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Attention biases in preoccupation with body image: an ERP study of the role of social comparison and automaticity when processing body size

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Highlights:

- Attention biases to body size were studied in women with high and low preoccupation.
- Early and late ERP components were used as neural correlates of attention biases.
- Social comparison processes were manipulated with personalized self- and peer-images.
- Preoccupied women exhibited an earlier bias to enlarged bodies of both self and peer.
- They allocated sustained attention only to changes in self, mainly size enlargements.

Abstract

Appearance-related attention biases are thought to contribute to body image disturbances. We investigated how preoccupation with body image is associated with attention biases to body size, focusing on the role of social comparison processes and automaticity. Thirty-six women varying on self-reported preoccupation compared their actual body size to size-modified images of either themselves or a figure-matched peer. Amplification of earlier (N170, P2) and later (P3, LPP) ERP components recorded under low vs. high concurrent working memory load were analyzed. Women with high preoccupation exhibited an earlier bias to larger bodies of both self and peer. During later processing stages, they exhibited a stronger bias to enlarged as well as reduced self-images and a lack of sensitivity to size-modifications of the peer-image. Working memory load did not affect these biases systematically. Current findings suggest that preoccupation involves an earlier attention bias to weight increase cues and later over-engagement with own figure.

Keywords: ERP, N170, P2, P3, LPP, preoccupation, body image, attention bias, body size, self-images, social comparison, automaticity
1. Introduction

Disturbed body image is a multifaceted construct that involves distorted perceptions of (i.e., the perceptual component) as well as negative affect toward (i.e., the cognitive-affective or attitudinal component) ones’ body (Cash & Brown, 1987; Cash & Deagle, 1997; e.g., Cash, Fleming, Alindogan, Steadman, & Whitehead, 2002; Thompson, 2004). Disturbed body image facilitates the development and maintenance of eating disorders (e.g., Fairburn, Cooper, & Shafran, 2003; Stice, Marti, & Durant, 2011; Williamson, White, York-Crowe, & Stewart, 2004) as well as body dysmorphic disorder (e.g., Veale, 2004). It is also related to unhealthy weight control behaviors (Neumark-Sztainer, Paxton, Hannan, Haines, & Story, 2006), poor subjective quality of life (Mond et al., 2013), depression, and low self-esteem (Paxton, Neumark-Sztainer, Hannan, & Eisenberg, 2006). These detrimental outcomes and the growing prevalence (e.g., Fiske, Fallon, Blissmer, & Redding, 2014; Mond et al., 2013) add urgency to the need to understand the mechanisms underlying disturbed body image.

In this paper, we focus on preoccupation - the cognitive-affective component of disturbed body image that involves body dissatisfaction, related negative emotions (e.g., Cash et al., 2002), and dysfunctional concern with appearance (e.g., Thompson, 2004). We conceptualized preoccupation as a dimensional construct underlying eating disorders (cf., Holm-Denoma, Richey, & Joiner, 2010; Wildes & Marcus, 2013) and other psychopathology (cf., Mond et al., 2013; Veale, 2004) and used the Preoccupation with body-image and body-weight subscale of Eating Disorder Assessment Scale (EDAS; Akkermann, 2010) to assess related individual differences.

Cognitive-behavioral theories of eating disorders (e.g., Williamson et al., 2004) implicate attention biases toward appearance-related information as a key mechanism of preoccupation with body image and related constructs. Attention bias has been defined as a
tendency to over-prioritize information that is salient for some cognitive schema (e.g., Aspen, Darcy, & Lock, 2013; Williamson et al., 2004). It can be viewed as a maladaptive extreme of motivated attention, a broader phenomenon of preferential processing of information with high motivational significance (e.g., Pessoa, 2015; Pourtois, Schettino, & Vuilleumier, 2013; Schupp, Flaisch, Stockburger, & Junghöfer, 2006). Over-evaluation of low body weight and slim body shape (e.g., Fairburn et al., 2003; Williamson et al., 2004) should render body size information a particularly relevant target for motivated attention in people who are preoccupied with body image.

To the best of our knowledge, no prior study has investigated how attention biases relate to preoccupation with body image. However, numerous studies associating attention biases with constructs that are closely linked to preoccupation, such as body dissatisfaction (e.g., Rodgers & DuBois, 2016) as well as eating disorders (e.g., Aspen et al., 2013; Faunce, 2002), indicate that high preoccupation is likely to bias attention toward appearance-related stimuli. Many specific aspects regarding attention biases to body size, however, are undetermined (e.g., Rodgers & DuBois, 2016). For instance, it is unclear whether and how these biases depend on the evaluation context as well as whether automatic and controlled biases should be distinguished. In the present study, we investigated both questions in women with low and high preoccupation with body image.

First, we were interested in whether preoccupation-related attention biases to body size differ when people examine their own figure and when they compare themselves to a peer. Preoccupation-related constructs have often been linked to social comparison i.e., the evaluation of ones’ perceived qualities against the qualities of others (e.g., Groesz, Levine, & Murnen, 2002; Schaefer & Thompson, 2014; Thompson, Coover, & Stormer, 1999). For instance, people who are dissatisfied with their bodies tend to engage more in appearance-focused social comparisons (e.g., Myers & Crowther, 2009), particularly in the upward
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direction (e.g., Bailey & Ricciardelli, 2010; O’Brien et al., 2009). More specifically, they have been shown to focus more on their own unattractive and others’ attractive body areas (e.g., Blechert, Nickert, Caffier, & Tuschen-Caffier, 2009; Jansen, Nederkoorn, & Mulken, 2005; Roefs et al., 2008). To the best of our knowledge, however, no study has directly investigated the role of body size in guiding attention during self-observation vs. social comparison (Rodgers & DuBois, 2016). Previously documented asymmetric and self-deprecating biases (e.g., Blechert et al., 2009; Jansen et al., 2005; Roefs et al., 2008) suggest that people with high preoccupation with body image are likely to attend more to “fatness” cues (e.g., body size increases) in self and to “thinness” cues (e.g., body size decreases) in others. Testing that hypothesis requires, however, that the processing of body size is isolated from the processing of other aspects of perceived attractiveness such as the body proportions (e.g., waist to hip ratio) and fitness.

