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Authors
Brown, Tiffany
Shott, Megan
Frank, Guido

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Body Size Overestimation in Anorexia Nervosa: Contributions of Cognitive, Affective, Tactile and Visual Information

Tiffany A. Brown, Ph.D.[1], **Megan E. Shott, B.S.**[1], **Guido K. W. Frank, M.D.**[1,*]
[1]Department of Psychiatry, University of California, San Diego

Abstract

Body image disturbance (BID) in anorexia nervosa (AN) is poorly understood and the individual contribution of perceptual, cognitive, and affective components remains unclear. This study compared females with AN and matched healthy controls (HC) on a perceptual size estimation task. Participants (AN *n*=19 M[SD] age=16.97[2.24], HC *n*=19, age=15.77[2.17]) were blindfolded and estimated the size of neutral objects, safe foods, unsafe foods, and parts of their bodies (hips, waist, knees, ankle) over three blocks using: 1) no sensory information (baseline), 2) tactile information, and 3) added visual information. There were no significant differences between AN and HC on neutral and safe or unsafe food objects. Participants with AN were significantly more likely to overestimate their body size across blocks compared to HC. Both groups made fewer errors on unsafe foods and body parts when using tactile or visual information compared to baseline. Exploratory analyses revealed significant correlations between body size overestimation and drive for thinness and body dissatisfaction in the AN group, with body dissatisfaction being the most robust. Results suggest that both deficits in tactile and visual perception and affective factors play a role in BID for young women with AN.

Keywords

eating disorders; affective; body image disturbance; body size estimation; perception; body dissatisfaction

[*]Correspondence regarding this article should be addressed to: Guido K. W. Frank, University of California, San Diego, UCSD Eating Disorder Center for Treatment and Research, 4510 Executive Dr., Suite 315, San Diego, CA 92121. Phone: 858-486-3338 Fax: 858-534-6727 gfrank@health.ucsd.edu.

Author Statement

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Conflicts of Interest

The authors have no relevant financial or non-financial interests to disclose.

1. Introduction

Body image disturbance (BID), or a distortion in the way one's body weight or shape is experienced, is one of the core diagnostic criteria of anorexia nervosa (AN) and has been implicated in the etiology, maintenance, and relapse of the disorder (Glashouwer, Van der Veer, Adipatria, de Jong, & Vocks, 2019). However, BID remains one of the more puzzling and complex symptoms of AN; indeed, BID often increases as individuals begin to restore weight, is one of the last symptoms to remit, and often proves resistant to treatment (Bamford, Attoe, Mountford, Morgan, & Sly, 2014; Eshkevari, Rieger, Longo, Haggard, & Treasure, 2014). The complexity of BID may be due, in part, to the multidimensional nature of this construct. Previous research supports that body image includes perceptual (accuracy of one's judgment of their shape, weight, and size), cognitive (beliefs about body weight, shape, or appearance and the mental representation of one's own body), and affective (feelings of (dis)satisfaction towards one's body) components (Cash & Deagle, 1997). Behavioral manifestations of BID can include body checking (frequent weighing, touching, measuring, or pinching of body parts) and body avoidance (wearing baggy clothes, avoiding seeing or having others see one's body). A better understanding of the components driving BID in AN is critical to help identify more targeted treatments and improve outcomes.

Accurate assessment of BID continues to pose a challenge in research on AN, where the perceptual component of BID is often assessed through visual body size estimation tasks that either use metric (e.g., tape measure, movable markers) or depictive (e.g., photo or video distortion) methods (Mölbert et al., 2017). While previous research has been mixed in terms of whether individuals with AN exhibit disturbed body size estimation (e.g., Hennighausen, Enkelmann, Wewetzer, & Remschmidt, 1999), recent reviews support that adolescents and adults with AN overestimate body size compared to controls (Gardner & Brown, 2014; Mölbert et al., 2017). Indeed, a recent meta-analysis supported moderate effect size differences between individuals with AN or BN and controls (Hedge's g = .63; Mölbert et al., 2017). Notably, in this meta-analysis, larger effect sizes for body size overestimations were found between AN and controls when using metric versus depictive assessments of body size (Mölbert et al., 2017). Thus, differences in methodology used to assess perceptual deficits may, in part, help explain previous inconsistent results in the literature. Additionally, while individuals with AN tend to overestimate whole body size, there is some evidence to support that certain body parts may have a greater likelihood of being overestimated. For example, body parts that are more subject to fluctuations in weight or body size (e.g., waist) are more likely to be overestimated in eating disorder patients compared to controls than body parts that are less influenced by weight fluctuations (e.g., shoulders; Mölbert et al., 2017). Critically, in AN, body size overestimation more broadly has been associated with increased negative affect, anxiety, body dissatisfaction, drive for thinness, eating disorder symptom severity, poor outcome, and relapse (Freeman, Thomas, Solyom, & Koopman, 1985; Gardner, 2011; Hagman et al., 2015; Øverås et al., 2014). Thus, results support that individuals with AN tend to overestimate their body size compared to controls, particularly in visual metric tasks, and this overestimation is related to AN symptoms, anxiety, and negative affect.

