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The sex of body images modulates size estimations and lateralized responses in body perception

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ABSTRACT
Previous findings suggest a right hemispheric contribution to body image distortions only in women. Here we set out to replicate this finding and investigate whether the sex of the body image would play a role in this lateralization. We report here two experiments of body size estimation using the divided visual field methodology. In Experiment 1 we found no effect of visual field, participant sex, and body image sex. We discuss the results in terms of the androgynous-like stimuli appearance. In Experiment 2 we increased the dimorphism of body image stimuli. Surprisingly, we observed a different pattern. Both men and women overestimated the size of female models presented in both visual fields, but the size of male models was underestimated for presentations in the left visual field compared to presentations in the right visual field. We found no differences between men and women. Our results suggest that the differences in lateralization of body image distortions between men and women observed in previous studies can be attributed to the sex of the body image. To the best of our knowledge, this is the first study to show that the sex of the body image modulates lateralization and body image distortion.

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KEYWORDS Body image; visual perception; hemispheric specialization; body perception; psychophysics

Body image distortion is a common phenomenon in men and women, and it modulates own's body satisfaction and mental health (Hagman et al., 2015; Nicoli & Junior, 2011; Zaccagni, Masotti, Donati, Mazzoni, & Gualdi-Russo, 2014). It has been extensively reported that women overestimate body sizes and distort body images to a greater extent than men, as well as have greater levels of body dissatisfaction (Lokken, Ferraro, Kirchner, & Bowling, 2003; Quittkat, Hartmann, Düsing, Buhlmann, & Vocks, 2019).

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Yet, despite the agreement in the literature about the effects of negative body image representation upon people, there are different proposals about the origin/cause of these body image distortions.

Behavioural evidence suggests that body image distortions and body dissatisfaction are related to basic cognitive mechanisms, such as mental imagery, visual working memory, visual attention, and response inhibition (Auchus, Kose, & Allen, 1993; Darling, Uytman, Allen, Havelka, & Pearson, 2015; Stephen, Sturman, Stevenson, Mond, & Brooks, 2018). For instance, the extent of body image distortion is negatively correlated to performance in mental imagery tasks (Auchus et al., 1993). Accordingly, low visual memory span and poor visual imagery skills predicted body dissatisfaction in healthy participants in a study by Darling et al. (2015). Another stream of work focuses on the attentional component of visual processing. Stephen et al. (2018) showed that people with higher degrees of body dissatisfaction pay more attention to thin bodies and show greater visual adaptation effects to thinner body images. Their results also showed that women direct more fixations towards thin bodies than men, but no difference in body satisfaction was found between the sexes. A third line of studies explains body image distortions in terms of visual adaptations. For example, Brooks, Mond, Stevenson, and Stephen (2016) showed that women had greater visual adaptation effects to distorted images of their own and others' bodies (i.e., normal bodies seemed fatter after exposure to distorted thin bodies, and vice versa) than men. More importantly, the visual adaptation was transferred from others' bodies to their own body, meaning that women distort their own body image after exposure to distorted images of unknown people. The authors suggest that visual adaptation to extreme body types depicted on media can be a reasonable explanation for body distortions in women.

The perceptual and cognitive systems that process body images rely on a highly specialized neural network, noticeably involving the extrastriate body area (EBA) (Downing, Jiang, Shuman, & Kanwisher, 2001) and the fusiform body area (FBA) (Peelen & Downing, 2004). The EBA and the FBA contribute differently to the analysis of the human body appearance: while the EBA is specialized in features and fragmented analysis of body parts, the FBA integrates them into whole-bodies representations and identity (Chan, Peelen, & Downing, 2004; Hodzic, Kaas, Muckli, Stirn, & Singer, 2009; Taylor, Wiggett, & Downing, 2007). Neural body image processing may also be a lateralized process. There is evidence suggesting the existence of lateralized patterns depending on the sex of the observer and on the body part being processed. For instance, Blanke, Ionta, Fornari, Mohr, and Maeder (2010) found asymmetrical patterns of brain activation during a visual imagery task in which participants had to imagine perspective drawings of full human bodies and partial upper human bodies. Their results suggested a right-hemisphere dominance for the mental imagery of human bodies.

Further, imagining full and partial upper bodies produced a different asymmetrical pattern of activations in the extrastriate cortex. Specifically, the left EBA was significantly activated only during imagery of full bodies, whereas the right fusiform face area (FFA) was activated during imagery of both full and partial upper bodies. The authors also presented evidence for a right-hemisphere dominance in the temporo-parietal junction and the premotor cortex.

Interestingly, this right-hemisphere dominance in processing human body images seems to be modulated by the sex of the observer, as reported in psychophysical and neuroimaging studies. Aleong and Paus (2010) showed that only women had greater BOLD responses in the right hemisphere compared to the left hemisphere in both the EBA and FBA. Moreover, Mohr, Porter, and Benton (2007) observed a fatter overestimation bias for the perception of body images processed initially in the right brain hemisphere only in women. Accordingly, Mohr and Messina (2015) proposed altered brain networks in the right hemisphere associated with eating disorders. Body image overestimation and dissatisfaction are more common in patients with eating disorders than in healthy controls (e.g., Mohr et al., 2011), and eating disorders are more prevalent in women than in men (American Psychiatric Association, 2013; Fairburn & Harrison, 2003; Johnson & Wardle, 2005; Lewer, Bauer, Hartmann, & Vocks, 2017). Therefore, it is reasonable to assume that brain lateralization may play a role in the processing of body image distortions and in the differences observed between men and women.

