs & Arnold, 2012). Although

it could also be argued that the midpoints of colour (processed through an opponent mechanism) are perceived as a grey colour, there are indeed multiple shades of grey that are often difficult to distinguish (Webster & Leonard, 2008). However, it should be noted that not all stimulus properties encoded through a multichannel model have a perceptible 'neutral' point, for example, spatial frequency. Further reasoning for the prediction that body size is visually encoded through two channels comes from studies of face perception, where expansion and contraction of faces were deemed to be processed through opponent coding (Burkhardt et al., 2010). Accordingly, a specific set of predictions can be made in how the adaptation aftereffect should influence the subject's percentage change from baseline to post-adaptation test for what the average body image would look like. The average or 'normal' body will be the composite image of a number of identities, while the two test images will be a $\pm 3\%$ distortion of this neutral. Individuals assigned to the expanded group will be exposed to differing levels of 'fat' images, while those in the contracted group will view 'thin' bodies.

1.7.1.1. Hypothesis 1a. It is hypothesised that adaptation effects will occur, on average, for both the expanded and contracted groups. This means that there should be significant differences between baseline and test in each group, averaged across all levels. That is, PPAS will differ significantly from zero in each group, with positive scores in the contracted group and negative scores in the expanded group.

1.7.1.2. Hypothesis 1b. Assuming body size is encoded through an opponent process, it is predicted that increasing adaptor extremity would result in a more pronounced aftereffect. That is, the least extreme distortion level should produce the smallest PPAS. Additionally, the most extreme distortion level should produce the largest change from baseline to post-adaptation tests. A projected pattern of results is demonstrated in Figure 6, while figure 7 presents a pattern of results that would indicate a multichannel process.

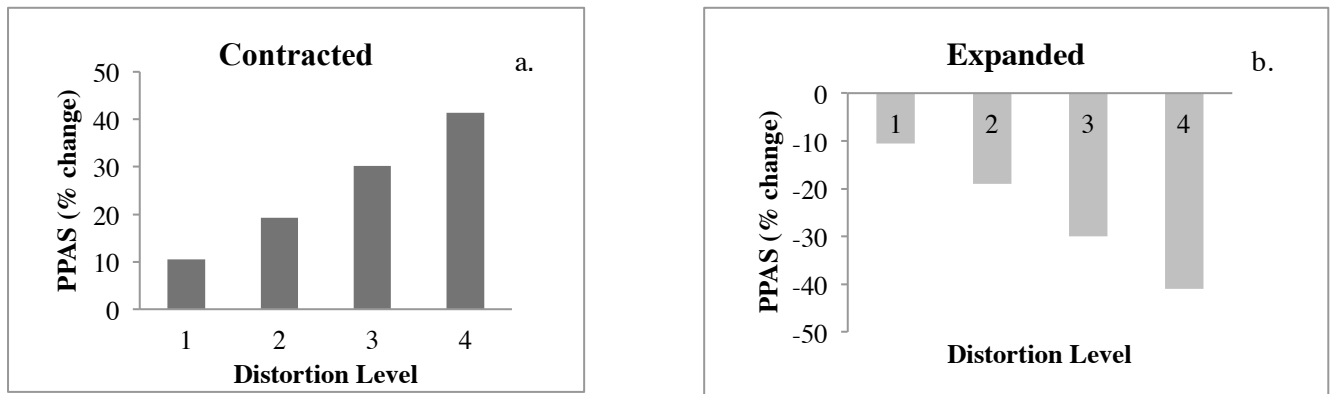


Figure 6: Expected pattern of results in an opponent process. In the contracted group (a.), this is expressed as an increasing positive relationship between PPAS and level. In the expanded group (b.), there would exist a linearly decreasing between PPAS and level.

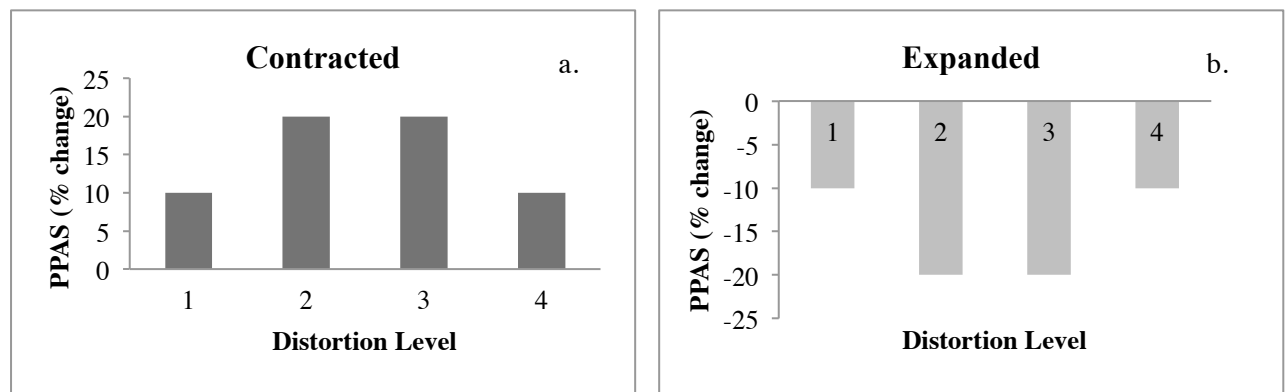


Figure 7: Prospective pattern of results for multichannel process. In the contracted group (a.), this is seen through levels one and four having less positive PPAS than levels two and three. In the expanded group (b.), this is expressed as levels one and four displaying less negative PPAS than levels two and three.

1.7.1.3. Hypothesis 1c. Assuming the pilot study reduced the asymmetry between the expanded and contracted stimuli, aftereffect magnitude is expected to be roughly equal but in opposite directions in the expanded and contracted groups. Therefore not only is the pattern

of results expected to be similar (as stated in hypothesis 1c), but so is the magnitude of each group. Therefore, it is expected that the PPAS magnitude would increase along with the adaptation level (i.e. as the images become more distorted), in similar proportions in each group.

1.7.2. Hypothesis 2. Body satisfaction is a prominent feature of why this research is being conducted. It is of empirical interest to further explore the relationship between body satisfaction and susceptibility to adaptation. Glauert et al. (2009) discovered no significant correlations between body satisfaction and susceptibility to adaptation, with one exception: Higher dissatisfaction was related to decreased susceptibility only when adapted to fat bodies. Extending these findings beyond correlations between body satisfaction and adaptation susceptibility are predicted when controlling for whether the participant wants to be larger or smaller. Furthermore, it is expected that the proportion of times expanded/contracted images are chosen before adaptation will also be correlated with body satisfaction when controlling for direction of desirability.

1.7.2.1. Hypothesis 2a. It is predicted that body satisfaction will be positively correlated with baseline accuracy. That is, as satisfaction decreases, the participant will select one image substantially more than the other, on average at baseline (Fig. 8).

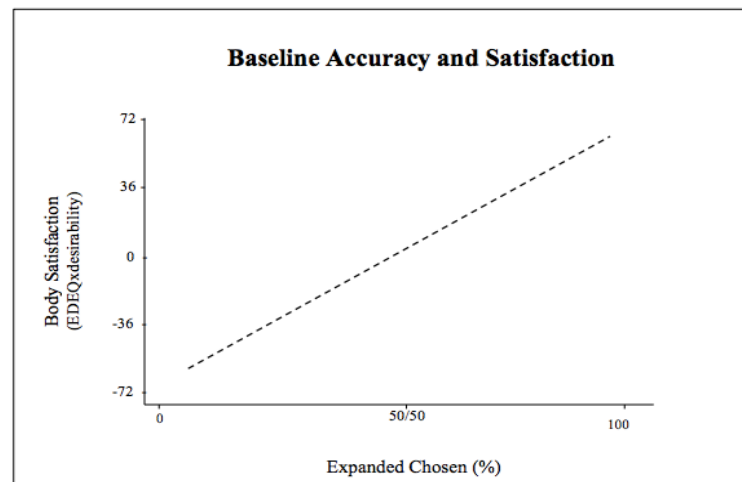


Figure 8: Prospective regression line indicating correlation between body satisfaction and the average percentage of times the expanded test image is chosen before adaptation. Negative satisfaction scores indicate a strong desire to be slimmer, while strongly positive a strong desire for largeness, and scores closer to zero indicates higher satisfaction. Those who desire thinness are expected to select the expanded image seldom, while individuals preferring a fuller figure are predicted to select it often.

1.7.2.2. Hypothesis 2b. It is predicted that body satisfaction will negatively correlate with susceptibility to aftereffect if adaptor exposure is aligned with direction of desirability (Fig. 9). Susceptibility will be calculated as the PPAS averaged across all four levels. That is, as satisfaction decreases, PPAS scores will be more extreme if exposure is in direction of desirability. For example, it is predicted that dissatisfied participants who desire thinness will have a larger PPAS than satisfied individuals, but only when exposed to contracted images during adaptation (Fig. 9a). Similarly, dissatisfied participants seeking largeness should maximise PPAS extremity (i.e. have the most negative scores) when exposed to expanded images during adaptation (Fig. 9b).