In addition to visual overestimation of body size, a small body of research supports that individuals with AN are also more likely to overestimate the size of high-energy food objects (e.g., a cream bun) versus equally sized non-food objects (e.g., a jewelry box) compared to healthy controls (Yellowlees, Roe, Walker, & Ben-Tovim, 1988). Similarly, individuals with AN estimated the volume of small and medium-sized meals as being significantly larger than control women (Milos et al., 2013). However, it is unclear whether this overestimation would occur only in high-calorie foods, or foods typically perceived by patients as “unsafe”, compared to lower calorie or “safe” foods.

The perceptual component of BID has perhaps been the most controversial. Neurobiological research has implicated that alterations in the parietal lobes (which have roles in spatial and body representations, body ownership, and visuospatial processing) may play a role in altered bodily perception in AN (Gaudio & Quattrocchi, 2012; Preston & Ehrsson, 2016). As such, some research has speculated that neural-based perceptual disturbances may drive BID in AN (Dakanalis et al., 2016). Others suggest that the cognitive and affective features (e.g., drive for thinness and fear of weight gain) of BID may play a larger role in driving body image distortions than perceptual disturbances, citing the lack of research supporting that body perception per se is altered in AN, outside of cognitive/affective influences (Frank & Treasure, 2016; Hagman et al., 2015; Mölbert et al., 2018). Notably, the mechanisms of BID and the relative contribution of perceptual distortions versus cognitive and affective features remain unclear.

Importantly, while most assessments of body size estimation use visual methods, perceptual impairments relevant to BID may also be non-visual, including tactile, proprioceptive, and interoceptive - all of which have demonstrated impairments in individuals with AN (Crucianelli, Cardi, Treasure, Jenkinson, & Fotopoulou, 2016; Gaudio, Brooks, & Riva, 2014; Jenkinson, Taylor, & Laws, 2018; Pollatos et al., 2008). Indeed, during a tactile task in which participants were asked to estimate the distance between two pointers of a caliper touched lightly on their skin, individuals with AN overestimated the size of the distance compared to controls (Keizer et al., 2011). Individuals with AN have also demonstrated impaired accuracy in proprioception, or orientation of the body position in space, compared to controls (Epstein et al., 2001; Gaudio & Quattrocchi, 2012; Gaudio & Riva, 2013); however, other studies have found no differences between AN and controls on proprioceptive tasks (Goldzak-Kunik, Friedman, Spitz, Sandler, & Leshem, 2012). Thus, it is unclear how non-visual tactile feedback may affect body size estimation in AN.

Given the complexity of potential perceptual impairments in AN, additional research is needed to help distinguish potential visual versus non-visual (e.g., tactile) perceptual contributions to BID and how these factors are related to specific symptoms of AN. Thus, the present study sought to compare differences between individuals with AN and healthy controls on size estimation of neutral objects, safe and unsafe foods, and body parts in three blocks: (1) a baseline block without tactile or visual information, (2) a tactile block, and (3) a visual block. We hypothesized that overall, participants’ errors would decrease from the baseline to tactile to visual blocks, given recent research supporting that estimation accuracy for objects in healthy individuals was better in visual than tactile conditions (Szubielska & Balaj, 2018). We also hypothesized that AN participants would overestimate the size of AN-salient stimuli (body parts, unsafe foods), across blocks, compared to controls. Additionally, in exploratory analyses, we examined correlations between inaccuracy of size estimation and measures of cognitive-affective symptoms of eating pathology, body image-related pathology (body dissatisfaction, body checking), and general psychopathology in both groups to help better understand how visual and tactile size estimation may be related to AN symptoms. While we expected size overestimation to be associated with greater AN and mood symptoms, given that previous research has not separated tactile and visual size estimation, we did not have more specific hypotheses for this aim.