Particularly, the study by Mohr et al. (2007) is essential for the experiments we report here. They used the adaptive method of constants procedure associated with the divided visual field paradigm to behaviourally assess the functional brain asymmetries in body image perception of men and women. The circuitry of the visual pathways validates the divided visual field paradigm since the right and the left brain hemispheres initially receive and process contralateral stimulus presentation from the left (LVF) and right visual field (RVF), respectively (Bourne, 2006). In their psychophysical experiment, Mohr et al. (2007) presented to the participants distorted images of themselves, another person, and a bottle of soda. The stimuli were randomly presented for 125 ms in the central visual field (CVF), LVF, or RVF. Participants had to answer whether the presented stimuli were fatter or thinner than memory representations of the respective real body/object. The researchers found a fatter bias for both men and women in RVF presentations, but fatter bias for body presentations in the LVF was only found in women. This led the researchers to conclude that the right brain hemisphere plays a role in body image distortions in women. However, to the best of our knowledge, no direct or conceptual replication studies were carried out nor any further exploration of this brain asymmetry effect was conducted since then.

The procedure adopted by Mohr et al. (2007) required participants to make size judgements based on memory representations (i.e., the test and the comparison stimuli were not simultaneously presented) and participants had to judge their own body sizes. Thus, we consider that it is not clear whether the body image distortions reported by the authors were related to memory distortions, emotional biases, or perceptual processes. These distinctions are important not only to understand body image processing but also to elucidate which of two possible explanations for image distortions are more likely: the first one accounts for distortions of the visual perception, and the second account for distortions of mental imagery, with the latter approach receiving more support (Smeets, Ingleby, Hoek, & Panhuysen, 1999). Furthermore, in Mohr et al. (2007) female participants only observed female body images (i.e., their own bodies and another female body), thus it is unclear whether the LVF fatter bias would occur to the same extent for male body images. Moreover, it is possible that female participants were more susceptible to emotional bias during the task since they commonly report greater body dissatisfaction than men (Frost & McKelvie, 2004; Furnham, Badmin, & Sneade, 2002; Pingitore, Spring, & Garfieldt, 1997).

To shed some light on these inquiries, we designed two behavioural experiments to attenuate the influence of memory and emotion on the participant's answers. Additionally, we sought to test whether the sex of the observed bodies plays a role in body image distortions and lateralization. To achieve this goal, we conducted two experiments using the method of constant stimuli – a classical psychophysical method – combined with the divided visual field paradigm (Bourne, 2006). Many studies have implemented the divided visual field paradigm to investigate lateralization on size estimation, human body perceptual distortion, and complex stimuli processing, e.g., words, faces, and bodies (de Moraes, Faubert, Vasques, Cravo, & Fukusima, 2017; Jończyk, 2015; Smeets & Kosslyn, 2001). Advantageously, a behavioural approach may be sensitive to a functional perceptual asymmetry that is not assessed by neurophysiological techniques. Further, neurophysiological and behavioural data are not always convergent. To eliminate memory bias, all stimuli were presented simultaneously to the participants, and virtual models were used instead of real bodies known to the participants to lessen the influence of emotions. And finally, we presented body images of both sexes to all participants to investigate the effects of the sex of the body image on body image distortions. Based on previous findings (Mohr et al., 2007) we predicted:(i) an overall greater perceptual distortion in women than men; (ii) a fatter bias for body images presented to the LVF in women but not in men; and (iii) overall greater size estimations for female bodies. Regarding the interaction between the sex of the participant and the sex of the body image, we could only predict: (iv) a greater perceptual distortion in women observing female instead of male bodies.

General method

Overview

Here, we report two experiments where participants performed a computerized body size estimation task. In both experiments, the distorted stimulus (i.e., the test stimulus) was displayed in one visual field and the original undistorted stimulus (i.e., the standard stimulus) was presented simultaneously in the opposite visual field. Participants had to indicate which stimulus was fatter. For both experiments, we calculated participants' psychometric functions and points of subjective equality (PSE) in each experimental condition. In a size estimation experiment, the PSE is the threshold in which the participant overestimates the size of the test stimulus on half of the trials.

Participants

Using the results of Mohr et al. (2007) we calculated their interaction of interest (sex and stimuli place, $F(2,116) = 7.50$) effect size of approximately $\eta p^2 = 0.11$. We used this effect size to calculate the minimum sample size to reach 90% power with our current design (two within factors and one between), which was 19 participants per between level.[1] Since the calculated effect size was large, we set out to collect data with the largest feasible sample size greater than 38 participants and managing our time and resources to conduct the study. Note that the sample size in experiment 2 is smaller because we had to cope with funding limitations; nonetheless, it is above our minimum threshold.

All participants from both experiments were university students or staff who volunteered to participate. They were only refunded in case of eventual expenses for participating in the experiment, otherwise, they received no compensations. Written informed consent was obtained from each participant prior to participation, in which they acknowledged that they would not be identified and that their data would be fully anonymized. Both experiments were carried out in accordance with the Code of Ethics of the World Medical Association (Declaration of Helsinki) and were approved by the local Ethics Committee (CAAE#07412012.5.0000.5407). All participants were right-handed, had normal or corrected to normal visual acuity assessed by Snellen charts, and reported no sensory or neurological impairment. Right-handedness was measured by the Edinburgh Handedness Inventory (Oldfield, 1971).

[1]We performed the sample size calculation and power analysis using PANGEA webpage (Westfall, 2016). The power analysis can be accessed via the open science framework website at https://osf.io/gd7z5/?view_only=0a35055f9b5a45718922515f4ec25fa8.

Materials and procedure

Each experiment was conducted in individual and single sessions in a dark and adapted room. Both experiments shared the same core experimental design, only differing in the number of trials and stimuli set. The method of constant stimuli (Simpson, 1988) and the divided visual field method (Bourne, 2006) were implemented for stimuli presentation. Both experiments consisted of blocks of trials, with one block for each stimulus type (i.e., male body, female body, and soda bottle). The block order was counterbalanced across participants. For every trial, participants had to decide which one of two presented stimuli was fatter. One of these stimuli was the original standard stimulus and the other was the test stimulus (i.e., a distorted version of the standard stimulus to look fatter or thinner).