Second, we were interested in whether the biases associated with high preoccupation emerge on the level of automatic or controlled attention. Cognitive-behavioral theories of eating disorders propose that attention biases toward disorder-relevant information are relatively automatic (Williamson et al., 2004). Testing this proposal remains an important research aim with implications for selecting appropriate interventions (e.g., Aspen et al., 2013). Generally, a process can be considered automatic if it a) unfolds relatively fast and b) potentially outside of conscious awareness as well as c) is independent of explicit goals and d) capacity-limited cognitive resources (Moors, 2016). It is likely that attention biases characterizing people with high preoccupation meet some of these criteria. For instance, behavioral studies using the dot-probe and Stroop tasks suggest that people with eating disorders and high body dissatisfaction exhibit attention biases toward appearance-related stimuli irrespective of explicit goals (Aspen et al., 2013; Faunce, 2002; Rodgers & DuBois, 2016). In the present study, we focused on the processing speed feature of automaticity that
has received less attention with somewhat conflicting results (e.g., Gao et al., 2011, 2014; Horndasch, Heinrich, Kratz, & Moll, 2012; Mai et al., 2015). We also investigated the resource independence (i.e., efficiency) feature of automaticity that, to our knowledge, has so far not been studied. Focusing on automaticity in conjunction with evaluation context allowed us to also test the possibility that social comparison may have different effects on automatic and controlled attention biases.

1.1. Electrocortical Correlates of Attention Biases

Analysis of event-related potentials (ERPs) is well-suited for assessing attention biases on the neural level as motivated attention has been shown to enhance the amplitudes of many relatively early as well as late ERP components (e.g., Pourtois et al., 2013). The ERP components associated with early and more automatic attention include the N170 and the P2. The N170, a temporal negativity peaking between 140 and 200 ms, is thought to reflect structural encoding of face and body stimuli (Eimer, 2000). Its sensitivity to motivated attention is suggested by larger amplitudes for motivationally salient stimuli such as emotional compared to neutral faces (e.g., Hinojosa, Mercado, & Carretié, 2015) and nude compared to clothed bodies (e.g., Alho, Salminen, Sams, Hietanen, & Nummenmaa, 2015; Hietanen, Kirjavainen, & Nummenmaa, 2014). Regarding body size processing, larger N170 responses have been elicited by schematic figures of obese compared to normal and underweight bodies (Schupp & Renner, 2011). The existing evidence associating preoccupation-related constructs with N170 responses to body size stimuli, however, is inconclusive (e.g., Gao et al., 2011; Groves, Kennett, & Gillmeister, 2017; Mai et al., 2015).

The P2, a fronto-central positivity visible from 180 and 200 ms (Carretié, Hinojosa, Martín-Loeches, Mercado, & Tapia, 2004; Carretié, Mercado, Tapia, & Hinojosa, 2001; Luck & Hillyard, 1994), is another potential correlate of automatic motivated attention (Carretié et al., 2004, e.g., 2001). In addition to emotional stimuli (Carretié et al., 2004, 2001; Delplanque,
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Lavoie, Hot, Silvert, & Sequeira, 2004; Eimer, Holmes, & McGlone, 2003; Kanske & Kotz, 2007), the P2 can be enhanced by fatness and thinness words (Gao et al., 2011), and schematic images of obese compared to normal and underweight bodies (Schupp & Renner, 2011). The potential relationship between preoccupation and P2 responses to body size has received little attention beyond the finding that pictures of overweight bodied elicit stronger P2 responses in women with bulimia nervosa (Mai et al., 2015).

The ERP components associated with later and more controlled motivated attention include the P3 and the Late Positive Potential (LPP). The P3 is a midline positivity peaking between 250 and 500 ms in response to task-relevant as well as otherwise motivationally significant stimuli (Hajcak, Weinberg, MacNamara, & Foti, 2011; Olofsson, Nordin, Sequeira, & Polich, 2008; Picton, 1992; Polich, 2007). Two subtypes of P3 have been distinguished: a frontally peaking P3a, reflecting stimulus-driven attention capture, and a parietally peaking P3b, reflecting more task-driven attention (Delplanque et al., 2004; Polich, 2007). P3-like components have also been registered in response to body size stimuli, although their association with preoccupation-related constructs remains unclear (Gao et al., 2011; Mai et al., 2015).

The LPP is a sustained centro-parietal positivity overlapping initially with the P3b (for about 300 - 500 ms) and continuing up to several seconds. It is thought to reflect sustained attentive processing as well as cognitive evaluation of stimulus meaning (e.g., Foti, Hajcak, & Dien, 2009; Hajcak, MacNamara, & Olvet, 2010; Schupp et al., 2006; Weinberg, Hilgard, Bartholow, & Hajcak, 2012). LPP sensitivity to motivated attention is suggested by amplified responses to affective and evolutionarily significant content (Cuthbert, Schupp, Bradley, Birbaumer, & Lang, 2000; Schupp, Cuthbert, et al., 2004; Schupp et al., 2000; Schupp, Ohman, et al., 2004; Weinberg & Hajcak, 2010). LPP amplifications have also been reported during body size processing but with somewhat mixed results regarding connections with
preoccupation-related constructs (Horndasch et al., 2012; Mai et al., 2015). Taken together, this body of research suggests that successive ERP components from the N170 to the LPP are sensitive to body size processing and may reveal attention biases related to high preoccupation with body image.

1.2. Present Study and Hypotheses

The first objective of the current study was to investigate how preoccupation-related attention biases to body size are moderated by the context of self-observation vs. social comparison. The second objective was to assess the automaticity of attention biases across the two contexts. Toward these ends, we designed an experiment where women with varying levels of self-reported Preoccupation with body-image and body-weight (Akkermann, 2010) compared the mental representation of their actual body size to size-modified (from -10% to +10%) images of themselves and an unfamiliar peer. The condition with self-images was designed to model evaluation of one’s own body size, whereas the condition with peer-images was designed to model social comparison. The size-modified images of both conditions were created in relation to the figure of each participant.

The modulation of ERP components (N170, P2, P3, and LPP) by size-modifications were used to assess attention biases toward body size. The sensitivity of attention biases to evaluation context was isolated by comparing responses to self-images and peer-images. The automaticity of attention biases was estimated from the speed and resource independence of ERP modulations. Biases emerging in earlier ERP components were deemed more automatic than biases emerging in later components. Biases that were insensitive to concurrent working memory (WM) load imposed by a version of the Sternberg task (Sternberg, 1966) were considered more automatic than biases that were reduced by high WM load.

We predicted that women with high preoccupation have more pronounced and more automatic attention biases toward body size modifications than women with low
preoccupation. We also hypothesized that in women with high preoccupation, attention biases to body size interact more strongly with the evaluation context and do so in a self-deprecating manner (cf., Blechert et al., 2009; Jansen et al., 2005; Roefs et al., 2008). This would be evident in stronger attention bias to enlarged images during self-observation and to reduced images during social comparison.

2. Method

2.1. Participants

The final sample consisted of 36 adult Caucasian women (age range 18 – 27 years; $M = 20.31$, $SD = 2.01$). Originally 41 volunteers were recruited via university mailing lists and social media. 37 participants completed the EEG experiment, one was excluded due to excessive EEG artifacts (see section 2.5. EEG Recording, Preprocessing, and Data Reduction).