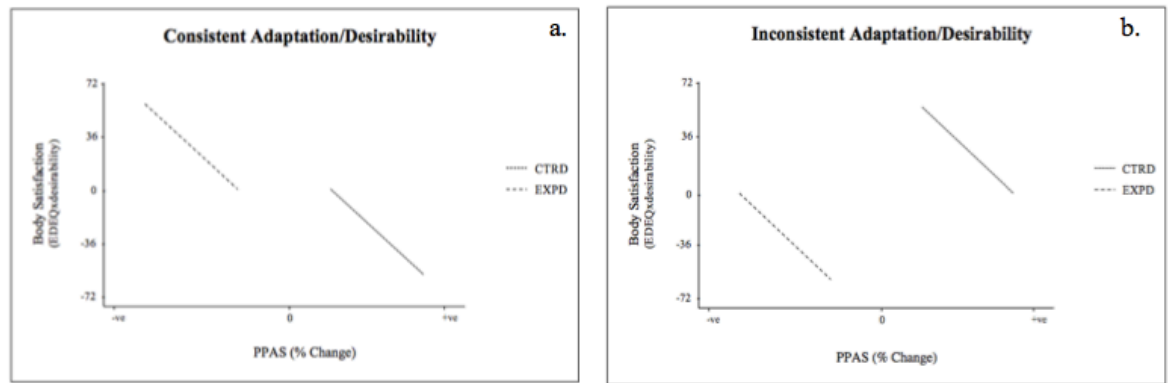


Figure 9: Prospective regression line indicating correlation between body satisfaction and average PPAS when adaptation direction is consistent (a) and inconsistent (b) with that of participant desirability. The more satisfied the participant, the less extreme average PPAS across all levels. When adaptation group is the same direction as desirability, effects are predicted to be more extreme. The opposite is predicted when group is the opposite to that of desirability, in that effects are ‘blunted’.

1.7.2.3. Hypothesis 2c. As seen in Glauert et al. (2009), it is predicted that as satisfaction decreases, adaptation susceptibility will be ‘blunted’ if direction of adaptation is the reverse of participant desirability (Fig. 9b). That is, dissatisfied individuals seeking thinness are expected to have smaller change PPAS than satisfied participants when exposed to expanded images. Similarly, participants low on satisfaction that desire largeness should have less extreme PPAS scores than satisfied individuals when adapting to contracted images.

2. Method

2.1. Stimulus Development

2.1.1. Photography. All images were from the Macquarie University database of body images. The investigator also contributed towards collecting and photographing participants for the database. Full body images of each photographed participant were created from a digital photograph. Every photographed participant in the database posed in front of a grey background in the standardised anatomical position (standing upright with feet and palms facing forward at approximately shoulder width apart). Photography took place in a temperature-controlled booth painted with Munsell N5 neutral grey, illuminated by 15 high-accuracy d65 fluorescent Philips tubes mounted in high frequency electronic battens. There was no other light source in the room during photography, to reduce any variation between each image. Additionally, all images were taken using the same Canon camera, and settings including custom, white balance and ISO always remained the same. Participants were provided with clean, tight-fitting clothing (grey shorts from Cotton On and grey singlet from Supre) so that their figure was visible in the photograph. Additionally, all makeup and jewellery was removed, and all hair was pulled back with both a hair elastic and headband prior to the photograph being taken. Photographed participants had their height measured, and weight was recorded using the Tanita SC-330 body composition analyser.

2.1.2. Adaptation Images. Ten female identities from the Macquarie University database of body images were chosen for the adaptation images in the main study. These identities were chosen because they were the closest in BMI to the direct middle of the ‘healthy’ range of 22 (mean=22.06). Each of these identities was then distorted in increments of 10% up to a maximum 80% both in the expanded and contracted directions. The entire body from the neck to the toes was selected, and distorted using the ‘spherize’ tool set to ‘horizontal’ in Adobe Photoshop, with the ‘feather’ feature set to 200 pixels. This resulted in

17 distorted images of each identity, including the original un-manipulated image, leaving a total of 170 images. Finally, a black bar was placed over the face of each image, in order to ensure that any aftereffects recorded were only due to body adaptation. Due to the nature of the ‘feather’ setting, the extreme distortions required, and the need to include all body parts (from shoulders to toes) within the borders of the ‘spherize’ function, it was impossible to maintain appropriate manipulations without also altering face shape. Therefore, it was particularly important to cover the faces completely in order to prevent any incidental face adaptation aftereffects, as they are already known to be robust for many facial features and stimulus dimensions including size (Burkhardt et al., 2010; Robbins et al., 2007; Storrs & Arnold, 2012; Webster & MacLeod, 2011).

2.1.3. Familiarisation and Test Images. Eight female identities independent of the adaptation identities were chosen from the Macquarie University database of body images for the familiarisation image in the main study. These identities were chosen due to their similarity in BMI to the midpoint of ‘healthy’, which equated to the same mean BMI as the adaptation identities (mean=22.06). A composite identity of these eight images was developed using Psychomorph software, in which each of the original identities was delineated with 306 points. This composite was then manipulated in the same way as the adaptation images

2.2. Pilot Study

A pilot study was developed using these images, where the investigator asked ten members of family and friends to rate each image on an eight-point Likert scale. The scale ranged from one (looks extremely thin) to eight (looks extremely fat), where options two to seven were used to denote very thin, moderately thin, slightly thin, slightly fat, moderately fat and very fat respectively. No neutral point was provided as an option in order to avoid indecisive responding by the participants.

Two additional identities were distorted in a similar manner to the pilot images, and were presented to each participant as practice. These 10 practice images were used to demonstrate the approximate range of body sizes the pilot participants would be rating. Directly after this, each of the 187 (17 composite, 170 adaptors) pilot images were randomly placed in a Powerpoint document, where they were presented in a forward direction for one half of the pilot participants, and backwards for the other half to dilute order effects.

2.2.1. Recalculating Distortion Levels. The means and standard deviations of the scores for each image (17/identity) were calculated in Microsoft Excel. Graphpad Prism was then used to fit both the top and bottom halves of the identity curves separately, to determine whether the expanded and contracted groups could appropriately be fit to a single curve. This process determined that two identities were not symmetrically rated (i.e. the expanded and contracted image ratings fit to different curves), and were thus no longer considered viable stimuli. The remaining eight symmetrically rated identities were then each graphed onto their cumulative Gaussian curves, which also calculated their individual means and standard deviations (Fig. 10; Composite identity). This curve was then used to determine the most appropriate distortion percentage to create the eight levels (four in each group) of adaptation in the experiment. Each identity was then distorted again using Photoshop, according to the cumulative Gaussian curve fit, resulting in stimuli consistent with the perceived body sizes of each identity, rather than reliance on BMI.

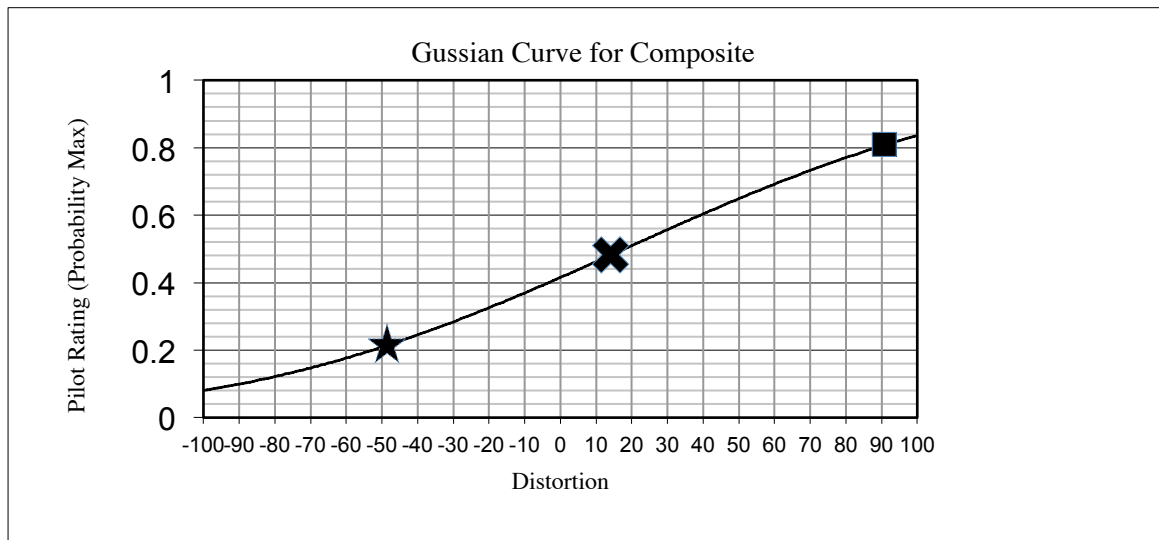


Figure 10: Gaussian curve for the composite identity (which was to be the familiarisation image), given the mean (mean = 17.93, signified by the cross) and standard deviation (SD = 83.89) calculated from the results of the pilot study. This curve was then used to calculate the most appropriate amount of distortion per level and group. Distortions required for level four of the contracted (star) and expanded (square) groups are also signified.

A list of the updated distortion levels per identity can be seen in Table 1. The Y-value indicates the scale score of the pilot, proportioned through 0 and 1 (i.e. a probability scale). That is, a Y-value score of 0.5 indicates the ‘neutral’ point of each identity, since the probability for it to be described as either ‘fat’ or ‘thin’ is equivalent. Y-values between 0.2 and 0.425 signify contracted images, and 0.575-0.8 the expanded. Each level increases by increments of 0.075, since a probability score of more than 0.5 indicated a re-calculated distortion of over 100%, which did not comply with the current method of manipulation. Furthermore, the pilot only tested for images up to +80%, so investigators were reluctant to use images much larger than this.