Each trial began with the presentation of a central fixation cross for 500 ms, in order to drive the participant's gaze to the centre of the screen. It was immediately followed by a brief 100-ms stimuli presentation in which two body images were presented simultaneously against a white background. In half of the trials, the undistorted body image (standard stimulus) was presented to the LVF, and the distorted body image (test stimulus) was presented to the RVF. In the other half of the trials, the placement was flipped. The sequence of visual field stimuli presentation was randomized in each block. At the same time that the stimuli were shown, the fixation cross transformed into a circle to improve fixation control by keeping the exogenous attention at the centre of the screen and thus avoiding a saccade away from the centre. After the stimuli presentation, a response screen was shown, and participants had to indicate on a keypad with his or her right hand which stimuli was the fatter one. Trials were self-paced with each trial initiated by participants pressing the enter key and ending with the response screen. Participants initiated the trials and responded in a numerical keypad using their right hand. Participants were instructed to focus on accuracy instead of speed and to always keep their gaze at the central fixation point during the stimulus presentation. Only pictures of the same type were presented simultaneously for size comparison (e.g., test male body *vs.* standard male body). Figure 1 illustrates a single trial sequence.

The experiment was displayed on a 19-in. LED monitor (resolution: 1920 × 1080 pixels; refresh rate: 60 Hz). Experimental tasks were programmed using E-prime software (Psychology Software Tools, Inc., Version 2.0.10.242). Participants' heads were positioned 57 cm away from the display throughout the experimental tasks with the aid of a chinrest.

Data analysis

We fitted maximum likelihood estimation functions to the psychometric data of visual field (LVF and RVF) and stimulus type (male and female

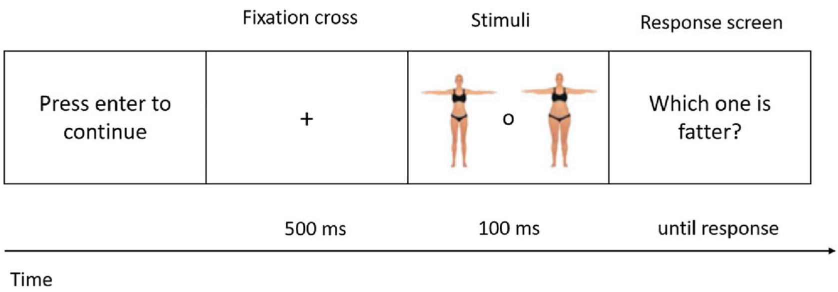

Figure 1. Representation of a single trial of experiments 1 and 2. Each trial began with a waiting screen in which the participant had to press a key which triggered a fixation point, followed by a brief stimuli presentation. Participants had to indicate which image (i.e., the image presented to the left or right visual field) was fatter after the stimuli presentation.

bodies) at the individual level to calculate the point of subjective equality (PSE) of each participant in each condition. The PSE is the value (size value in our experiment) of the test stimuli that the participant estimates as being equal in size to the standard stimulus. In our experiments, the zero value is assigned as the value of the original undistorted stimulus (i.e., standard stimulus). Thus, PSEs lower than zero mean that the participant is overestimating the test stimulus (i.e., perceiving it fatter), and PSEs higher than zero mean that the participant is underestimating the test stimulus (i.e., perceiving it thinner). PSEs were calculated for each participant in each experimental condition. We performed a three-way mixed-design ANOVA ($\alpha = .05$) looking at participants' PSE changes. We used Visual Field (LVF and RVF) and Stimulus Type (male and female bodies) as within-participant factors, and Sex as a between-participant factor. We used the software JASP (Version 0.1.0.0; JASP Team, 2019) and Jamovi (Version 1.0.1.0; The jamovi project, 2019) for statistical analysis.

Experiment 1

Pictures of 3D virtual models (male and female) or a non-corporeal object (a soda bottle) were briefly presented to the RVF and LVF simultaneously. Participants had to decide which one was fatter.

Method

Participants

Sixty healthy and right-handed participants (30 women) ranging from 18 to 31 years old (mean age = 23.7, SD = 3.2) volunteered to participate in the experiment.

Stimuli

Two distinct 3D human models (one male and one female) were generated in DAZ 3D (Version 4.9.1.30; Daz Productions, 2015), one male and one female. Additionally, we used a picture of a soda bottle retrieved from Google Images (https://images.google.com/) as a control object (see also Mohr et al., 2007). Each original stimulus (Figure 2, Panel A) was distorted using Corel Draw X5 (CorelDRAW Graphics Suite X5, version 15.2.0.686) cylindrical distortion along the x-axis to create the test stimuli. Each stimulus was distorted in 10 different levels, five "fatter" and five "thinner", with every level being an increase or decrease of 5% in cylindrical distortion. The maximum cylindrical distortion for fatter or thinner was 25% (Figure 2, Panel B). Images subtended a visual angle of 19∘ tall and a range of 4.5∘ to 7.0∘ wide. Stimuli were presented with its centre 7.5∘ to the left or to the right from the fixation cross.

Procedure

Participants completed the experiment in a single session of approximately 60 min. The session was divided into four blocks, one training block and three experimental blocks. At the beginning of the experiment, participants completed the training block, which was composed of four trials with random stimuli. Upon completing the training block successfully, experimental blocks began. Participants completed a total of three experimental blocks: a female body block, a male body block, and a soda bottle block. Each experimental block consisted of 440 trials. In each block, the test stimuli were presented 40 times for each step of cylindrical distortion, and in half of these presentations it was presented to the LVF and the other half to the RVF. In other words, the test stimulus of 5% of cylindrical distortion was presented 20 times to the RVF and 20 times in the LVF, as was the test stimulus with 10% distortion, and so on. All trials were randomized, and the block order was counterbalanced across subjects. Materials, data analysis, experimental design, and trial procedures are described above in the general method section.