2. Methods

2.1 Participants and Procedure

Participants for the present study were girls and young women with AN (n = 19) and healthy controls (HC, $n = 19$) between the ages of 12 and 21 years (see Table 1 for demographics). Participants with AN were recruited through the Eating Disorders Program (inpatient or day treatment) at Children’s Hospital Colorado within the first two weeks of treatment admission. HCs were recruited from the local community via flyers and had a lifetime history of body weight between 90% and 110% of ideal body weight since menarche, no history of psychiatric or major medical illness. Both AN and HC participated between October 2008 – September 2011. Groups were age- and ethnicity-matched and thus did not differ by age or race/ethnicity, $\chi^2(3) = 3.44$, $p = .33$, with 76.3% identifying as Caucasian, non-Hispanic, 7.9% as Asian, 2.6% as African American, and 13.2% as Hispanic. Groups also did not differ by years of education.

As part of eligibility screening, HCs under 18 years old ($n = 17$) were interviewed with the Diagnostic Interview Schedule for Children (DISC) Predictive Scales (Lucas et al., 2001) to assess for psychological symptoms. Individuals with AN under the age of 18 ($n = 12$) completed the Clinical Diagnostic Interview Schedule for Children 4.0 to assess all major psychiatric diagnoses (Shaffer, Fisher, Lucas, Dulcan, & Schwab-Stone, 2000), while individuals over age 18 were assessed with the Structured Clinical Interview for DSM-IV Axis I Disorders (First, Spitzer, Gibbon, & Williams, 1996). Participants with AN met DSM-IV-TR (APA, 2000) criteria for AN. Eleven participants with AN (57.9%) had comorbid major depressive disorder, 10 (52.6%) had a comorbid anxiety disorder, and 1 (5.3%) had a substance use disorder. Thirteen of the participants with AN (68.4%) were prescribed a serotonin reuptake inhibitor and no individuals with AN were prescribed an atypical antipsychotic or other medication.

Written informed consent was obtained from parents and adults and assent was obtained from adolescents. All research procedures were approved by the local Colorado Multiple Institutional Review Board. After confirming eligibility, participants completed validated self-report surveys before completing the perceptual task.

2.2 Measures

Depression—Depression was assessed using the Child Depression Inventory (CDI; Kovacs & Beck, 1977). Adults were not administered the CDI, and thus analyses for the

CDI represent the subset of participants under 18 (n=32). The CDI is a well-validated, 28-item assessment that measures emotional and function depressive symptoms in children and adolescents (Kovacs & Beck, 1977). Cronbach's alpha was excellent in the present study (α=.96).

Anxiety—Anxiety was assessed using the State-Trait Anxiety Inventory (STAI; Spielberger, Gorsuch, & Lushene, 1970). The STAI is a well-validated 40-item self-report measure that assesses state and trait anxiety (Spielberger & Vagg, 1984). Internal consistency was excellent (State α=.96, Trait α=.97).

Eating Disorder Symptoms—Eating Disorder Symptoms were assessed using the Eating Disorder Inventory-3 (EDI-3; Garner, 2004), is a well-validated measure of eating disorder symptomatology (Clausen et al., 2011) and was administered through an online scoring program The present study used the Drive for Thinness and Body Dissatisfaction subscales, given that these represent core aspects of AN psychopathology, and the Interoceptive Deficits subscale, given the relevance of interoception in perception. Given the use of the online program, Cronbach's alpha was unavailable.

Body checking—Body checking was measured using the Body Checking Questionnaire (BCQ; Reas, Whisenhunt, Netemeyer, & Williamson, 2002) to assess a behavioral feature of BID that may be correlated with perceptual deficits (Linardon et al., 2019). The BCQ is a 23-item well-validated measure that assesses body checking related to overall appearance, checking of specific body parts, and idiosyncratic checking rituals (Calugi et al., 2006). The total score was used as an indicator of overall body checking. Internal consistency was excellent (α=.96).

