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# Attentional biases to body shape images in adolescents with anorexia nervosa: An exploratory eye-tracking study

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ABSTRACT

Body image distortion (BID) plays an important role in the etiology and maintenance of anorexia nervosa (AN). Previous studies of BID in AN showed small biases in visual scanning behavior (VSB) towards images of body shapes. The aim of this study is to investigate biases in VSB when body shape images compete with images with a different theme (social interactions) for subjects' attention. When images of thin body shapes (TBS) were presented alongside images of social interactions, AN patients ($n=13$) spent significantly more time looking at TBSs rather than at social interactions, but controls ($n=20$) did not. When images of fat body shapes (FBS) were presented alongside images of social interactions, AN patients spent significantly more time looking at FBSs rather than at social interactions, but controls did not. When images of TBSs, FBSs and social interactions were presented alongside each other, AN patients demonstrated a hierarchy in their attention allocation, choosing to spend the most viewing time on TBS images, followed by FBS images and then images with social interactions. Under the three experimental conditions, AN patients demonstrated large biases in their visual scanning behavior (VSB). Biases in VSB may provide physiologically objective measures that characterize patients with AN.



## 1. Introduction

Anorexia nervosa (AN) is a severe and potentially chronic disorder with high mortality (Harris and Barraclough, 1998; Hannerz et al., 2001; Arcelus et al., 2011; Rosling et al., 2011), and onset that is typically in adolescence (Hoek and van Hoeken, 2003). Body image distortion is pathognomonic of AN (American Psychiatric Association, 2000; Zhu et al., 2012) where patients over-estimate both their own and other women's body sizes (Tovee et al., 2000; George et al., 2011). Behavioral expressions of body-size over-estimation are dietary restraint, repeated checking of shape and/or weight (body checking) and the avoidance of seeing shape and/or weight when patients start to gain weight (body avoidance) (Shafran et al., 2004). While research is limited, evidence suggests that body image disturbance in AN is based on cognitive evaluative dissatisfaction (Epstein et al., 2001; Skrzypek et al., 2001; Gao et al., 2013). The cognitive behavioral theory of AN suggests that the psychopathological process accounting for the persistence and severity of AN may be a maladaptive cognitive schemata where individuals judge themselves largely in terms of their eating habits, body shape/weight and their ability to control those factors (Williamson, 1996; Jung and Lennon, 2003; Luck et al., 2005), whereby being underweight is associated with positive attributes (Ahern et al., 2008). These beliefs about body weight and shape lead to behavior such as repeated body checking that provides AN patients with a sense of control (Shafran et al., 2004), and to biases in emotion processing of body shape stimuli that may be associated with their strong fears of gaining weight and their relentless pursuit of thinness (Williamson et al., 1999; Zhu et al., 2012).

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0165-1781/

Historically, selective attention (attention bias) in AN to body shape images has largely been inferred through the use of the Stroop (Long et al., 1994; Overduin et al., 1995; Sackville et al., 1998; Lee and Shafran, 2004) and the Dot-probe tests (Shafran et al., 2007; Lee and Shafran, 2008). Meta-analyses of the Stroop interference test for body shape related words suggested that patients with AN demonstrate the modest interference for shape related words (Dobson and Dozois, 2004) in general, as well as for body shape words with negative overtones (large body physique) (Johansson et al., 2005). Studies with the dot-probe paradigm (Shafran et al., 2007) suggest that patients with AN have the modest attention bias to negative body shape related words and pictures. However, both paradigms provide an indirect measure of attention bias and have significant limitations. These limitations include the possibility that non-attention processes are responsible for the observed response bias and an inability to provide a full picture of the manner in which the word or picture was observed or looked at by the participant (Lee and Shafran, 2004).

A more direct and sensitive method to assess attention biases is to study visual scanning behavior (VSB). Unlike the Stroop and Dot-probe tests which only measure behavioral end products of cognitive processes, VSB provides a continuous measure of attention throughout the visual scanning process (Hermans et al., 1999). The method has been utilized to study attention bias in eating disorders (ED) with regard to body image and body size estimations. George et al. (2011) found that all female participants tend to fixate on the abdominal region. However, women with AN had a wider fixation pattern when compared to controls that incorporates collar bones, thighs, and the hip prominences. Jansen et al. (2005) found that women with ED symptoms demonstrated decreased attention to their own 'beautiful' body parts, and greater attention to their own 'ugly' body parts , while healthy controls focused more on their own 'beautiful' body parts and less on their own 'ugly' body parts. When viewing other bodies the pattern was reversed: high symptom participants allocated more attention to the beautiful parts of other bodies, and controls focused more on the ugly parts of the other bodies (Jansen et al., 2005). Blechert et al. (2009) found that bulimic patients, when considering other women's bodies, were more attentive than controls to images of thin body shapes and less attentive than controls to images of fat body shapes. This focus on the positives of other bodies was also supported by a study by Janelle et al. (2003). Women with greater body image disturbance avoided looking at the abdomen and thigh of endomorphic women ('ugly' parts of other bodies) when compared to controls and the investigators hypothesized a cognitive avoidance pattern. However, in a second, later study, Janelle et al. (2009) reported that when specifically considering the time course of attention allocation, women with high body image disturbance tended to focus on areas typical of body dissatisfaction (e.g., abdomen) during the latter stages of the viewing process whether they were looking at themselves or other women. These results fall in line with the results of Gao et al., (2013) who demonstrated that women with low and medium body mass indexes had more difficulty disengaging their attention from fat body images when they were more dissatisfied with their body weight. Finally, in a study that compared visual scanning patterns of adolescents with AN and controls, little difference was found between the two groups on pictures of underweight, normal-weight and overweight women apart from a greater focus on unclothed areas of the body by AN subjects (Horndasch et al., 2012).