Results

Figure 3 shows the mean PSE for men and women in each experimental condition along a 95% confidence interval (CI) error bars. To determine body image distortions, participants' PSE were analysed in a $2 \times 2 \times 3$ (Sex $\times$ [Visual Field $\times$ Stimulus Type]) ANOVA.[2] Mauchly's test indicated that the assumption of sphericity was violated ($p < .05$), therefore degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity.

[2]For more details, we provide a full analysis in the Open Science Framework website at https://osf.io/4yq3f/?view_only=0a35055f9b5a45718922515f4ec25fa8.

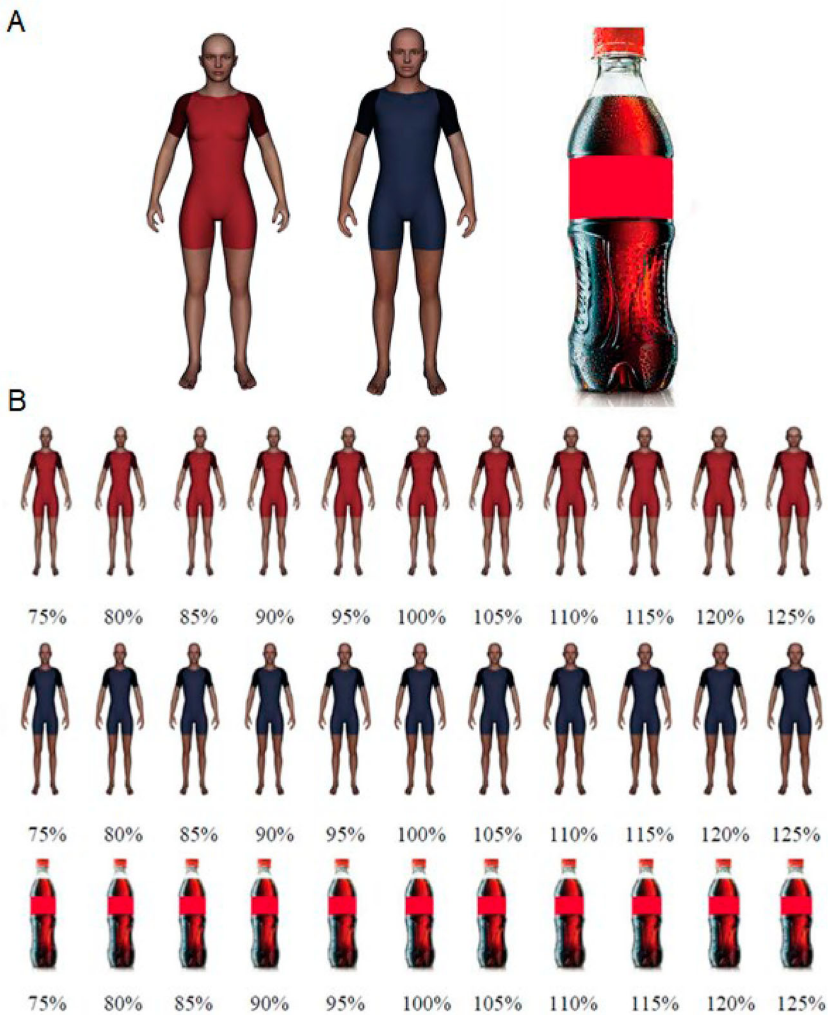

Figure 2. (A) The female and male body images, and the soda bottle used as stimuli in Experiment 1 are shown in the left, middle and right, respectively. (B) Stimuli of male, female and soda bottle distorted using Corel draw cylindrical distortion.

Contrary to previous results, the analysis indicated no significant interactions (all $p > .37$ and $\omega^2 = 0$) and no significant main effect of any factor (all $p > .13$ and $\omega^2 < .02$). The predicted interaction between sex and visual field (see Mohr et al., 2007) was non-significant, $F(1,58) = .75$, $p = .38$, $\omega^2 = 0$.

Discussion

Analyses of participants' PSEs revealed no main effects or interactions and participants' means are all close to zero for all stimuli and visual fields

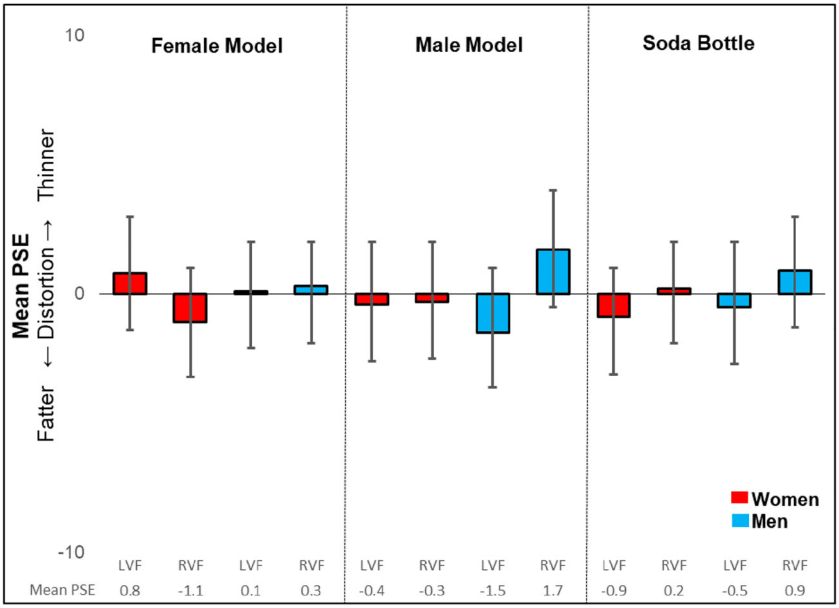

Figure 3. Experiment 1 mean PSE of men and women for each stimulus type and visual field presentation. RVF stands for Right Visual Field and LVF stands for Left Visual Field. Error bars denote within-subject 95% CI. Male participants mean PSEs are represented by blue bars and female participants mean PSE by red bars. The mean values of each condition are shown at the bottom of the figure.

