Implicit mechanisms of body image alterations: The covert attention exposure effect

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Abstract
Visual exposure to extreme-sized bodies elicits explicit self-body image variations. Several features of such modulation remain to be clarified. In this study we explored whether this effect: (i) acts on implicit mechanisms in modifying one's body-size perception, (ii) is body-exposure-specific also at the implicit level, and (iii) is modulated by interoceptive sensibility. We assigned a covert attention task to 100 women, exposing them to extreme-sized bodies (thin and fat) or extreme-sized objects (thin and fat bottles). Before and after the attentional exposure, we tested the association between the "self/others" and "thin/fat" concepts using an Implicit Association Test. We also collected a measure of interoceptive sensibility by means of a self-report questionnaire. Results showed that participants exposed to fat bodies implicitly presented a stronger association between the "self" and "thin" concepts. This association was significantly weaker in the group exposed to thin bodies. This effect was absent after exposure to thin and fat bottles. Notably, participants with a higher tolerance of negative bodily interoceptive signals were less susceptible to the malleability of body image exerted by the exposure attentional task. Our findings shed new light on the relationship between the perception of internal (e.g., visceral) and external (e.g., visual) signals in the representation of our body.

Keywords Attention · Visual perception · Embodied perception

Introduction

Body image is a multidimensional construct that refers to our mental picture of diverse aspects of our body (Muth & Cash, 1997; Slade, 1988). The concept of body image can be separated into two components: one relates to the affective disposition towards one's body appearance (e.g., how people think, feel, and behave concerning their physical attributes in relation to others), and the other mainly to the perception of body size (e.g., body size estimation and shape evaluation) (Skrzypek, Wehmeier, & Remschmidt, 2001). In this study, we focused on the implicit aspects of the latter component.

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Evidence has shown that visual exposure to extreme bodies may modulate both components at the explicit level. For instance, visual exposure to pictures of thin bodies, such as those presented in the media, may have a detrimental effect on body image in females: visual exposure to images of thin women may trigger pathological conditions, such as eating disorders (Bessenoff, 2006; Corning, Krumm, & Smitham, 2006; Stice, 2002) or self-image dissatisfaction (Bessenoff, 2006; Cash & Smolak, 2011; Preston & Ehrsson, 2016; Thompson, Heinberg, & Tantleff-Dunn, 1991). Notably, body-image satisfaction may be influenced in both upward and downward directions. Some studies have demonstrated that women presented with thin bodies show a significant decrease in satisfaction over their own body image. Conversely, exposure to oversized bodies improves their level of satisfaction (Moreno-Domínguez, Servián-Franco, Reyes del Paso, & Cepeda-Benito, 2018). However, some authors did not find such an effect (Cash, Cash, & Butters, 1983; Champion & Furnham, 1999). For instance, a study by Cash and colleagues found no differences in overall body satisfaction judgment in a group of women exposed to thin and plainer models (Cash et al., 1983).

Concerning the body-size perception component, it has been demonstrated that following a brief visual adaptation to

manipulated thin or fat bodies, individuals perceived normal-sized bodies as fatter or thinner, depending on whether they were exposed to, respectively, wide or narrow body distortions (Brooks, Mond, Stevenson, & Stephen, 2016; Glauert, Rhodes, Byrne, Fink, & Grammer, 2009; Hummel, Grabhorn, & Mohr, 2012; Hummel, Rudolf, Untch, Grabhorn, & Mohr, 2012; Winkler & Rhodes, 2005). For instance, Winkler and Rhodes (2005) exposed participants to distorted bodies (thinner or fatter than usual) for 5 min. Before and after the adaptation, participants were asked to judge the attractiveness and normality of 110 test body pictures. Results showed that when women were exposed to thin bodies, the body size they considered normal and ideal became thinner. The reverse effect occurred when women were exposed to fat bodies (Winkler & Rhodes, 2005). This after-effect was also consistent across identities: after adapting to a picture of their own body or unfamiliar thin bodies, participants perceived pictures of their own body or unfamiliar bodies as being fatter than actual or thinner than actual if exposed to picture of their own body or unfamiliar fat bodies (Hummel, Rudolf, et al., 2012). Furthermore, the after-effect also modulated the perceived body size when objects (coke bottles) were used as adaptation stimuli (Glauert et al., 2009), although this finding was not replicated using wide or narrow bars as adaptation stimuli (Hummel, Grabhorn, & Mohr, 2012). It is important note that the after-effect induced by the adaptation to fat bodies is not always present. For instance, Hummel and colleagues (Hummel, Grabhorn, and Mohr, 2012) have found a unidirectional adaptation effect caused only by the thin adaptation condition (Hummel, Grabhorn, & Mohr, 2012).

Although existing literature has demonstrated that visual exposure to extreme-sized bodies could alter body image, many important aspects remain to be clarified, specifically those concerning the body size component. First, whether this effect specifically concerns changes involving the self-perceived body size has not been investigated. Furthermore, whether this effect also relies on implicit exposure-response mechanisms is currently unknown. In previous studies, participants were typically explicitly asked to pay attention to the pictures of bodies and make an explicit judgment on a picture seen on the screen. Second, although it has been shown that visual exposure effect at the explicit level may not occur if individuals are exposed to geometrical shapes, it is currently unknown whether this phenomenon at the implicit level may also be induced by the exposure to thin or fat real-world objects. Third, the integration between the perception of interoceptive and exteroceptive signals may play a role in the construction of one's body representation (Emanuelsen, Drew, & Köteles, 2015; Tsakiris, Jimenez, & Costantini, 2011; Zamariola, Cardini, Mian, Serino, & Tsakiris, 2017). Interoception is a multidimensional construct defined as the sense of one's own internal bodily signals. A variety of methods have been used to quantify interoception, and

according to recent conceptualization (Garfinkel et al., 2016), interoception consists of three dimensions: (i) interoceptive accuracy, which is an objective measure of the ability to detect internal bodily signals (tested by means of counting or discriminating own heartbeats (Katkin, Morell, Goldband, Bernstein, & Wise, 1982; Schandry, 1981)), (ii) interoceptive sensibility, which is a measure of the subjective impression of how well individuals think they are able to perceive interoceptive signals (tested by means of self-reported questionnaires such as the Body Perception Questionnaire (Porges, 1993) or the Multidimensional Assessment of Interoceptive Awareness (MAIA (Mehling et al., 2012)), and (iii) interoceptive awareness, defined as metacognitive insight into one's own interoceptive accuracy performance (a subjective estimation of the confidence-accuracy correspondence (Garfinkel, Seth, Barrett, Suzuki, & Critchley, 2015). It has been shown that lower interoception predicts greater body image dissatisfaction (Emanuelsen et al., 2015). As visual exposure to bodies modulates an individual's own body image, it could be possible that differences in how individuals perceive their internal signals can influence body image malleability.

