Psychiatry Research 190 (2011) 115–120

Contents lists available at ScienceDirect

Psychiatry Research

journal homepage: www.elsevier.com/locate/psychres

Tactile body image disturbance in anorexia nervosa

Anouk Keizer [a,*], Monique Aldegonda Maria Smeets [b], Hendrik Christiaan Dijkerman [a], Marcel van den Hout [b], Irene Klugkist [c], Annemarie van Elburg [d], Albert Postma [a,e]

[a] Experimental Psychology, Helmholtz Research Institute, Faculty of Social and Behavioural Sciences, Utrecht University, Utrecht, The Netherlands
[b] Clinical & Health Psychology, Faculty of Social and Behavioural Sciences, Utrecht University, Utrecht, The Netherlands
[c] Department of Methodology & Statistics, Faculty of Social and Behavioural Sciences, Utrecht University, Utrecht, The Netherlands
[d] Rintveld Center for Eating Disorders, Altrecht Mental Health Institute, Zeist, The Netherlands
[e] Department of Neurology, University Medical Centre Utrecht, Utrecht, The Netherlands

ARTICLE INFO

Article history:
Received 2 November 2010
Received in revised form 15 February 2011
Accepted 26 April 2011

Keywords:
Body representation
Body dissatisfaction
Eating disorders
Mental imagery
Size perception
Touch perception

ABSTRACT

Body image disturbances are central to anorexia nervosa (AN). Previous studies have focused mainly on attitudinal and visual aspects. Studies on somatosensory aspects thus far have been scarce. We therefore investigated whether AN patients and controls differed in tactile perception, and how this *tactile body image* related to visual body image and body dissatisfaction. The Tactile Estimation Task (TET) measured tactile body image: Two tactile stimuli were applied to forearm and abdomen, and, while blindfolded, participants estimated the distance between the two tactile stimuli between their thumb and index finger. The Distance Comparison Task (DCT) measured visual body image. Compared to controls ($n = 25$), AN patients ($n = 20$) not only visualized their body less accurately, but also overestimated distances between tactile stimuli on both the arm and abdomen, which might reflect a disturbance in both visual and tactile body image. High levels of body dissatisfaction were related to more severe inaccuracies in the visual mental image of the body, and overestimation of tactile distances. Our results imply that body image disturbances in AN are more widespread than previously assumed as they not only affect visual mental imagery, but also extend to disturbances in somatosensory aspects of body image.

1. Introduction

The disturbed experience of body weight and shape is a central diagnostic criterion of anorexia nervosa (AN) (American Psychiatric Association, 2002): Despite their emaciated appearance, AN patients experience their body as too fat. This disturbance in body image is considered to be a key factor in the development, maintenance and relapse of AN (Killen et al., 1996; Stice, 2002; Stice and Shaw, 2002; Keel et al., 2005). In addition body image problems are often found to persist after otherwise successful treatment (Carter et al., 2004; Exterkate et al., 2009). Literature on body image in AN has focused mainly on attitudinal (e.g. body dissatisfaction) and visual aspects of body image (Smeets, 1997; Smeets et al., 1997; Skrzypek et al., 2001; Garner, 2002; Farrell et al., 2005), which were found to correlate (Sunday et al., 1992; Cash and Deagle, 1997; Benninghoven et al., 2007), implying a mutual relationship. Cash and Deagle (1997) showed that AN patients are more dissatisfied with their body than controls ($d = 1.10$) and that this disturbance in body attitudes is much larger than that of the visual body image disturbance ($d = 0.64$).

Even though body image is regarded as a multifaceted concept including cognitive/affective and perceptual aspects of how one's own body is experienced (Cash, 2002; Cash and Pruzinsky, 2002), surprisingly little is known about somatosensory aspects of body image in AN. A few studies have, however, shown that AN patients have a decreased interoceptive awareness and sensitivity. AN patients not only demonstrate a decreased ability to identify and discriminate between visceral sensations related to hunger and satiety (Fassino et al., 2004; Matsumoto et al., 2006; Pollatos et al., 2008), but also find it difficult to recognize physiological stress symptoms such as an increased heart rate (Miller et al., 2003; Zonnevylle-Bender et al., 2005). These findings imply that AN patients have a deficit in recognizing bodily signals, which may extend to deficits in somatosensory perception as well. Therefore, the main aim of the current study was to investigate whether AN patients suffer a disturbance in *tactile body image*.

Previous research suggests that two forms of touch can be distinguished in the brain, primary tactile perception (such as an external object pressing on the skin) and secondary tactile perception (including metric/spatial information and requiring rescaling; Spitoni et al., 2010). We are especially interested in secondary tactile perception, because extracting metric information from the skin surface involves additional computational processing stages over perceiving mere contact to the skin (Dijkerman and De Haan, 2007; Spitoni et al., 2010). It is thought that during these additional

* Corresponding author at: Experimental Psychology, Faculty of Social and Behavioural Sciences, Utrecht University, P.O. Box 80140, 3508 TC, Utrecht, The Netherlands. Tel.: +31 30 2531897; fax: +31 30 2534511.
E-mail address: A.Keizer@uu.nl (A. Keizer).

0165-1781 © 2011 Elsevier Ireland Ltd. Open access under the Elsevier OA license.
doi:10.1016/j.psychres.2011.04.031

processing stages touched locations on the skin are linked to a mental body representation (Spitoni et al., 2010).

