Waiting longer, feeling fatter: Effects of response delay on tactile distance estimation and confidence in females with anorexia nervosa

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ABSTRACT

Research suggests that anorexia nervosa (AN) patients overestimate their own body size. However, researchers are divided over whether this overestimation stems from perceptual or non-perceptual differences. In this study, we investigated the influence of non-perceptual factors in tactile size estimation, in a sample of AN patients (N = 30), recovered AN (REC) patients (N = 29) and healthy controls (N=31), by manipulating the role of allowed response time. We further investigated the relationship between allowed response time and participants' confidence in their tactile judgments. Participants were asked to estimate tactile distances presented on the skin of either a salient (abdomen) or non-salient (arm) body part, either directly after stimulus presentation or after a 5 second delay. Confidence of estimation accuracy was measured after each response. Results showed that allowing AN and REC more time to respond caused them to estimate tactile distances as larger. Additionally, AN patients became less confident when given more time to respond. These results suggest that non-perceptual influences cause AN patients to increase their estimates of tactile distances and become less certain of these estimates. We suggest that previous findings—where AN patients estimate tactile distances as larger than HC—may be due to non-perceptual differences.

Keywords: anorexia nervosa; tactile distance estimation; confidence; body image; body representation

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1. INTRODUCTION

Anorexia nervosa (AN) patients display an extreme fear of gaining weight while being (severely) underweight. In addition, AN is characterized by body image disturbance (BID) (American Psychiatric Association, 2013)—a crucial feature of the disorder, associated with both maintenance and onset, and shown to be a predictor for relapse (Carter et al., 2004; Stice & Shaw, 2002).

BID is considered to consist of two components: attitudinal—patients profess to holding negative attitudes towards their own body size—and perceptual—patients overestimate their own body size (Cash & Deagle, 1997). Recently, the perceptual component has attracted significant attention, with researchers discovering that AN patients overestimate their own body size in a number of domains. For example, not only do patients visually judge their bodies as larger than reality, they also perceive affordances, and move as if their bodies were larger than reality (Engel & Keizer, 2017; Gadsby, 2017; Guardia et al., 2012; Guardia et al., 2010; Keizer et al., 2013; Metral et al., 2014). These biases are generally considered to be specific to patients' own bodies, as they are not present when patients are required to estimate the size of other bodies (Guardia et al., 2012), or inanimate objects (Smeets, 1997; Engel et al., 2020). Many of these differences have also been found in recovered (REC) patients (Engel & Keizer, 2017).

Apart from differences in visual size estimation, affordance perception, and movement, AN patients appear to perceive touch as if their bodies were larger than reality (Keizer et al., 2011; Keizer et al., 2012; Risso et al., 2020; Spitoni et al., 2015 cf. Mergen et al., 2018). Specifically, research shows that AN patients estimate tactile distances as larger than healthy controls (HC). This difference is more pronounced on body parts that are salient in AN (e.g. abdomen, waist) compared to those that are not (e.g. sternum), and on the horizontal rather than vertical axis (Risso et al., 2020; Spitoni et al., 2015). The standard interpretation of these findings attributes them to perceptual differences between AN patients and HC. For example, one hypothesis claims that, in the case of AN, tactile signals are mapped onto a representation of skin surface which is distorted in ways stereotypical of an overweight body (wider along the thighs and waist). This distortion causes patients to experience distances as wider on salient body parts, along the horizontal axis (Spitoni et al., 2015; Gadsby, 2017; cf. Keizer, et al., 2012).

One point of contention within BID research is how to interpret evidence that AN patients overestimate their own body size. While many assume that overestimation stems from misperception of the body, an alternative interpretation is that overestimation stems from differences in cognitive and evaluative attitudes regarding body size (Smeets, 1997). This issue has plagued BID research since its emergence in the 1980s (Ben-Tovim et al., 1990), and the debates are still ongoing (Cornelissen et al., 2019; Mölbert et al., 2018; Wignall et al., 2017). The issue also problematises findings from tactile perception research. Rather than perceiving tactile distances to be wider, attitudinal factors may cause AN patients to *estimate* tactile distances as wider than HC. These factors could take many forms, for example: patients' belief that certain body parts are overweight, their emotions associated with certain body parts (Øverås et al., 2014), or demand characteristics involved in the setup (i.e. patients' beliefs about how the experimenter desires them to perform) (Proctor & Morley, 1986).