Table 1:

New Distortion Calculation

Level		Y-value	X-Value							
Identity			1	2	3	4	6	8	9	10
	4	0.2	-53	-49	-49	-38	-40	-42	-46	-46
	3	0.275	-32	-31	-39	-20	-24	-25	-28	-29
	2	0.35	-15	-15	-21	-5	-10	-10	-12	-13
	1	0.425	1	0	-5	10	3	4	2	2
		0.5	17	15	11	24	16	18	16	16
	1	0.575	33	29	27	38	28	31	30	30
	2	0.65	49	44	44	52	42	45	44	44
	3	0.725	66	60	61	68	56	60	60	60
	4	0.8	87	79	82	86	72	78	78	80

Distortions updated according to the pilot study, for each identity at each level and group.

Identities five and seven are missing, as they were not symmetrically rated by participants and were therefore not viable.

Essentially, this entire process was performed in order to obtain the most perceptually comparable images for each identity, distortion level and direction. Using Graphpad allowed us to determine whether an identity was rated symmetrically, in terms of expanded and contracted images appropriately fitting the same sigmoid function. This process also enabled the most perceptually equivalent stimuli for each adaptor level, as well as ensuring that the expanded images were perceived as equally as 'fat' as the contracted were 'thin' (Winkler & Rhodes, 2005). Therefore, instead of examining distortion level in terms of a fixed

percentage, the remainder of the study will be discussed as levels one (the least distorted) to four (the most distorted). For example, level four in the expanded group would mean the participant was exposed to the most expanded adaptors, and so on.

2.2.1.2. Reference and Test Images. Only one ‘neutral’ image was developed from the composite image (which was a +18% distortion of the original identity, Fig. 10). This was then distorted another plus and minus 3% to create the test images, leaving a total of three images of the composite identity (Fig. 11).



Figure 11: Original composite (left) and familiarisation image (right). Original neutral was distorted by 18% as indicated by the pilot study, in order to be rated as perceptually ‘neutral’.

2.3. Main Experiment

The main experiment examined how increasing levels of adaptor extremity results in differing aftereffect size. The main dependent variable was PPAS, and was measured to determine the size and direction of the aftereffect. All body images were presented using Matlab ® version 7, operating Psychophysics Toolbox extensions (Kleiner et al., 2007) through an adapted version of the code used in Brooks et al., (2015). The entire experiment was run on a Toshiba, 21” colour monitor working at a resolution of 1024x768 pixels and 45 frames per second.

2.3.1 Participants. Twenty-four university undergraduate students enrolled in first year psychology at Macquarie University, and an additional three members of the investigator's friends and family participated in the study (Mean age=21.68, SD=7.498, 12 males). Undergraduate students were recruited from the Macquarie University subject pool website and were given course credit for their participation, and participants known to the investigator were offered payment at a rate of \$20/hour to participate in the study. All participants had normal or corrected-to-normal vision. Five participants showed signs in their data of clicking through the course of the study regardless of stimulus (i.e. had either been clicking the left or right mouse key regardless of stimulus), so their data was excluded from analysis. One participant dropped out of the study, thus not completing all four levels of the experiment, so her data was also excluded from analysis. This left data collected from a total of 21 participants (Mean age=25.17, SD=9.581, 11 males).

Each participant, including those known to the investigator, was naïve to the aims and hypotheses of the study. As a visual perception experiment, the inclusion of friends and family as participants is warranted due to the nature of such tasks being difficult or impossible to falsify based on social desirability. Furthermore, all participants were naïve to the hypotheses of the experiment.

2.3.2. Design. The main experiment employed a 2x4 mixed design. The between-subjects independent variable was the type of adaptor presented, and had two groups including expanded (N=12) and contracted (N=9). Each participant completed all four levels of distortion extremity, thus the within-subjects independent variable was adaptor distortion level. Adaptor level was randomised in the first session of the experiment, with the level of the second session being randomised from the remaining three adaptor extremities, and so on. The dependent variable was the change from the baseline test phase to adaptation test in percentage of times the expanded image was chosen during

test, otherwise known as the PPAS. This was expressed as the percentage of times expanded image was chosen prior to adaptation minus after adaptation.

2.4. Procedure

The main experiment ran over four sessions, with each level tested on different days to reduce the influence of any lingering adaptation effects. All sessions were identical, except for the first, in which demographics including age and gender were collected. Additionally, the weight and shape concerns subscale, a 12-item questionnaire adapted from the Eating Disorder Examination Questionnaire (EDEQ), was also recorded in the first session as a measure of body satisfaction. All four sessions of the experiment consisted of a familiarisation phase followed by five practice trials, a baseline test phase, two minutes of adaptation, and a final post-adaptation test phase similar to the baseline, but with six-second top-ups in between each trial.

2.4.1. Demographics and Body Satisfaction. Participants input their gender and at the onset of the first session of the study. A measure of body satisfaction was obtained using an adapted version of the weight and shape concerns subscale of the EDEQ. All information regarding demographics and body satisfaction were collected on the laptop at the onset of the study.

2.4.1.1. Eating Disorder Examination Questionnaire. The 12-item scale provided to participants was a modified version of two of the subscales assessing weight and shape concerns (Fairburn & Beglin, 1994). Items are usually phrased temporally (e.g. ‘How many days over the last 28 have you desired a flat stomach?’), since the EDEQ is generally used as a diagnostic tool for eating disorders and was less appropriate for a non-clinical population. These were rephrased as more global questions in terms of how much each item applied to them (e.g. ‘How intense is your desire to have a flat stomach?’), as the participants were selected from the general rather than clinical population. Response options ranged from 0

(not at all) through 2 (somewhat) and 4 (moderately), to 6 (markedly). One item assessing preoccupation of weight and shape is included in both subscales, but was only asked once for the purpose of the present study. Each item of the questionnaire was asked sequentially on a separate screen, where a point and click was used to indicate response. Each item score was added with a maximum score 72, where higher scores indicate lower body image satisfaction. A thirteenth item, 'To obtain my ideal body shape, I would need to be', with the response options 'Smaller' and 'Larger', was included to obtain a directionality of dissatisfaction.

2.4.1.1.1. Weight Concern Subscale. The Weight Concerns Subscale is a five-item self-report measure assessing importance of weight ("How much does your weight influence what you think of yourself as a person?"), reaction to prescribed weighing ("How much would it upset you if you were asked to weigh yourself once a week -no more, no less- for the next four weeks?"), preoccupation with weight and shape ("How much has thinking about weight and shape impacted on things you are interested in?"), dissatisfaction with weight ("How dissatisfied are you with your weight?"), and desire to lose weight ("How strong is your desire to lose weight?") (Fairburn & Beglin, 1994). The subscale has good concurrent validity with the previously favoured Eating Disorders Questionnaire ($r=0.79$, $p<0.001$), and excellent test-retest reliability ($\alpha=0.92$, $p<0.001$) (Mond, Hay, Rodgers, Owen, & Beumont, 2004).

2.3.1.1.2. Shape Concern Subscale. The Shape Concerns Subscale is an eight-item self-report measure assessing importance of having a flat stomach, preoccupation with weight and shape, fear of gaining weight, feelings of of fatness, dissatisfaction with shape, discomfort seeing body, and avoidance of exposure ("How uncomfortable do you feel about others seeing your shape or figure?"). The subscale has good concurrent validity with the previously favoured Eating Disorders Questionnaire ($r=0.78$, $p<0.001$), and excellent test-retest reliability ($\alpha=0.94$, $p<0.001$) (Mond et al., 2004).

2.4.2. Familiarisation. Participants were seated 57cm away from the monitor, as at this distance, one centimetre of visual space equates to one degree in the receptive field of view. All instructions were provided verbally. They were presented with the familiarisation composite image (Fig. 12b) for one minute at the start of each session (or after the questionnaire in the first session), and were asked to consider this image as the ‘normal’ reference image from that point forward.

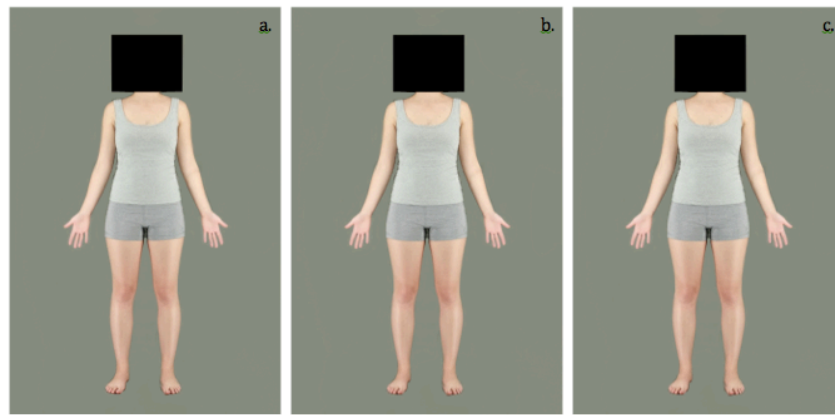


Figure 12: Familiarisation (b) and test images (a;c) presented in the study. Image b. was the instructed ‘normal’ figure, where image a. was distorted by -3% and c. by +3%. After a one-minute familiarisation of image (b), participants were instructed to select which of the two test images was most similar to it. After adaptation, the same task was presented with a six-second top-up adaptation following each trial.