The concept of mental body representation refers to the multiple abstract perceptual representations of the body in the brain that store information about the shape and size of body parts, their position in space and the integration of the parts into a structural whole (Paillard, 1999; Gallagher, 2005; Dijkerman and De Haan, 2007; Serino and Haggard, 2010). It has been suggested that these mental body representations are constructed from and reciprocally influenced by input from various senses such as vision and touch (Serino and Haggard, 2010). Moreover, certain aspects of body representations may not only be influenced by bottom-up sensory input, but also by top-down cognitive, semantic and affective representations: In perception of the body or sensations on the skin, top-down information is used (Paillard, 1999; De Vignemont et al., 2005; Gallagher, 2005; Dijkerman and De Haan, 2007).

Touch is necessarily perceived in reference to the own body. Since somatosensory afferents do not provide bottom-up information about the size of a body part (Serino and Haggard, 2010), it is crucial to tap into other sources of information, providing top-down input, such as vision (Taylor-Clarke et al., 2004) or perhaps mental imagery, in order to make size estimations of tactile objects. In addition, top-down processes related to, for example, body dissatisfaction could influence and distort mental representations, making it plausible that AN patients estimate the size of external tactile stimuli in reference to a disturbed mental representation of the body. In healthy individuals it was indeed shown that after experimentally inducing a disturbed experience of the body, tactile perception of distances was altered (Taylor-Clarke et al., 2004; De Vignemont et al., 2005).

Previous work has already demonstrated that top-down processes related to body attitudes can lead to marked visual body image disturbances. For example, Smeets and Kosslyn (2001) found that AN patients' visual body image disturbance results from body size distortions in memory rather than perception (see also Kosslyn, 1987; Smeets et al., 1999). While AN patients' visual size discrimination is undisturbed (Garfinkel et al., 1978; Smeets et al., 1999), thinking about the self as fat (i.e. high body dissatisfaction) may cause size distortions of the visual mental body image. One proposed mechanism held that “thinking fat” activated prototypical images of fat somatotypes which interfere with the construction of a visual mental image of the body and distort it in the direction of fatness (Smeets and Kosslyn, 2001; Mohr et al., 2007). Following this line of reasoning, we believe an investigation of body size representations within multiple modalities in AN is warranted. Therefore we specifically investigated whether AN patients demonstrate a disturbance in tactile aspects of body image, and explored how this disturbance related to body dissatisfaction and visual aspects of body image.

2. Methods

2.1. Participants

The present research was approved by the local medical ethical committees of the involved institutions. Forty-five Dutch females participated: 20 AN patients and 25 healthy controls. All participants were over 18 years of age, free from medication that could influence psychomotor speed (e.g. due to sedative effects, drowsiness, or psychomotor impairment), and scar tissue (e.g. due to self-injuring behavior, a surgery, or an accident) or skin problems (e.g. a rash due to allergies) on their forearms and abdomen. Participants received a monetary reward for a 90-minute session.

AN patients were recruited from an eating disorder clinic outpatient population. All patients received treatment as usual and were diagnosed with AN ($n=15$) or the AN subtype of Eating Disorder Not Otherwise Specified (EDNOS) ($n=5$) by administering the Eating Disorder Examination (EDE; Fairburn and Cooper, 1993) and a psychiatric interview. We included both AN patients and AN subtype EDNOS patients who no longer or had never fulfilled the AN Body Mass Index (BMI) and/or amenorrhea criterion, as symptoms are similar although less severe in EDNOS (Williamson et al., 2002). Mean disease duration was 8.4 months (±6.5): Note that patients may have previously received treatment elsewhere. Healthy controls were recruited from a student population. Based on their measured weight and height, all controls had a healthy BMI (18.5 to 25) and the presence of an eating disorder was excluded by administering the Eating Disorder Diagnostic Scale (EDDS) (Stice et al., 2004). Mean age was 22.30 years (±3.01) for AN patients and 21.32 years (±2.19) for controls, $t(43)=1.26$, $P=0.213$. Mean BMI was 18.54 (±2.03) for AN patients; and 21.43 (±1.77) for controls, $t(43)=-5.11$, $P<0.001$. Note that the mean BMI in the AN group is relatively high as the AN group consists of both AN patients and EDNOS patients.

2.2. Instruments and procedures

2.2.1. Body dissatisfaction

The Dutch translation of the Body Shape Questionnaire (BSQ; Cooper et al., 1987) assessed body dissatisfaction. This widely used, 34-item, self-report questionnaire with an internal consistency of $\alpha=0.97$ (Pook, et al., 2008) assessed concerns regarding body shape during the last 4 weeks on a 6-point Likert-scale (e.g. “Did you avoid social events (such as parties) because you felt bad about your body size?”). Cronbach's α in the current sample was 0.99.

2.2.2. Tactile body image

The Tactile Estimation Task (TET; adapted version based on Taylor-Clarke et al., 2004; De Vignemont et al., 2005; Anema et al., 2008) measured tactile body image. While participants were blindfolded, the experimenter pressed the two pointers of a caliper simultaneously and lightly on the skin. The distance between the two pointers was set at 50, 60, and 70 mm, with each distance being presented seven times in a random order on the right side of the body. Two body parts were tested in a counterbalanced order, the center of the right forearm (insensitive body area, see Fig. 1a) and the abdomen in the area below the belly button (sensitive body area, see Fig. 1b). We distinguished between sensitive and insensitive body areas to investigate whether body image disturbances in AN occur for any body part, or only for those subject to the highest level of body dissatisfaction. During the task, participants estimated the distance between the two tactile stimuli by varying the separation between their right thumb and index finger. The experimenter measured this estimation with the caliper (see Fig. 1c).