The sample was non-selective with regards to eating disorder psychopathology and body mass index (BMI). No information about formal psychiatric diagnoses was acquired. The mean BMI (based on self-reported weight and height) of the final sample was 21.70 kg/m$^2$ ($SD = 2.55$, range 17.40 – 27.55). The BMI of 28 participants (77.78% of the sample) was in the normal range (18.5 – 25 kg/m$^2$, World Health Organization), three participants (8.33%) were under- and five (13.89%) overweight.

No monetary compensation was offered for participation. Participants taking undergraduate psychology courses at the University of Tartu received research participation credit. Informed written consent was obtained from all participants. The study was approved by the Research Ethics Committee of the University of Tartu, Estonia.
2.2. Self-Reported Preoccupation

Individual differences in cognitive-affective body image disturbances were evaluated with the Preoccupation with body-image and body-weight subscale of Eating Disorder Assessment Scale (EDAS; Akkermann, 2010). The sample was divided into high (n = 13) and low (n = 23) preoccupation groups using the subscale’s clinical cut-off point. The descriptive statistics of demographic and questionnaire data for the two groups as well as the between-group pairwise t-test comparisons are presented in Supplementary Materials.

EDAS is a 29-item self-report questionnaire developed for screening purposes. It has four subscales that assess symptoms of eating disorders over the course of past three months on a 6-point Likert-type scale ranging from never (0) to always (5). The Preoccupation subscale measures the cognitive-affective component of eating disorder symptoms, capturing the tendency to assign undue significance to low body-weight (e.g., “I think I would be more successful if I were thinner”), evaluate one’s body negatively (e.g., “It is uncomfortable to see my body in the mirror”), and be overly concerned with potential negative judgements from others (e.g., “I am bothered by thoughts that people may criticize the way I look”). In line with good psychometric properties of EDAS (Akkermann, 2010), we observed a Cronbach’s α of .94 for the Preoccupation subscale in the current sample. The three other EDAS subscales, Restrained eating, Binge eating, and Purging measure the behavioral component of disturbed eating and were used only to describe the sample (see Supplementary Materials).

2.3. Stimuli

*Figure 1.* Example set of modified peer-images (face visible during the experiment).
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Twenty-two personalized body stimuli were created for each participant – 11 differently sized self-images for the self-observation condition and 11 differently sized peer-images for the social comparison condition. Examples of peer-images are presented in Figure 1. The face is pixelated for confidentiality but was visible during the experiment.

Participants were photographed wearing figure-hugging beige leggings and a top (provided by the experimenter) against a black background with frontal lighting from a standardized frontal position (chest level, 2 m distance). Following prepositioned markings, the photographer instructed the participant to stand straight with head upright, feet shoulder-width apart, arms raised to an angle of approximately 45 degrees, and facing the camera with a neutral expression. When necessary, clips were used in the back to ensure that clothes were fitting without any folds. Glasses were asked to be removed and hair was asked to be pushed back from the face or tied up if longer than shoulder length.

The photograph was digitally processed with Remodeler software (The Science Programming Team, http://www.scienceprogramming.com/) by modifying the width of chest, waist, hips, thighs, lower legs, upper arms, forearms, chin, and cheeks in steps of 2% from -10% to +10% without altering the shape of the skeleton. The program automatically increased or decreased the width of respective body-parts and smoothed out the transitions using anchor points positioned manually at the joints. Although this size modulation approach does not take into account the differences in body fat accumulation, it avoids more abnormal modifications to the figure (e.g., changes to the skeleton or head shape). This procedure resulted in five images with smaller (-2, -4, -6, -8, and -10%) and five images with larger (+2, +4, +6, +8, and +10%) figures than the participant’s actual body size. The original image (0%) was also included in the stimulus set.

The peer presented in the social comparison condition was an unfamiliar female from the same ethnic (Caucasian) and age group (23 years) as the participants and was
photographed under identical conditions. The same person served as the model peer for all participants. To personalize the stimuli, the image of the peer was first digitally altered to match each participant. Specifically, the width of the widest part of chest, hips (at the level of hip bones and buttocks), thighs, and upper arms as well as the width of the thinnest part of the waist were equalized. The matched peer image was then modified the same way as the original self-image in steps of 2% from -10% to +10%.

2.4. Procedure and Design

Participants came to the laboratory twice. On the first visit, they were introduced to the study, signed the consent form, had their picture taken, filled in EDAS and a demographic survey (including height and weight). On the second visit (average interval 12.89 days, SD = 8.50, range 1 to 35) they performed the size-comparison experiment and filled in additional questionnaires (for further information see Supplementary Materials).

The size-comparison experiment had two concurrent tasks with two within-subject conditions. As a primary task, the participant had to view images of herself (i.e., the self-observation condition) or the peer (i.e., the social comparison condition), compare each image to the mental representation of her actual body size, and indicate with mouse key press whether the depicted figure was larger or smaller than her own body. Concurrently, the participant performed a working memory (WM) task that required memorizing a sequence of either two (i.e., the low WM load condition) or six (i.e., the high WM load condition) consonants for the duration of each trial in order to indicate at the end of the trial whether a target consonant was in the initial list or not.

The experiment consisted of 132 self-observation trials and 132 social comparison trials (264 in total). In both conditions, 66 trials involved low concurrent WM load and 66 trials involved high concurrent WM load. On each trial (see also Figure 2), the participant first saw a black screen (i.e., inter-trial-interval – ITI) for a random duration between 750 and
1250 ms \((M = 1000\, \text{ms})\), followed by a fixation cross for 1500 ms. Then the WM task stimulus was presented in the middle of the screen for 1500 ms. The sequence of unique consonants was randomly drawn from Estonian alphabet and presented in a single row with capital letters. The four outer spaces were replaced with number signs (#) in the low WM load condition to assure visual similarity of the two types of stimuli. Then the body stimulus was presented. During the first 1500 ms the participant simply viewed the image to limit movement artefacts in the EEG signal during the period of interest. After 1500 ms larger than me (+) and smaller than me (–) cues appeared on the right side of the screen prompting the participant to give the size comparison response. The participant had unlimited time to respond but when no answer was given within 4500 ms after stimulus onset a reminder “Please respond” appeared on the left side of the screen. Immediately after the body size response, the WM task target character was presented together with was in the list (=) and was not in the list (×) response cues and unlimited time to answer. On 50% of the trials the target consonant was in the initial string. In case of an incorrect WM response the program waited until the participant corrected the response to help maintain task engagement.