To date, the studies of VSB have focused on the evaluation of the focus and pattern of attentional biases to somatic regions of the body when subjects look at images of themselves and/or controls. In these studies, the differences in VSB between AN patients and healthy controls are small and within groups variations are large, leading to significant overlap between the gaze patterns of the groups (Horndasch et al., 2012; von Wietersheim et al., 2012).

Given that the current literature rests on studies where visual stimuli have only images of one theme: body shapes, participants have never been provided with opportunities to shift their attention away from body shape images to images of a competing theme. We hypothesize, that the lack of opportunities to shift attention between images from competing themes reduces the observed differences in VSB between AN patients and healthy controls. To test this hypothesis, we explored the use of a new paradigm that we have used successfully to measure biases in VSB of patients with major depression disorder (Eizenman et al., 2003). In the new paradigm, participants are presented with visual stimuli that included images from different themes/categories and participants have adequate time to scan and re-scan the presented images. In such a paradigm, participants have more choice in the type of images they choose to focus on, and biases in VSB due to both early and late cognitive processing can be measured (Eizenman et al., 2003). Given that healthy controls tend to dwell on images with themes of positive social interactions (Eizenman et al., 2003), while AN patients may have a diminished response to pleasant pictures (Davies et al., 2011), and may derive less pleasure from social interactions (social anhedonia) (Tchanturia et al., 2012), we expect that by using images with social interaction alongside images of body shapes the differences in VSB between AN patients and healthy controls will increase.

Since frequent examination of specific body parts is a prominent clinical feature of AN and patients with AN find images with thin body shapes (TBS) and fat body shapes (FBS) more attention worthy than controls (Norris et al., 2006), we hypothesize the following:

1. When presented with visual stimuli (slides) that contain images of thin body shapes (TBS) and positive social interactions, adolescent AN patients will spend more time viewing TBS images when compared with controls.
2. When presented with slides that contain images of fat body shapes (FBS) along with images of positive social interactions, adolescent AN patients will spend more time viewing FBS images when compared with controls.

Finally, based on previous studies that suggest that symptomatic women are less attentive to images of fat body shapes and more attentive to images of thin body shapes (Janelle et al. 2003; Blechert et al., 2009), we hypothesize the following:

3. When presented with images of both TBSs and FBSs, adolescent AN patients will spend more time viewing TBS images than FBS images.

We carried out an experiment with three different conditions to test the above hypotheses. Data from the first and second conditions were used to test hypothesis 1 and 2, and hypothesis 3 was tested with data from condition 3.

## 2. Methods

### 2.1. Participants

AN patients were recruited from the intensive day treatment or inpatient program in the eating disorder clinic at a Canadian tertiary care, academic children's hospital. The focus of the treatment at the time of the study was refeeding, medical stabilization, alongside psychotherapy (including family based treatment). In this clinic, between 25 and 50% of patients were treated psychopharmacologically (usually with selective serotonin reuptake inhibitors and/or low dose atypical antipsychotics). Patients were included in the study if they were female, between the ages of 12 and 18 inclusive, and had a clinically confirmed DSM-IV-TR diagnosis of AN (American Psychiatric Association, 2000) following a locally developed semi-structured interview designed to ensure that all the relevant aspects required for a diagnosis were included in the assessment.[2] The diagnosis was made by a psychiatrist or psychologist as part of the clinical assessment that also screened for co-morbid disorders by reviewing symptoms that would allow for diagnosis based on DSM-IV criteria (American Psychiatric Association, 2000). Patients with co-morbid psychiatric diagnosis or substance use disorder were excluded. Both subtypes of AN were included to optimize the potential sample size. Patient characteristics, including treatment duration and body weight were also collected.

Control subjects were screened through phone interview and were included if they were female, between the ages of 12 and 18 inclusive, and self-reported never having been diagnosed with DSM-IV-TR diagnosis of an ED of any type, a co-morbid psychiatric disorder or a substance use disorder. The EAT-26 was used to screen for the presence of an ED in the control subjects, who were included if they scored below the clinical cut-off point of 20.

Consents or assents were completed by the participant and their parent in accordance with the institutional ethics guidelines. A total of 13 patient participants and 20 control participants were recruited. The mean age of controls (14.4 + 1.82 years) was not significantly different from AN patients (14.5 + 1.61 years). Ten patients had been diagnosed with AN-restricting subtype and three with AN-binge/purge subtype.