2.2.3. Visual body image

The Distance Comparison Task (DCT; Denis and Zimmer, 1992; Noordzij and Postma, 2005; Smeets et al., 2009) is not a classical body size estimation task; it is a task in which participants estimate the size of their body by manipulating a distorted visual stimulus depicting their own body until it is perceived as matching own size. The disadvantage of such a task would be that presenting a visual image will influence the person's own visual mental image, preventing an unbiased assessment of that image (see e.g. Kosslyn, 1987; Smeets et al., 1999; Smeets and Kosslyn, 2001). The DCT was designed to spontaneously activate the visual body image (i.e. a visual image *must* be constructed in order to conduct the task and derive size estimates) without presenting a visual depiction of the body. The DCT is based on the so-called “image-scanning paradigm” (see Smeets et al., 2009) in which a visual mental image of one's own body is constructed and used when judging size differences between word-pairs. In each trial two word-pairs were presented, both representing a horizontal distance on the body. Each word-pair consisted of two identical body parts, representing the left and right side of the body, e.g. ear-ear and hip-hip. Participants were subsequently asked to indicate whether the last presented word-pair reflected a larger or smaller distance on their own body than the first presented word-pair. For example, participants had to indicate whether the horizontal distance between their left and right hip was larger or smaller than the horizontal distance between their left and right ear; see Fig. 2.

We demonstrated an inverse relation between reaction time (RT) and the absolute distance between the word-pair combinations confirming that a visual mental image was generated and used during the task. For example, the distance difference between ear-ear and hip-hip is large, as the ears are close to each other, while the hips are not, resulting in small RTs. Word-pairs consisted of the body parts waist, hips, and thighs (sensitive body parts), and ears, shoulders, armpits, elbows, and knees (insensitive body parts). A total of 28 word-pair combinations (e.g. a trial consisting of shoulder-shoulder paired with hip-hip) were presented twice in two cycles in a counterbalanced order; word-pair combinations within the cycles were randomized. Presentation times of the word-pairs were based on Smeets et al. (2009).

3. Results

3.1. Tactile body image

The effect of distance between the two simultaneously applied tactile stimuli on the index finger-thumb separation was not relevant to the aims of the current study and did not interact with group, $F(2,42)=2.48$, $P=0.096$; therefore, responses on the three distances were averaged, and the analyses were proceeded without stimuli distance as a variable. Mean distance estimation in the TET was 80.60 mm (±13.18) for AN patients and 49.88 mm (±12.47) for controls. A mixed repeated measures analysis of variance (ANOVA) showed a significant main effect of group, $F(1,43)=64.16$, $P<0.001$,

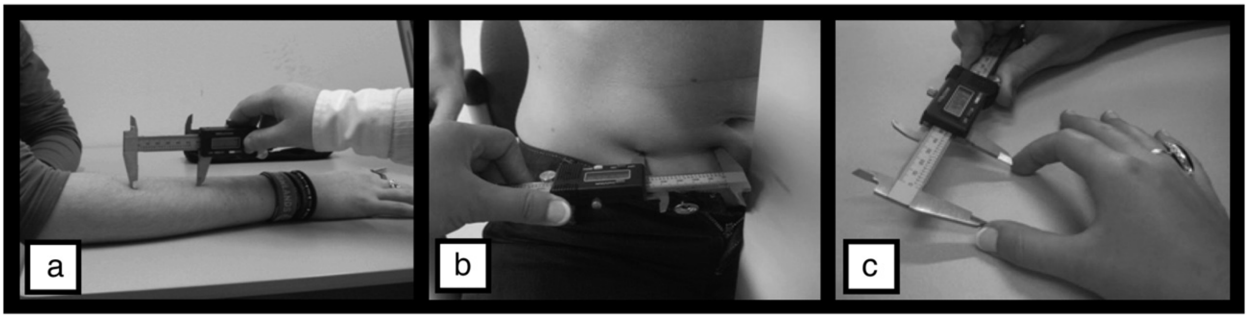

Fig. 1. Example trial Tactile Estimation Task (TET). a. Tactile stimuli applied to the arm. b. Tactile stimuli applied to the abdomen. c. Experimenter measuring the distance estimation.

$d = 2.47$, indicating that AN patients made larger distance estimations than controls (see Fig. 3). There was no main effect of body part, $F(1,43) = 1.64$, $P = 0.208$, nor an interaction between body part and group, $F(1,43) = 1.76$, $P = 0.192$. A Bonferroni-corrected one-sample *t*-test, demonstrated significant deviation from the mean applied distance of 60 mm in the AN group, $t(19) = 6.99$, $P < 0.001$, $d = 1.62$, and control group, $t(24) = -4.06$, $P < 0.001$, $d = 0.86$, but in opposite directions (see Fig. 3). The continuous variable BMI was not included as a covariate in the model as it showed no main effect, $F(1,42) = 1.49$, $P = 0.229$, nor an interaction with body part, $F(1,42) = 2.27$, $P = 0.140$ or group, $F < 1$, while the main effect of group remained significant, $F(1,42) = 31.41$, $P < 0.001$.

Taken together, AN patients showed a disturbance in tactile distance estimation: Regardless of the sensitivity of the body part, they overestimated the distance between two tactile stimuli relative to controls. While AN patients overestimated tactile distances with regard to the actual applied distance, controls underestimated tactile distances.

3.2. Visual body image

As individuals differ in actual body size, the distance differences to be judged in the DCT varied as well per participant. We took this into consideration by analyzing the data with Multilevel (ML) regression analysis (Hox, 2002) in MLwiN 2.0 (Goldstein et al., 1998). Following Smeets et al. (2009), measurements associated with RTs smaller than 200 ms and longer than 4000 ms, and measurements associated with distance differences larger than 25 cm were removed from the dataset, resulting in 2126 datapoints.