For analyses of the behavioral responses collected during the size comparison and the WM task see Supplementary Materials. These analyses revealed that there were no significant differences between preoccupation groups in body size perception and WM task performance. They also confirmed that higher WM load led to reduced WM response accuracy, indicating sufficient increase in cognitive demand.
The experiment was conducted in an electrically shielded, sound attenuated, and dimly lit room. The experiment was run on a Windows computer with the Psychtoolbox and Matlab software. The stimuli were presented on a 19-inch cathode ray tube monitor at a one-meter distance. In both tasks participants responded by pressing a mouse key with their right thumb. The mouse was held vertically so that left and right key corresponded to upper and lower cue on the screen (see Figure 2), respectively.

Before the experiment, participants practiced the tasks with 8 trials, one from each stimulus identity and WM load condition combination presented in a randomized order and with randomly selected body size. The experimenter remained in the testing room during practice trials to answer questions and give corrective feedback as necessary.

The experiment consisted of three identical blocks (see Figure 3) with 88 trials that were divided into sub-blocks based on the stimulus identity (self vs. peer) and WM task load (low vs. high). Each block began with four sub-blocks involving the self-observation condition with changing WM load (low load → high load → low load → high load). In each sub-block, 11 differently sized self-images were presented once in randomized order. The four self-image sub-blocks were followed by four peer-image sub-blocks (i.e., the social comparison condition) with identical design. Participants were notified when the stimulus identity was about to change and were then also reminded of the task instructions.

![Figure 3. Experiment structure.](image)

After every WM load sub-block (11 trials), there was a resting break with participant-controlled length. During these breaks, automatic feedback was given about WM response.
accuracy to foster task engagement. At the end of the experiment participants were also given automatic feedback about the accuracy of their body size estimates in the self-observation and the social comparison condition. Several self-report measures were also incorporated to the design but were not analyzed in the present study (see Supplementary Materials).

2.5. EEG Recording, Preprocessing, and Data Reduction

Continuous EEG was recorded with a BioSemi ActiveTwo system from 32 scalp locations and two linked earlobes. Four additional electrodes were used on bipolar horizontal and vertical ocular locations to capture eye movements. During recording, the CMS/DRL reference scheme with 512 Hz sampling rate and .16 – 100 Hz band-pass filter was used. Offline processing was performed with EEGLAB (Makeig, Debener, Onton, & Delorme, 2004) and Matlab software. Data were first down-sampled to 256 Hz and all scalp channels were re-referenced to linked earlobes. Independent Component Analysis was used to computationally remove ocular artifacts. The Infomax algorithm was trained on 6-second epochs (-1000 to 5000 ms relative to WM stimulus onset) of 1 Hz high-pass filtered data. Components corresponding to blinks and eye movements were identified visually and removed before reconstructing the unfiltered continuous data. The ICA-pruned data were then band-pass filtered from .25 to 30 Hz and cut into segments covering -400 to 1500 ms from body stimulus onset. Pre-stimulus voltage from -200 to 0 ms relative to body stimulus onset was subtracted as baseline. Segments with artifacts were automatically excluded based on the ±75μV threshold criterion. One of the 37 participants taking part in the EEG experiment was excluded from analyses due to losing more than 50% of trials in at least one stimulus size (11 sizes) by stimulus identity (self, peer) by concurrent WM load (low, high) design cell. On average 93.32% (SD = 5.77, range 78.79 – 100%) of EEG data was retained.

1 The retention rate was independent of stimulus identity (self, peer), size-category (reduced, naturalistic, enlarged), and their interactions (ps > .11; repeated measures ANOVA). There was a significant
For analyses, the ERP waveforms were averaged for each combination of stimulus identity, WM load and one of three body size categories: reduced images (-10, -8, -6, and -4%), naturalistic images (-2, 0, and +2%) and enlarged images (+4, +6, +8, and +10%).

For all ERP components of interest, mean amplitudes (µV) were computed across a representative time-window and cluster of electrodes identified based on prior studies, observed grand averaged ERP waveforms, and a size-sensitivity localizer. First, grand average ERP waveforms were visually inspected to define suitable time-windows for N170, P2, P3, and LPP. For the mean amplitude of each time-window a size sensitivity localizer was produced. The localizer involved collapsing responses to reduced and enlarged images and comparing them to responses to naturalistic images disregarding experimental conditions and preoccupation groups (cf., Luck & Gaspelin, 2017). Bilaterally symmetric electrode clusters were identified at locations where the strongest size-sensitivity overlapped with the theoretical scalp distribution of each component (for a figure depicting size-sensitivity topographies see Supplementary Materials). As a result of this procedure, the N170 was quantified at temporal electrode sites (P7 and P8) from 100 to 200 ms after stimulus onset. The P2 and P3 were assessed across a fronto-central electrode cluster (Fz, FC1, FC2, Cz) from 200 to 300 ms and from 300 to 400 ms, respectively. Finally, the LPP was computed across a central-parietal electrode cluster (Cz, CP1, CP2, Pz) from 450 to 1000 ms.

2.6. Statistical Analyses

For the mean amplitude of each ERP component, a separate mixed factorial ANOVA was performed with stimulus identity (2 levels: self, peer), WM task load (2 levels: low load, interaction with WM load \((F_{1,35}) = 6.04, p < .05, \eta^2_p = .15\), indicating that slightly more data were lost in the low \((M = 92.60\%, SD = 8.48)\) compared to the high WM load \((M = 94.07\%, SD = 7.19)\) condition.

Note that as a result of dividing the 11 stimulus sizes into three groups, there were less trials in the naturalistic \((M = 16.86, SD = 1.39, range 11 – 18; averaged within the two stimulus identity by two WM load condition combinations)\) compared to reduced \((M = 22.46, SD = 1.87, range 16 – 24)\) and enlarged \((M = 22.27, SD = 1.95, range 14 – 24)\) size-categories.
high load), and stimulus size-category (3 levels: reduced, naturalistic, enlarged) as repeated factors and preoccupation group (2 groups: high score, low score) as a between subject categorical factor. Partial eta square ($\eta^2_p$) effect sizes are reported and a $p < .05$ significance threshold is used. When appropriate, the Greenhouse-Geisser corrected $p$-values and degrees of freedom are reported. Significant interactions were decomposed using post-hoc Tukey’s tests to correct for multiple comparisons. To analyze the time-course of significant amplifications within the 550 ms LPP window, mass-univariate approach was used (Groppe, Urbach, & Kutas, 2011) conducting comparisons for each time-point and applying the false discovery rate (FDR) correction for the relevant ANOVA or t-test $p$-values (Benjamini & Yekutieli, 2001).

When describing and interpreting the results we focus on the interaction effects involving preoccupation group and body stimulus size-category that are relevant for our hypotheses, highlighting between-group differences in size-sensitivity (i.e., the modulation of ERPs by body stimulus size-category). Using the MorePower software, we computed the observed power of this study to detect small, medium, and large effect sizes for these interactions (Campbell & Thompson, 2012). We determined 10% power to detect small effects ($\eta^2_p = .01$), 43% power to detect medium effects ($\eta^2_p = .06$), and 84% power to detect large effects ($\eta^2_p = .14$).