### 2.2. Materials

#### 2.2.1. Self-report test

All participants completed the Eating Attitudes Test (EAT-26) (Garner et al., 1982) on the day their visual scanning behaviors were recorded. The 26-item Eating Attitudes Test (EAT-26) (Garner et al., 1982) is a widely used standardized measure of EDs. It produces a total score as well as three subscale scores (dieting, bulimia and oral control subscales). It has a 6-point scale that ranges from "never" to "always". Scores that are greater than or equal to 20 on the EAT-26 are associated with abnormal eating attitudes and behavior congruent with an ED. The EAT-26 has acceptable criterion-related validity by significantly predicting group membership with an accuracy rate of 90% (Mintz and O'Halloran, 2000) and high internal consistency, (standardized Cronbach's $\alpha = 0.9644$). (Ambrosi-Randic and Pokrajac-Bulian, 2005; Dunker and Philippi, 2005).

#### 2.2.2. Visual stimuli

Visual stimuli were organized into slides that were presented on a computer monitor. Each slide had four images with differing themes that were arranged in a $2 \times 2$ configuration. Each condition has a different set of slides. Slides for the first condition had two images with the theme of TBS (e.g. bony hip, thin subject) and two images with the theme of positive social interactions (e.g., adult holding a baby). Slides for the second condition had two images with a theme of FBSs (e.g. "love handles", fat subjects) and two images with a theme of positive social interactions. Slides for the third condition had one image from each of the themes of TBSs, FBSs, positive social interactions and neutral objects (clouds, chair, etc.).

In all three conditions, positive social interactions and neutral images were selected from the International Affective Picturing System (IAPS) database of images (Bradley and Lang, 2007) by a psychiatrist with an expertise in mood disorders. Images of positive social interactions had high valences (greater than 6) and medium arousal (4–6) (Lang et al., 2008). Images of neutral objects had low arousal (less than 4). Since there are no reports of attentional biases towards neutral images in patients with eating disorders, the VSB on images with neutral objects can provide a reference level against which the VSB of patients with AN and healthy controls can be evaluated.

TBS and FBS images were not available from IAPS (Bradley and Lang, 2007) and instead were selected from pictures available on the internet (Spring and Bulik, 2014). The pictures chosen were reviewed by four members of the research team who were experts in the field. The images were included if the subject in the image was female and was noticeably underweight or overweight or if the image was of a body part (hip, thigh) that was female and emphasized the underweight or overweight state of the person in the image. Images were excluded if they contained a complex background. Images that might unduly draw the attention of all viewers, because of unusual or special content such as pictures of celebrities, the morbidly thin, or obese, or the inappropriately dressed were excluded. All images were in color with a resolution of $589 \times 442$ pixels.

During the three conditions of the experiment participants looked at a total of 78 slides. The slides included 48 test slides, 16 slides for each condition, and 30 filler slides. Filler slides had four images of neutral objects (scenery) and were used to mask the purpose of the experiment. The images from each category were randomly positioned (i.e., for the set of 16 slides, each category of stimuli appeared in each quadrant of the slide the same number of times). The 48 test slides for the three conditions were randomly dispersed with the filler slides. The participants were only instructed to look at the images on the screen.

#### 2.2.3. Recording and estimation of visual scanning parameters

The slides were presented on a 19″ computer monitor (resolution: $1280 \times 1024$ pixels) that is part of EL-MAR's Visual Attention Scanning Technology (VAST, EL-MAR Inc. Toronto, Ontario, Canada). VAST incorporates a binocular gaze estimation system (Guestrin and Eizenman, 2006) that records eye-gaze positions and pupil-sizes, a display to present visual stimuli, real-time processing algorithms to estimate a set of visual scanning parameters (Eizenman et al., 2003; Hannula et al., 2010), and a monitoring station to control and supervise the progress of the experiment. Processing of eye-gaze data includes the segmentation of gaze-position data to saccades and fixations, the association of fixations and saccades with images on the slides and the estimation of visual scanning parameters (Sturm et al., 2011). The relative fixation time (RFT) on each image on a slide (a parameter of VSB that is used in this paper) is calculated by dividing the sum of all the fixation times on each image by the sum of all the fixation times on all the images on the slide. The monitoring station allows the operator to select the slides to be presented, to control the eye-tracker's procedures and the experimental protocol (e.g., calibration, start recording), and to monitor the participant's gaze-position (the images that are presented to the participant are also presented on the monitoring station and the participant's gaze position is superimposed on these images) during the experiment.