Mean *accuracy* score on the DCT was 66.88% (± 10.91) for AN patients and 74.73% (± 15.20) for controls, $d = 0.59$. The final logistic ML model for accuracy included the significant predictors distance

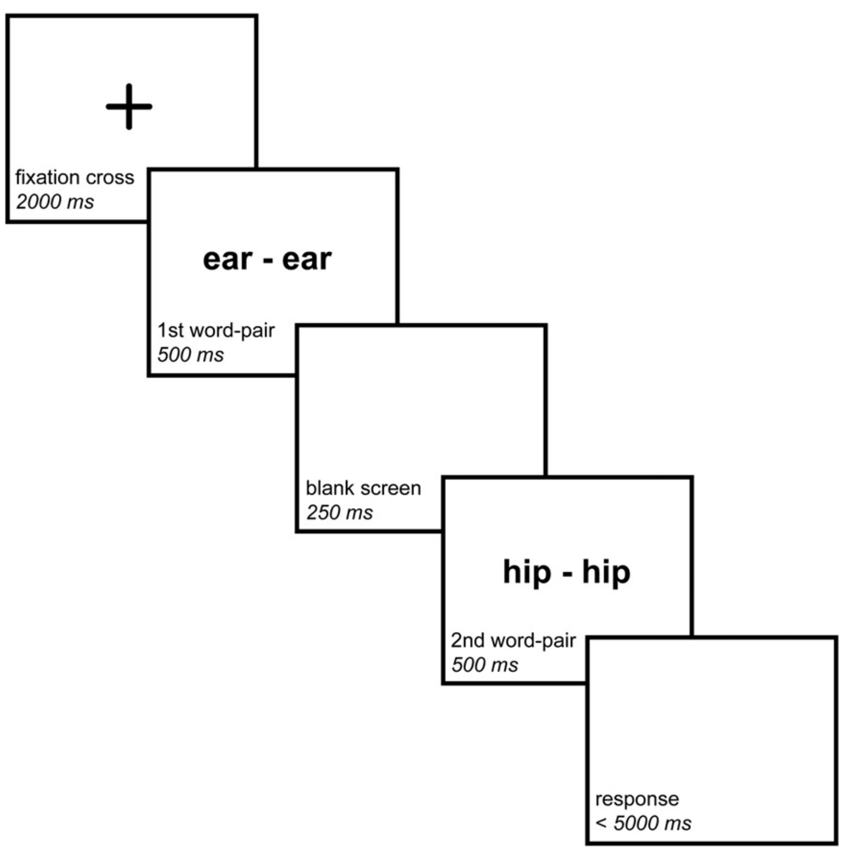

Fig. 2. Example trial of the Distance Comparison Task.

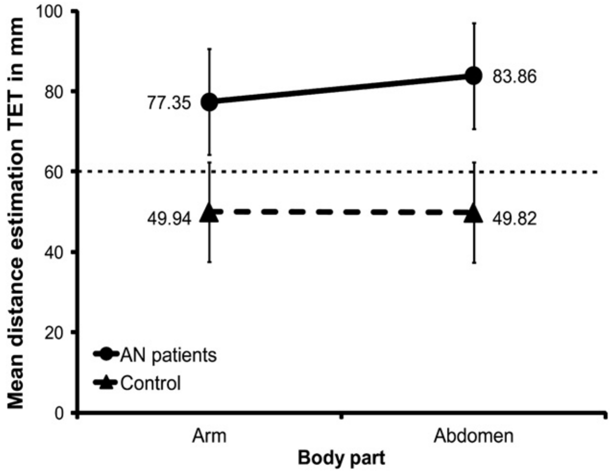

Fig. 3. Main effect of group, indicating that compared to controls, anorexia nervosa (AN) patients overestimated tactile distances in the Tactile Estimation Task (TET). In both groups distance estimations deviated from the actual applied distance of 60 mm. Vertical lines depict standard deviations. The dashed line at 60 mm represents an accurate distance estimation.

difference, $B_{distance\ difference}=0.09$, $P<0.001$, and group, $B_{group}=0.45$, $P=0.011$. Sensitivity of the word-pair and BMI were removed from the model as they did not significantly predict accuracy, $B_{sensitivity}=-0.06$, $P=0.341$; $B_{BMI}=0.05$, $P=0.213$.

Mean *RT* in the DCT was 1683.91 ms (±534.95) for AN patients and 1665.02 ms (±673.72) for controls. The final ML model for RT included the significant predictor distance difference, $B_{distance\ difference}=-17.56$, $P<0.001$. Sensitivity, group and BMI were not included in the model as they did not significantly predict RT, $B_{sensitivity}=-52.56$, $P=0.081$; $B_{group}=-6.07$, $P=0.382$; $B_{BMI}=0.76$, $P=0.494$.

Taken together, in both the AN and control group, larger distance differences were easier to evaluate than smaller distances differences. More importantly, AN patients appeared to have constructed an unrealistic visual mental image of their body compared to controls, as AN patients were less likely to correctly indicate which of two word-pairs represented the largest horizontal distance on their body.

3.3. Relation between body dissatisfaction and tactile body image

AN patients showed significantly higher levels of body dissatisfaction (BSQ) than controls, $t(43)=8.70$, $P<0.001$, $d=2.48$, with a total BSQ score of 95.85 (±39.46) for AN patients and 23.16 (±12.60) for controls. Separate linear regression analysis showed that BSQ score was significantly related to accuracy in the DCT, $\beta=-0.41$, $P=0.005$, $R^2=0.17$, and TET distance estimation, $\beta=0.66$, $P<0.001$, $R^2=0.44$. After controlling for BSQ score, there was no significant relation between TET distance estimation and DCT accuracy, $\beta=-0.05$, $P=0.692$. BMI was not included in the models as it did not correlate with DCT accuracy score, $r=0.27$, $P=0.069$, and despite the significant correlation with TET distance estimation, $r=-0.57$, $P<0.001$, it did not improve the model significantly, $\beta_{BM}=-0.11$, $P=0.432$; $\beta_{TET}=0.60$, $P<0.001$, $R^2=0.45$, $R^2\Delta=0.01$. Taken together, as BSQ scores increased, the size of TET distance estimates increased accordingly, while accuracy on the DCT decreased, implying that severity of body dissatisfaction was related to severity of both visual and tactile aspects of body image disturbances.