3. Results

Table 1 summarizes the results of the separate mixed factorial ANOVAs for N170, P2, P3, and LPP. Panel A of Table 1 lists the main and interactive effects of stimulus identity, stimulus size-category, and concurrent WM task load on the mean amplitude of respective ERP components while panel B lists the interactions with preoccupation group. The table omits preoccupation group main effects on the ERP amplitudes, none of which reached
statistical significance \((ps > .39)\). Means and standard errors involved in these comparisons can be found in Supplementary Materials.

3.1. N170

The main effect of stimulus size-category on N170 mean amplitude was statistically significant (see panel A of Table 1). Compared to naturalistic images both reduced and enlarged images induced on average significantly more negative N170 amplitudes \((ps < .05)\). Mean N170 amplitudes in response to reduced and enlarged images did not differ \((p = .99)\). There was, however, also a significant interaction between preoccupation group, stimulus size, and WM load (see panel B of Table 1). According to the post-hoc decomposition of this three-way interaction, stimulus size-category modulated the N170 amplitudes significantly only in preoccupied women and only during the high WM load condition. Specifically, under high WM load enlarged bodies elicited more negative N170 response than naturalistic bodies in women with high preoccupation \((p < .01, \text{other } ps > .35); \text{see Figure 4})\).
Figure 4. The modulation of N170 by stimulus size-category in women with high (n = 13) and low (n = 23) preoccupation under high and low WM load. Averaged ERP waveforms for reduced (-10, -8, -6, and -4%), naturalistic (-2, 0, and +2%), and enlarged (+4, +6, +8, and +10%) images from electrodes P7 and P8. The time-window used for calculating mean N170 amplitudes is separated with vertical dashed lines.

3.2. P2

For P2 the main effects of stimulus identity and size-category were statistically significant (see panel A of Table 1). The mean P2 amplitude was more positive in response to self-images (i.e., during the self-observation condition) than in response to peer-images (i.e., during the social comparison condition). Post hoc comparisons revealed that enlarged images elicited on average stronger P2 response than both reduced and naturalistic images (ps < .01) while the latter two did not differ (p = .96). There were no significant interactions with preoccupation group (see panel B of Table 1).

3.3. P3

The main effects of stimulus identity and size-category were statistically significant also for P3 (see panel A of Table 1). As for P2, the mean P3 amplitude was more positive in
response to self-images than in response to peer-images. Post hoc comparisons revealed that enlarged images elicited a stronger response than naturalistic images ($p < .05$) but not reduced images ($p = .21$). Responses to naturalistic and reduced images did not differ ($p = .70$).

The significant interaction between stimulus identity and size-category was qualified by preoccupation (see panel B of Table 1). From the perspective of stimulus identity effects, post hoc comparisons revealed that in the low preoccupation group the P3 responses to self-images and peer-images did not differ in the reduced ($p = .99$) or enlarged ($p = .25$) category and were only slightly amplified for self-images in the naturalistic category ($p < .1$). In the high preoccupation group, no stimulus identity effect was observed for reduced ($p = .39$) or naturalistic images ($p = .99$). Enlarged self-images, however, elicited significantly stronger P3 than enlarged peer-images ($p < .001$).

From the perspective of size-sensitivity (see Figure 5), the post hoc decomposition of the three-way interaction between stimulus identity, stimulus size-category, and preoccupation group revealed that in the low preoccupation group, mean P3 amplitudes did not differentiate body size category neither for self- nor peer-images ($ps > .79$). In women with high preoccupation, however, enlarged self-images elicited stronger P3 compared to naturalistic self-images ($p < .05$; for other self-image size-contrasts $ps > .57$) while there were no differences between the three size-categories of peer-images ($ps > .99$).
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3.4. LPP

3.4.1. Mean LPP amplitude.

The main effects of WM load, stimulus identity, and stimulus size-category on mean LPP amplitude were statistically significant (see panel A of Table 1). High concurrent WM load reduced the mean LPP compared to low WM load. Self-images elicited on average stronger LPP than peer-images. Reduced images elicited stronger LPP than naturalistic images ($p < .001$) and enlarged images elicited stronger LPP than naturalistic ($p < .001$) as well as reduced images ($p < .01$).

Both the significant two-way interaction between stimulus identity and preoccupation group (see panel B of Table 1) and the significant two-way interaction between stimulus
identity and size-category (see panel A of Table 1) were qualified by the significant three-way interaction between stimulus identity, stimulus size-category, and preoccupation group (see panel B of Table 1). From the perspective of stimulus identity effects, post hoc comparisons revealed that mean LPP responses to self- and peer-images did not differ in the low preoccupation group ($p > .32$). In the high preoccupation group, however, enlarged self-images elicited significantly stronger mean LPP amplitude compared to enlarged peer-images ($p < .001$). For reduced images, the identity difference approached statistical significance ($p = .05$) and for naturalistic images there was no difference ($p > .99$).

From the perspective of size-sensitivity (see Figure 6), the post hoc decomposition of the three-way interaction between stimulus identity, stimulus size-category, and preoccupation group shows that in women with low preoccupation enlarged self-images elicited stronger LPP compared to naturalistic self-images ($p < .001$). The LPP of reduced self-images did not differ significantly from the LPP of naturalistic ($p = .71$) or enlarged ($p = .23$) self-images. The difference between mean LPP in response to enlarged and naturalistic peer-images approached statistical significance ($p = .06$). Responses to reduced peer-images differed neither from responses to naturalistic ($p = .52$) nor enlarged peer-images ($p > .99$). In women with high preoccupation, the LPP modulations by stimulus size-category interacted more strongly with stimulus identity. Both reduced ($p < .05$) and particularly enlarged ($p < .001$) self-images elicited stronger LPP than naturalistic self-images. The mean LPP in response to enlarged and reduced self-images did not differ significantly ($p = .26$). In the high preoccupation group, LPP responses did not differ according to the size-category of the peer-image ($p > .99$).
Figure 6. The modulation of LPP by stimulus size-category in women with high (n = 13) and low (n = 23) preoccupation while viewing self- and peer-images. Averaged ERP waveforms for reduced (-10, -8, -6, and -4%), naturalistic (-2, 0, and +2%), and enlarged (+4, +6, +8, and +10%) images from electrodes Cz, CP1, CP2, and Pz. The time-window used for calculating mean LPP amplitudes is separated with vertical dashed lines. Grey areas depict significant differences between three size-categories (mass-univariate ANOVA, FDR-corrected p < .05).