A fruitful way in which perceptual and attitudinal influences on body size estimation can be experimentally teased apart is through the manipulation of allowed response time. For example, while intuitive responses based off perception occur quickly, cognitive reasoning takes longer (Rubinstein, 2007). In all previous studies that found differences in tactile distance estimation between AN and HC, responses were self-paced: participants were given as much time as they desired to respond (Spitoni, personal communication, Keizer et al., 2011; 2012). This design allows participants time to reflect on beliefs and emotional attitudes regarding their own body size, which may bias the response in distance judgment (D'Amour & Harris, 2017). Therefore, these findings may confound perceptual with attitudinal influences.

In addition to evidence suggesting that patients misestimate their own body size, multiple strands of evidence suggest that AN patients exhibit low confidence in their body attitudes and perceptions. For example, a number of studies employ semi-structured interviews to investigate the confidence patients exhibit in their beliefs about being overweight (Konstantakopoulos et al., 2012; Mountjoy et al., 2014). These results suggest that many patients exhibit low confidence in relation to such beliefs. Other research focuses on the confidence patients exhibit in their perception of their own bodily states. These results suggest that patients exhibit low confidence in their perception of interoceptive sensations such as hunger and heartbeat (Fassino et al., 2004; Jenkinson et al., 2018; Kinnaird et al., 2020). However, the confidence patients hold in their tactile experiences of their own bodies has yet to be explored.

This study investigates the extent to which estimates of tactile distances in AN and REC patients are influenced by non-perceptual factors, by investigating the role of allowed response time in tactile size estimation tasks. In this design, participants were asked to estimate tactile distances presented on the skin of either a salient (abdomen) or non-salient (arm) body part, either directly after stimulus presentation (direct condition) or after a 5 second delay (delayed condition). By asking for a direct response, we minimize the opportunity for the cognitive evaluation that can occur during a longer response window (delayed response) (Rubinstein, 2007). We thus test whether tactile size estimation is, in part, influenced by attitudinal factors. We also include a confidence measure to investigate whether between-group differences in estimation confidence could be found—in line with recent proposals regarding eating disorders and confidence in bodily perception and belief (Fassino et al., 2004; Jenkinson et al., 2018; Kinnaird et al., 2020).

We expected an influence of delayed response on tactile size estimates in AN patients. Specifically, we expected delayed estimates to be larger in our AN group, and for this effect to be amplified in salient body parts. However, we expected no differences between direct and delayed conditions for the HC and REC groups, as neither of these groups exhibit negative body attitudes of the same severity as AN patients (Engel & Keizer, 2017). Over both delayed and direct conditions, we expected REC patients to estimate tactile distances as larger than HC (albeit smaller than AN), consistent with evidence of persistent perceptual dysfunction within this group.

We further expected that AN patients would report lower confidence ratings on average compared to HC and REC. We also expected group differences in confidence ratings to interact with response delay, such that confidence ratings increase in HC, but decline in AN over time.

2. METHOD

2.1 Ethics statement

This study was approved by Monash University Human Research Ethics Committee (MUHREC ProjectID: 19265&19131). All participants provided signed informed consent before taking part.

2.2 Preregistration

Experimental hypotheses, methods, and planned analyses were preregistered prior to data collection: <https://aspredicted.org/blind.php?x=sf2w3e>. We aimed to recruit 30 participants into each group.

2.3 Participants

Participants were females recruited through the Eating Disorders Victoria Facebook page, Twitter, and posters distributed around various higher education institutions in the Melbourne metropolitan area. All participants were compensated for their time.

AN and REC patients were included if they had a present or past diagnosis of AN and REC, respectively, obtained from a psychiatrist or general physician. This diagnosis was verified with the EDE-Q. Our criteria for REC patients was twofold; REC patients had successfully completed treatment for their eating disorder and reported that they were no longer in need of treatment. Self-reported diagnosis was then checked with the EDE-Q. When the EDE-Q matched the self-reported diagnosis, these participants were included in the REC group. HC were included if they had no history of ED.

We recruited 98 individuals who fit our inclusion criteria. Eight were excluded as they failed to discriminate two simultaneously presented points on the skin of the arm or abdomen at a distance of 40mm (Weinstein, 1968). For a thorough description of the two-point discrimination task, see Supplementary Material. Our final sample consisted of 30 AN patients, 29 REC patients, and 31 HCs (see Table 1 for demographics).

2.4 Materials and procedure

After providing signed, informed consent, participants completed a demographic questionnaire and the following questionnaires and tasks in the order they are listed below.