2.3 Perceptual Size Estimation Task

During the task, 16 objects were presented in a randomized order and fell into one of four categories: neutral (compact disc (CD), tissue box, credit card, paper towel roll), safe foods (orange, diet soda can, single-serve Yoplait yogurt container, cabbage), unsafe foods (stick of butter, pint of ice cream, 2-liter soda, sandwich cookie), or body parts (knee, ankle, waist, hips). For food items, the same standard plastic orange and cabbage head were used for each subject to standardize sizes and minimize error between subjects. Food items were selected to be familiar to a wide variety of subjects. Experimenters specified the general size of the items (e.g., a medium-sized orange, regular stick of butter, medium-sized cabbage, one individual sandwich cookie, 1 can of soda, etc.) and specified brands (e.g., Oreo) to help ensure that subjects had the same item in mind across objects. During each block, participants were asked to estimate the width of each object or body part after the experimenter listed the 16 objects in a randomized order. The order was the same for each participant. Participants were asked to estimate the object size between their pointer fingers with arms and fingers completely outstretched straight in front at a 90-degree angle for approximately 5 seconds while the experimenter obtained measurements. While participants' ability to keep their arms outstretched could influence measurement error, all participants were young people with no history of tremors or movement disorders. Participants were all able to keep their arms still during measuring, tolerated the procedures, and there were no complaints about fatigue. The experimenter used a tape measure to determine the distance between fingers to the nearest 0.5 cm. The randomized list of object names was read through twice so that participants provided two estimations per object in each block. The two estimations were averaged across trials to provide a single estimation for each of the 16 objects. After the task was completed, the participants' body parts were measured while the participants stood against a wall. The experimenter asked the participant to indicate where on her body she was identifying her knee width and this area was measured to the nearest 0.5 cm. This was repeated for the ankle, waist, and hip. However, participants were told to rate their hip measurements at the width of their hip bone and their waist at the crest of the pelvis, after the female experimenter demonstrated where this area would be found. Measurements for the objects were obtained to the nearest 0.5 cm. Two measurements per object per block were obtained. Percent error was calculated for both measurements of each object and then averaged to obtain a mean percent error for a particular object. The mean percent error of each object (4 total) was then averaged to yield a mean percent error for the overall object (e.g., safe foods).

The task included three blocks: 1) a *baseline block* in which participants were blindfolded and asked to estimate the size of various objects or their body parts based on the experimenter naming the item; this was considered "baseline" as participants were given neither tactile nor visual information to inform estimates 2) a *tactile block*, in which participants were allowed to touch the object or their body part, while blindfolded for 6 seconds, before estimating their size (of note, as participants were able to touch the items, this block also includes elements of haptic perception. For brevity we will refer to as this block as "tactile" throughout) and 3) a *visual block*, in which participants were allowed to directly view, but not touch, the item or their body part for 6 seconds before being blindfolded again and estimating their size.

2.4 Data Analyses

Statistical analyses were run using IBM Statistical Package for the Social Sciences (SPSS, Version 25). T-tests compared HC and AN on demographic variables and self-report surveys. Participants' percent error of size estimation was calculated by subtracting the actual value of the size of the object or body part from the person's estimated size divided by the actual value and multiplied by 100 ([estimated – actual]/actual × 100). A multivariate general linear model was run to compare percent error between groups (HC, AN) across the three blocks (baseline, tactile, visual) and object categories (neutral, safe foods, unsafe foods, and body parts). Given the small sample size, we also report observed power for all main effects and interactions within the results section. Post-hoc comparisons were Bonferroni-corrected. Pearson correlations for study variables were run using bootstrapping with 95% confidence intervals between self-report measures and estimation errors in HC and AN separately. A false discovery rate (FDR) correction was applied to control for Type I error and only correlations that survived this correction were interpreted (Benjamini & Hochberg, 1995; Westfall, 2011).

3. Results

AN participants had a lower BMI and reported greater depression, anxiety, drive for thinness, body dissatisfaction, interoceptive deficits, and body checking compared to HC (see Table 1).