In the current study, we addressed these issues, administering a covert visual attention task to 100 young women, exposing them to fat and thin bodies or fat and thin objects. Visual attention is crucial to generating the after-effect (Stephen et al., 2019; Stephen, Sturman, Stevenson, Mond, & Brooks, 2018). Before and after the attentional exposure, we collected an implicit index of body-size perception by means of an Implicit Association Test (IAT) paradigm (Greenwald, Mcghee, Jordan, & Schwartz, 1998; Greenwald, McGhee, & Schwartz, 1998; Greenwald, Nosek, & Banaji, 2003). Crucially, none of the above tasks involved explicit judgments concerning body-size perception. The IAT is one of the most widely used paradigms to measure implicit attitudes (Greenwald & Farnham, 2000; Greenwald et al., 1998; Teige-Mocigemba, Klauer, & Sherman, 2010). It assesses the strength of automatic/implicit associations between target categories (e.g., self/others) and attribute categories (e.g., thin/fat). Typically, participants are required to categorize a set of stimuli by pressing two response buttons. Stimuli belonging to opposite categories (e.g., self/others) and valence attributes (e.g., fat/thin words) are first presented separately; then categories and attributes are associated in pairs (e.g., self – thin, others – thin). Thus, both target categories and attributes are arranged on bipolar dimensions by comparing the response latencies for two differently combined categorization tasks. The IAT assumes that a stronger association between categories and attributes causes increased difficulty in categorizing stimuli in one of the two conditions.

We also collected measures of interoceptive sensibility using the MAIA to investigate whether interoceptive sensibility may modulate the effect induced by the attentional exposure on the self-body image (Mehling et al., 2012). We

hypothesized that (i) the attentional exposure to extreme bodies modulates body-size perception also at the implicit level, (ii) body-image alterations selectively occur after attentional exposure to extreme-sized bodies but not extreme-sized objects, and (iii) the interoceptive sensibility may influence the alterations of the implicit self-body image (measured thought the IAT) caused by attentional exposure to extreme-sized bodies.

Materials and method

Participants

One hundred healthy females (age range = 19–56 years, M = 24.02 years, SD = 5.87 years; education M = 16.36 years, SD = 2.13 years) participated in the study. A measure of body mass index (BMI) was collected using a self-report assessment (BMI range = 18–30 kg/m^2, M = 20.62, SD = 2.48). All participants were native Italian speakers, had a normal or corrected-to-normal vision, and had no previous history of mental or neurological illness. None of the participants reported a previous history of eating disorders, and at the time of testing, none was on a restrictive diet, as assessed by a non-standardized self-reported questionnaire with yes/no responses ("Have you been diagnosed with an eating disorder (e.g., anorexia nervosa, bulimia nervosa, binge eating disorder)?" and "Are you on a restrictive diet?")).

Informed consent was obtained prior to participation in the experiment according to the Declaration of Helsinki. The experimental protocol received ethical approval from the Ethics Committee of the Department of Brain and Behavioral Sciences, University of Pavia. The study followed a factorial design: Participants were randomly assigned to one of four conditions, indicating the attentional exposure to fat or thin bodies and fat or thin bottles. The four groups of participants did not differ in age ($F_{3,96}$ = .676, p = .569, η^2_p = .021), education ($F_{3,96}$ = .453, p = .716, η^2_p = .014), BMI ($F_{3,96}$ = 2.222, p = .090, η^2_p = .065), trait ($F_{3,96}$ = 0.312, p = .817, η^2_p = .010) and state anxiety ($F_{3,96}$ = 0.587, p = .625, η^2_p = .018).

We calculate the sensitivity of our experiment with G*Power 3.1. We set the sample size at 100, alpha at .05 and power at .8. Adopting these parameters, the target interaction Group*Time, with four groups and two measures each, would be detectable as significant with an effect size of f(U) = .344, equivalent to a partial eta squared of .106, which is typically identified as a relatively small effect size. This result suggested that our sample with our experimental design is sensitive enough to capture small effects.

Tasks

Implicit Association Test (IAT)

We used the IAT to measure implicit associations between "self" and "thin" using two target categories, "self" and "others," and stimuli from the two attribute categories, "thin" and "fat." Five words for each category of interest (Italian words for the "self" concept, io, me, mio, mia, and me, and for the "others" concept, essi, esse, altri, altri, and loro), five words each related to thin and fat attributes (Italian words for "thin" attribute, esile, sottopeso, secco, gracile, and asciutto, and for "fat" attribute, robusto, sovrappeso, grosso, corpulento, and adiposo) were selected as stimuli.

At the beginning of the experiment, participants were fully instructed on the categories and attributes word stimuli, and they were asked to classify words presented at the center of the screen under one of the two categories/attributes using the "a" (left key) and "l" (right key) buttons of the computer keyboard with the right and left index fingers, respectively. They were instructed to respond as quickly and accurately as possible. Participants were trained to categorize stimuli from the two target categories ("self"/"others") and stimuli from the two attribute categories ("thin"/"fat") in two separate blocks. Then, participants classified stimuli in a combined task in which categories and attributes were associated with the same response key with a randomized presentation. In block 1, participants were asked to classify categories to either "self" (by pressing the left key) or "others" (by pressing the right key). In block 2, participants classified concepts of "thin" (by pressing the left key) and "fat" (by pressing the right key). In block 3, target categories and attributes were presented together in the same trial, and participants were asked to press the left key to classify "self-thin" words and the right key to classify "others-fat" words (congruent condition). In block 4, keys for "self" and "others" words classification were reversed (i.e., the left key for "others"-related words and the right key for "self"-related words). Finally, in block 5, target categories and attributes were again presented together, but with a reverse classification compared to block 3: participants were asked to press the left key to classify "others-thin" words and the right key to classify "self-fat" words (incongruent condition). In all blocks, the words to be categorized appeared at the center of the screen, whereas concept pairs were simultaneously presented on the screen on the left and right upper corners.