2.4.3. Baseline Test Phase. Prior to adaptation, using a two-alternative forced choice method, participants were shown the two test images (composite image distorted +3% and -3%, Figure 12a and c), side by side. The side of the screen each image was displayed on was randomised for each trial, including the practice phase. Participants were asked to select which of the two images appeared most ‘normal’, or similar to the aforementioned

familiarisation image. The baseline phase included five practice trials, followed by 40 real test trials.

Responses were recorded with a mouse click, where a left mouse click indicated they thought the left image looked more normal, and a right mouse click indicated the right image appeared more normal. Participants were verbally encouraged to answer as quickly as possible. The images were displayed until the selection was made, up to a maximum of three seconds, after which the screen turned grey. Participants were required to make a decision on all trials, even if the test pictures had been taken away after the three-second display. There was a 100ms inter-stimulus interval between each trial.

The baseline ‘score’ was calculated as the percentage of times the expanded image was chosen. Since the familiarisation image lay midway between the two test images, baseline scores should remain at approximately 50%. The baseline was recorded not only to act as a control pre-adaptation, but also as a guide to indicate the accuracy of body size estimation in participants.

The two test and familiarisation (normal) images were 70% the size of the adaptation images formatted to a standard height of 720 pixels and width of 480 pixels to reduce the effects of low-level or retinotopic aftereffects.

2.4.4. Adaptation. An initial two-minute adaptation phase followed baseline. Participants were presented with eight different images of bodies (as described in 2.2.1.) for three seconds, meaning each of the eight bodies was displayed five times over the course of adaptation. This amounted to a total main adaptation time of 15 seconds for each identity in each session. Participants viewed an adaptation image from one of the four levels in their assigned test group – either expanded (N=12) or contracted (N=9) (Fig. 12). The images were presented in a randomised fashion to prevent order effects. Level one was the least distorted of each group (i.e. the most similar to ‘normal’), while level four was the most distorted. This

meant that level four was either the ‘fattest’ or ‘thinnest’ image per identity, for the expanded and contracted groups respectively. Each participant would only ever observe one of these images in the adaptation of any given session, along with the other seven identities of the same level and group.

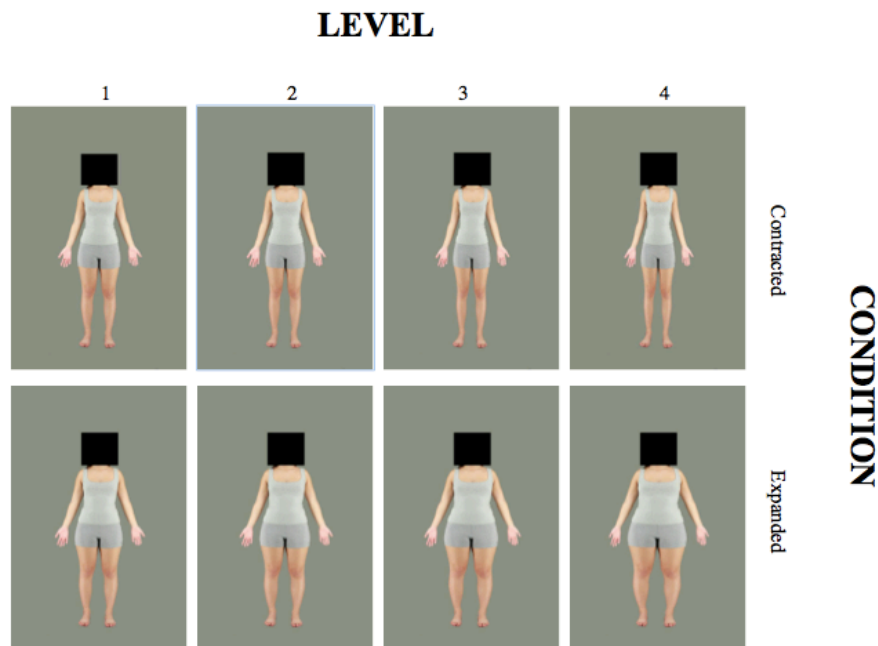


Figure 12: An example of the adaptation images. Each identity (in this case, identity number ten) produced four images for each the expanded and contracted images. Each individual participated in one group only.

2.4.4.1 Post-Adaptation Test Phase. The post-adaptation test phase was identical to the baseline test procedure, but with a six second top-up adaptation in between each trial. The images shown in the top-up adaptations were the same eight images in the initial adaptation, meaning the level was consistent throughout. Again, the order of the presentation of the images was randomised. There was a 200ms inter-stimulus interval in between each trial.

2.4.5. Repetition Across Levels. The entire process (from sections 2.3.2 to 2.3.5.) was repeated in full another three times with different levels of adaptor extremity, meaning

participants attended four sessions in total. The order in which levels were presented was counterbalanced. Similarly, participants were randomly allocated to either the expansion or contracted group at the beginning of their first session. Whether the participant was exposed to expanded or contracted adaptors was maintained throughout their four sessions. There was a time period of at least 12 hours between each session, to avoid any lingering adaptation effects. Although some participants undertook the experiment in different locations to the others, all four sessions were always in the same location, ensuring that all four sessions remained constant for each participant. All but three of the participants undertook the experiment in a testing laboratory in Macquarie University, while the rest participated in the home office of the investigator. They were generally similar locations, in terms of lighting, wall-colour, and desk height.

3. Results

3.1. Pilot Study

As expected, participants' subjective perception of normal was somewhat misaligned with an objective measure, in this case BMI. An expansion of between 13% and 23% was required on the original neutral identities in order for them to be deemed perceptually normal by participants, according to the pilot ratings and cumulative Gaussian plots. Furthermore, this upward shift in 'normal' transferred throughout the continuum of distortion for each identity. For example, the composite identity required a shift from 0% to +18% distortion to be considered 'normal', from +10% to +28% distortion to be considered 'slightly fat', and so on.

3.2. Main Study

Each participant's score is discussed in terms of PPAS. Higher values indicate that the participant chose the expanded image fewer times in the post-adaptation trial than baseline, while negative values represent participants who chose the expanded image more post-adaptation than pre-adaptation. Any significant change in score from baseline test to post-adaptation test indicates a distortion aftereffect as a result of adaptation.

3.2.1. Baseline Data. Baseline scores demonstrated that participants chose the expanded and contracted image relatively equally, on average. They tended to choose the expanded image ($Mean = 53.92\%$, $SD = 10.45$) slightly more often than the contracted image, although this difference was not significant according to a one-sample t-test ($t(20) = 1.722$, $p = .100$).

3.2.2. Hypothesis 1. To test whether adaptation aftereffects differed across level and group, PPAS scores were analysed using version 22 of SPSS with repeated measures t-tests and a repeated measures General Linear Model (GLM). Planned contrasts were then used to test whether a linear or quadratic relationship existed between levels. Each group was

analysed independently, with adaptor level and PPAS as the factors analysed for each group. The family-wise type one error rate was set at 0.05. In order to do this, the dataset was split by adaptor group, and each was analysed separately.

3.2.2.1. Hypothesis 1a. It was hypothesised that aftereffects would occur for each group, on average. This was tested using a repeated-measures GLM, which returned non-significant omnibus results for both the expanded ($F(3,11) = 2.48, p = .078$) and contracted ($F(3,8) = .693, p = .565$) groups. Mauchley's test was not violated in either the expanded (Mauchley's $W = 0.708, p = 0.646$) or contracted (Mauchley's $W = 0.867, p = .966$) groups, indicating the assumption of sphericity remained intact.

3.2.2.2. Hypothesis 1b. It was predicted that body size would be encoded through an opponent process, meaning that an increase in adaptor extremity would result in a more extreme PPAS. Although no significant overall aftereffects were detected in either group, there was evidence of a significant linear relationship between PPAS and level, but only in the expanded group ($F(3,11) = 5.370, p = .041$). Although significance was obtained, the dataset still appears somewhat vague, for two main reasons. First, level one procured an adaptation effect in the opposite direction to expected, although this difference was not significantly different to baseline ($t(11) = 1.196, p = .257$) (Fig. 13a).

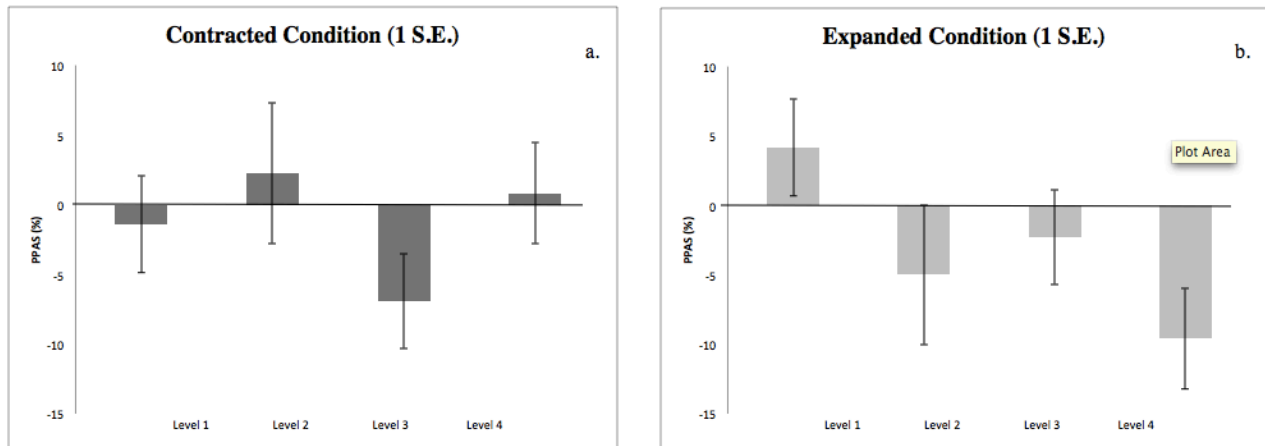


Figure 13: Change in selection percentage of expanded test image between baseline and post-adaptation test (PPAS) per distortion level of adaptor, in the expanded (a) and contracted (b) groups. Error bars represent Standard error of the mean (SEM).