4. Discussion

In the present experiment we investigated body image disturbances in AN patients at three levels. AN patients not only demonstrated higher levels of body dissatisfaction and an inappropriate visual mental image of their body than controls, but also overestimated the size of tactile distances. There was no difference in magnitude of overestimation between sensitive and insensitive body parts in both the TET and DCT, implying a more generalized tendency of AN patients to conceptualize their body as inappropriate. We further found that high levels of body dissatisfaction were related to more severe tactile and visual body image disturbances.

One explanation for this finding holds that body image disturbances in AN in the tactile and visual modality result from top-down influences of body dissatisfaction on the mental body representations necessary in tactile size estimation (Taylor-Clarke et al., 2004; De Vignemont et al., 2005; Serino and Haggard, 2010) and visual imagery (e.g. Lupyan et al., 2010). The high levels of body dissatisfaction encountered in AN patients may influence mental body representations, which in turn could distort size estimates related to their own body in the visual and tactile domain.

This line of reasoning is supported by behavioral (e.g. Smeets and Kosslyn, 2001; Taylor-Clarke et al., 2004; Lupyan et al., 2010) and neuroimaging research (e.g. Van Kucyk et al., 2009). For example, behavioral studies showed that in healthy individuals size perception of external objects varied depending on the mental representation of the body part it was touching, despite the fact that across different locations on the body afferent input was constant (Taylor-Clarke et al., 2004; De Vignemont et al., 2005). Further, neuroimaging research implies that AN patients are more emotionally involved when processing body- and disease-related stimuli (e.g. Uher et al., 2005; Van Kucyk et al., 2009): Increased activity was found in the anterior cingulate cortex (e.g. Wagner et al., 2003; Friedrich et al., 2010) and amygdala (e.g. Miyake et al., 2010), while decreased activity and gray matter density was found in brain areas important in visual body processing (e.g. extrastriate body area; Uher et al., 2003; Suchan et al., 2010) and perceiving body size and shape (e.g. posterior parietal cortex, Goethals et al., 2007; Van Kucyk et al., 2009; Mohr et al., 2010). These findings imply that indeed top-down information in body processing is more dominant in AN patients compared to controls. Interestingly, controls showed relative underestimation of tactile distances. This finding echoes earlier studies on tactile distance perception in individuals without an eating disorder (Taylor-Clarke et al., 2004; Anema et al., 2008). Underestimation by healthy controls characterizes performance on visual body image tasks as well (e.g. Smeets and Kosslyn, 2001; Nederkoorn, et al., 2008). Thus, body dissatisfaction and body size representation seem inversely related. Actual BMI did not influence the results from either the TET or DCT, which makes it unlikely that the fluctuating body mass of AN patients due to treatment has influenced the findings (see also McCabe et al., 2006; Mussap et al., 2007).

An alternative explanation for the current findings is that higher order mental representations of size have become distorted via a *bottom-up* route. However, there are several findings that challenge this interpretation. First, it is unlikely that the *visual* body image disturbance is the result of an elementary perceptual deficit, as it has been found that AN patients and controls do not differ in visual object-size estimation (e.g. Garfinkel et al., 1978; Cash and Deagle, 1997). In addition research indicated that perceptual sensitivity for changes in visual stimuli related to both their own body and the body of others is equal for AN patients and controls (see e.g. Smeets, et al., 1999). These findings suggest that although AN patients overestimate their body size in visual body image tasks compared to controls, this is unlikely to result from bottom-up differences in visual processing. In addition, overestimation of *tactile* distances by AN patients is unlikely to have resulted from a perceptual disturbance at, for example, receptor level, as previous research indicated that AN patients and controls do not differ in vibration thresholds (Pauls et al., 1991) and that bulimia nervosa (BN) patients and controls do not differ in pressure thresholds measured with Von Frey filaments (Faris et al., 1992).

On the other hand: even if unlikely, a bottom-up explanation for the phenomena demonstrated in this article cannot be completely ruled out. For example, studies including healthy subjects showed that after reducing afferent transmission due to anesthesia of the thumb, this resulted in an increased perception of the size of the thumb (Gandevia and Phegan, 1999). Therefore, future studies should include psychophysical assessments of tactile sensation and discrimination, such as the two-point threshold, to fully address this issue. Related to this, based on the finding of nonselective overestimation of distance on both the arm and the abdomen, an alternative explanation of these findings could be that AN patients generically overestimate size or distance. Previous studies have shown that AN patients and controls do not differ making visual size estimates of neutral objects (e.g. Garfinkel et al., 1978; Cash and Deagle, 1997). We expect similar results for the tactile domain. However, to completely rule out this alternative explanation, research is needed in which participants make size estimations of objects using a different type of somatosensory input. For example, future studies could focus on haptic size estimation, by including a task in which participants estimate the size of a wooden block using active tactile exploration of the object with the fingers.