This procedure included 220 trials. Each practice block (1, 2, and 4) consisted of 20 trials, and critical combined blocks (3 and 5) consisted of 80 trials each. In the IAT scoring, the response times (RTs) were balanced with the accuracy by substituting RTs of error trials with the average RT of the same condition and adding a fixed penalty of 600 ms to those trials (Greenwald et al., 2003). The final score (Greenwald's d) was calculated as a standardized difference between the two blocks

that combine categories and attributes (i.e., (Block 5 RTs – Block 3 RTs)/ Blocks 3 and 5 pooled SD). Higher Greenwald's d scores represent a stronger implicit association between "self" and "thin" concepts.

Exposure phase: covert attention task

Stimuli. Twelve fat and thin body stimuli were created using the Make Humans software (http://www.makehumancommunity.org). For "normal" woman body, we took as a reference the default software character with average height and weight, as defined in the software manual. In order to choose its fat and thin counterparts, in an online pilot study, we asked 60 women (who did not take part in the subsequent experiment) to indicate an equivalent fat and thin body (among six fat and six thin characters) using the standard one as a reference. Three bottles of the same color as the bodies were drawn, inscribed with the bodies' contours (excluding the arms), producing "normal,", "fat," and "thin" bottles.

Task. With this set of stimuli, participants were given a modified version of the Posner spatial cueing task (Doricchi, Macci, Silvetti, & Macaluso, 2010; Posner, 1980) in four different exposure conditions for 15 min: fat body, thin body, fat bottle, and thin bottle. Each participant completed one condition only. The Posner paradigm is a classical test of attention. It measures the participant's ability to direct attention toward the target stimulus, which can be spatially cued (valid trials) or uncued (invalid trials), usually by an arrow indicating the spatial location were the target stimulus is about to appear on the screen. The participant is asked to press as quickly as possible the key corresponding to the location where the target stimulus appears. Typically, participants are faster in the valid trials and slower in the invalid trials, demonstrating that the spatial cue orients visual attention, which enhances the stimulus processing at that cued location. In this study, we used this paradigm to direct the covert attention of the participants towards fat and thin bodies and bottles. This allowed us to control for the participants' involvement in the attentional exposure to the desired target stimulus: faster RTs in valid compared to invalid trials indicated an effective participants' attentional focus on the target stimulus.

Each trial began with the presentation of a central fixation cross (size $0.8° \times 0.8°$) surrounded by two lateral boxes (size $3.5° \times 3.5°$), one centered $7.3°$ to the left and the other $7.3°$ to the right of the central fixation. All stimuli were presented in color against a white background. This "Fixation" period lasted 800–1,000 ms (uniform distribution) and was followed by a "Cue" period lasting 1,400–1,800 ms (uniform distribution). At the beginning of the Cue period, an arrow pointing to the left or right box could appear. On target disappearance, the arrow cue returned to white for the entire 1,200-ms period allowed for response collection ("Response" period). Participants were asked to press the left or right arrow on the keyboard with their right index finger as fast as possible in response to the target location appearance (left or right side of the screen). On valid trials, the target was presented in the box cued by the arrow. On invalid trials, the arrow pointed to the box opposed to the one cued. On catch trials, a normal-sized body was presented with equal probability in one of the two boxes. In the latter case, participants were required to hold their response. Catch trials had a twofold purpose: they served to detect false alarms (tendency to give positive responses), and they allowed an implicit comparison between the fat/thin target and the reference normal body/bottle. Participants were required to hold their gaze on the central fixation cross throughout the task (see Fig. 1). Each participant completed the attentional task containing only one target stimulus (body fat, body thin, bottle fat, or bottle thin). The normal-sized body and bottles were used in the four conditions in catch trials in which participants were told to hold their response.

Interoceptive sensibility

We used the MAIA (Calì, Ambrosini, Picconi, Mehling, & Committeri, 2015; Mehling et al., 2009) to measure interoceptive sensibility, which has been conceptualized as a subjective judgment of self-competence in detecting internal signals (Garfinkel et al., 2016). It consists of 32 items that are made up from eight separate subscales: (i) noticing: awareness of uncomfortable, comfortable, and neutral body sensations; (ii) not-distracting: tendency not to ignore or distract oneself from sensations of pain or discomfort; (iii) not-worrying: tendency not to worry or experience emotional distress with sensations of pain or discomfort; (iv) attention regulation: ability to sustain and control attention to body sensations; (v) emotional awareness: awareness of the connection between body sensations and emotional states; (vi) self-regulation: ability to regulate distress by attention to body sensations; (vii) body listening: active listening to the body for insight; and (viii) trusting: experience of one's body as safe and trustworthy. Responses to each item were given on a 6-point scale, ranging from never (0) to always (5). Scores for each subscale were computed as the mean of all associated items. For more details on the scoring instructions, see www.osher.ucsf.edu/maia. We used the Italian version of the MAIA; its psychometric properties and factorial structure revealed acceptable reliability and a dimensionality comparable to that of other available versions of MAIA versions (internal reliability varied between 0.53 and 0.80; Calì et al., 2015). Notably, the attention regulation subscale correlates to the Heartbeat Perception Task scores (Schandry, 1981), a measure of interoceptive accuracy (Calì et al., 2015).

Additional measures

Participants were also asked to complete a questionnaire to evaluate their level of anxiety with the State-Trait Anxiety Inventory (STAI) (Spielberger, Gorsuch, Lushene, Vagg, & Jacobs, 1983). The STAI is a psychological inventory based on a 4-point Likert scale and consists of 40 questions on a self-report basis. The STAI measures two types of anxiety, namely state anxiety (anxiety about an event) and trait anxiety (anxiety level as a personal characteristic). We used the STAI to estimate possible anxiety disorders (scores > 60) that might have influenced interoception sensibility scores (Domschke, Stevens, Pfleiderer, & Gerlach, 2010; Paulus & Stein, 2010). In our sample, the STAI X1 scores ranged from 23 to 56 (M = 34.7, SD = 6.7), whereas the STAI X2 scores ranged from 24 to 57 (M = 40.5, SD = 7.3).

Procedure

At the beginning of each session, participants performed the IAT that served as the baseline. Next, they completed the exposure phase, where they were given the Posner spatial cueing task for approximately 15 min. After the attentional task, the IAT was administered a second time to participants to detect any possible implicit effect induced by the exposure phase. Half of the participant sample completed the above-mentioned scales and questionnaires at the beginning of the experiment and the other half at the end of the experiment, in a randomized order. The administration of tests was randomized across participants in order to control for possible influences of scales and questionnaires on the attentional and IAT tasks and vice versa. All participants completed the experiment in a single session lasting around 45 min.