Table 2 presents mean percent error on the perception task between groups (HC, AN), blocks (baseline, tactile, visual), and objects (neutral, safe foods, unsafe foods, body parts). For the multivariate model, there was a significant main effect of diagnostic group, $F(1, 36) = 6.03$, $p = .02$, partial ¤ ^{2} = .14, observed power = .67, such that AN participants generally had greater errors across blocks and objects compared to HC. Further, there was a main effect of block, $F(1.68, 60.38) = 10.01$, $p < .001$, partial ¤ ^{2} = .22, power = .98, such that participants had fewer errors in the tactile ($p = .01$) and visual blocks ($p = .001$) compared to the baseline block, whereas there were no significant differences between the tactile and visual blocks ($p = .75$). There was also a main effect of object, $F(1.64, 59.03) = 9.88$, $p < .001$, partial ¤ ^{2} = .22, power = .96, such that averaged across participants, greater overestimation was made for unsafe foods compared to neutral objects ($p < .001$) and safe foods ($p < .001$). No other significant differences were found between objects (*p*s >.08).

Regarding interactions, there was a significant Block × Object interaction, $F(4.92, 177.02) = 3.17$, $p = .01$, partial ¤ ^{2} = .08, power = .87. Post-hoc comparisons revealed that there were significant differences between blocks in the neutral, $F(2,35) = 6.27$, $p = .005$, unsafe, $F(2,35) = 11.94$, $p < .001$, and body part objects, $F(2,35) = 4.39$, $p = .002$, but not for safe foods, $F(2,35) = 3.00$, $p = .06$. Specifically, for neutral objects, visual information resulted in significantly fewer errors compared to the tactile and baseline blocks (*p*s = .02), while the tactile block was not significantly difference from baseline (p >.99). For unsafe foods and body parts, participants made significantly fewer errors in the tactile and visual blocks compared to baseline (*p*s <.03), whereas there were no significant differences between tactile and visual blocks (*p*s >.54). There was also a significant Group × Object interaction, $F(1.64, 59.03) = 16.94$, $p < .001$, partial ¤ ^{2} = .32, power = .99, such that AN participants significantly overestimated the size of their body parts averaged across blocks compared to HC (p <.001)[1] and that the magnitude of this effect across blocks was large ($d = 1.21 – 1.64$; see Table 2); however, no significant differences were found between groups for neutral ($p = .82$), safe food ($p = .41$), or unsafe food ($p = .28$) objects. There was neither a significant Group × Block interaction, $F(1.68, 60.38) = 1.05$, $p = .35$, partial ¤ ^{2} = .03, power = .21, or a significant Group × Block × Object interaction, $F(14.92, 177.02) = 0.68$, $p = .64$, partial ¤ ^{2} = .02, power = .24.[2]

Table 3 presents bootstrapped, FDR-corrected correlations between the self-report measures and errors on the perception task. Notably, BMI did not correlate with any measurements for either group. For HC, no significant correlations were found.

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[1]Separate exploratory models were run across specific body parts and the pattern of results was consistent across hips, waist, knees, and ankles (data not shown but available upon request).

[2]Sensitivity analyses were run controlling for SSRI use. Results supported that SSRI use was not a significant covariate, $F(1, 35) = 0.22$, $p = .64$, partial ¤ 2= .01, observed power = .07, and did not interact with Block, $F(1.67, 58.48) = 0.67$, $p = .49$, partial ¤ 2 = .02, observed power = .15, or Object, $F(1.61, 56.35) = 0.61$, $p = .51$, partial ¤ 2 = .02, observed power = .14, or Group $F(1.67, 35) = 0.14$, $p = .83$, partial ¤ 2 < .01, observed power = .07.

For AN participants, errors on the baseline block for body parts were associated with drive for thinness (95% CI = .36 to .85) and body dissatisfaction (95% CI = .51 to .92). Errors on the tactile and visual blocks for body parts were associated with body dissatisfaction scores (95% CI tactile = .41 to .92; 95% CI visual = .35 to .88). There were no other correlations that survived FDR correction.

4. Discussion

The present study examined a perceptual size estimation task in adolescents with AN compared to HC. Results support that across objects and body parts, both AN and HC participants made fewer errors when they were able to use tactile or visual information compared to baseline. Notably, AN participants were significantly more likely to overestimate their body size across all blocks compared to HC, and this was consistent across body parts. Critically, AN participants still overestimated their body size by 33–35% generally, while HC underestimated their body size by 2–4% after being provided with tactile and visual information. In exploratory correlational analyses, in the AN group, body size overestimation was associated with greater cognitive, affective, and behavioral symptoms of eating disorders; however, of these symptoms, body size overestimation was most robustly associated with body dissatisfaction.