presentations. These results suggest that there are no distortions in body perception and no sex differences in body size estimation in both brain hemispheres. In Mohr et al. (2007), RVF presentation resulted in a general size overestimation for both men and women, and a fatter bias was also observed in LVF presentations but only for women. We did not find any of those differences to be statically significant in our data. Likewise, other studies do not support Mohr et al. (2007) findings. A previous study that implemented the divided visual field paradigm to investigate body image distortions found a thinner bias in the right hemisphere when health women estimate sizes of someone else's body (Smeets & Kosslyn, 2001).

Different outcomes from Mohr et al. (2007) may be a result of experimental design differences. In our experiment, we presented the standard stimuli simultaneously with the test stimuli, and in the former study, participants had to compare the distorted stimuli with the stored representation of the veridical body or object from memory. This suggests that memory representations may have played a role in body size overestimation distortions, i.e., they did not derive from perceptual processes, but from distorted memory representations. This is in line with a recent review that highlights the role of cognitive biases such as attention and memory (Rodgers & DuBois, 2016) in body image distortions. Additionally, emotional bias may also account for differences in the results. Mohr et al. (2007) presented pictures of real persons, including pictures of participants' own bodies, whereas we presented pictures of 3D virtual models, which we believe do not trigger a bodily self-reference in the participants. Greater body dissatisfaction is associated with greater body image distortion both in eating disorders patients and healthy controls (Hagman et al., 2015; Mable, Balance, & Galgan, 1986), and women are more prone to body dissatisfaction than men (Demarest & Allen, 2000). Therefore, it is reasonable to assume that emotions may have played a bigger role in body perception in the mentioned study (Mohr et al., 2007). We designed the present study targeting perceptual processes, with all participants judging sizes of male and female models. Hence, we believe the influence of other psychological processes (e.g., emotion and memory) were strongly attenuated – which can partially account for results without fatter bias or sex effects.

Another possibility for the absence of any asymmetry or sex effect in our results might be related to a limitation we became aware of once we analysed the data. We considered both the male and the female body images we used in our experiment to be highly androgynous. This led us to consider that the sex-related differences of the observed body image may play a role in body image distortions. Therefore, we decided to design a follow-up experiment using virtual models with greater sexual dimorphism between male and female body images.

Experiment 2

Two body image pictures were presented simultaneously in each visual field and participants were asked to indicate which of the two stimuli was fatter. In this second experiment, we used stimuli of body images with increased sexual dimorphism to shed some light on whether the sex of the stimuli has an influence on body image distortions. Additionally, we switched to a more realistic and organic method of body shape distortions to modify stimuli (virtual models) appearance to become fatter or thinner.

Method

Participants

Forty healthy and right-handed participants (20 women) ranging from 17 to 28 years old (mean age = 20.7, SD = 2.7) volunteered to participate in the experiment.

Stimuli

Two distinct 3D human models were generated in DAZ 3D (Version 4.9.1.30; Daz Productions, 2015), one male and one female (see Figure 4, Panel A). The male and female 3D models were distorted in eight different levels: four levels fatter and four levels thinner. Male and female body images were distorted using the "shape" tab of the software DAZ 3D to look thinner or fatter. Every thinner level was an increase of 25% of the "emaciated" option in DAZ 3D for both male and female models. Every fatter level was a 25% increase in the "portly" option for male models or a 25% increase in the "pear figure" option for female models (Figure 4, Panel B). Images subtended a visual angle of 14∘ tall, 3∘ wide and were presented with its centre 8∘ to the left or right of the fixation circle.

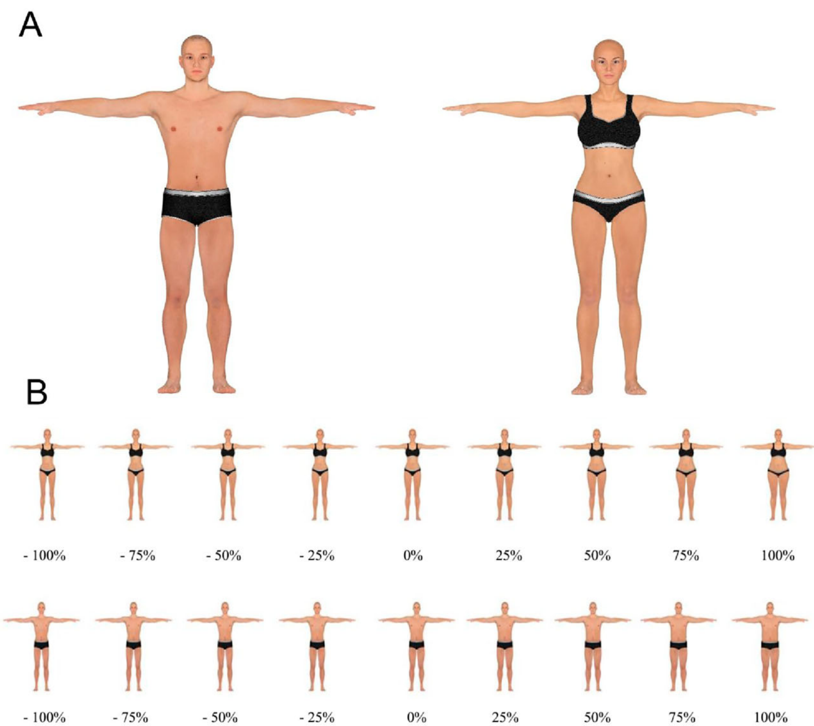

Figure 4. Stimuli presented in Experiment 2. (A) A female body image (right) and a male body image (left) used as stimuli in Experiment 2. (B) Distorted female (up) and male (down) 3D models used as stimuli; central-right images show fatter levels of body image distortion, and central-left images show thinner levels of body image distortion. DAZ 3D was used to generate and distort all stimuli.