Similarly, as can be seen in figure 13a, level 3 appears to deviate from the linear trend. No evidence supporting linear relationship was discovered in the contracted group ($F(3,8) = .012, p = .915$). Neither group demonstrated significant quadratic relationships between variables ($F(3,11) = 5.370, p = 0.780$ for expanded; $F(3,8) = .167, p = .694$ for contracted).

3.2.2.3. Hypothesis 1c. In order to demonstrate the validity and reliability of the pilot study (which aimed to combat the perceptual asymmetry between fat and thin stimuli), it was predicted that the aftereffects present would be equal and opposite of their same-level opposite-group counterparts. There was no evidence of significant aftereffects at any level in the contracted group ($t(8) = -.280, p = .786$ for level one; $t(8) = .672, p = .521$ for level two; $t(8) = -1.849, p = .102$ for level three; $t(8) = .128, p = .902$ for level four). While there was evidence supporting a significant effect in level four of the expanded group ($t(11) = -2.566, p = .026$), levels one to three demonstrated no significant differences ($t(11) = 1.198, p = .257$,

$t(11) = -1.010, p = .334, t(11) = -.689, p = .505$ respectively). Due to this difference (as well as the significant linear relationship between PPAS and level in the expanded, but not contracted group), no further testing was required to determine that this hypothesis was unsupported.

3.2.3. Hypothesis 2. Correlational analyses were used to test whether relationships existed between body image satisfaction, susceptibility to aftereffects, group, and baseline accuracy. Body satisfaction was calculated as the raw EDEQ score multiplied by minus one for participants who desired to be smaller, and positive one (i.e. remained the same) for participants who desired to be larger in order to account for directionality of desirability. Baseline accuracy was calculated as the percentage of times the expanded image was chosen on pre-adaptation test, averaged across all four levels. The participant's average baseline score minus their average post-adaptation test score, or their average PPAS, was how susceptibility to adaptation was determined.

3.2.3.1. Hypothesis 2a. There was no evidence of a significant correlation between baseline accuracy and either raw EDEQ scores ($r(19) = -.043, p = .854$) or body satisfaction ($r(19) = -.094, p = .687$) (Fig. 15).

3.2.3.2. Hypotheses 2b and 2c. After this initial test, susceptibility scores were correlated with EDEQ scores ($r(19) = -.141, p = .542$), as well as body satisfaction scores ($r(19) = .102, p = .661$) (Fig. 15), which both returned results that were non-significant. Because there was no evidence found suggesting an overall correlation between susceptibility, baseline accuracy, EDEQ scores and body satisfaction, the dataset was split by group. There was still no evidence of a significant correlation between satisfaction and susceptibility in either the expanded ($r(10) = .087, p = .787$) or contracted ($r(7) = -.008, p = .983$) groups. Since no relationship had been determined, direction of desirability was withdrawn, although even raw EDEQ scores did not

significantly correlate with baseline accuracy ($r(10) = .132, p = .682$ for expanded, $r(7) = -.390, p = .300$ for contracted). Additionally, no significant relationship was discovered between raw EDEQ scores and susceptibility ($r(10) = -.075, p = .816$ for expanded, $r(7) = -.143, p = .751$ for contracted).

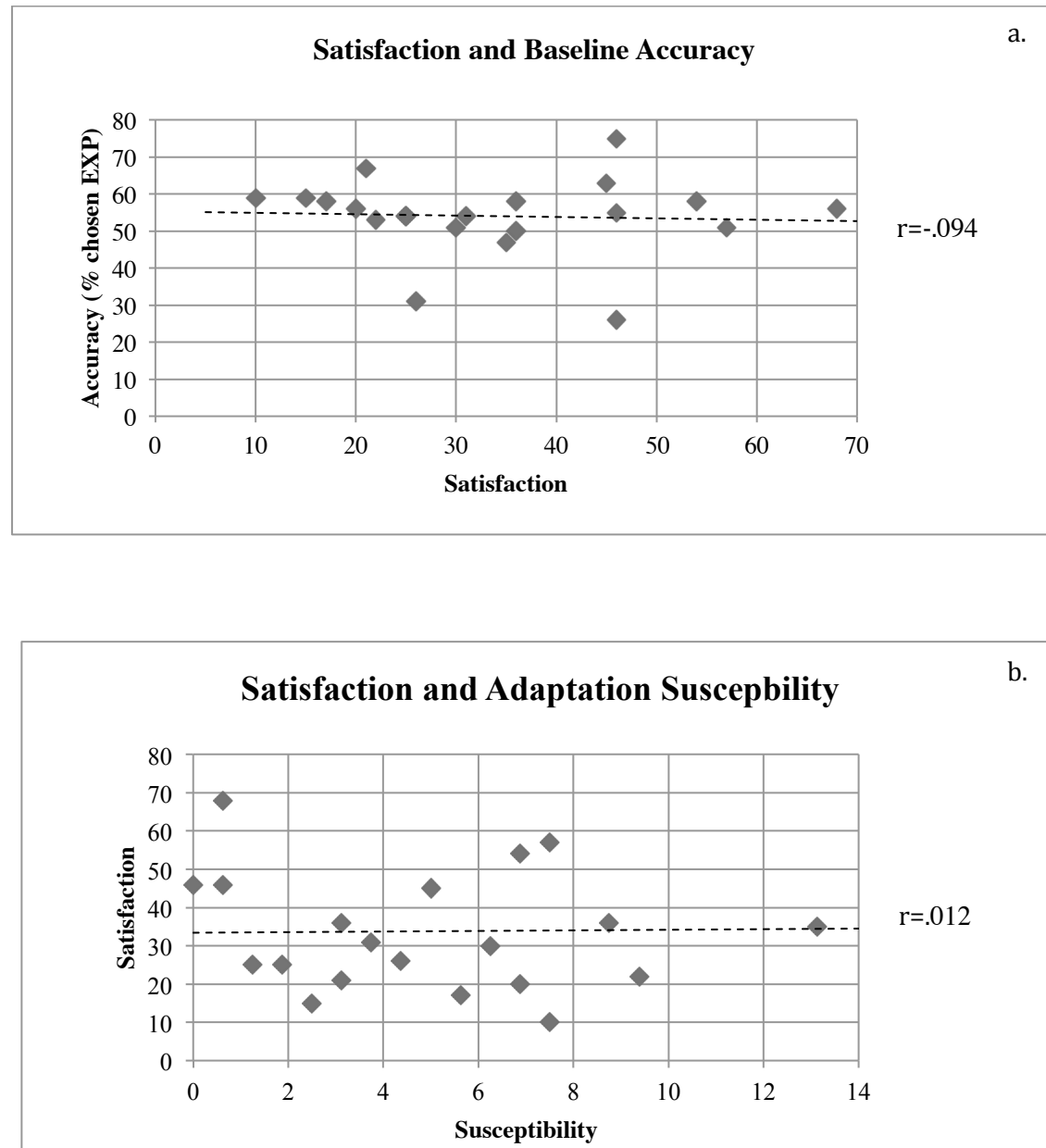


Figure 15: The relationships between body image satisfaction and both baseline accuracy (a.) and adaptation susceptibility (b.) returned correlation coefficients that were not significant

4. Discussion

4.1. Summary of Results

The current study aimed to determine whether body size is visually encoded through a multichannel or opponent process. This was tested in a mixed-design adaptation paradigm, where participants were asked to determine which of two images (one expanded by 3% and one contracted by 3%) appeared most like the image previously defined as normal. The overall results of this study partially supported the hypothesis that body size is visually encoded through an opponent process, in that a linear relationship between adaptor extremity and aftereffect size was demonstrated only in the expanded group. However, these results must be interpreted with caution due to no significant aftereffects being present in the contracted group, even when distortion level was most extreme. Despite this reasoning, the lack of significance in the contracted group is particularly troubling, seeing as body size aftereffects have been demonstrated repeatedly in prior research (Glauert et al., 2009; Hummel, Grabhorn, et al., 2012; Hummel et al., 2013; Hummel, Rudolf, et al., 2012; Winkler & Rhodes, 2005). The results from the peripheral hypotheses remained unsupported, as there were no significant relationships between any measures of body satisfaction and baseline accuracy or aftereffect susceptibility. These findings were true both for each group individually, as well as when the entire dataset was grouped together. Despite its limitations, this study is among the first to explore the way in which the human figure is visually encoded, and has thus far been the only investigation into the number of neural channels responsible for processing body size.

4.2. Stimulus Development

In order to provide stimuli that most closely represented a ‘normal’ figure, a number of test stimuli were presented in a pilot study to a group of 10 willing

participants. Each un-manipulated identity shown in the pilot was of a female with a BMI of approximately 22, which is considered the middle of the normal range of 'healthy'. However, this pilot study demonstrated that each of these identities would need to be expanded by 13-23% (depending on the identity) in order to match participants' visual definition of 'normal'. This was particularly intriguing, as it is consistent with the findings by Winkler and Rhodes (2005), who determined an asymmetry between expanded and contracted figures. Although Winkler and Rhodes (2005) were testing aftereffects, while the pilot was measuring non-adapted perception, it is possible that the asymmetry they noted could have been due to a lateral shift between objective measures of body size and perception, as seen in the present study.