### 2.3. Procedure

On the day of the test, a research assistant explained the testing procedure to each participant and a consent form was signed. Patients were blinded to the hypotheses but were told that the study examined pupil and eye movement responses to visual images. Visual scanning patterns and pupil-sizes were recorded and analyzed. During the test, participants could move their heads freely within 1 cubic foot, (supports natural viewing of visual stimuli) and could not see the experimenter without shifting her gaze away from the monitor. Participants sat at a distance of approximately 65 cm from the monitor so that the visual angle subtended by each of the four images on each slide was approximately ($15.2^\circ \times 11.4^\circ$). The horizontal and vertical separation between any two images was greater than $2.5^\circ$. Following a five points calibration procedure in which the participant was asked to follow a moving target on the computer screen the participant looked at the 78 slides. Each slide was presented for 12 s for a total presentation time of 15.6 min. The first five slides were filler slides and served to familiarize the participants with the testing procedure. The 48 test slides for the three conditions were randomly distributed with the filler slides. At the end of the visual scanning procedure participants completed the EAT-26 (Garner et al., 1982).

### 2.4. Analysis

For each participant, the average relative fixation times (RFT) on each category of images for each condition were calculated. The data were then evaluated to determine (a) the effects of image properties such as color, contrast, intensity, corners, etc., (saliency), and (b) the use of two types of images (whole body and body parts) for TBS and FBS images on RFTs. Correlation analysis indicated that image saliency (Harel et al., 2007) did not affect RFTs of either group (*p*-values were all non-significant) and *t*-tests found no significant differences between the RFTs of AN-patients on images of whole person images and body parts (Condition 1: $t\ (12) = -0.92$, $p = 0.377$; Condition 2: $t\ (12) = -0.47$, $p = 0.649$). Based on these tests, RFTs were not normalized by the saliency of the images in each category and the RFTs of both whole body images and body parts images were averaged to obtain the RFTs on TBS and FBS for each participant.

The data were explored with descriptive analyses, including the means and standard deviations of the EAT-26 total and subscale scores, participants' age, the number of fixations on an image, the duration of a fixation on an image and RFTs on the images in each of the three conditions. A mixed design repeated measures ANOVAs (SPSS Inc., 2007) were performed to study between and within group

[2] The assessment covers AN symptoms, BN symptoms and included a formal nutritional assessment that reviewed their total daily intake, the foods they would eat and the ones they avoided, their total daily activity, and bingeing/purging behaviors (including pattern, frequency and any sense of loss of control), their perceptions about their current and past weight or shape (including any perceptions that they thought that they were too fat, even when obviously underweight), the importance of their weight being at a certain level, their goals related to weight or shape, their cognitions and emotions related to their body shape and weight, their desire to lose weight or avoid gaining weight, the reasons for any eating or weight related restriction/behaviors and their cognitions or feelings about gaining weight or increasing their intake (including any fear of gaining weigh tor being fat). It also covered changes in their eating patterns, their current height and weight, their past highest and lowest weights and when they occurred, their menstrual history and any medical complications related to their eating or purging behaviors. It would also review other ED symptoms such as rumination, pica and chewing and spitting out food, and selective eating. All of the DSM-IV diagnostic criteria for AN, BN and EDNOS are covered.

**Table 1**
EAT scores for cases with anorexia nervosa patients ($n=13$) and controls ($n=20$).

| | Mean | S.D. | $t$ (d.f.) | Significance |
|---|---|---|---|---|
| Dieting subscale | | | | |
| Control | 2.05 | 1.82 | 4.29 (12.27) | $p=0.001$ |
| AN[a] | 18.77 | 13.97 | | |
| Bulimia subscale | | | | |
| Control | 0.15 | 0.49 | 4.002 (12.16) | $p=0.002$ |
| AN[a] | 5.62 | 4.91 | | |
| Oral control subscale | | | | |
| Control | 2.00 | 2.53 | 3.89 (15.48) | $p=0.001$ |
| AN[a] | 8.23 | 5.40 | | |
| Total score | | | | |
| Control | 4.20 | 4.10 | 4.44 (12.51) | $p=0.001$ |
| AN[a] | 32.62 | 22.83 | | |

[a] AN: anorexia nervosa.

differences. In Conditions 1 and 2, the ANOVA analysis had a between-subjects factor of diagnostic groups (Control, AN) and a within-subjects factor of image types (experiment 1: TBS/social or experiment 2: FBS/social). In Condition 3, the ANOVA analysis had a between-subjects factor of diagnostic groups (Control, AN) and a within-subjects factor of image types (TBS, FBS, social, neutral). Where significant Group X Image type interactions were found, post-hoc paired comparisons ($t$-tests) with Bonferroni corrections were used to determine the significance of the differences between the control and the AN patient group. Significance levels for all statistical tests were set to $p=0.05$.

## 3. Results

The mean EAT-26 score for the AN group and the control group can be found in Table 1. Eight (61.5%) of the AN had a duration of illness that was greater than one year at the time of the study. The mean percent of expected healthy weight was 90.1% and ranged from a low of 73.2% to 100% of their expected health weight.