Across all objects, participants generally improved with tactile and visual information, with both HC and AN being able to use these sensory inputs to help improve accuracy. Specific to BID, it is notable that for AN participants, even after being provided with additional tactile and visual information, overestimation was still high across baseline, tactile, and visual blocks (>30%), suggesting potentially poor tactile-visual integration. Consistent with previous literature (Gardner & Brown, 2014; Mölbert et al., 2017), we found evidence of overestimation across body parts in AN participants, regardless of whether that body part is directly affected by weight fluctuations. Importantly, to the extent that individuals with AN overestimated their knees, an area that is typically not perceived as “fat”, and the degree of overestimation across blocks suggests that altered perception or integration of proprioceptive signals may play a role in BID. While previous research has supported that certain body parts, such as the waist, are more likely to be overestimated than others in AN (Gardner & Brown, 2014; Mölbert et al., 2017), a recent meta-analysis supported large effect sizes across specific body parts including the face, shoulder, waist, and hips ($r = 0.67$ to $r = 0.85$; Mölbert et al., 2017). Taken together, this may suggest that overestimation may differ across body parts, but the magnitude of this difference may be minimal, which may explain the lack of significant differences across body parts in the present study. Notably, low power may have also influenced effects in this study.

Exploratory correlation results support that body size overestimation in AN is associated with the severity of cognitive (drive for thinness) and affective (body dissatisfaction) features of BID (Cash & Deagle, 1997; Epstein et al., 2001; Frank & Treasure, 2016; Hagman et al., 2015; Mölbert et al., 2018; Walker, White, & Srinivasan, 2018). The persistence of the association between overestimation and body dissatisfaction, even after providing tactile and visual feedback, reinforces the affective component involved in body size overestimation. Additional research is needed to determine if body dissatisfaction persists as one of the most robust correlates of body size overestimation. Alternatively, there may be perceptual aspects of body integration that contribute to this phenomenon, as suggested by the gross body size misestimation in the AN group even after tactile and visual information. Thus, it could be possible that the visual system in AN does not process this information correctly, as hypothesized for body dysmorphic disorder (Dhir et al., 2018). Alternatively, body parts may be highly negative conditioned stimuli, which may lead to a ceiling effect for corrective tactile/visual input.

Previous neurobiological research supports that feelings of body dissatisfaction are related to neural processing in the anterior cingulate and the insula, brain regions involved in emotion, interoception, and monitoring the physiological state of the body (Preston & Ehrsson, 2016) that have been previously implicated in AN (Kaye et al., 2013; Frank, Shott, Riederer, & Pryor, 2016). These “affective body representation” regions are functionally connected to the parietal cortex, which is responsible for the perceptual representation of one’s body (Preston & Ehrsson, 2016). Thus, body size overestimation and body dissatisfaction may interact through affective (anterior cingulate, insula) and perceptual (posterior parietal cortex) brain regions, which may play a role in the etiology and maintenance of BID in AN. Future additional research combining body size estimation tasks with functional neuroimaging (e.g., Mohr et al., 2010) will be critical to help better understand the mechanisms of BID.

Contrary to our hypotheses, we did not find support for significant differences between groups on food size estimation, either for unsafe or safe foods, although both groups overestimated the size of unsafe foods compared to safe or neutral objects. Results could suggest a potential lack of food size overestimation in AN; however, methodological differences in previous research may also help explain discrepant effects. Yellowlees and colleagues (1988) used different food stimuli and presented food visually on a screen, instead of allowing participants to touch and then subsequently see the food items, as in the present study. Different from previous research (Milos et al., 2013), the present study included predominately packaged unsafe foods (e.g., bottles, boxes), which may have limited size overestimation. Further, the present study did not use a manipulation check to confirm that the foods in the study were considered “safe” or “unsafe” by participants, which will be critical for future research.