3.4.2. Temporal dynamics of LPP modulation by stimulus size-category.

Mass-univariate ANOVAs and t-tests (FDR corrected p < .05) were used as post-hoc analyses to decompose the significant three-way interaction between stimulus identity, stimulus size-category, and preoccupation group on LPP (see panel B of Table 1) from the perspective of the time-course of modulations to LPP waveform by stimulus size-category.

In the low preoccupation group, mass-univariate ANOVA (see Figure 6) revealed that the temporal dynamics of LPP size-sensitivity were very similar in response to self- and peer-images. For self-images, the LPP differentiated stimulus size from 420 to 867 ms (duration 447 ms) and for peer-images from 445 to 863 ms (duration 418 ms). Pairwise mass-univariate t-test contrasts for different stimulus size-categories were used to disentangle the ANOVA effects. Enlarged self-images amplified the LPP compared to naturalistic self-images from
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437 to 867 ms (duration 430 ms). Reduced self-images amplified the LPP compared to naturalistic self-images only within a short time-window from 580 to 705 ms (duration 125 ms) and enlarged self-images amplified the LPP compared to reduced self-images from 397 to 652 ms (duration 255 ms). Enlarged peer-images amplified the LPP compared to naturalistic peer-images from 445 to 883 ms (duration 438 ms). Reduced peer-images amplified the LPP compared to naturalistic peer-images from 520 to 795 ms (duration 275 ms). There were no time-windows with significant difference between enlarged and reduced peer-images.

In the high preoccupation group, mass-univariate ANOVA (see Figure 6) revealed that for self-images the LPP modulations by stimulus size-category emerged sooner and lasted longer (405-1230 ms, duration 825 ms) than the time-window used for mean LPP analysis. Also, an earlier sensitivity period was evident which temporally overlapped with the more frontally analyzed P2 and P3 (245-315 ms, duration 70 ms). According to pairwise mass-univariate t-test contrasts, enlarged self-images amplified the LPP compared to naturalistic self-images already from 280 to 1330 ms (duration 1050 ms). Reduced self-images amplified the LPP compared to naturalistic self-images from 535 to 1040 ms (duration 505 ms).

Enlarged self-images amplified the response compared to reduced self-images significantly from 234 to 308 ms (duration 74 ms), from 440 to 535 ms (duration 95 ms), and from 668 to 735 ms (67 duration ms). In the high preoccupation group, there were no time-windows where the difference between any of the peer-image size-categories reached statistical significance.

4. Discussion

We investigated how preoccupation with body image relates to automatic and controlled attention biases to the body size of oneself and others. Thirty-six women with varying levels of self-reported Preoccupation with body-image and body-weight took part in an EEG experiment where they compared the mental representation of their actual body size
to a series of size-modified images (from -10% to +10%) of themselves and a peer with matched figure. Attention biases were operationalized as modulations of ERP components reflecting body size processing as well as motivated attention (N170, P2, P3, and LPP). Two conditions, one with self-images and another with peer-images were designed to differentiate attention biases to body size in the self-observation and social comparison context, respectively. The automaticity of biases was assessed by comparing the speed and resource independence of ERP modulations. Specifically, biases detected during earlier processing stages were deemed more automatic than biases detected during later stages and biases that were insensitive to concurrent WM load were considered more automatic than biases that were reduced by high WM load.

We predicted that women with high preoccupation exhibit more pronounced, more automatic, and more self-deprecating attention biases. The results partly supported these predictions but revealed a more nuanced pattern. Specifically, the preoccupation-related biases in body size processing clustered into a context-insensitive early phase (i.e., N170 and P2) and a context-sensitive later phase (i.e., P3 and LPP). During the context-insensitive phase, women with high preoccupation exhibited an earlier bias to enlarged images. During the context-sensitive phase, a stronger bias toward enlarged self-images and to lesser extent also toward reduced self-images was evident, together with an absence of sensitivity to size modifications of the peer-image. In the following sections, we will interpret this pattern making comparisons to the low preoccupation group and previous literature.

4.1. Biases in Early and Late Attention

Our findings suggest that during early processing stages, all participants exhibited an attention bias toward enlarged body sizes. In line with previous findings (Schupp & Renner, 2011), P2 amplitudes were enhanced by enlarged compared to reduced and naturalistic images. Early sensitivity to all enlarged images in both groups could reflect automatic
negativity bias (e.g., Carretié et al., 2001). Echoing prior reports (e.g., Gao et al., 2011; Mai et al., 2015), this bias was evident even earlier in women with high preoccupation, but only under high concurrent cognitive load. Specifically, the high preoccupation group exhibited amplified N170 in response to enlarged images compared to naturalistic images under high but not low WM load. We also found larger P2 amplitudes for self-images compared to peer-images, suggesting that stimulus identity was differentiated and self-referential information was prioritized at this stage (cf., Hodzic, Muckli, Singer, & Stirn, 2009; Tacikowski & Nowicka, 2010). This effect did not depend, however, on body size or preoccupation.

Interesting context-specific group differences were observed for more controlled motivated attention. Women with high preoccupation exhibited faster and more pronounced biases to enlarged self-images but also to reduced self-images and a simultaneous lack of sensitivity to the size of the peer. Specifically, in women with low preoccupation, the fronto-central P3 responses did not differ between size categories in either context. Meanwhile, their centro-parietal LPP showed a short-lived bi-directional sensitivity to body size modifications that was evident in both contexts but slightly larger and skewed toward body size increases during self-observation. In women with high preoccupation, by contrast, the P3 responses were amplified for enlarged compared to naturalistic and reduced self-images while no size-related modulations emerged for peer-images. These biases were maintained and extended during the LPP where the high preoccupation group showed amplified responses to bidirectional self-image modifications with the amplification being faster, stronger, and longer lasting for enlarged images. At the same time, their LPP responses continued not to distinguish the body size of the peer.

These results suggest that all women showed some motivated attention towards enlarged images. This could be explained by negative affective response to size modifications that took the images further away from prevalent Western sociocultural norms of
attractiveness (e.g., Frederick, Forbes, & Anna, 2008; Swami et al., 2010). The preferential processing of enlarged images of oneself that was apparent in both groups could reflect larger motivational significance of unpleasant depictions of oneself compared to someone else (Cuthbert et al., 2000; Hajcak et al., 2010, 2011; Schupp, Cuthbert, et al., 2004; Schupp et al., 2006; Weinberg & Hajcak, 2010). Group differences in the P3 and LPP findings meanwhile suggest that the high preoccupation group perceived size increases in self-images as even more unpleasant and motivationally more significant than women in the low preoccupation group. Importantly, women with high preoccupation had elevated LPP response also to reduced self-images suggesting they considered these stimuli also motivationally more significant than women with low preoccupation. It is possible that due to thinner body-ideals in high preoccupied women (cf., Glauert, Rhodes, Byrne, Fink, & Grammer, 2009), the reduced self-images induced relatively stronger positive emotional arousal by virtue of being closer to that ideal.