Statistical analyses plan

We first evaluated whether the different groups were paying equal attention during the exposure phase. This is a prerequisite to evaluating the eventual directional effect of the exposure. We used a Bayesian analysis of variance (ANOVA) (Rouder, Morey, Speckman, & Province, 2012) as implemented in JASP 0.8.6 (JASP Team, 2018), with the factor group (body thin, body fat, object thin, or object fat) as a predictor of the orienting index. The Bayesian ANOVA produces a Bayes factor (BF) as the main output index. The BF_{01} indicates the probability in favor of the null over the alternative hypotheses (e.g., a $BF_{01} = 12$ means that H_0 is 12 times more likely than H_1 to be true, suggesting that the different conditions are equivalent). A value of 1 indicates that both the hypotheses have the same probability of being true. Evidence in favor of the alternative hypothesis would have $BF_{01} < 1$, while evidence in favor of the null hypothesis would have a $BF_{01} > 1$.

Once we ascertained that participants paid the same level of attention during the different exposure phase, we evaluated whether exposure to the different conditions induced a directional effect in self-representation. We thus ran a frequentist ANOVA on the Greenwald d scores of the IAT collected before and after the exposure phase. The ANOVA included a
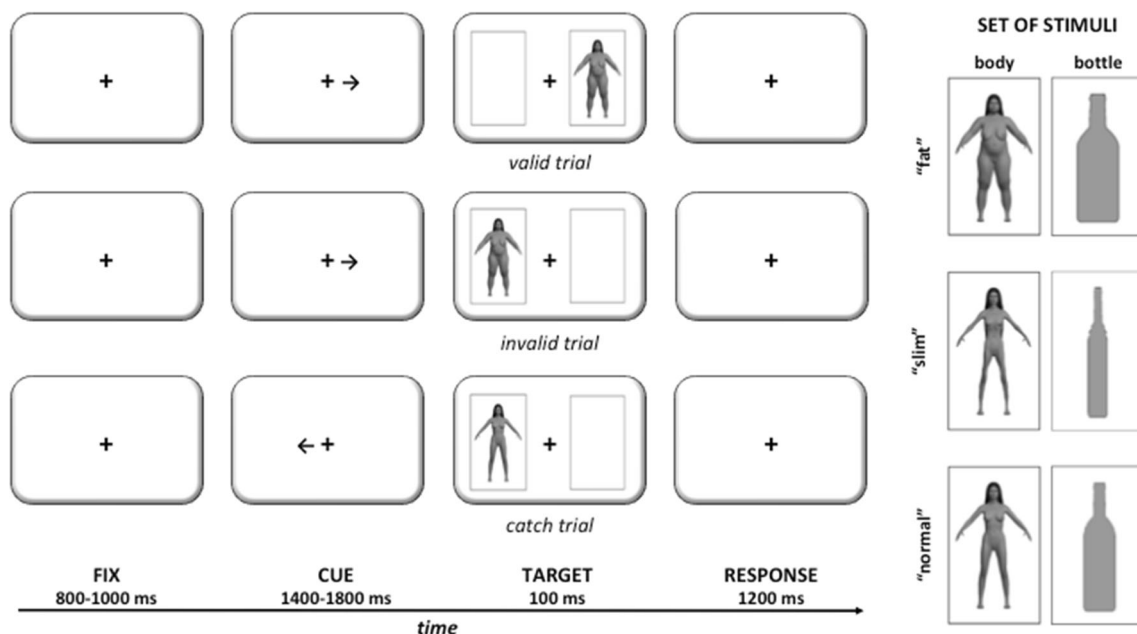

Fig. 1 Attentional task. At the beginning of each trial a fixation cross appeared for 800–1,000 ms, and then a cue arrow appeared indicating the left or right side of the screen. After 1,400–1,800 ms, a target lasted for 100 ms in the cued position (valid trials) or uncued position (invalid trial). The subjects were required to indicate the side where the target appeared using the left or right keyboard arrows as quickly and accurately as possible. In 20% of cases, a normal-sized body/bottle could appear, and subjects were required to hold their response (catch trial)

repeated-measure factor Time (before and after) and a between-subjects factor Group (body thin, body fat, object thin, and object fat) resulting in a 2 × 4 mixed ANOVA design. For the post hoc analysis, we calculated the delta score for each group (post-pre), and we then matched the different groups with a series of t-tests that were Bonferroni-Holm corrected (α = .008), reporting Cohen's d as the effect size measure.

Finally, we assessed the role of interoceptive sensibility by analyzing the self-reported questionnaire (MAIA). We modelled a linear regression analysis using the absolute value of Greenwald's d changes induced by the exposure phase (|d after – d before|) as the dependent variable, and we used the eight MAIA subscales scores as a covariate (predictors). We used a forward method in order to deal with predictors' multicollinearity. The dependent variable was normally distributed, whereas the predictors were log10-transformed to fit a normal distribution. All the regression assumptions were met: (i) the relationship between the predictors and dependent variable was linear; (ii) the values of residuals were independent (Durbin-Watson = 1.99); (iii) the variance of residuals was constant; (iv) the values of the residuals were normally distributed. Furthermore, to deal with outliers affecting the values of the estimated regression coefficients, we performed a case-wise diagnostic on standardized residuals. We excluded from the subsequent analyses two outliers (outside ± 3 SDs).

We chose to use the absolute value of Greenwald's d changes induced by the exposure phase (|d after – d before|) as the dependent variable based on the following potential scenario: It could be possible that the more a person is aware of one's own body sensations, the less he or she might be influenced by external models, because it has been demonstrated that high interoceptive individuals experience a weaker illusion of ownership toward a fake limb in the Rubber Hand Illusion paradigm (Tsakiris et al., 2011). In our case, the absolute value of Greenwald's d change would capture the strength of the influence of external models, independently from the direction of the effect.

Results

The different groups were paying equal attention during the Posner-like exposure phase. The orienting index calculates the advantage of responding to the valid-cue targets versus the invalid-cue targets normalized on the reaction time (Salvato, De Maio, & Bottini, 2017; Salvato, Patai, McCloud, & Nobre, 2016; Salvato, Patai, & Nobre, 2016). The BF_{01} supports the hypothesis that the orienting effect magnitude was equivalent between groups (BF_{01} = 7.181). Therefore we can assume that the different groups were influenced by the validity of the cue equally. Importantly, the orienting index (mean = 0.014, 95% credible interval [0.009, 0.019]) was greater than 0 (Bayesian one-sample t-test > 0, BF_{10} > 1,000), replicating the classic results of the Posner-like experiments (Salvato et al., 2017, 2016, 2016); this suggests that our participants were paying attention to the task and were influenced by the cues.