The present study has implications for interventions targeting BID in AN. Our results that overestimation of body size in AN is related to drive for thinness and body dissatisfaction supports the potential utility of cognitive-behavioral approaches that target cognitive, affective, and behavioral aspects of body image to help reduce BID (Cash, 2008; Fairburn, 2008; Stice, Rohde, Butryn, Menke, & Marti, 2015). Finally, both AN and HC improved their accuracy after being provided with tactile, and less so for visual, information about the size of the objects, including their body size. As such, interventions that provide tactile and visual feedback about body size may be useful, such as “hoop therapy” (Keizer et al., 2019), in which patients step inside different size hoops and lift them over their heads in an attempt to correct BID. However, despite improvements, AN patients consistently overestimated their body size across blocks, suggesting that providing multisensory feedback cannot fully correct BID.

The present study benefitted from several strengths, including an experimental design in a clinical sample of AN patients and the use of a matched control group. However, there are also limitations to consider in interpreting our results. In particular, the sample size was rather small, which limited our statistical power to detect significant effects, particularly for interactions between objects and blocks. Thus, future research should replicate results in a larger, adequately powered sample. Further, the sample consisted of adolescent female, treatment-seeking AN patients of limited racial and ethnic diversity. As such, results may not generalize to other demographics groups. Most AN participants were on medications, which may have also influenced results; however, SSRI use was not a significant covariate in analyses. Further, we had a fixed order of block presentation and we could not identify whether there would have been a difference in estimation if we had presented the visual information before the tactile information. Relatedly, the baseline block was always administered first (e.g., not counterbalanced), which cannot rule out that our results may be due to practice or expectancy effects. Of note, if there were learning effects, results suggest that both groups learned similarly across non-body part items. Future research should randomize perceptual blocks to help determine whether effects can be attributed to increased perceptual input. We did not include a measure of body image avoidance, a relevant aspect of BID. Additionally, the body part task was self-referential and assessed relative body size overestimation. That is, we did not include a body part block in which participants were asked to estimate the size of a neutral body or another person's body. Further, we cannot account for previous familiarity, or lack thereof, with some of the items (e.g., CDs), which may have influenced size estimation. While food items were standardized across participants, food items that vary in real life (e.g., oranges, cabbages) may have influenced results for the baseline block. Further, previous research (Milos et al., 2013, Yellowlees et al., 1988) used food items that varied in size to a greater degree than the present study, which may have influenced results. Additionally, approximately 50% of the AN sample were diagnosed with anxiety and/or depression, which may have influenced findings.

While BID represents perhaps one of the most perplexing and often protracted symptoms of AN, result from the present study add to an increasing body of literature on factors associated with BID. Results from the present study support and extend previous research by demonstrating that adolescents with AN consistently overestimate their body size compared to HC participants and that the level of overestimation is particularly associated with body dissatisfaction. Future neuroscience-based research should continue to investigate factors related to the etiology and maintenance of BID in AN to help provide more targeted and efficacious treatments.

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Highlights

- Youth with anorexia nervosa (AN) overestimated their body size compared to controls
- AN and controls did not differ on size estimation for neutral and food objects
- Both groups made less estimation errors after added tactile or visual information
- For AN, body size overestimation was robustly related to body dissatisfaction.

Table 1

Differences between Healthy Controls and Individuals with Anorexia Nervosa on Demographics and Self-Report Variables

	Controls			AN			
	N	**Mean**	**SD**	**N**	**Mean**	**SD**	***p***
Age	19	15.77	217	19	16.97	2.24	.10
Years of Education	19	9.21	0.92	18	10.17	2.18	.09
BMI	19	20.90	2.50	19	16.90	1.05	<.001
CDI	18	2.94	2.39	14	23.29	9.39	<.001
STAI State	18	27.67	6.11	17	58.59	13.98	<.001
STAI Trait	18	28.61	6.02	17	59.06	13.71	<.001
EDI Drive for Thinness	19	2.95	3.08	19	21.58	5.92	<.001
EDI Body Dissatisfacu xn	19	3.53	4.09	19	28.26	10.26	<.001
EDI Interoceptive Deficits	19	2.95	3.39	19	16.68	8.44	<.001
BCQ Total	19	35.84	10.81	19	70.32	16.41	<.001

Note. BMI = body mass index; CDI = Child Depression Inventory (range = 0–54) ; STAI = State-Trait Anxiety Inventory (range = 20–80); EDI = Eating Disorders Inventory-3 (Drive for Thinness range = 0–28, Body Dissatisfaction range = 0–40, Interoceptive Deficits = 0–36); BCQ = Body Checking Questionnaire (range = 23–115)