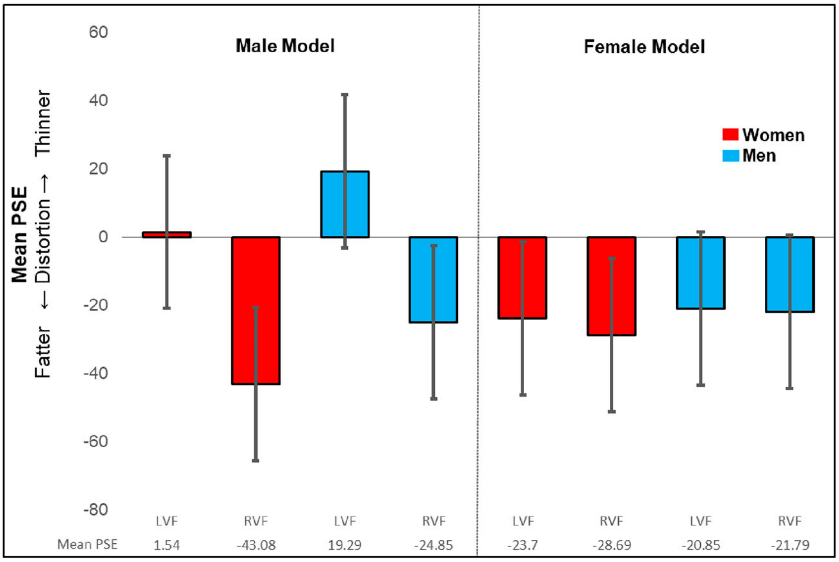

Figure 5. Experiment 2 mean PSE of Men and Women for each stimulus type and each visual field presentation. RVF represents Right Visual Field and LVF represents Left Visual Field. Error bars indicate within-subject 95% CI. Male participants mean PSEs are represented by blue bars and female participants mean PSE by red bars. The mean values of each condition are shown at the bottom of the figure.

Procedure

Participants completed the experiment in a single session of approximately 40 min. The session was divided into three blocks, one training block and two experimental blocks. At the beginning of the experiment, participants completed the training block, which was composed of four trials. Upon completing the training block successfully, the two experimental blocks began: female body block and male body block. Each experimental block consisted of 360 trials, and each level of distorted stimulus was presented 20 times in each visual field. All trials were randomized and the order of blocks was counterbalanced across subjects. Materials, data analysis, experimental design, and trial procedures are described above in the general method section.

Results

Figure 5 shows the mean PSE along 95% confidence interval (CI) bars for men and women in each experimental condition. To check for body image distortions, participants' PSE were analysed in a $2 \times 2 \times 2$ (Participant Sex $\times$ [Visual Field $\times$ Body Image Sex]) ANOVA.[3] There was no significant main effect of

[3]Even though we report here main effects for the sake of completeness, we were mostly not interested in the main effects. Therefore we consider that our analysis focusses on only four tests, the three 2-way

Participant Sex, $F(1,38) = 3.36$, $p = .07$, $\omega^2 = .05$, and the sex of the Body Image, $F(1,38) = 3.82$, $p = .05$, $\omega^2 = .03$. However, unlike in Experiment 1, there was a significant main effect[4] of Visual Field, $F(1,38) = 4.58$, $p = .039$, $\omega^2 = .06$, with body image presentations in the RVF (Mean PSE = −29.6, SD = 34.1) being more overestimated compared to body image presentations in the LVF (Mean PSE = −5.93, SD = 64.5).

Surprisingly, the ANOVA revealed a significant interaction between Visual Field and Body Image Sex, $F(1,38) = 7.34$, $p = .01$, $\omega^2 = .09$. Tukey post-hoc comparisons of this interaction revealed that male models are underestimated (i.e., perceived as thinner) in the LVF in comparison with male models in the RVF (Mean Difference = 44.38, SE = 13.44, $p = .008$), and with female models in both LVF (Mean Difference = 32.69, SE = 9.79, $p = .007$) and RVF (Mean Difference = 35.66, SE = 12.64, $p = .032$). Interactions between Participant Sex and Body Image Sex, $F(1,38) = 1.14$, $p = .29$, $\omega^2 = .00$; between Participant Sex and Visual Field, $F(1,38) = .01$, $p = .91$, $\omega = 0$; and the triple interaction, $F(1,38) = 0.1$, $p = .9$, $\omega^2 = 0$, were all non-significant.

We conducted additional one sample t-tests against zero across all participants to further investigate which conditions resulted in lateralized behaviour. This is a not-planned exploratory analysis that we conducted after the paper was submitted to review. We corrected our alpha level to 0.0125 (Bonferroni correction) to correct for multiple comparisons. Our results show that only the condition of male body presented in the LVF was non-significant, $t(39) = 0.77$, $p = 0.44$, $d = 0.12$. Female presentations in both LVF, $t(39) = -5.88$, $p < 0.001$, $d = -0.93$, and RVF, $t(39) = -6.21$, $p < 0.001$, $d = -0.98$, were significant. Male presentations in the RVF was significant as well, $t(39) = -5.28$, $p < 0.001$, $d = -0.83$.