These preliminary results set a suitable scenario for evaluating the impact of the exposure phase to the different pictures during the Posner-like experiment and the IAT test measuring the association between the self and the attributes of body size.

The ANOVA evaluating the effect of the exposure on the IAT highlighted a statistically significant interaction ($F_{3,96}$ = 4.433, p = .006, η^2_p = .122), suggesting that the pre-post change is different according to the exposure received during the Posner exposure phase. The two main factors were not significant per se (Time: $F_{1,96}$ = 0.129 p = .720, η^2_p = .001; Group: $F_{3,96}$ = 0.161 p = .922, η^2_p = .005) (Fig. 2). Post hoc analyses showed that the only significant difference was between the group exposed to fat bodies and the group exposed to thin bodies (see comparisons in Table 1). From the graphical representation, we can observe that the size of the picture induces similar effects for bodies and objects, namely the exposure to a specific size increases the association of the self with the opposite size. However, it is worth noting that this trend is strongly enhanced by the exposure during the exposure phase to bodies, instead of objects, as shown by the significant difference between the body-thin and body-fat groups (p = .006, Cohen's d = .892), which is lacking in the bottle-thin and bottle-fat comparison (p = .546, Cohen's d = .413; Fig. 2).

Finally, the results of the regression indicated that the model was significant ($F_{(1,96)}$ = 9.1; p = .003). It was found that the IAT score change was negatively predicted by the "not-worrying" subscale (b = −0.11; p = .003) (Table 2). The R^2 value was 0.09, thus the model containing the not-worrying subscale explained 9% of the variation in IAT change.

Discussion

In line with previous findings, this study found body image modifications after attentional exposure to bodies. Additionally, we found that this effect: (i) also relies on implicit mechanisms, (ii) is body-shape-specific also at the implicit level, and (iii) is modulated by interoceptive sensibility. Previous studies have mainly focused on the explicit effect of exposure to fat and thin bodies on the perception of body size and shape.

At the explicit level, it has been demonstrated that visual exposure to distorted body size (fatter or thinner than usual) modulates explicit judgments in body-size visual perception, as predicted by an adaptation paradigm (Brooks et al., 2016; Hummel, Grabhorn, & Mohr, 2012; Hummel, Rudolf, et al., 2012; Winkler & Rhodes, 2005). Other studies have been mainly focused on the explicit affective effect of visual
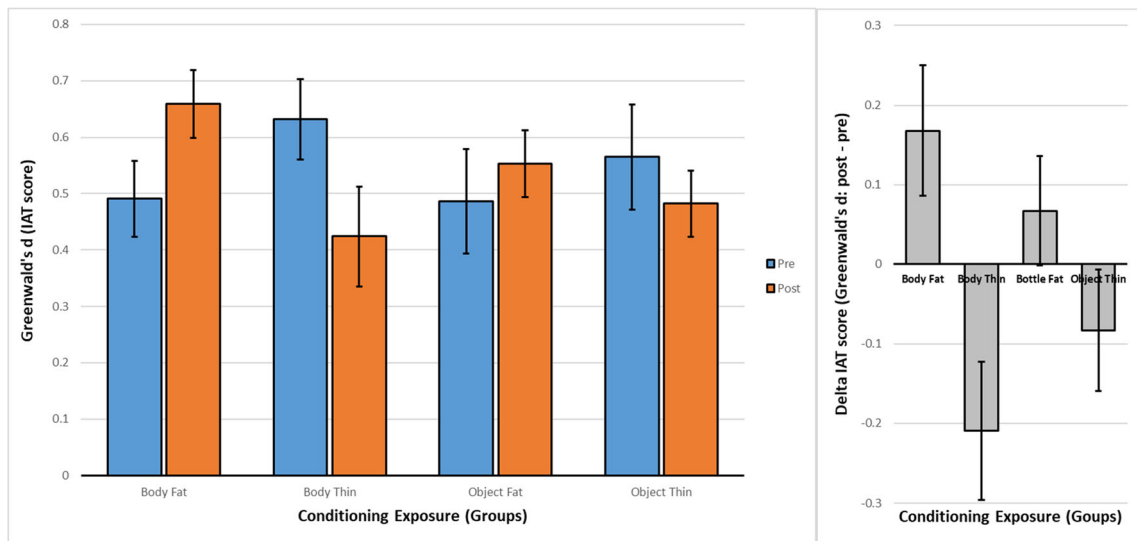
Fig. 2 Results. The left panel shows the pre- and post-Greenwald's IAT scores (mean) for the groups exposed to one of the four conditions. The right graph depicts the delta values (post-pre) of the Greenwald's scores (mean) in the four exposures. In both graphs, the bars represent standard errors

exposure to a "canonically" beautiful body shape. The most common task consisted of the explicit verbal evaluation of body sizes after explicit exposure to media-like images and videos of thin and overweight models (Bessenoff, 2006; Moreno-Domínguez et al., 2018; Myers & Biocca, 1992). Our results further demonstrated the occurrence of such an after-effect at a more implicit non-affective level. We found that participants exposed to fat bodies implicitly presented with a stronger association between the "self" and "thin" concepts. Such an association was significantly weaker in the group exposed to thin bodies. The experimental paradigm used primarily tested the implicit level both in the visual exposure (i.e., covert attention to bodies) and in the outcome measure (i.e., IAT), providing evidence for the existence of an implicit substrate in which body image arises.

Our experiment further indicated that at the implicit level this phenomenon is body-specific, as we did not find the same results when women were exposed to extreme-sized objects (thin and fat bottles). Some studies have used objects, such as cars or houses, as control stimuli, and demonstrated no effect

on body image after visual exposure to this type of stimuli (Hamilton & Waller, 1993; Posavac, Posavac, & Posavac, 1998; Posavac, Posavac, & Weigel, 2003). Nevertheless, they did not control for the size of the objects, leaving open the possibility that the physical size of the stimulus may have induced this effect. Notably, more recently Hummel and colleagues used wide and thin bars as control stimuli (Hummel, Grabhorn, & Mohr, 2012. They demonstrated that the visual adaptation to objects did not bias the body-perception explicit judgments. Nevertheless, such a result is not consistent (Glauert et al., 2009). In this study, we further demonstrated that at the implicit level, a general subtlety or width object feature *per se* is not sufficient to induce the reverse self-image modulation, but that corporeal characteristics of the visual stimuli are crucial to generate it.