When TBS images were presented alongside images with social interactions (condition 1), the control group's visual scanning patterns differed from that of the AN group. The mean RFTs on images of TBS and images of social interactions, for the AN group and the control group (Table 2), are shown in Fig. 1. A mixed-design repeated measures ANOVA revealed significant main effect of image type $F\,(1, 31)=42.19$, $p<0.001$, $\eta_p^2=0.58$ and a significant interaction effect between participant group and image type, $F\ (1,\ 31)=36.15$, $p<0.001$, $\eta_p^2=0.54$. Post-hoc analysis revealed that (a) the AN group spent significantly more time observing TBS images as compared to social images ($t(12)=9.00$, $p<0.001$, $d=4.84$) while control participants spent similar times on TBS and social images ($t(19)=0.36$, $p=0.721$); and (b) the AN group spent significantly more time than healthy controls observing TBS images ($t(31)=6.01$, $p<0.001$, $d=2.09$). For each group, the mean RFTs on images of TBS and images of social interactions sum up to 50%[3] and therefore the observation that the AN group spent significantly more time than controls on TBS images is equivalent to the statement that AN patients spent significantly less time than controls on images with social interactions.

To gain more insights into the differences between the RFTs on images of body shapes and images of social interactions, the two parameters whose product determines fixation time (mean number of fixations on an image and the average duration of a fixation on an image) were analyzed separately. For the AN group, the mean number of fixations on TBSs, $8.92\pm0.43$, was significantly larger ($t(12)=8.45$, $p<0.001$, $d=3.82$) than the mean number of fixations on social images, $3.52\pm0.32$. Also, the average duration of a fixation on a TBS, $401.35\pm13.22$ ms was significantly longer ($t(12)=4.45$, $p<0.001$, $d=2.01$) than that on a social image, $295.19\pm15.05$ ms. For healthy controls the mean number of fixations on TBSs, $6.36\pm0.29$ was similar ($t(19)=1.13$, $p=0.271$) to the mean number of fixations on social images, $5.77\pm0.30$. The average duration of a fixation on TBSs, $401.66\pm12.48$ was not significantly longer than the average duration of a fixation on social interactions, $443.71\pm17.99$ ($t(19)=-2.09$, $p=0.975$). There were no significant differences in the initial orientation (time and frequency of first fixations) towards images with TBSs and images with social interactions between AN patients and healthy controls.

When FBS images were presented alongside images with social interactions (Condition 2), the control group's visual scanning patterns differed from that of the AN. The mean RFTs on images of FBSs and images of social interactions, for the AN group and the control group (Table 2), are shown in Fig. 2. A mixed-design

[3] The sum of all the RFTs on a slide is 100%. Since slides in Condition 1 has two images of TBS and two images of social interactions, the average RFTs on a single image of TBS and a single image of social interactions sum up to 50%.

**Table 2**
Mean relative fixation time (RFT) for anorexia nervosa patients and controls.

| | Image-type | Mean RFT[a] % | 95% Confidence interval | |
|---|---|---|---|---|
| | | | Lower bound % | Upper bound % |
| AN[b] ($n=13$) | | | | |
| Condition 1 | Thin body shape | 37.42 | 34.42 | 40.43 |
| | Social interactions | 12.58 | 9.57 | 15.59 |
| Condition 2 | Fat body shape | 31.51 | 27.43 | 35.58 |
| | Social interactions | 18.49 | 14.42 | 22.57 |
| Condition 3 | Thin body shape | 47.46 | 41.25 | 53.68 |
| | Fat body shape | 27.58 | 23.54 | 31.62 |
| | Social interactions | 15.32 | 11.33 | 19.31 |
| | Neutral objects | 9.64 | 7.18 | 12.09 |
| Control ($n=20$) | | | | |
| Condition 1 | Thin body shape | 25.48 | 22.71 | 28.25 |
| | Social Interactions | 24.52 | 21.75 | 27.29 |
| Condition 2 | Fat body shape | 25.24 | 22.87 | 27.62 |
| | Social Interactions | 24.76 | 22.38 | 27.13 |
| Condition 3 | Thin body shape | 29.42 | 26.19 | 32.65 |
| | Fat body shape | 28.33 | 24.50 | 32.15 |
| | Social Interactions | 26.44 | 22.25 | 30.64 |
| | Neutral Objects | 15.81 | 12.94 | 18.68 |

[a] RFT: Relative Fixation Time.
[b] AN: anorexia nervosa.

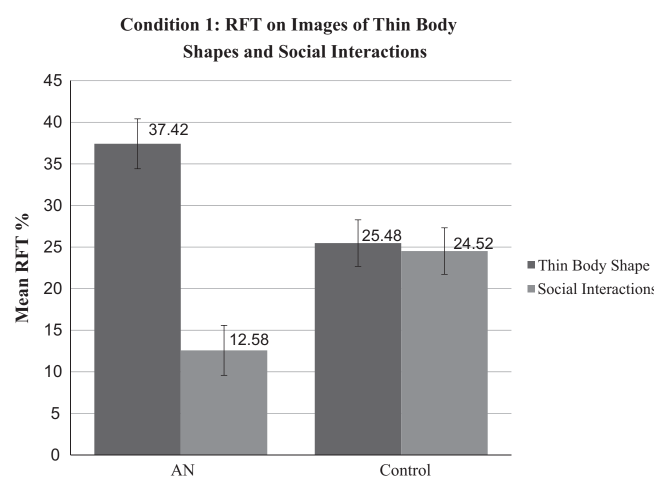


**Fig. 1.** Mean relative fixation times (RFTs) on images of thin body shapes and images of social interactions (vertical bars indicate 95% confidence intervals) for patients with anorexia nervosa (AN) and healthy controls.