Finally, in previous research using visual body size estimation tasks in which participants estimated the width of their body or specific body parts, demand characteristics have been proposed as confounding factors (Proctor and Morley, 1986). We deem an explanation in terms of demand characteristics unlikely here. With respect to the visual task, the DCT was designed specifically to prevent influences of demand effects (see also Smeets et al., 2009). The DCT is a complex RT task requiring a quick response. Even if the participant can guess the hypothesis, it is hard to come up with a strategy at the level of individual trials aimed at confirming that hypothesis. Nonetheless, AN patients' visual mental image of the body was inappropriate compared to that of controls. With respect to the tactile task, in the TET both instructions and stimuli were kept neutral. Participants were not asked to estimate the size of their body or a certain body part; they merely had to indicate the size of tactile stimuli applied to their skin. Participants were specifically instructed to estimate as accurately as possible the size of an external stimulus based on what they felt on their skin. In view of this, it is unlikely that participants *consciously* and strategically altered their distance estimations in order to confirm or disconfirm the hypothesis. Taken together, we believe it is more likely that overestimation of tactile distance on the skin by AN patients reflects top-down processes, e.g. in the way of activated attitudes about the body influencing size estimates, rather than conscious decisions to please the experimenter.

It should be noted that the current results are correlational, and that neither body dissatisfaction nor body image was experimentally manipulated. The disturbances found in the AN group were already present at the time of testing, making it impossible to draw conclusions regarding the direct cause of body representation disturbances in AN. It is likely that a reciprocal causal relationship exists between body dissatisfaction and body image. If this is the case, the implication would be that body size representation disturbances can be improved by interventions at either the level of cognition and affect as well as visual or tactile body image levels. Future studies could focus on both directions. For example by decreasing body dissatisfaction in Cognitive Behavior Therapy (CBT) or by directly influencing tactile and visual body image in a training program (Salemink, 2008) in which accurate feedback reduces the tactile and visual body image disturbance. Should such training programs prove to be successful in reducing body image disturbances, they could be useful in treatment as well. Previous studies emphasized the importance of targeting body image disturbances in the treatment of eating disorders in order to attain full recovery without residual body image problems (e.g. Keel et al., 2005; Bardone-Cone et al., 2010; Nico et al., 2010). Our findings reaffirm this importance for AN patients specifically as it appears that body image disturbance is more severe than previously assumed: They do not limit themselves to body dissatisfaction and unrealistic visual mental images of the body, but extend to deficiencies in somatosensory perception.

In summary, we found that AN patients create an inappropriate visual mental image of their body. More interestingly, AN patients also overestimate tactile distances. This may indicate that body image disturbances in AN extend from visual to somatosensory perception. Both the visual and tactile body image disturbances were related to body dissatisfaction, which, supported by findings from behavioral and neuroimaging studies, argue for top-down influences of body dissatisfaction on the visual mental image of their own body and the perception of tactile distances.

Acknowledgements

This work was supported by two Vidi research grants from NWO (Netherlands Organization for Scientific Research) to M.A.M. Smeets (452-03-334) and to H.C. Dijkerman (452-03-325). We thank Marieke Toffolo for her assistance in data collection and Dineke Temmink for providing photographs of the Tactile Estimation Task.

References

American Psychiatric Association, 2002. Diagnostische Criteria van de DSM-IV-TR, 2nd ed. American Psychiatric Association, Washington, DC.

Anema, H.A., Wolswijk, V.C., Ruis, C., Dijkerman, H.C., 2008. Grasping Weber's Illusion: the effect of receptor density differences on grasping and matching. Cognitive Neuropsychology 25, 951–967.

Bardone-Cone, A.M., Harney, M.B., Maldonado, C.R., Lawson, M.A., Robinson, D.P., Smith, R., Tosh, A., 2010. Defining recovery from an eating disorder: conceptualization, validation and examination of psychosocial functioning and psychiatric comorbidity. Behaviour Research and Therapy 48, 194–202.

Benninghoven, D., Raykowski, L., Solzbacher, S., Kunzendorf, S., Jantschek, G., 2007. Body images of patients with anorexia nervosa, bulimia nervosa and female control subjects: a comparison with male ideals of female attractiveness. Body Image 4, 51–59.

Carter, J.C., Blackmore, E., Sutandard-Pinnock, K., Woodside, D.B., 2004. Relapse in anorexia nervosa: a survival analysis. Psychological Medicine 34, 671–679.

Cash, T.F., 2002. Beyond traits. Assessing body images states. In: Cash, T.F., Pruzinksy, T. (Eds.), Body Image: A Handbook of Theory. Research and Clinical Practise, Guilford, New York, pp. 163–170.

Cash, T.F., Deagle, E.A., 1997. The nature and extent of body-image disturbances in anorexia nervosa and bulimia nervosa: a meta-analysis. International Journal of Eating Disorders 22, 107–125.

Cash, T.F., Pruzinsky, T., 2002. Future challenges for body image theory, research and clinical practice. In: Cash, T.F., Pruzinksy, T. (Eds.), Body Image: A Handbook of Theory. Research and Clinical Practise, Guilford, New York, pp. 509–516.

Cooper, P.J., Taylor, M.J., Cooper, Z., Fairburn, C.G., 1987. The development and validation of the Body Shape Questionnaire. International Journal of Eating Disorders 6, 485–494.

De Vignemont, F., Ehrsson, H.H., Haggard, P., 2005. Bodily illusions modulate tactile perception. Current Biology 15, 1286–1290.

Denis, M., Zimmer, H.D., 1992. Analog properties of cognitive maps constructed from verbal descriptions. Psychological Research 54, 286–296.

Dijkerman, H.C., De Haan, E.H.F., 2007. Somatosensory processes subserving perception and action. Behavioral and Brain Sciences 30, 189–239.

Exterkate, C.C., Vriesendorp, P.F., De Jong, C.A.J., 2009. Body attitudes in patients with eating disorders at presentation and completion of intensive outpatient day treatment. Eating Behaviors 10, 16–21.

Fairburn, C.G., Cooper, Z., 1993. The eating disorder examination. In: Fairburn, C.G., Wilson, G.T. (Eds.), Binge Eating: Nature, Assessment and Treatment. Guilford Press, New York, pp. 317–331.