The potential mechanism underlying this effect may be related to a simple visual exposure, a self-identification, or a social comparison with the observed stimuli. As demonstrated

Table 1 Post hoc comparisons on Greenwald's d delta scores (post-pre) for the group factor

		Mean difference	t	Cohen's d	p_{holm}
Body Fat	Body Thin	0.377	3.386	0.892	0.006
	Object Fat	0.101	0.912	0.268	0.546
	Object Thin	0.251	2.257	0.635	0.105
Body Thin	Object Fat	-0.275	-2.475	-0.704	0.075
	Object Thin	-0.126	-1.130	-0.308	0.546
Object Fat	Object Thin	0.150	1.345	0.413	0.546

Note that Cohen's d does not correct for multiple comparisons

Table 2 Results of the regression analysis

Predictors	b	t	p-value
Not-worrying	-0.108	-3.024	0.003
Excluded variables			
Noticing	0.052	0.521	0.603
Not-distracting	0.057	0.579	0.564
Attention regulation	0.027	0.278	0.782
Emotional awareness	-0.078	-0.796	0.428
Self-regulation	-0.014	-0.147	0.883
Body listening	-0.05	-0.511	0.61
Trusting	-0.067	-0.679	0.499

Dependent variable: absolute value of Greenwald's d changes

by Hummel and colleagues (Hummel, Grabhorn, and Mohr, 2012; Hummel, Rudolf, et al., 2012) and in the current study, visual exposure *per se* does not necessarily influence body image (Hummel, Grabhorn, & Mohr, 2012). Exposing individuals to abstract or more complex shapes does not modulate body-size perception. The self-identification hypothesis also entails some limitations: it has been demonstrated that adaptation to certain body shapes transfers across different identities (Hummel, Rudolf, et al., 2012). Hummel and colleagues (Hummel, Grabhorn, and Mohr, 2012; Hummel, Rudolf, et al., 2012) have found the adaptation after-effect even with pictures of bodies not belonging to the participants. This study used a virtual body and replicated those findings. Lastly, previous research has also suggested that a social comparison between the individual's own and the observed body may modulate body image (Festinger, 1954; Moreno-Domínguez et al., 2018). Whether this social comparison is explicitly (consciously) or implicitly (unconsciously) made remains a matter of debate (Moreno-Domínguez et al., 2018; Want, 2009).

Furthermore, this study found that body-image-implicit malleability was modulated by interoceptive sensibility. Specifically, participants who better tolerate negative body signals such as sensations of pain and discomfort (i.e., those with higher scores on the not-worrying scale), which also indicates better emotion regulation (Mehling et al., 2009), were less susceptible to the effect of visual exposure. These results are in line with previous literature demonstrating the existence of a relationship between higher-level body representation and interoception (Salvato et al., 2017; Salvato, De Maio, & Bottini, 2019; Tsakiris et al., 2011; Zamariola et al., 2017). For instance, Tsakiris et al. (2011) have shown that higher interoceptive accuracy (measured by a classical heartbeat-monitoring task) predicted a weaker embodiment towards a fake limb in the Rubber Hand Illusion paradigm. The authors suggested that individuals with lower interoceptive abilities would rely more on exteroceptive signals, as in the case of the visual-tactile stimulation occurring in the Rubber Hand Illusion task. This might make the lower-sensitivity subjects easier targets for external (i.e., visual) manipulation regarding bodily information, and the current findings further support this evidence. Our result may also be explained by the fact that individuals with lower interoceptive abilities have higher body dissatisfaction (Emanuelsen et al., 2015), and for this reason they may be more prone to the modulation of their own body image effected by external visual signals. Alternatively, the reason for the correlation between the exposure-effect magnitude and the not-worrying scale could be explained by a potential participants' discomfort/dissatisfaction feeling caused by the implicit perception of their body size, which was prompted by the visual exposure. Indeed, it has been demonstrated that the individual's level of body satisfaction may influence selective attention to thin or fat bodies, and in turn modulate the magnitude and direction of the visual-adaptation effect to distorted body size (Stephen et al., 2018). It could be interesting to explore the existence of the relationship between the level of body satisfaction and interoceptive sensibility (not-worrying scale).

In perspective, this study may offer a potential therapeutic tool for patients suffering from eating disorders (EDs). For instance, body-image disturbances are one of the core symptoms of anorexia nervosa (AN) at both implicit (Cserjési et al., 2010) and explicit levels (Cash & Deagle, 1997; Garner & Garfinkel, 2005; Myers & Biocca, 1992). Patients with AN typically perceive themselves as fatter than their real size (Cash & Deagle, 1997; Garner & Garfinkel, 2005; Myers & Biocca, 1992). Mirror-exposure therapy has been shown to improve AN patients' body image (for a recent review, see Griffen, Naumann, & Hildebrandt, 2018). This treatment involves the visual exposure of patients to their own reflected image, perceived as fatter. Notably, a study on this clinical population using a visual-adaptation paradigm has demonstrated that patients show the expected after-effects following exposure to images of fat bodies (i.e., a perceptual "thinning"). However, no after-effects were found following visual adaptation to thin bodies (Mohr, Rickmeyer, Hummel, Ernst, & Grabhorn, 2016). As recently proposed by Challinor et al. (2017), visual adaptation to extreme-sized body stimuli may be applied to ED patients to reduce body image disturbances (Challinor et al., 2017). Given this background, our study could possibly be applied to AN patients' treatment by exposing patients to the fat-body condition, as it may re-balance the impaired perception of one's own body as fatter than in reality, thus ameliorating patients' distorted body image. This hypothesis needs to be carefully evaluated in pilot studies before its application in large clinical samples.

Limitations

This study had some limitations. For instance, we did not collect any measure of body satisfaction. It has recently been found that the level of body satisfaction may modulate attention to thin and fat bodies, which in turn modulates the magnitude and direction of visual adaptation to body size (Stephen et al., 2018). It could be interesting to explore the relationship between body satisfaction, attention, and the implicit modulatory effect on body image. Furthermore, we used a between-subjects design, and future studies may explore individual differences in being exposed to both body-related and non-body-related stimuli. Lastly, although interoceptive sensibility represents one of the interoception dimensions, as a self-report measure, it could be affected by biases in the judgments. These limitations may be considered as a starting point for future research.

Compliance with ethical standards

Conflicts of interest The authors declare that they have no conflicts of interests.