4.3. Hypothesis 1

The main aim of the present study was to determine whether body size was visually encoded through an opponent or multichannel process. An opponent process was predicted, due to body size not having one single clear 'neutral' point that often exemplifies stimulus dimensions encoded through a multichannel mechanism, for example direct eye gaze (Calder et al., 2008), or body (Lawson et al., 2009) and face (Lawson et al., 2011) orientation.

4.3.1. The Expanded Group

4.3.1.1. Support for Opponent Coding. In the case of the expanded group, increasing adaptor extremity indicated images that had been digitally manipulated as increased in overall body size. Increases in PPAS along with this expansion in body size signalled a larger aftereffect, since the adaptation images were perceived as fatter. This is because, as expected, participants in the expansion group selected the expanded test image more often in the post-adaptation phase than prior to adaptation. This finding is consistent with prior research, demonstrating that appropriate aftereffects occurred as per

group. That is, adaptation to expanded images resulted in the increase in the body size perceived as ‘normal’, a finding congruent with prior research (Glauert et al., 2009; Hummel, Grabhorn, et al., 2012; Hummel et al., 2013; Hummel, Rudolf, et al., 2012; Re et al., 2011; Robinson & Kirkham, 2014).

Although obtaining an adaptation aftereffect following the presentation of expanded figures is congruent with prior research, the most novel and interesting finding of the current study is the pattern of aftereffects following differing levels of adaptation. The aftereffect size increased linearly along with adaptor expansion, a finding consistent with opponent coding (Calder et al., 2008; Pond et al., 2013). Due to this, it can be deduced that body size is encoded via a norm-based process, implying that there exist two broadly tuned neural channels, each of which are responsible for detecting opposite extremes of the body size scale. That is, one neural channel is maximally tuned towards visually encoding slim bodies, while the other is responsible for encoding fat figures.

The way in which body size is perceived is dependent on the firing rates of each respective neural channel, as described in section 1.3.1. Therefore, hypothetically the ‘normal’ figure would have activated each of the neural channels equally (Calder et al., 2008; Pond et al., 2013; Rhodes & Jeffery, 2006; Rhodes et al., 2013). Following the exposure to an enlarged figure, the ‘fat’ channel became adapted, thus shifting the perceived ‘normal’ in the larger direction, as indicated by participants tending to choose the expanded test image more often after baseline (Robbins et al., 2007). The more perceptually enlarged the adaptors, the more pronounced this distortion.

4.3.1.2. Complications with Interpretation. Although statistical analysis returned a significant result for a linear relationship between PPAS and level in the expanded group, closer inspection of the data is required. First, the omnibus F-test indicates no overall effect of adaptation at all, where independent testing by each level returned non-

significant results in levels one through three. The inability to detect independent aftereffects at these levels of distortion is problematic, in that prior research has demonstrated that adaptation is possible with similar levels of contraction (Hummel, Rudolf, et al., 2012).

There are a number of reasons why the three least distorted groups in the expanded group could possibly have not produce significant aftereffects. Most importantly, using test images that differed by a distortion of only 6% (one by +3 and the other by -3) resulted in an extremely insensitive test. In order for significance to be obtained with difficult to discern test images, a large sample size would be required. Having a design that is not sensitive enough is detrimental, in that even if adaptation had occurred, being unable to distinguish between the two figures would have rendered the aftereffects powerless. It may have been difficult for participants to reliably distinguish between these two images, meaning a slightly larger distortion or sample size would be required to obtain significant results. A small sample size and insensitive design may also provide an explanation for why, at first glance, the pattern of results does not appear to satisfactorily correspond with an opponent process explanation, as seen in figure 12a.

Since the present data was in some ways inconsistent with prior research, in that the aftereffects were non-significant, it is still important to interpret the significant linear relationship in the expanded group with caution. Because there was a significant linear, but not quadratic relationship between PPAS and level in the expanded group, the present study still provides tentative evidence of an opponent process model of body size estimation. Future studies will aim to increase the power of the present design by recruiting more participants, as well as widening the distortion gap between the two test figures.

4.3.2. Explaining Results from Contracted Group. Although evidence from the expanded group is somewhat congruent with an opponent coding framework, the contracted group failed to provide any significant linear trend between adaptor extremity and aftereffect magnitude (figure 12b). Even more troubling was the inability to obtain any aftereffect at any level, even when adaptors were maximally contracted. This is particularly problematic, as adaptation to thin figures has already been demonstrated as relatively robust throughout a number of studies (Glauert et al., 2009; Hummel, Grabhorn, et al., 2012; Hummel, Rudolf, et al., 2012). Due to the inability to observe a linear increase in PPAS along with the extremity of contraction in adaptors, the evidence supporting an opponent process model of body size estimation must be interpreted with caution.

There are a number of reasons that could potentially explain why no observable contraction adaptation effects were detected in the present data sample. First, the relatively high non-compliance and dropout rate resulted in a smaller than intended sample size in the contracted group ($n=9$), meaning it had less power than the expanded group ($n=12$). Additionally, including test images that were just 3% distortions of the familiarisation image resulted in a design that was potentially not sensitive enough, particularly with such a small sample. Because it was extremely difficult to distinguish between the two images, even large aftereffects may have been unlikely to detect with a subject pool of only nine. This may also be why the omnibus F-test was not significant in either group.

One final explanation as to why the two groups deviated so vastly may lie in the heavy reliance on the pilot study. As previously mentioned, the means and standard deviations for each identity from the pilot study indicated that all the original (0% distorted) images tended to be rated as ‘slightly thin’ by participants (see section 4.2).

For example, according to the pilot, the composite image needed to be distorted by +18% to obtain a 'normal' body size. Essentially, this meant that the distortion curve for that identity would have been shifted upwards by 18% if it were to be used as an adaptation identity (which it was not, as it was the test identity).

However, although the pilot study aimed to provide appropriate adaptation images by balancing the stimuli in terms of subjective perception (rather than objective measures of weight), using the pilot study to determine the image distortion in the main experiment could be problematic if participants were dishonest with their responses. Asking participants to label an individual as 'extremely fat' could have invoked general issues with self-report measures, including social desirability biases, in that it could refute the moralistic views of self, including tolerance (Paulhus & John, 1998). Essentially, blatantly labelling an individual as 'fat' may be seen as shallow and negative, which may contradict the moralistic self-image of the participant. It should be noted that the pilot participants were reluctant to rate any of the images as 'extremely fat', even if they had been expanded by 80%. Some verbalised this reluctance, with one expressing 'I don't want to be mean', implying that at least some participants were somewhat censoring their scoring. Furthermore, some expressed the aforementioned issues with the images, including 'I would have rated this an 8, but the arms are too skinny'. Reasoning to avoid higher scores for images, even for images expanded by +80%, could have therefore influenced the main study if ratings given weren't necessarily aligned with perception, but rather social desirability.

The composite image can again exemplify this issue with the pilot study and self-report measures in terms of distortion level for each group. While the contracted group resulted in distortions of -52%, -32%, -14% and +2 (levels four to one), the expanded groups images would have been more objectively extreme, with distortions of +88%,

+60%, +50% and +40% respectively. If the shift upwards in distortion was due, at least in part, to biased responses in the pilot, the expanded adaptors may have been more extreme than their contracted group counterparts. Therefore, although the intention of the pilot study was to aid the development of equally fat and thin adaptors for each level, reluctance to rate images as ‘extremely fat’ could have incidentally resulted in asymmetric distortion levels. Since there was an apparent lack of ‘extremely fat’ images, the investigators were forced to include contracted adaptors that may have been too subtle to instigate a strong enough aftereffect to previously discussed design issues.

4.3.2.1. Multiple Adaptor Identities. Another important aspect of the sensitivity of the present study lies in the transfer of aftereffect between identities. While Winkler and Rhodes (2005) demonstrate that aftereffects can cross adaptor-test identity, Brooks et al., (2015) has noted that although there is an overlap between ‘self’ and ‘other’ body identities, the neural channels responsible for encoding them are still distinct. Therefore, it is possible that the size of the aftereffect has been somewhat reduced (although not completely negated) by using completely independent adaptation and test images. Reducing the aftereffect magnitude is particularly problematic when considering the small sample size in the contracted group, as well as the overall issues with using two difficult to distinguish test images. However, since multiple adaptor identities were used, there would likely have been a stronger identity crossover than in Brooks et al., (2015), where only a single identity was adapted.

Providing participants with multiple adaptor identities not only served to strengthen adaptor-test identity crossover, but also aimed to reduce boredom in three ways. First, adapting to one image for two minutes, followed by an additional two minutes in total of top-up adaptation, could quickly become boring for the participants. This in turn could prevent them from looking at the picture for the entire allotted period

of time, meaning they would not properly adapt to the image. Furthermore, it is important to remain mindful of the central focus of this field of research, and general applications to real-world issues. Realistically, individuals often view multiple of the same body type within their surroundings, for example, seeing thin females in western media. Therefore not only did using multiple adaptor identities prevent the effect being ‘blunted’, but also produced a study in which participants would remain more attentive, and provides a more accurate representation of real life.