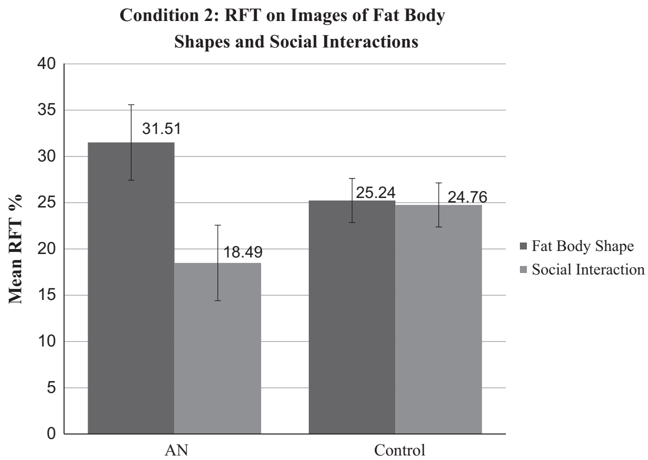


**Fig. 2.** Mean relative fixation times (RFTs) on images with fat body shapes and images with social interactions (vertical bars indicate 95% confidence intervals) for patients with anorexia nervosa (AN) and healthy controls.

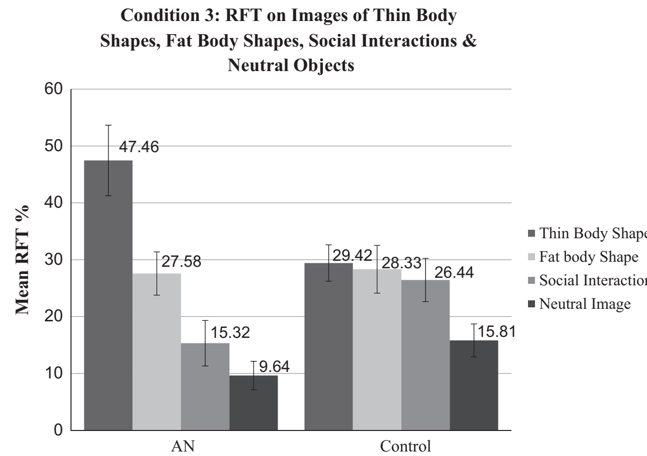


**Fig. 3.** Mean relative fixation times (RFTs) on images of thin body shapes, fat body shapes, social interactions and neutral objects (vertical bars indicate 95% confidence intervals) for patients with anorexia nervosa (AN) and healthy controls.

repeated measures ANOVA revealed significant main effect of image type $F$ (1, 31)=10.78, $p$=0.003, $\eta_p^2$=0.26 and a significant interaction effect between participant group and image type, $F$ (1, 31)=9.25, $p$=0.005, $\eta_p^2$=0.23. Post-hoc analysis of pairwise comparisons revealed that the AN group spent (a) significantly more time observing FBS images (as compared to social images) ($t$(12)=3.48, $p$=0.004, $d$=1.87) while controls spent similar times on both types of images ($t$(19)=0.21, $p$=0.833), and (b) The AN group spent significantly more time than healthy controls observing FBS images ($t$(31)=3.04, $p$=0.004, $d$=1.06). As the mean RFTs on images of FBS and images of social interactions sum up to 50%, the observation that the AN group spent significantly more time than controls on FBS images is equivalent to the statement that AN patients spent significantly less time than controls on images with social interactions.

For the AN group, the mean number of fixations on FBSs, 7.93 ± 0.55, was significantly larger ($t$(12)=3.38, $p$=0.006, $d$= 1.68) than the mean number of fixations on social images, 4.85 ± 0.42. Also, the average duration of a fixation on a FBS, 375.44 ± 11.05 msec was significantly longer ($t$(12)=2.46, $p$=0.030, $d$=0.80) than that on a social image, 340.60 ± 12.34 ms. For healthy controls the mean number of fixations on FBSs, 6.30 ± 0.28, was similar ($t$(19)=0.96, $p$=0.347) to the mean number of fixations on social images, 5.87 ± 0.24, and the average duration of a fixation on FBSs, 417.51 ± 15.27, was not significantly longer than the average duration of a fixation on social interactions 431.57 ± 13.41 ($t$(19)= −0.81, $p$=0.785). There were no significant differences in the initial orientation (time-to and frequency-of first fixations) towards images with FBSs and images with social interactions between AN patients and healthy controls.