References

Bessenoff, G. R. (2006). Can the media affect us? Social comparison, self-discrepancy, and the thin ideal. *Psychology of Women Quarterly*. doi:https://doi.org/10.1111/j.1471-6402.2006.00292.x

Brooks, K. R., Mond, J. M., Stevenson, R. J., & Stephen, I. D. (2016). Body image distortion and exposure to extreme body types: Contingent adaptation and cross adaptation for self and other. *Frontiers in Neuroscience*. doi:https://doi.org/10.3389/fnins.2016.00334

Calì, G., Ambrosini, E., Picconi, L., Mehling, W. E., & Committeri, G. (2015). Investigating the relationship between interoceptive accuracy, interoceptive awareness, and emotional susceptibility. *Frontiers in Psychology*, 6(August), 1–13. doi:https://doi.org/10.3389/fpsyg.2015.01202

Cash, T. F., Cash, D. W., & Butters, J. W. (1983). Mirror, Mirror, on the Wall...?. *Personality and Social Psychology Bulletin*. doi:https://doi.org/10.1177/0146167283093004

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

Cash, T. F., & Smolak, L. (2011). Body image. a handbook of science, practice and prevention. In *Journal of Gerontological Nursing*. doi:https://doi.org/10.1007/SpringerReference_223404

Challinor, K. L., Mond, J., Stephen, I. D., Mitchison, D., Stevenson, R. J., Hay, P., & Brooks, K. R. (2017). Body size and shape misperception and visual adaptation: An overview of an emerging research paradigm. *Journal of International Medical Research*. doi:https://doi.org/10.1177/0300060517726440

Champion, H., & Furnham, A. (1999). The effect of the media on body satisfaction in adolescent girls. *European Eating Disorders Review*, 7(3), 213–228. doi:https://doi.org/10.1002/(SICI)1099-0968(199906)7:3<213::AID-ERV229>3.0.CO;2-W

Corning, A. F., Krumm, A. J., & Smitham, L. A. (2006). Differential social comparison processes in women with and without eating disorder symptoms. *Journal of Counseling Psychology*. doi:https://doi.org/10.1037/0022-0167.53.3.338

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

Domschke, K., Stevens, S., Pfleiderer, B., & Gerlach, A. L. (2010). Interoceptive sensitivity in anxiety and anxiety disorders: An overview and integration of neurobiological findings. *Clinical Psychology Review*. doi:https://doi.org/10.1016/j.cpr.2009.08.008

Doricchi, F., Macci, E., Silvetti, M., & Macaluso, E. (2010). Neural correlates of the spatial and expectancy components of endogenous and stimulus-driven orienting of attention in the posner task. *Cerebral Cortex*. doi: https://doi.org/10.1093/cercor/bhp215

Emanuelsen, L., Drew, R., & Köteles, F. (2015). Interoceptive sensitivity, body image dissatisfaction, and body awareness in healthy individuals. *Scandinavian Journal of Psychology*. doi:https://doi.org/10.1111/sjop.12183

Festinger, L. (1954). A theory of social comparison processes. *Human Relations*. doi:https://doi.org/10.1177/001872675400700202

Garfinkel, S. N., Seth, A. K., Barrett, A. B., Suzuki, K., & Critchley, H. D. (2015). Knowing your own heart : Distinguishing interoceptive accuracy from interoceptive awareness. *Biological Psychology*, 104, 65–74. doi:https://doi.org/10.1016/j.biopsycho.2014.11.004

Garfinkel, S. N., Tiley, C., O'Keeffe, S., Harrison, N. A., Seth, A. K., & Critchley, H. D. (2016). Discrepancies between dimensions of interoception in autism: Implications for emotion and anxiety. *Biological Psychology*. doi:https://doi.org/10.1016/j.biopsycho.2015.12.003

Garner, D. M., & Garfinkel, P. E. (2005). Body image in anorexia nervosa: measurement, theory and clinical implications. *The International Journal of Psychiatry in Medicine*. doi:https://doi.org/10.2190/r55q-2u6t-lam7-rqr7

Glauert, R., Rhodes, G., Byrne, S., Fink, B., & Grammer, K. (2009). Body dissatisfaction and the effects of perceptual exposure on body norms and ideals. *International Journal of Eating Disorders*. doi: https://doi.org/10.1002/eat.20640

Greenwald, A. G., & Farnham, S. D. (2000). Using the implicit association test to measure self-esteem and self-concept. *Journal of Personality and Social Psychology*. doi:https://doi.org/10.1037/0022-3514.79.6.1022

Greenwald, A. G., Mcghee, D. E., Jordan, L. K., & Schwartz, J. L. K. (1998). Measuring Individual Differences in Implicit Cognition. *Journal of Personality and Social Psychology*. doi:https://doi.org/10.1037/0022-3514.74.6.1464

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

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

Griffen, T. C., Naumann, E., & Hildebrandt, T. (2018). Mirror exposure therapy for body image disturbances and eating disorders: A review. *Clinical Psychology Review*. doi:https://doi.org/10.1016/j.cpr.2018.08.006

Hamilton, K., & Waller, G. (1993). Media influences on body size estimation in anorexia and bulimia. An experimental study. *British Journal of Psychiatry*.

Hummel, D., Grabhorn, R., & Mohr, H. M. (2012). Body-shape adaptation cannot be explained by adaptation to narrow and wide rectangles. *Perception*. doi:https://doi.org/10.1068/p7197

Hummel, D., Rudolf, A. K., Untch, K. H., Grabhorn, R., & Mohr, H. M. (2012). Visual adaptation to thin and fat bodies transfers across identity. *PLoS ONE*. doi:https://doi.org/10.1371/journal.pone.0043195

JASP Team (2018). JASP (Version 0.8.6)[Computer software]

Katkin, E. S., Morell, M. A., Goldband, S., Bernstein, G. L., & Wise, J. A. (1982). Individual Differences in Heartbeat Discrimination. *Psychophysiology*. doi:https://doi.org/10.1111/j.1469-8986.1982.tb02538.x

Mehling, W. E., Gopisetty, V., Daubenmier, J., Price, C. J., Frederick, M., & Stewart, A. (2009). *Body Awareness : Construct and Self-Report Measures*. 4(5). doi:https://doi.org/10.1371/journal.pone.0005614

Mehling, W. E., Price, C., Daubenmier, J. J., Acree, M., Bartmess, E., & Stewart, A. (2012). The Multidimensional Assessment of Interoceptive Awareness (MAIA). *PLoS ONE*. doi:https://doi.org/10.1371/journal.pone.0048230