4.4. Hypothesis 2

It was hypothesised that body image satisfaction, whether it be direct EDEQ scores or body dissatisfaction scores accounting for direction of desirability, would be related to accuracy of perception and susceptibility to adaptation. Although little prior evidence has suggested a relationship between body image satisfaction and susceptibility to adaptation, it was predicted that an improvement in the images used, as well as the repeated-measures design may shed more light on the matter. One finding within this field of research includes the positive relationship between accuracy of body size estimation and body image satisfaction, where as satisfaction increased so did the tendency for inaccuracy (Glauert et al., 2009). It was believed that this finding would only be emphasised when considering the direction of dissatisfaction, as the aforementioned study assumed that dissatisfaction indicated a desire for a more slender physique. This is because it was anticipated that those who desired a slimmer figure would inaccurately perceive bodies as larger, and the reverse would be expected for individuals who desired a larger body size. However, no such relationship was determined, even when separately considering both group and direction of desirability.

Overall, contrary to all predictions, no significant relationships were found between any measures of susceptibility, accuracy and body image satisfaction, even

when analysed separately by group. This was true when assessing EDEQ scores with and without the inclusion of desirability ratings, when both disregarding and accounting for group separately, and when considering the direction of susceptibility scores. This is possibly due to the lack of power, mainly stemming from a small sample size of just 21. Additionally, large standard deviations, with high EDEQ scores a rarity in the sample, would have made finding any kind of significant correlation difficult, particularly in such a small sample size.

4.5. Limitations and Future Directions

Limitations of the present study involve issues with the design, including the importance of the familiarisation phase, and the use of only female figures. Other limitations such as a small sample size, and reduction of power due to the insensitive design, will also be further explored, and methodology choices such as using PPAS instead of PSN will be explained. Developing an understanding of these issues has enabled the investigator to improve the design, with one of the future prospects being to re-test with the appropriate corrections made. Additionally, knowing the limitations of the current design may help broadly improve other future studies, that will inevitably be utilised to better understand how body size and shape is visually encoded.

4.5.1. Reliance on Familiarisation. Although the intention of the present study was to determine mechanisms underlying visual body size adaptation, Calder and colleagues (2008) also note that adaptation occurs for any stimulus, including a perceptively ‘neutral’ stimulus dimension. Therefore, the incidental adaptation phase when participants were familiarising to ‘normal’ must also be considered a general limitation of the design. As discussed in section 1.3.2, while adapting to ‘neutral’ produces no effect in an opponent process, it does create some influence if body size were to be encoded through more than two neural channels. In a multichannel model, an

increased amount of ‘normal’ responses would be expected for body sizes slightly expanded and contracted to the familiarised image (Calder et al., 2008). However, the 2AFC design did not allow for this in either of the test phases, since the familiarisation image was not provided as an option during each test phase trial. It should be noted that the familiarisation image was equidistant in distortion level from each of the two test images ($\pm 3\%$). This, in addition to the evidence suggesting body size is encoded through only two neural channels, means that the issues of adapting to a neutral image are likely to be redundant (Calder et al., 2008; Pond et al., 2013).

Additionally, the importance of a familiarisation phase lies in there being no absolute ‘normal’ body size and shape. It is not ideal to rely so heavily on participants’ recollection of an image, particularly in such a difficult task. However, not having an instructed normal figure could have incurred floor and ceiling effects, which are problematic in that no data can be extracted beyond them. Therefore, if floor (or ceiling) effects were observed in all levels, it would be impossible to determine whether a pattern existed, and whether they signified opponent or multichannel processing. However, since no floor or ceiling effects were ever observed, and the direction of adaptation in each group corresponded with prior research (Glauert et al., 2009; Hummel, Grabhorn, et al., 2012; Hummel et al., 2013; Hummel, Rudolf, et al., 2012; Winkler & Rhodes, 2005), the inclusion of an attributed ‘neutral’ is far more beneficial than detrimental to the methodology of the study.

One final issue with including a familiarisation phase at the onset of each session lies in the order in which each phase of the study was conducted. The baseline phase had to be prior to the post-adaptation phase, and the familiarisation had to be before the baseline phase. This was true in every session, as the baseline phase could not follow adaptation since lingering aftereffects would likely skew the result in the direction of the

assigned group. Therefore, there is a slight chance that order effects could partially contribute towards the findings, in that participants could have had a better recall following familiarisation (in the baseline), than they would have had a few minutes after (post-adaptation). That being said, prior research using different methods has repeatedly demonstrated body-size adaptation effects (Glauert et al., 2009; Hummel, Grabhorn, et al., 2012; Hummel et al., 2013; Winkler & Rhodes, 2005), plus this issue of order would not incur differing strengths of aftereffect for each level (which were also randomised), as was observed in the present study.

4.5.2. Exclusively Female Stimuli. Another methodological restriction of the present study is that only female identities were displayed throughout. This could be limiting in that the generalisability of findings to all bodies is in question. Although there was evidence supporting an opponent process for encoding body size in females, it cannot be claimed with certainty that the same mechanisms are responsible for encoding male bodies. This is particularly pertinent due to evidence suggesting that gender-specific aftereffects occur in human bodies, and that adaptation is stronger when the gender of the adaptor is the same as the participant (Palumbo et al., 2013). Furthermore, both males and females participated in the study, despite the presentation of only female figures. Again this could be problematic in that it is possible that the females could have identified the stimuli as ‘self’ more with the images than the males, which has shown to be of importance when visually processing body shape (Brooks et al., 2015; Palumbo et al., 2013). Future studies would incorporate a similar methodology with male bodies, in order to be able to confidently state whether all human body size is encoded through an opponent process.

4.5.3. Point of Subjective Normality versus PPAS. The current design deviates from a vast amount of the body perception literature, as PPAS, rather than PSN, was calculated as the main dependent variable. Although calculating the PSN through a staircase paradigm was

originally intended for the present study, it was soon discovered that a significant overlap between adaptor and test images might be problematic. Only a certain range of body sizes can be considered ‘normal looking’ enough to pass as a human figure, particularly when distorting the identities using Photoshop, as is the case for the present study (described in section 2.2.2). Since some large changes in PSN are expected, the staircase stimuli would need to accommodate such changes. Because of these large aftereffects, the test stimuli would need to include distortions as high as $\pm 30\%$, in order to avoid ceiling and floor effects, after which no more relevant information can be interpreted.

It is important to note at this stage that the reason why it would have been problematic should the adaptation and test stimuli overlapped in distortion. It is important to note that adaptation is constantly occurring, even to perceptively ‘neutral’ stimuli (Calder et al., 2008). Therefore, following adaptation, participants would have continued to adapt to the test images presented to them. This additional adaptation would inflate the intentionally induced aftereffects, resulting in a more extreme aftereffect than was initially induced. This would not be problematic should adaptor and test images overlap in all four levels of each group, meaning that this incidental adaptation would have remained constant. This would mean that either the least distorted level would have needed to be distorted more than $\pm 30\%$, or that all levels had to be distorted within the range of $\pm 30\%$. Neither of these options were ideal, since they both restrict the testable distortion range.

Restricting the testable distortion range is problematic, because it would require smaller steps in distortion between each level. Having only small steps between levels could have led to un-interpretable data, as relatively large increases in adaptor extremity would be required to incur aftereffects different enough to determine the way in which body size is encoded. Furthermore, only perceptibly human stimuli would stimulate the neurons of interest, meaning that all stimuli developed needed to be within the realm of realistic body

size and shapes. This means that outrageously distorted body shapes (which would have been required if all adaptors had to be a minimum of $\pm 30\%$) would not only be difficult using the current methods of manipulation, but also may not be testing the intended neural structures.

The alternative method used in the present study has been explored in the face perception literature (Little, DeBruine, & Jones, 2011). Just like through PSN calculations (either through method of adjustment or a staircase paradigm), the current design enabled both accuracy of perception, as well as measurement of aftereffects. Presenting the two test stimuli that were identical within each trial also avoids the previously discussed issues of compounding the intended adaptation with the post-adaptation test trials for a few reasons. First, since the two test images were only slightly distorted, the additive effect would be much less than if a staircase paradigm was used for the post-adaptation test. Additionally, every group was presented with the same identical images the same number of times. This would not have been the case with a staircase design, because as the post-adaptation test trials continue, distortion level would narrow according to their response (and therefore their direction of adaptation). Furthermore, since participants were exposed to images that were symmetrically distorted from 'normal', any additive adaptation effects would effectively be cancelled out. Finally the 2AFC method allows for a greater range of distortion levels for adaptors, since adaptor and test image stimuli should not overlap in distortion.

4.5.4. Design Sensitivity. The main limitation of the present study could have been the inability to record adaptation effects in the contracted group, and could be explained through test stimuli that were too similar for such a small sample size. It is possible that the inability to record aftereffects, where previous studies have had no such issues, could be due to the inability to differentiate between the two test images. At distortions of merely $\pm 3\%$, a difference of only 6% in test images may have reduced the ability to record adaptation aftereffects, particularly in the contracted group due to the

smaller sample size. This difficulty would have been compounded by the small sample size, since difficult to distinguish test images would have required a larger sample to reliably obtain significance. Future studies would aim to extend on the current methodology, but with $\pm 5\%$ distortion of the familiarisation, thus producing more distinguishable test images. Although the current study is not aiming to investigate the aftereffects themselves, but rather as a pattern, being able to reliably measure adaptation is still of critical importance. Evidence demonstrating the linear relationship between adaptor extremity and aftereffect size for 'thin' bodies would also need to be demonstrated in order to convincingly indicate that body size is encoded through an opponent process.