Faris, P.L., Raymond, N.C., De Zwaan, M., Howard, L.A., Eckert, E.D., Mitchell, J.E., 1992. Nociceptive, but not tactile, thresholds are elevated in bulimia nervosa. Biological Psychiatry 32, 462–466.

Farrell, C., Lee, M., Shafran, R., 2005. Assessment of body size estimation: a review. European Eating Disorders Review 13, 75–88.

Fassino, S., Pierò, A., Gramaglia, C., Abbate-Daga, G., 2004. Clinical, psychopathological and personality correlates of interoceptive awareness in anorexia nervosa, bulimia nervosa and obesity. Psychopathology 37, 168–174.

Friedrich, H.-C., Brooks, S., Uher, R., Campbell, I.C., Giampietro, V., Brammer, M., Williams, S.C., Herzog, W., Treasure, J., 2010. Neural correlates of body dissatisfaction in anorexia nervosa. Neuropsychologia 48 (10), 2878–2885.

Gallagher, S., 2005. How the Body Shapes the Mind. Oxford University Press, Oxford.

Gandevia, S.C., Phegan, C.M.L., 1999. Perceptual distortions of the human body image produced by local anaesthesia, pain cutaneous stimulation. The Journal of Physiology 514, 609–616.

Garfinkel, P.E., Moldofsky, H., Garner, D.M., Stancer, H.C., Coscina, D.V., 1978. Body awareness in anorexia nervosa: disturbances in body image and satiety. Psychosomatic Medicine 40, 487–498.