Discussion

The results of Experiment 2 revealed a significant interaction between Visual Field and Body Image Sex. The mean PSE of male body presentations in the LVF is greater than the mean PSE of male body presentations in the RVF and female body presentations in both visual fields. Additional one sample t-tests confirm these results. Our data indicate that both men and women estimate the size of female bodies equally in both RVF and LVF. However, our data also suggest that there is an asymmetry in body image distortions when estimating the size of male bodies. On average, both men and women estimated the size of male models presented to the LVF more accurately or even

interactions, and the single 3-way interaction. For that reason consider an alpha level of 0.0125 (Bonferroni correction) for error control in the ANOVA test (Cramer et al., 2016). The *p*-values reported here are raw ANOVA outputs, therefore not corrected for multiple comparisons.

[4]This main effect is not considered significant if we use the corrected alpha level of .0125 (see footnote 3).

underestimated in some cases (i.e., thinner bias) compared to presentations in the RVF. Conversely, both men and women overestimate the size of male models stimuli presented to the RVF if compared to LVF presentations. Together, our results indicate that: (i) men and women present a similar pattern of size estimation, (ii) body image perception is generally overestimated (i.e., a fatter bias), but this does not apply for male body LVF presentations (i.e., a thinner bias), and (iii) there is a lateralized size estimation bias for male body perception, but not for female body perception.

We make some considerations regarding the study conducted by Mohr et al. (2007) in the light of the interaction between the factors Visual Field and Body Image Sex found here. In their study, participants underwent three different experiments, one for each stimulus type (i.e., a picture of oneself, a picture of the experimenter, and a picture of a soda bottle). A general fatter bias was found for both men and women when judging pictures of the experimenter in both visual fields and pictures of themselves presented in the RVF. However, when judging pictures of themselves presented in the LVF, women but not men presented a fatter bias. Mohr and colleagues concluded that only women have a fatter bias in the right hemisphere for their own body image perception but not men. The problem of this conclusion is that, because the experimenter was a woman, the stimuli set with the experimenter's body image contained only female body images, hence the women participating in this experiment only estimated sizes of female bodies. Similarly, to our results, both men and women overestimated the experimenter's body pictures (condition equivalent to our female virtual model) presented in the RVF and the LVF. Moreover, the differences found in Mohr et al. (2007) in which women overestimated pictures of themselves presented in both RVF and LVF, while men overestimated pictures of themselves presented only in the RVF, also fits our data. That is because in our second experiment female bodies were estimated similarly in both visual fields while male bodies were only overestimated in the RVF when compared to the LVF. It may be the case that the asymmetries identified by Mohr and colleagues were due to differences in the sex of the observed bodies rather than differences in the sex of the observers. Note also that the effect size that we calculated of Mohr et al. (2007) study ($\eta p^2 = 0.11$) is near to the effect size we report here ($\eta p^2 = 0.16$), therefore it is likely that we are reporting the same effect.[5] Moreover, the fact that both men and women had similar response patterns across both our experiments strengthens this hypothesis. To summarize, we propose that the sex of the observed body, rather than the sex of the observer, may cause a lateralized effect found in body size estimation tasks that have its basis in perceptual processes.

[5]We provide a full analysis with all effect sizes at the Open Science Framework website at https://osf.io/m7p3z/?view_only=0a35055f9b5a45718922515f4ec25fa8.

We should clarify that, while it seems tempting to interpret our results by claiming that female bodies are overestimated in both visual fields and male bodies are overestimated in the RVF and underestimated in the LVF, we will refrain from doing so. To eliminate memory bias and assess perception-level distortions, we presented present both stimuli (i.e., standard and test) simultaneously. The choice of this experimental design entails a limitation in our method: the PSE is a relative measure of one visual field relative to its contralateral visual field. For that reason, we cannot interpret the PSE in absolute terms. In other words, if the mean PSE in the RVF is negative it means that on average, participants overestimated body images presented in the RVF only when they compared it to the standard stimulus presented in the LVF. The opposite is true. For this reason, it is difficult to interpret the situation in which the PSEs are negative in both visual fields, such as is the case of female bodies. One possible explanation is that there is no distortion because the bias of one visual field cancels out the bias of the contralateral field. However, this is an oversimplistic account that overlooks the fact that the results are an average estimation of PSEs, therefore this effect may not be consistent across all participants in all trials. Also, there is no mathematical relationship between PSEs as each psychometric calculation was done independently in each visual field (i.e., each PSE was a comparison between a set of test stimuli in that visual field and a standard stimulus in the contralateral field). Therefore, it is possible that stimuli presented in both visual fields were overestimated when compared to the standard stimulus in the contralateral field, yet, this interpretation is speculative. To conclude, although our method limits the interpretation of PSEs in absolute terms, this does not hinder our main findings: (i) there is an asymmetry for male body perception but not for female bodies, (ii) specifically, male bodies were underestimated in the RVF compared to presentations in the LVF and to female body presentations in both visual fields.

General discussion

Previous studies linked body image distortions to the sex of the observer, brain asymmetries, altered brain networks, the functioning of high-level cognitive processes (e.g., visual memory, imagery and attention) and to the presence of psychopathologies (Dakanalis et al., 2016; Mohr et al., 2007; Mohr & Messina, 2015; Smeets et al., 1999; Smeets & Kosslyn, 2001). Yet, the role of each processing level where the distortions can occur is still unclear (Gaudio & Quattrocchi, 2012). Our study complements previous literature by adding a new variable to body image distortions and pinpointing the processing level where they occur. Specifically, our results show that the sex of the observed body plays a role in modulating body image distortion at the perceptual level.

In Experiment 1, we observed no distortions on body image perception for participants of both sexes. However, the stimuli set was highly androgynous. When we replaced those androgynous models with more dimorphic body images in Experiment 2, this pattern changed. In the second experiment, participants of both sexes estimated female body images similarly across both visual fields. Based on previous results (Mohr et al., 2007), we speculate that female bodies were overestimated in both visual fields in our experiment. Conversely, participants estimated male body images presented in the LVF thinner than male body images presented in the RVF. Together, our results suggest that (i) the sex of the body image presented is a key variable in body image distortions, (ii) a lateralized process takes place in this effect, particularly for male bodies, (iii) participants' sex does not affect the results, (iv) body image distortion occurs at the perceptual-level, and (v) the right brain hemisphere play different roles as the sex of the body image changes.