4.5.5. The Pilot Study. The issue with social desirability bias when piloting images is a limitation that has already been discussed in section 4.3.2. While socially desirable response bias may have been somewhat unavoidable, since a self-report scale was the most appropriate method to test each image, future studies could reduce its effects in some simple ways. Avoiding having to give ratings out loud to a known individual could alleviate some of the pressures experienced by participants. This could be achieved through a computerised system, where a certain level of perceived anonymity can be maintained. Using a computerised (or even written) system of obtaining self-reported measures could also enable participants to be more honest, since rating an individual as 'extremely fat' could be more difficult to speak than to write, particularly in front of a known experimenter, as was the case in the present study.

4.5.6. Future Directions. Future studies will aim to amend present issues, including replication of the present design using more distinguishable test images at a distortion of $\pm 5\%$ (rather than 3%) of the familiarised 'normal'. Other future endeavours stemming from the present study will also focus on the relationships between

accuracy of body size perception, susceptibility to adaptation and body image satisfaction. Although no evidence supported any type of connection between these constructs, it is possible that the small sample size and narrow spread of EDEQ scores hindered the ability for significant correlations to be determined. Lack of power was further compounded by the hypotheses of the present study splitting the group by both direction of desirability and group. Further research involving a larger sample size and a wider spread of EDEQ scores could aid a more conclusive and informative dataset. This is especially relevant when discussing future between-subjects methodologies, as participants would not be required to continually return with little to no relevant information pertinent to the specific question being collected.

4.6. Conclusion

The main aim of the present study was to better understand the neural underpinnings of visual body size estimation. It was predicted that body size would be visually encoded via an opponent (two-channel) rather than multichannel (three or more channels) mechanism. Further aims of the study were to gather more information about the relationship between body image satisfaction and variables including perception accuracy and adaptation susceptibility. Adaptations to four different levels of body distortion produced aftereffects somewhat consistent with an opponent model (linear relationship between adaptor extremity and aftereffect magnitude) in the expanded (but not contracted) adaptor group. No evidence was found of a relationship with body satisfaction and either accuracy of perception, or susceptibility to adaptation. Issues with the present design may have contributed towards the difficulties in obtaining significant effects. Heavy reliance on the pilot study, which could have been prone to social desirability bias, as well as a small sample size and insensitive design are issues that can be addressed and improved. Future studies would aim to amend this lack of sensitivity by

both recruiting more participants, and using more distinguishable test stimuli (distortion of $\pm 5\%$ rather than $\pm 3\%$). Gaining a better understanding of how humans visually encode body size through the use of an adaptation paradigm will ultimately enable better overall models of body size estimation, which could eventually lead to improvements in our current knowledge of maladaptive body image processing.

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Appendix A: Modified EDEQ

Please select the appropriate number below (each was presented separately on a screen, with ovals representing selection choices).

Questions	Not at all		Some what		Mod erate		Markedly	
1. How intense is your desire to have a flat stomach?	0	1	2	3	4	5	6	
2. How much has thinking about weight and shape impacted on things you are interested in (for example, working, conversing, reading etc.)?	0	1	2	3	4	5	6	
3. How intense is your fear that you might gain weight?	0	1	2	3	4	5	6	
4. How fat have do you tend to feel?	0	1	2	3	4	5	6	
5. How strong is your desire to lose weight?	0	1	2	3	4	5	6	
6. How much does your weight influence what you think of yourself as a person?	0	1	2	3	4	5	6	
7. How much does your shape influence what you think of yourself as a person?	0	1	2	3	4	5	6	
8. How much would it upset you if you were asked to weigh yourself once a week (no more, no less) for the next four weeks?	0	1	2	3	4	5	6	
9. How dissatisfied are you with your weight?	0	1	2	3	4	5	6	
10. How dissatisfied are you with your shape?	0	1	2	3	4	5	6	
11. How uncomfortable are you seeing your body (for example, seeing your body in the mirror, in a shop window reflection etc.)?	0	1	2	3	4	5	6	
12. How uncomfortable do you feel about others seeing your shape or figure (for example, communal change rooms, when swimming or wearing tight clothes)?	0	1	2	3	4	5	6	

Please select the response that most applies to you.

For me to obtain my ideal weight and shape, I would need to be:

Smaller

Larger

Appendix B: Consent Form Main

Department of Psychology
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MACQUARIE UNIVERSITY NSW 2109



Phone: +61 (0)410 476 296
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Chief Investigator's / Supervisor's Name & Title: Associate Professor Kevin Brooks

Participant Information and Consent Form

Name of Project: Body Size Estimation: Multichannel or Opponent Process?

You are invited to participate in a study of body size perception. The purpose of the study is to better understand the neurological mechanisms responsible for visually encoding body size.

Robyn Ordman (0410 476 296, robyn.ordman@students.mq.edu.au) is conducting the study in order to meet the requirements of the Masters of Research program under the supervision of Kevin Brooks (9850 7796, kevin.brooks@mq.edu.au) of the Department of Psychology.

If you decide to participate, you will be asked to provide some demographic information and undergo an assessment of body image satisfaction. For the main experiment, you will be asked to familiarise yourself with a composite image of a human figure. Following familiarisation will be a baseline task, where you will be asked to decide whether a given image is an expanded or contracted version of the composite image. After baseline is recorded, you will view an array of images for two minutes. You will then be asked to complete a task similar to the baseline portion of the study. The above process (except for the collection of demographic information and body satisfaction) will need to be completed a further 3 times, with at least 3 days in between each session. There is a minimal possibility that some participants to become distressed when asked to reflect on their current levels of body satisfaction. If at any stage of the experiment you encounter any level of distress, please notify the researcher and the experiment will be terminated immediately. Please note that should any distress occur, you can contact campus wellbeing on 9850 7479. Walk-in services are also available any time on level 2 of the Lincoln building (C8A). The entire study should not take longer than 2 hours (30 minutes per session), for which you will be credited either \$40 payment or 2 hours worth of credit points.

Any information or personal details gathered in the course of the study are confidential, except as required by law. No individual will be identified in any publication of the results. The data collected for this study will be stored in a password-protected computer and in lockable files in C3A, and will only be accessible to Robyn Ordman and Kevin Brooks. A summary of the results of the data can be made available to you on request via email (robyn.ordman@students.mq.edu.au).

Participation in this study is entirely voluntary: you are not obliged to participate and if you decide to participate, you are free to withdraw at any time without having to give a reason and without consequence.

I, *(participant's name)* have read *(or, where appropriate, have had read to me)* and understand the information above and any questions I have asked have been answered to my satisfaction. I agree to participate in this research, knowing that I can withdraw from further participation in the research at any time without consequence. I have been given a copy of this form to keep.

Participant's Name: _____
(Block letters)

Participant's Signature: _____ Date: _____

Investigator's Name: _____
(Block letters)

Investigator's Signature: _____ Date: _____

The ethical aspects of this study have been approved by the Macquarie University Human Research Ethics Committee. If you have any complaints or reservations about any ethical aspect of your participation in this research, you may contact the Committee through the Director, Research Ethics & Integrity (telephone (02) 9850 7854; email ethics@mq.edu.au). Any complaint you make will be treated in confidence and investigated, and you will be informed of the outcome.

(INVESTIGATOR'S [OR PARTICIPANT'S] COPY)

Appendix C: Consent Form Photography

Department of Psychology
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MACQUARIE UNIVERSITY NSW 2109



Phone: +61 410 476 296

Email: robyn.ordman@students.mq.edu.au

Chief Investigator's / Supervisor's Name & Title: Associate Professor Kevin Brooks

Participant Information and Consent Form

Name of Project: Body Size Estimation: Multichannel or Opponent Process?

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Robyn Ordman (0410 476 296, robyn.ordman@students.mq.edu.au) is conducting the study in order to meet the requirements of the Masters of Research program under the supervision of Kevin Brooks (9850 7796, kevin.brooks@mq.edu.au) of the Department of psychology.

If you decide to participate, you will be asked to provide some demographic information and have your height and body composition measured. You will then be given specified clothing (a clean singlet and shorts) to wear and asked to stand in the anatomical pose for imaging. Photographs will be taken of you from both front and side angles. The entire study should not take longer than 15 minutes, for which you will be credited 15 minutes worth of credit points.

Any information or personal details gathered in the course of the study are confidential, except as required by law. No individual will be identified in any publication of the results. The data collected for this study will be stored in a password-protected computer and in lockable files in C3A, and will only be accessible to Robyn Ordman and Kevin Brooks. A summary of the results of the data can be made available to you on request via email (robyn.ordman@students.mq.edu.au).

Participation in this study is entirely voluntary: you are not obliged to participate and if you decide to participate, you are free to withdraw at any time without having to give a reason and without consequence.

I, *(participant's name)* have read *(or, where appropriate, have had read to me)* and understand the information above and any questions I have asked have been answered to my satisfaction. I agree to participate in this research, knowing that I can withdraw from further participation in the research at any time without consequence. I have been given a copy of this form to keep.

Participant's Name: _____
(Block letters)

Participant's Signature: _____ Date: _____

Investigator's Name: _____
(Block letters)

Investigator's Signature: _____ Date: _____

The ethical aspects of this study have been approved by the Macquarie University Human Research Ethics Committee. If you have any complaints or reservations about any ethical aspect of your participation in this research, you may contact the Committee through the Director, Research Ethics & Integrity (telephone (02) 9850 7854; email ethics@mq.edu.au). Any complaint you make will be treated in confidence and investigated, and you will be informed of the outcome.

(INVESTIGATOR'S [OR PARTICIPANT'S] COPY)