Fig. 3 shows the RFTs of the AN group and the control group (Table 2), when participants looked at slides with images of TBSs, FBSs, social interactions and neutral objects (Condition 3). A mixed design ANOVA revealed significant main effect of image type $F$ (2.09, 64.76)=50.25, $p < 0.001$, $\eta_p^2$=0.618, Greenhouse-Geisser correction of sphericity 0.696, and a significant interaction effect between image type and participant group, $F$ (2.09, 64.76)=17.16, $p < 0.001$, $\eta_p^2$=0.356. Post-hoc analysis revealed that in AN patients the mean RFT on TBSs was significantly higher than the mean RFT on FBSs ($t$(12)=5.00, $p < 0.001$, $d$=2.22), while in healthy controls the mean RFTs on TBS and FBS were similar ($t$ (19)=0.58, $p$=0.568). Also, the mean RFTs of AN patients on body shapes were significantly higher than the mean RFT on social images ($p < 0.001$, $d > 1.79$) while in healthy controls the mean RFTs on TBS and FBS were similar to the mean RFT on social interactions ($p > 0.367$). These results are similar to the results in Conditions 1 and 2. For both AN patients and healthy controls the mean RFTs on body shapes were significantly higher than the mean RFTs on neutral objects ($p < 0.003$, $d > 1.70$).

## 4. Discussion

The data in this study describe biases in VSB of adolescent AN patients. Because AN typically has an adolescent onset (Hoek and van Hoeken, 2003; Favaro et al., 2009), such biases may be more likely to be associated with the psychopathology of the illness early in its course than with the consequences of chronic starvation. The three conditions in this study provide evidence of robust and consistent biases in VSB. In each condition, the VSB of AN patients was significantly different from the controls. AN patients looked more at body shape images, whether thin or fat, rather than at images of social interactions while healthy adolescent controls show no preferences for either TBSs, FBSs or social images.

Even though adolescent AN patients and healthy controls have similar number of fixations on each slide, adolescent AN patients directed 71.3% of their fixations (Condition 1) to TBS and only 28.7% to images with social interactions while healthy controls have similar number of fixations on TBS and social interactions. Similar observations were made in Condition 2 of the experiment where adolescent AN patients directed 62.2% of their fixations to FBS and only 37.8% to images with social interactions while healthy controls have similar number of fixations on FBS and social interactions. These biases in visual scanning behavior are consistent with one of the prominent behavioral characteristics of patients with AN, i.e., repeated body checking (Shafran et al., 2004).

While patients with AN had much shorter fixations on images with social interactions (317.89 ms, average for Conditions 1 and 2) than on images with either TBS (401.35 ms) or FBS body shapes (375.44 ms), healthy controls did not. In a model proposed by Laubrock et al. (2013) the duration of a fixation is dependent on the interaction of foveal and peripheral activations. In their model, higher foveal compared to peripheral activations reflect a bias for prolonging the current fixation, while higher peripheral relative to foveal activations reflect a bias for shortening the current fixation. As AN patients exhibit significant attentional biases towards images of body shapes, it is reasonable to assume that foveal and peripheral activations in AN patients increase when body shape images appear in their central or peripheral fields, respectively, rather than images with social interactions. When AN patients fixate on images with social interactions, their foveal activation decrease (compared to the activation when they fixate on a body shape image) and their peripheral activation increase.[4] The combined effects of decreased foveal activation and increased peripheral activation during a fixation on an image with social interactions can explain the observation that fixation duration on social images is shorter than on body shape images in AN patients. In a similar manner, since healthy controls do not exhibit attentional biases towards images of body shapes, the model can explain the observation that for healthy controls the fixation duration on body shape images is not longer than that on social images.

Adolescent AN patients demonstrated a hierarchy in their attention allocation, choosing to spend the most viewing time on TBS images, followed by FBS images and then images with social interactions (Condition 3). Again, this pattern is not apparent in control participants. Differences between attention to body shape images (TBS or FBS) and social images in AN patients can be explained by the attention to body size, which is a core element of AN, and the frequent examination of specific body parts, which is a prominent clinical feature of AN. The observation that AN patients allocate more attention to TBSs than to FBSs requires more explanation. Unlike previous results (Gao et al., 2013) in a non-clinical population, this study suggests that AN patients have more difficulty disengaging from images of TBSs than images of FBS. This contradiction might stem from the different roles that TBS images and FBS images are playing for AN patients. Images of thin people are attractive to patients with AN as they represent what they aspire to become and are used to bolster motivation to maintain weight loss behavior (Norris et al., 2006). Images of fat people are used by AN patient as a tool (warning) for helping motivate adherence to weight loss behaviors (Norris et al., 2006). Since such considerations may not be as prominent in a non-clinical population it might explain the contradiction between the results of the two studies. The results in this study suggest that adolescent AN patients are more likely to look at images that are consistent with their goals than at images that serve as warnings.