Taken together the results from Experiment 1 and Experiment 2, we can infer that stimuli dimorphism drives perceptual distortion since body size distortions increased along with dimorphism across the experiments. The mean PSEs were close to zero in Experiment 1 (androgynous stimuli set) and distanced from zero in Experiment 2 (dimorphic stimuli set). Additionally, because there was an increase in lateralized responses in Experiment 2, we can assume that lateralization in perceptual body image distortions is associated with greater body image dimorphism. The literature shows many examples of how dimorphism influences visual perception and cognition (e.g., Foo, Simmons, & Rhodes, 2017; Ludwig & Pollet, 2014; Sadr, Troje, & Nakayama, 2005), and how dimorphism-related processes modulate functional and anatomical differences between the brain hemispheres (e.g., Lewis & Diamond, 1995).

Our results corroborate previous findings in the literature suggesting the presence of a brain asymmetry underlying body image distortions. Previous studies showed that body images presented to the left brain hemisphere are overestimated (Mohr et al., 2007; Smeets & Kosslyn, 2001), which is in line with our finding that female and male body images presented to the RVF are overestimated by women and men. Conversely, we found that participants (from both sexes) responded differently to female and male body images presented to the LVF, overestimating the former but underestimating the latter (when compared to the contralateral field). Together with neuroimaging evidence suggesting a right-hemisphere dominance in the processing of full-body images (Blanke et al., 2010), our findings support the hypothesis that the right brain hemisphere may have a major role in modulating body size estimations depending on the stimulus type (i.e., sex of the observed body).

Our results could also explain why women tend to report greater body dissatisfaction than men (Frost & McKelvie, 2004; Furnham et al., 2002; Pingitore et al., 1997). While we observed asymmetry in the processing of male body images, this was not observed for female bodies. This specific asymmetry suggests that there is a balancing effect between both brain hemispheres during the processing of male bodies, but not female bodies. We believe that it supports the idea of a fatter bias in the right brain hemisphere (Mohr et al., 2007) only for female bodies. In Mohr et al. (2007), the researchers used a between-subject design and concluded that the fatter bias observed in women (but not men) was related to the sex of the participants. To our understanding, their assumption is partially correct because their participants initially judged their own body images (thus estimated sizes of body images of their own sex). The fact that the sex of the participants yielded no different results when the same set of pictures (photograph of the experimenter) was presented to both men and women (Mohr et al., 2007) further supports our claim that the sex of the observed body affects lateralization. To the best of our knowledge, our study is the first psychophysical experiment reported that implemented a within-subject design in which men and women judged both female and male bodies. Additionally, our results can be associated with the fact that women's bodies are under more aesthetic pressure than men's bodies in general and can help to explain how this social pressure affects body image processing in the brain.

Regarding the processing levels where the body image distortions occur, Smeets et al. (1999) proposed two possible mechanisms. The first accounts for disturbances of the visual perception, wherein distortion takes place at the level of registration of the visual pattern during perception (titled as the bottom-up approach). The second explanation accounts for distortions of mental imagery as higher-level visual representations, wherein distortions are originated at the level of reconstruction of the visual pattern during imagery (titled as the top-down approach). Smeets et al. (1999) argue that their data corroborate the top-down approach, as they found no differences in perceptual sensitivity measures between anorexic and healthy participants. Thus, they propose that body image distortions do not have a perceptual cause. However, our data shows the opposite. In our experiments, participants compared two side-by-side bodies of both sexes, instead of comparing bodies or silhouettes with mental representations. Our experimental design assessed visual perception distortions of body images, thus it allowed us to disentangle perceptual distortions from memory and/or mental imagery distortions and attitudinal (subjective) biases of the participants (Gardner, 1996), providing evidence of body image distortion at the perception level.

To summarize, the present work provides new evidence on the relevance of the sex of the observed body image in the laterality of human body visual perception, by showing that only male bodies produced lateralized responses. Based on findings by Mohr et al. (2007), we speculate that female bodies were overestimated in both visual fields and male bodies were overestimated only in the LVF. Nonetheless, these findings must be seen in the light of some constraints of generality (see Simons, Shoda, & Lindsay, 2017), since our sample's profile was very specific (healthy young adults) and our stimuli set was composed of virtual models instead of real human bodies. We must also be careful in interpreting findings produced by the divided visual field paradigm (Bourne, 2006), as it is an inferential method to explore functional brain asymmetries. Yet, because previous reports fit our data (e.g., Mohr et al., 2007), we believe that our results will be reproducible in similar settings and we have no reason to suppose that they depend on other characteristics of the participants, methods, or context.

The results reported here broaden the knowledge about the hemispheric specialization in the human brain and contribute to the understanding of the sex differences in body image perception and distortions. We designed this study to specifically target the perceptual component of body image processing, for future studies, we suggest that researchers also control other sources of confounding variables. For instance, future experiments should enable one to interpret PSEs in absolute terms. Furthermore, other potential confounding variables in the attitudinal component could be mitigated by assessing participants' level of body dissatisfaction, their body mass index, and the presence of eating or body dysmorphic disorders. Studies on how brain asymmetries play a role in memory and mental imagery are also warranted. Finally, more research is required to elucidate how the right brain hemisphere modulates body image perception and its relations to the sex of the observed body.

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Disclosure statement

No potential conflict of interest was reported by the author(s).

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Data availability statement

Full analyses of all statistical tests along with the original data are provided in the Open Science Framework website as supplemental material. The web addresses to these materials are provided in footnotes throughout the manuscript. The data for all experiments are available at https://osf.io/gm9z4/?view_only=0a35055f9b5a45718922515f4ec25fa8.

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