4.2. The Role of Social Context in Body Size Processing

One aim of this study was to consider the role of social context in modifying the attention biases to body size involved in preoccupation. We found significant group differences in contextual effects on size sensitivity during later attention biases captured by the P3 and LPP. Women with low preoccupation had very similar responses to images of themselves and the peer, suggesting that the evaluation context was largely irrelevant for body size processing. It is possible that, beyond enlarged self-images eliciting negative arousal as mentioned above, these participants allocated attention to size modifications mostly in service of the experimental task of detecting bi-directional modifications in relation to their actual figure. With respect to this goal, size-modifications of the self were no more relevant than size-modifications of the peer. By contrast, the distribution of attention biases observed for preoccupied women cannot be easily explained by task goals. In this group, the size-
sensitivity of P3 and LPP was increased in response to self-images and completely removed in responses to peer-images. The salience of body size information was therefore highly dependent on the evaluation context.

Greater motivational significance of enlarged self-images in women with high preoccupation, as indicated by largest LPP responses, is consistent with eye-tracking studies that have documented body dissatisfaction related attention biases to unattractive body areas in self-images (Jansen et al., 2005; Roefs et al., 2008). They offer also partial support to our hypothesis that women with high preoccupation exhibit a self-deprecating tendency when processing body size information. The lack of size-sensitivity for peer-images in women with high preoccupation, however, diverges from our predictions and prior studies documenting amplified LPP responses to pictures of underweight female bodies in teenage girls with anorexia nervosa (Horndasch et al., 2012) and adult women with bulimia nervosa (Mai et al., 2015). A number of mechanisms could underlie this finding. First, women with high preoccupation may have been overly focused on the internal mental representation of their own appearance during the social-comparison task and therefore paid less attention to the peer-image on the screen. This interpretation is in line with a functional magnetic resonance imaging (fMRI) study where women with bulimia nervosa demonstrated an activation pattern indicative of increased self-focus and reduced processing of body contours of the stimuli when comparing themselves to slim women (Van den Eynde et al., 2013). Second, assuming that preoccupied women prefer to engage primarily in upward social comparisons (cf., O’Brien et al., 2009; Schaefer & Thompson, 2014), a peer with a similar figure may not have been a preferred target of attention for this group. Third, it is possible that women with high preoccupation were oversensitive to size differences in their own body and undersensitive to size of others. As a result, the relatively small size differences presented in this study may have been sufficient to be motivationally significant when applied to the self but insufficient...
when applied to a peer. Fourth, women with high preoccupation may have exhibited different scanning patterns during the self-observation and the social comparison condition (cf., Jansen et al., 2005; Roefs et al., 2008). When viewing self-images, they may have focused on body areas that are typically more informative about body size (e.g., waist, hips) whereas in peer-images they may have focused elsewhere.

Regardless of the exact underlying mechanism, the lack of size-sensitivity during the social comparison condition suggests that women with high preoccupation may process the body size of peers inefficiently. This interpretation is in line with previous findings that body-dissatisfied people underestimate the prevalence of higher body mass (Seifert, Arnell, & Kiviniemi, 2008) and do not update their body norms or ideals in response to exposure (Glauert et al., 2009). Together with over-attentiveness to changes in one’s own figure in general and size increases in particular, social comparison deficiencies may play an important role in reinforcing existing body image disturbances.

4.3. Automaticity of Attention Biases to Body Size

A second focus of this study concerned the distinction between automatic (i.e., faster and resource-independent) and controlled (i.e., slower and resource-dependent) attention in preoccupation-related biases to body size. The results supported one of our hypotheses that attention biases to body size are more automatic in women with high preoccupation in terms of processing speed. Greater processing speed was indicated by the observation that the biases recorded in both groups during the P2 and LPP were partially visible in the high preoccupation group already by the preceding N170 and P3, respectively. Specifically, an early bias toward enlarged images, captured by amplified P2 was visible in the high

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3 It is important to note, however, that the lack of sensitivity to peer-image size modifications apparent for P3 and LPP amplitudes did not translate into statistically significant distortions in perceived body size when women with high preoccupation compared their actual body size to peer-images. For more information about behavioral results see Supplementary Materials.
preoccupation group already in N170 responses to the same images, albeit only under high concurrent WM load (we will consider this interaction in more detail below). This finding suggests that in women with high preoccupation the prioritization of body size information can occur already during the structural encoding of stimuli (Eimer, 2000; Thierry et al., 2006). Similarly, a bias toward enlarged self-images observed for both groups during LPP was visible in the low preoccupation group already during the P3 window. Therefore, the process whereby enlarged self-images capture capacity-limited sustained attention may also be relatively more automatic in women with high preoccupation.

Our hypothesis that attention biases would be less dependent on the availability of cognitive resources in the high preoccupation group was not confirmed. The number of consonants participants held in working memory did not influence group differences in ERP responses to different body size stimuli. This finding indicates that regardless of the level of preoccupation, attending to body size required similar amounts of cognitive resources. It is possible that the WM task employed in this study did not impose sufficiently high demand for the hypothesized differences in attention biases to be revealed. However, both the EEG and behavioral results suggested that high WM load trials did induce a marked increase in cognitive load. High WM load attenuated the LPP amplitudes, indicating that less sustained attention was allocated to the body stimuli (e.g., MacNamara, Ferri, & Hajcak, 2011). Furthermore, the response accuracy was significantly reduced in the high WM load condition, confirming greater task difficulty (see Supplementary Materials).

Unexpectedly, we found that decreased availability of cognitive resources during the high WM load condition revealed a group difference whereby enlarged images enhanced the N170 amplitude in women with high preoccupation. This surprising finding should be interpreted with caution as early visual ERPs are commonly believed to be relatively independent of cognitive control (e.g., Pourtois et al., 2013; Schupp et al., 2006; Uusberg et
Preoccupation and attention biases to body size. However, the finding is reminiscent of evidence that increased cognitive load can reduce the ability to ignore task-irrelevant information (Lavie, 2010). It is therefore possible that for high but not low preoccupation participants, cognitive control resources were habitually recruited to avoid early attention becoming overly engaged with weight increase cues. When some of these resources were occupied with the concurrent task (i.e., during the high WM load condition), the habitual inhibition processes may have been interrupted, resulting in earlier prioritization of enlarged images.

Taken together, the present findings support the notion that preoccupation-related attention biases to appearance stimuli can be automatic (e.g., Williamson et al., 2004). They complement previous evidence of unintentionality (e.g., Aspen et al., 2013; Faunce, 2002) by showing how biased attention to body size also operates faster in women with high preoccupation. Our findings indicated that body size processing is equally dependent on working memory resources in women with low and high preoccupation. However, we found tentative evidence that in preoccupied women cognitive control resources may be needed to inhibit early prioritization of body size increases.