Table 2

Mean Percent Error on the Perception Task across Object, Block, and Group

		Healthy Controls		Anorexia Nervosa			
Object	**Block**	**M**	**SD**	**M**	**SD**	***p***	***Cohen's d***
Neutral	Baseline	17.78	18.55	15.30	14.86	.65	.15
	Tactile	13.04	18.44	16.76	13.91	.49	.23
	Visual	9.05	19.10	11.32	18.77	.71	.12
Safe Foods	Baseline	21.00	24.14	22.67	16.16	.80	.08
	Tactile	11.37	20.18	17.21	14.29	.31	.33
	Visual	11.00	22.32	17.47	22.87	.38	.29
Unsafe Foods	Baseline	36.59	22.55	37.05	25.79	.95	.02
	Tactile	20.89	19.32	31.07	15.75	.08	.58
	Visual	18.25	23.26	27.40	18.03	.18	.44
Body Parts	Baseline	6.95	16.71	42.43	37.97	.001	1.21
	Tactile	−2.36	15.80	33.17	26.69	<.001	1.62
	Visual	−4.56	19.05	35.97	29.33	<.001	1.64

Table 3

Correlations between Study Variables and Errors on the Perception Task across Groups

Object	Block	Age	BMI	CDI	STAI State	STAI Trait	EDI DT	EDI BD	EDI ID	BCQ Total
					Healthy Controls					
Neutral	baseline	−.16	.06	.09	−.31	−.47	−.30	−.26	−.31	.19
	tactile	.04	.16	.14	−.06	−.26	−.16	−.14	−.05	.28
	visual	.03	.17	.08	.02	−.22	−.15	−.09	−.09	.21
Safe foods	baseline	−.36	−.30	.30	−.09	−.28	−.16	−.23	<.01	.24
	tactile	−.02	.08	−.05	−.16	.36	−.30	−.25	−.14	.04
	visual	−.02	.14	−.03	−.11	−.31	−.15	−.09	−.07	.27
Unsafe foods	baseline	−.33	−.24	.14	.07	−.30	−.19	−.15	−.42	.18
	tactile	.06	.04	.09	.02	−.25	−.34	−.18	−.25	.12
	visual	−.10	.11	−.02	.17	−.17	−.28	−.11	−.25	.18
Body parts	baseline	−.20	.01	.54	−.07	−.07	.08	−.03	−.04	.40
	tactile	.17	.23	.21	−.31	−.20	−.16	−.06	−.02	−.01
	visual	.28	.26	.32	−.09	<.01	.07	.06	.12	.32
					Anorexia Nervosa					
Neutral	baseline	.31	.16	.50	.33	.32	.47	.54	.28	.23
	tactile	−.01	.21	.14	−.13	−.01	−.15	.05	.03	−.17
	visual	.33	.21	.35	.04	.12	.09	.10	.31	.07
Safe foods	baseline	.51	−.30	.50	.36	.34	.37	.28	41	.15
	tactile	−.06	.26	.22	.17	.26	.26	.31	.18	.21
	visual	.18	.16	.48	.23	.30	.33	.26	.37	.18
Unsafe foods	baseline	.26	.06	.37	.22	.22	.44	.34	.24	.23
	tactile	−.31	.31	−.32	−.29	−.24	.03	−.06	−.25	−.22
	visual	.05	.24	.21	.01	.05	.41	.09	.16	.22
Body parts	baseline	.38	.09	.51	.53	.49	$.64^{**}$	$.74^{***}$	.44	.57
	tactile	.26	.16	.54	.46	.46	.52	$.74^{***}$	.48	.48
	visual	.40	.24	.60	.44	.45	.53	$.67^{**}$	.48	.51

Note. Asterisks indicate correlations that remained significant after FDR-correction. BMI = body mass index; CDI = Child Depression Inventory; STAI = State-Trait Anxiety Inventory; EDI DT = Eating Disorders Inventory-3 Drive for Thinness Subscale; EDI BD = Eating Disorders Inventory-3 Body Dissatisfaction Subscale; EDI ID = Eating Disorders Inventory-3 Interoceptive Deficits Subscale; BCQ = Body Checking Questionnaire.

$^{*}p<.05$,

$^{**}p<.01$,

$^{***}p<.001$.