Mohr, H. M., Rickmeyer, C., Hummel, D., Ernst, M., & Grabhorn, R. (2016). Altered visual adaptation to body shape in eating disorders: Implications for body image distortion. *Perception*. doi:https://doi.org/10.1177/0301006616633385

Moreno-Domínguez, S., Serviàn-Franco, F., Reyes del Paso, G. A., & Cepeda-Benito, A. (2018). Images of thin and plus-size models produce opposite effects on women's body image, body dissatisfaction, and anxiety. *Sex Roles*. doi:https://doi.org/10.1007/s11199-018-0951-3

Muth, J. L., & Cash, T. F. (1997). Body-image attitudes: What difference does gender make? *Journal of Applied Social Psychology*, 27(16), 1438–1452. doi:https://doi.org/10.1111/j.1559-1816.1997.tb01607.x

Myers, P. N., & Biocca, F. A. (1992). The elastic body image: the effect of television advertising and programming on body image distortions in young women. *Journal of Communication*. doi:https://doi.org/10.1111/j.1460-2466.1992.tb00802.x

Paulus, M. P., & Stein, M. B. (2010). Interoception in anxiety and depression. *Brain Structure & Function*. doi:https://doi.org/10.1007/s00429-010-0258-9

Porges, S. (1993). Body perception questionnaire. *Laboratory of Developmental Assessment, University of Maryland*.

Posavac, H. D., Posavac, S. S., & Posavac, E. J. (1998). Exposure to media images of female attractiveness and concern with body weight among young women1. *Sex Roles*. doi:https://doi.org/10.1023/A:1018729015490

Posavac, H. D., Posavac, S. S., & Weigel, R. G. (2003). Reducing the impact of media images on women at risk for body image disturbance: three targeted interventions. *Journal of Social and Clinical Psychology*. doi:https://doi.org/10.1521/jscp.20.3.324.22308

Posner, M. I. (1980). Orienting of attention. Quarterly journal of experimental psychology, 32(1), 3–25

Preston, C., & Ehrsson, H. H. (2016). Illusory obesity triggers body dissatisfaction responses in the insula and anterior cingulate cortex. *Cerebral Cortex*, 26(12), 4450–4460. doi:https://doi.org/10.1093/cercor/bhw313

Rouder, J. N., Morey, R. D., Speckman, P. L., & Province, J. M. (2012). Default Bayes factors for ANOVA designs. *Journal of Mathematical Psychology*, 56(5), 356–374. doi:https://doi.org/10.1016/j.jmp.2012.08.001

Salvato, G., De Maio, G., & Bottini, G. (2017). Exploring biased attention towards body-related stimuli and its relationship with body awareness. *Scientific Reports*, 7(1). doi:https://doi.org/10.1038/s41598-017-17528-2

Salvato, Gerardo, De Maio, G., & Bottini, G. (2019). Interoceptive sensibility tunes risk-taking behaviour when body-related stimuli come into play. *Scientific Reports*, 9(1), 2396. doi:https://doi.org/10.1038/s41598-019-39061-0

Salvato, Gerardo, Patai, E. Z., McCloud, T., & Nobre, A. C. (2016). Apolipoprotein ε4 breaks the association between declarative long-term memory and memory-based orienting of spatial attention in middle-aged individuals. *Cortex*, 82, 206–216. doi:https://doi.org/10.1016/j.cortex.2016.06.002

Salvato, Gerardo, Patai, E. Z., & Nobre, A. C. (2016). Preserved memory-based orienting of attention with impaired explicit memory in healthy ageing. *Cortex*, 74, 67–78. doi:https://doi.org/10.1016/j.cortex.2015.10.019

Schandry, R. (1981). Heart Beat Perception and Emotional Experience. *Psychophysiology*. doi:https://doi.org/10.1111/j.1469-8986.1981.tb02486.x

Skrzypek, S., Wehmeier, P. M., & Remschmidt, H. (2001). Body image assessment using body size estimation in recent studies on anorexia nervosa. A brief review. *European Child and Adolescent Psychiatry*. doi:https://doi.org/10.1007/s007870170010

Slade, P. D. (1988). Body image in anorexia nervosa. *British Journal of Psychiatry*.

Spielberger, C. D., Gorsuch, R. L., Lushene, P. R., Vagg, P. R., & Jacobs, A. G. (1983). Manual for the State-Trait Anxiety Inventory (Form Y). *Manual for the statetrait anxiety inventory STAI*. doi:https://doi.org/10.1007/978-1-4419-9893-4

Stephen, I. D., Hunter, K., Sturman, D., Mond, J., Stevenson, R. J., & Brooks, K. R. (2019). Experimental manipulation of visual attention affects body size adaptation but not body dissatisfaction. *International Journal of Eating Disorders*. doi:https://doi.org/10.1002/eat.22976

Stephen, I. D., Sturman, D., Stevenson, R. J., Mond, J., & Brooks, K. R. (2018). Visual attention mediates the relationship between body satisfaction and susceptibility to the body size adaptation effect. *PLoS ONE*. doi:https://doi.org/10.1371/journal.pone.0189855

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

Teige-Mocigemba, S., Klauer, K. C., & Sherman, J. W. (2010). A practical guide to Implicit Association Tests and related tasks. In *Handbook of Research Methods in Social and Personality Psychology*. doi:https://doi.org/10.1016/S1572-1000(05)00006-2

Thompson, J. K., Heinberg, L. J., & Tantleff-Dunn, S. (1991). The physical appearance comparison scale. *The Behavior Therapist*.

Tsakiris, M., Jimenez, A. T., & Costantini, M. (2011). Just a heartbeat away from one's body: interoceptive sensitivity predicts malleability of body-representations. *Proceedings of the Royal Society B: Biological Sciences*, 278(1717), 2470–2476. doi:https://doi.org/10.1098/rspb.2010.2547

Want, S. C. (2009). Meta-analytic moderators of experimental exposure to media portrayals of women on female appearance satisfaction: Social comparisons as automatic processes. *Body Image*. doi:https://doi.org/10.1016/j.bodyim.2009.07.008

Winkler, C., & Rhodes, G. (2005). Perceptual adaptation affects attractiveness of female bodies. *British Journal of Psychology*. doi:https://doi.org/10.1348/000712605X36343

Zamariola, G., Cardini, F., Mian, E., Serino, A., & Tsakiris, M. (2017). Can you feel the body that you see? On the relationship between interoceptive accuracy and body image. *Body Image*. doi:https://doi.org/10.1016/j.bodyim.2017.01.005