4.4. Limitations and Future Directions

The ethnically homogeneous sample with restricted BMI range limits the generalizability of the present findings until further replication. The relatively small number of participants, particularly in the high preoccupation group, also means that the study was adequately powered to detect only large effects. Therefore, some of the medium-to-large effects we observed should be interpreted with caution. However, it is important to note that the present findings were consistent across several ERP time-windows, and in case of the LPP, corroborated by more detailed time-course analyses.

A broader limitation of the study is the lack of information about psychiatric diagnoses. We conceptualized and measured preoccupation as a dimensional construct that
Preoccupation and attention biases to body size affects both people with and without psychopathology. However, as different eating disorders have been associated with different attention biases (e.g., Blechert, Ansorge, & Tuschen-Caffier, 2010), the present design could be adopted to more specific clinical samples. In addition to eating disorders, the body dysmorphic disorder (BDD) would be an interesting target. Although BDD is commonly characterized by preoccupation with a perceived flaw in the face or a specific body part (e.g., Veale, 2004), body weight and shape may also be the object of concerns (American Psychiatric Association, 2013). Future research could also extend the current approach to men with varying levels of preoccupation with body image (cf., Cho & Lee, 2013; Nikkelen, Anschutz, Ha, & Engels, 2012; Thompson, 2004). It would also be important to systematically assess the effect of objectively measured BMI on attention biases to body size.

Several modifications to the present study design could help sharpen the current interpretations and rule out alternative explanations. In order to believably manipulate stimulus identity, the images used in this study included faces. This, however, might have affected the N170 responses (e.g., de Gelder et al., 2010). Identity manipulations that allow the omission of the face could be adopted to facilitate more focused analyses of the body-sensitive N170. Introducing different models to the social comparison condition may help elucidate how body size processing depends on distinct features of physical attractiveness. Using a wider range of body sizes in both conditions would allow to clarify how attention biases to body size reductions and enlargements depend on the degree of modification. It would also be interesting to compare biases toward relative body size differences (the approach used in the current study) to biases toward bodies that are underweight, normal

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4 According to self-reported weight and height the BMI was statistically significantly larger in the high preoccupation group (see Supplementary Materials). We tested potential confounding effects of differences in self-reported BMI by performing separate mixed factorial ANOVAs for each ERP component with stimulus identity, WM task load, and stimulus size as repeated factors, preoccupation group as between subject categorical factor, and BMI as a between subject continuous factor. All interactions with preoccupation group presented in panel B of Table 1 remained statistically significant.
weight, and overweight on an absolute scale. More demanding WM tasks could be used to confirm general resource independence of attention biases to body size.

The present study also suggests interesting hypotheses for future research. First, the findings indicated that women with high preoccupation were overly engaged with their own appearance during social comparison. To test this, eye-movements could be recorded while self- and peer-images are presented simultaneously. Eye-tracking could also provide information about whether women with high preoccupation scan their own figure differently than the figure of the peer when trying to evaluate body size (cf., Jansen et al., 2005; Roefs et al., 2008). Behavioral measures, such as the dot-probe task, could also be incorporated to further understand the attention mechanisms involved. Explicit tests could also be designed for our interpretation of LPP findings that enlarged self-images induced more negative arousal and reduced self-images induced more positive arousal in women with high preoccupation.

The surprising result that increased WM load revealed a bias to enlarged body-sizes in women with high preoccupation during N170 as well as its’ potential link to cognitive control also deserve further investigation. Finally, the preoccupation-related pattern involving overattentiveness to oneself and under-attentiveness to others may play a significant role in reinforcing distortions in body size perception. To further explore this possibility, adaptive body size perception measures (cf., Gardner & Boice, 2004) may be needed to reveal group differences in body size estimates that were not significant in the present study (see Supplementary Material) but are suggested by previous findings (e.g., Cornelissen, Johns, & Tovée, 2013). Furthermore, longitudinal studies could help tease apart the roles of biased attention, distorted size perception, and negative attitudes toward one’s body in the development of eating disorders.

5. Conclusions
We investigated the relationship between preoccupation with body image and attention biases to body size by simultaneously considering the role of evaluation context (self-observation vs. social comparison) and automaticity (e.g., processing speed and efficiency). We found that self-reported preoccupation with body-image and body-weight was associated with an earlier and context-independent bias toward body size increases. Furthermore, during later processing stages, preoccupied women attended more to modifications of their own body size, with stronger and faster bias toward size enlargements. Meanwhile, they did not allocate additional attention to the size-modifications of the peer. This pattern suggests that preoccupation-related attention biases to body size are more automatic in the sense of processing speed; concern body size increases more than body size decreases; and involve an over-engagement with own body size that may hinder social comparison with appropriate targets.

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References


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Movements: *Psychosomatic Medicine, 71*(8), 907–912.
doi:10.1097/PSY.0b013e3181b4434d


doi:10.1177/01454455870114005


doi:10.1016/j.bodyim.2012.09.005


dissatisfaction among United States adults: Review and recommendations for future

Foti, D., Hajcak, G., & Dien, J. (2009). Differentiating neural responses to emotional pictures:

Frederick, D. A., Forbes, G. B., & Anna, B. (2008). Female Body Dissatisfaction and
Perceptions of the Attractive Female Body in Ghana, the Ukraine, and the United

biases among body-dissatisfied young women: An ERP study with rapid serial visual

tracking study on deployment of visual attention among females with body


M. (2010). Standing up for the body. Recent progress in uncovering the networks
involved in the perception of bodies and bodily expressions. *Neuroscience &
Preoccupation and attention biases to body size


Preoccupation and attention biases to body size


MacNamara, A., Ferri, J., & Hajcak, G. (2011). Working memory load reduces the late positive potential and this effect is attenuated with increasing anxiety. *Cognitive,
Preoccupation and attention biases to body size


Preoccupation and attention biases to body size


Preoccupation and attention biases to body size


Van den Eynde, F. V., Giampietro, V., Simmons, A., Uher, R., Andrew, C. M., Harvey, P.-O., Campbell, I. C., et al. (2013). Brain responses to body image stimuli but not food are


Table 1. Experimental effects on the mean amplitude of ERP components and interactions with preoccupation.

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<th>B. Interactions with preoccupation</th>
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</tbody>
</table>

Note. Results of the separate mixed factorial ANOVAs for each ERP component with stimulus identity (self, peer), stimulus size-category (reduced, naturalistic, enlarged), and WM task load (low load, high load) as repeated factors and preoccupation group (high score, low score) as a between subject categorical factor. G-G corrected p-values and degrees of freedom. Significant main and interaction effects (p < .05) are in bold.