The parameters that quantify VSB discussed so far (RFT, number of fixations, and fixation duration) provide measures for the relative attention that the images (TBS, FBS, social interactions) garner relative to each other. Thus, one cannot determine if the large visual scanning biases that were observed in Conditions 1 and 2 are due to positive attentional biases towards body shape images or negative attentional biases towards images with social interactions. Making use of the VSB of neutral images in Condition 3 can produce a perspective that may potentially provide some direction in determining the relative contributions of the positive and negative attentional biases to the observed results. As there have been no evidence in the literature to suggest that there are any attentional biases towards neutral images in patients with eating disorders, attention to neutral images can be assumed to be similar for the two groups. Under this assumption, a normalized attention score can be created such that a direct comparison of attention allocation to images from different categories may be made between the two groups. This normalized attention score is the ratio of the mean RFTs on images from each category over the mean RFT on neutral images and it indicates the attention that each category of images receives relative to the attention received by neutral images.

For the healthy control group, the normalized attention scores for TBS, FBS and social images are 1.86, 1.79, and 1.67 respectively (the larger the ratio, the larger the attention towards this category of images relative to the attention towards neutral images). For the AN patient group, the normalized attention scores for TBS, FBS, and social images are 4.92, 2.86, 1.59 respectively. These normalized attention scores are simply descriptive, but they suggest that AN patients pay more attention to body shape images than healthy controls. Both scores for images of thin body shapes and fat body shapes are greater for AN patients as compared to healthy controls, but the score for images of social interactions was similar to the respective score for controls. These observations suggest that the large biases in VSB of AN patients in Conditions 1 and 2 may be primarily due to attention biases towards body shapes.

This study shows larger and more robust biases in VSB of AN patients when compared with previous studies (Horndasch et al., 2012; von Wietersheim et al., 2012). Possible explanations for these more robust biases are associated with the methodology used in this study including, the provision of choice regarding the theme of the images that participants could attend to, the use of relatively large number of images to test each hypothesis (e.g., 32 images of TBSs in Condition 1), and the parameter used in the analysis, RFT, which reflects the participant's VSB over a relatively long time period (12 s/slide). The long observation time associated with the estimation of the RFT on each image increases the robustness of each estimate (increases the ratio of mean/variance) and the large number of estimates (images/hypothesis) increases the statistical reliability of the procedure. As the methodology is designed to contrast viewing patterns on whole images from different themes, the effects of individual preferences for specific somatic regions (e.g., what each individual consider to be the "ugliest" or the most "beautiful" body part) on the estimation of the parameters that quantifies VSB in this study are minimized.

This exploratory study has a number of limitations. First, it had a relatively small sample size of a total of 33 participants. Because of the small sample size, we could not analyze subtypes of AN, or perform analysis controlling for current BMI or length of illness. The study also relied on a convenience population of AN patients diagnosed through a clinical assessment with the use of a locally developed semi-structured interview. However, all the patients were in intensive treatment for an ED, confirming that the patients did in fact have a clinically significant restrictive ED. Even though the saliency of the images in the different categories was not correlated with the RFTs on the images, and did not affect the results of the study, the lack of subjective ratings (e.g., valence, arousal) for body shape images is a limitation of the study. Subjective ratings can facilitate comparisons between images in the different categories and might help to explain some of the variance in the observed biases in VSB. While the study provides robust results in terms of differences in the viewing patterns of AN patients and healthy controls, and the analysis suggest that these differing patterns are mainly due to attentional biases towards images of body shapes, it is impossible to confidently infer the exact contributions to VSB biases of mechanisms associated with diminished attention towards social images and mechanisms associated with the greater attention to body shape images.

## 5. Conclusion

AN is a complex illness that is hard to measure objectively and can be difficult to diagnose. This study shows that when adolescent participants looked at slides with images of thin or FBS and

[4] In our study when subjects fixate on an image with social interactions, the other three images on the slide, two images of body shapes and one image of social interactions, appear in their peripheral field. When subjects fixate on an image with a body shape, two images of social interactions and one image of a body shapes appear in their peripheral field. Therefore, in AN patients peripheral activation is larger when patients fixate on images with social interactions.

images of social interactions, the visual scanning behavior of AN patients could be differentiated from that of age matched controls. Given the dearth of objective biological measures available in mental health disorders, parameters of VSB may play a role in both the diagnosis and evaluation of recovery in patients with AN. If the robust VSB biases that were reported in this study are state characteristics of patients with AN rather than traits, they could be used as markers of recovery. If they are a trait rather than state they can be used as indicators for at risk individuals. These VSB biases might also be used to confirm the diagnosis of AN (for patients who minimize symptoms) and/or to differentiate between AN and EDs without a shape focus such as avoidant restrictive food intake disorder (DSM-5) (American Psychiatric Association, 2013). Further study is required to explore the clinical utility of VSBs.

Future directions would include studying this paradigm in a larger, more representative clinical sample in patients with AN at various stages of illness and recovery, as well as in patients diagnosed with other EDs such as bulimia nervosa, avoidant restrictive food intake disorder or binge eating disorder (DSM-5) (American Psychiatric Association, 2013). This paradigm could help improve the understanding of how patients with EDs process information related to body weight or shape and/or social interactions and if different types of EDs are associated with different information processing patterns. Results from future studies could potentially be used as a therapeutic intervention to treat AN and other EDs by helping patients become more aware of their attention biases.

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