Garner, D.M., 2002. Body image and anorexia nervosa. In: Cash, T.F., Pruzinksy, T. (Eds.), Body Image: A Handbook of Theory, Research and Clinical Practise. New York, Guilford, pp. 295–303.
Goethals, I., Vervaet, M., Audeneart, K., Jacobs, F., Ham, H., Van Heeringen, C., 2007. Does regional brain perfusion correlate with eating disorder symptoms in anorexia and bulimia nervosa patients? Journal of Psychiatric Research 41, 1005–1011.
Goldstein, H., Rasbash, J., Plewis, I., Draper, D., Browne, W., Yang, M., Woodhouse, G., Healy, M., 1998. A User's Guide to MLwiN. Institute of Education University of London, London.
Hox, J.J., 2002. Multilevel Analysis: Techniques and Applications. Lawrence Erlbaum Associates Inc, Hillsdale, NJ.
Keel, P.K., Dorer, D.J., Franko, D.L., Jackson, S.C., Herzog, D.B., 2005. Postremission predictors of relapse in woman with eating disorders. American Journal of Psychiatry 162, 2263–2268.
Killen, J.D., Taylor, C.B., Hayward, C., Haydel, K.F., Wilson, D., Hammer, L., Kraemer, H., Blair-Greiner, A., Strachowski, D., 1996. Weight concerns influence the development of eating disorders: a 4-year prospective study. Journal of Consulting and Clinical Psychology 64, 936–940.
Kosslyn, S.M., 1987. Seeing and imaging in the cerebral hemispheres: a computational approach. Psychological Review 94, 148–175.
Lupyan, G., Thompson-Schill, S.L., Swingley, D., 2010. Conceptual penetration of visual processing. Psychological Science 21, 682–691.
Matsumoto, R., Kitabayashi, Y., Narumoto, J., Wada, Y., Okamoto, A., Ushijima, Y., Yokoyama, C., Yamashita, T., Takahashi, H., Yasuno, F., Suhara, T., Fukui, K., 2006. Regional cerebral blood flow changes associated with interoceptive awareness in the recovery process of anorexia nervosa. Progress in Neuro-Psychopharmacology & Biological Psychiatry 30, 1265–1270.
McCabe, M.P., Ricciardeli, L.A., Sitaram, G., Mikhail, K., 2006. Accuracy of body size estimation: role of biopsychosocial variables. Body Image 3, 163–171.
Miller, S.P., Redlich, A.D., Steiner, H., 2003. The stress response in anorexia nervosa. Child Psychiatry and Human Development 33, 295–306.
Miyake, Y., Okamoto, Y., Onoda, K., Kurosaki, M., Shirao, N., Okamoto, Y., Yamawaki, S., 2010. Brain activation during the perception of distorted body images in eating disorders. Psychiatry Research: Neuroimaging 181, 183–192.
Mohr, C., Porter, G., Benton, C.P., 2007. Psychophysics reveals a right hemispheric contribution to body image distortions in women but not men. Neuropsychologia 45, 2942–2950.
Mohr, H.M., Zimmermann, J., Röder, C., Lenz, C., Overbeck, G., Grabhorn, R., 2010. Separating two components of body image in anorexia nervosa using fMRI. Psychological Medicine 40, 1519–1529.
Mussap, A.J., McCabe, M.P., Ricciardelli, L.A., 2007. Implications of accuracy, sensitivity and variability of body size estimations to disordered eating. Body Image 5, 80–90.
Nederkoorn, C., Roefs, A., Jansen, A., 2008. Do you see yourself through rose-coloured glasses? Body image disturbances in restrained and unrestrained eaters. Journal of Appetite 50, 563.
Nico, D., Daprati, E., Nighoghossian, N., Carrier, E., Duhamel, J.-R., Sirigu, A., 2010. The role of the right parietal lobe in anorexia nervosa. Psychological Medicine 40, 1531–1539.
Noordzij, M.L., Postma, A., 2005. Categorical and metric distance information in mental representations derived from route and survey descriptions. Psychological Research 69, 221–232.
Paillard, J., 1999. Body schema and body image: a double dissociation in deafferented patients. In: Gautchev, G.N., Mori, G.N., Massion, S.J. (Eds.), Motor Control, Today and Tomorrow. Academic Publishing House, Sofia, pp. 197–214.
Pauls, A.M., Lautenbacher, S., Strian, F., Pirke, K.-M., Krieg, J.-C., 1991. Assessment of somatosensory indicators of polyneuropathy in patients with eating disorders. European Archives of Psychiatry and Clinical Neuroscience 241, 8–12.
Pollatos, O., Kurz, A.-L., Albrecht, J., Schreder, T., Kleemann, A.M., Schöpf, V., Kopietz, R., Wiesmann, M., Schandry, R., 2008. Reduced perception of bodily signals in anorexia nervosa. Eating Behaviors 9, 381–388.
Pook, M., Tuschen-Caffier, B., Brähler, E., 2008. Evaluation and comparison of different versions of the body shape questionnaire. Psychiatry Research 158, 67–73.
Proctor, L., Morley, S., 1986. 'Demand characteristics' in body size estimation in anorexia nervosa. British Journal of Psychiatry 149, 113–118.
Salemink, E., 2008. Believing is Seeing. Ponsen & Looijen bv, Wageningen.
Serino, A., Haggard, P., 2010. Touch and the body. Neuroscience and Biobehavioral Reviews 34, 224–236.
Skrzypek, S., Wehmeier, P.M., Remschmidt, H., 2001. Body image assessment using body size estimation in recent studies on anorexia nervosa. European Child & Adolescent Psychiatry 10, 215–221.
Smeets, M.A.M., 1997. The rise and fall of body size estimation research in anorexia nervosa: a review and reconceptualization. European Eating Disorders Review 5, 75–95.
Smeets, M.A.M., Kosslyn, S.M., 2001. Hemispheric differences in body image in anorexia nervosa. International Journal of Eating Disorders 29, 409–416.
Smeets, M.A.M., Smit, F., Panhuysen, G.E., Ingleby, J.D., 1997. The influence of methodological differences on the outcome of body size estimation studies in anorexia nervosa. British Journal of Clinical Psychology 36, 263–277.
Smeets, M.A.M., Ingleby, J.D., Hoek, H.W., Panhuysen, G.E.M., 1999. Body size perception in anorexia nervosa: a signal detection approach. Journal of Psychosomatic Research 46, 465–477.
Smeets, M.A.M., Klugkist, I., van Rooden, S., Anema, H., Postma, A., 2009. Mental body distance comparison: a tool for assessing clinical disturbances in visual body image. Acta Psychologica 132, 157–165.
Spitoni, G.F., Galati, G., Antonucci, G., Haggard, P., Pizzamiglio, L., 2010. Two forms of touch perception in the human brain. Experimental Brain Research 207 (3-4), 185–195.
Stice, E., 2002. Risk and maintenance factors for eating pathology: a meta-analytic review. Psychological Bulletin 28, 825–848.
Stice, E., Shaw, H.E., 2002. Role of body image dissatisfaction in the onset and maintenance of eating pathology: a synthesis of research findings. Journal of Psychosomatic Research 53, 985–993.
Stice, E., Fisher, M., Martinez, E., 2004. Eating Disorder Diagnostic Scale: additional evidence of reliability and validity. Psychological Assessment 16, 60–71.
Suchan, B., Busch, M., Schulte, D., Grönermeyer, D., Herpertz, S., Vocks, S., 2010. Reduction of gray matter density in the extrastriate body area in women with anorexia nervosa. Behavioural Brain Research 206, 63–67.
Sunday, S.R., Halmi, K.A., Werdann, L., Levey, C., 1992. Comparison of body image estimation and eating disorder inventory scores in anorexia and bulimia patients with obese, and restrained and unrestrained controls. International Journal of Eating Disorders 11, 133–149.
Taylor-Clarke, M., Jacobsen, P., Haggard, P., 2004. Keeping the word a constant size: object constancy in human touch. Nature Neuroscience 7, 219–220.
Uher, R., Brammer, M.J., Murphy, T., Campbell, I.C., Ng, V.W., Williams, S.C.R., Treasure, J., 2003. Recovery and chronicity in anorexia nervosa: brain activity associated with differential outcomes. Biological Psychiatry 54, 934–942.
Uher, R., Murphy, T., Friederich, H.-C., Dalgeish, T., Brammer, M.J., Giampietro, V., Phillips, M.L., Andrew, C.M., Ng, V.W., Williams, S.C.R., Campbell, L.C., Treasure, J., 2005. Functional neuroanatomy of body shape perception in healthy and eating-disordered women. Biological Psychiatry 58, 990–997.
Van Kucyk, K., Gérard, N., Van Laere, K., Casteels, C., Pieters, G., Gabriëls, L., Nuttin, B., 2009. Towards a neurocircuitry in anorexia nervosa: evidence from functional neuroimaging studies. Journal of Psychiatric Research 43, 1133–1145.
Wagner, A., Ruf, M., Braus, D.F., Schmidt, M.H., 2003. Neuronal activity changes and body image distortion in anorexia nervosa. Neuroreport 14, 2193–2197.
Williamson, D.A., Womble, L.G., Smeets, M.A.M., Netemeyer, R., Thaw, J.A., Kutlesic, V., Gleaves, D.H., 2002. The latent structure of eating disorder symptoms: a factor analytic and taxometric investigation. The American Journal of Psychiatry 159, 412–418.
Zonnevylle-Bender, M.J.S., Van Goozen, S.H.M., Cohen-Kettenis, P.T., Jansen, L.M.C., Van Elburg, A., Van Engeland, H., 2005. Adolescent anorexia nervosa patients have a discrepancy between neurophysiological responses and self-reported emotional arousal to psychosocial stress. Psychiatry Review 135, 45–52.