2.4.1 Eating Disorder Examination Questionnaire (EDE-Q)

The EDE-Q (Fairburn & Beglin, 1994) was used to verify self-reported diagnosis of patients and screen for ED pathology in HC. The EDE-Q is a widely used, validated, self-report instrument to assess ED psychopathology (Aardoom et al., 2012). This approach (self-report, justified by the EDE-Q) has been used by other studies to distinguish clinical groups (Berg et al., 2011; Black & Wilson, 1995; Fairburn & Beglin, Anderson & Williamson, 2002). The validity and discriminability of the EDE are good, and the EDE-Q scores and Eating Disorder

Examination (EDE) interview (clinical diagnostic interview for ED) are highly correlated (see (e.g.) Mond et al. (2004)). The EDE-Q is recommended as a replacement of the EDE interview (Berg et al., 2011; Black & Wilson, 1995; Fairburn & Beglin, Anderson & Williamson, 2002).

Global scores in our sample were compared against normative data of a large community sample of Australian adult women (Mond et al., 2004). Higher scores reflect higher levels of eating disorder pathology.

2.4.2 Body Attitude Test (BAT)

The BAT (Probst et al., 1995) was used to compare the extent of negative body attitudes between groups. The BAT was developed for female patients suffering from eating disorders, and consists of four subscales. The total score across these scales is indicative of body attitudes, with higher scores reflecting more negative attitudes.

2.4.3 Tactile Distances Estimation Questionnaire (TDE-Q)

The TDE-Q was especially designed for this study to measure individuals' attitudes towards their own body parts. The TDE-Q consists of four questions; two questions tapping the evaluation of the salient (abdomen) and non-salient (arm) body part, another two questions of how this feeling varies over time. For example, regarding the salient body part, participants were asked '*How do you feel about the size of your abdomen?*', responding on a visual analogue scale (VAS) ranging from '*too thin*' to '*too fat*'. To assess variation over time, they were asked '*Does your evaluation of the size of your abdomen change during the day?*' Again, participants answered on a VAS with '*it is stable*' and '*it varies all the time*' as anchors. Responses were measured on a 0-100 scale. Note, the TDE-Q has not been formally validated.

2.4.4 Tactile Distance Estimation–Delayed (TDE-D)

An adapted version of the TDE task (Keizer et al., 2011) was developed to manipulate the time delay between tactile stimulation and estimation. In this *TDE-D* task, participants were presented with two tactile points applied with a calliper on the skin of the left forearm (Non-salient), on the proximo-distal axis, or the left side of the abdomen (Salient), on the medial-lateral axis. Participants were asked to estimate the distance between these two points by placing the index finger and thumb of their right hand on a tablet. Participants made their estimate when they heard a sound cue (10,000Hz tone). This cue was played directly after stimulus presentation (direct) or 5s post-stimulus (delayed).

Participants were instructed to close their index finger and thumb before each trial, and to respond as soon as they heard the sound. Practice trials were performed until participants responded directly on the audio cue. The right arm was placed on an elevated surface with the wrist above the tablet so that estimations could be made quickly (see figure 1). Distances of 50, 60, and 70mm were presented in a randomized order (total 5 trial repetitions per distance) for each Body-part (salient, non-salient) and Response-delay (direct, delayed) condition. The order of the Response-delay and Body-part condition blocks was counterbalanced across participants. All tactile stimuli were presented for 300ms. The experimenter maintained presentation time consistency by applying stimulation concurrent with a 300ms tone played to them through an earpiece.

Figure 1. Set up of estimates on arm (A) and abdomen (B). A calliper was used to present distances. The experimenter pressed a button on the calliper that was connected to an earpiece where an audio sound was played for 300ms (duration of stimulus presentation).

2.4.5 Confidence Rating

Our confidence questionnaire was hosted on Gorilla Experiment Builder (www.gorilla.sc). After each distance estimate, participants were asked ‘*How confident are you that your estimate is correct?*’ They responded on a VAS, with ‘total guess’ anchoring a rating of 0, and ‘complete confidence’ anchoring a rating of 100.

2.5 Data preparation and analysis

2.5.1 Planned analyses

EDE-Q subscale scores were derived by averaging item scores; EDE-Q global score was calculated from the average of subscale scores. BAT items were summed to derive subscale and total scores. Mixed ANOVAs were conducted in IBM SPSS Statistics for Windows, Version 25.0, to test between-subjects differences in EDE-Q and BAT scores. A mixed ANOVA was used to test for between-group differences in mean VAS scores on each item of the TDE-Q. P-values for planned comparisons were Bonferroni corrected.

TDE-D and Confidence tasks were modelled using mixed ANOVAs, with Group (AN; REC; HC) included as a between-subjects independent variable, and Body-part (arm; abdomen), Distance (50, 60, and 70mm), and Response-delay (direct; delayed) as within-subjects independent variables. In order to facilitate comparison of estimation accuracy across Distance levels, we normalised estimates using the following formula:

$$\text{Percentage misestimation} = (\text{Estimated Distance} - \text{Actual Distance}) / \text{Actual Distance} * 100.$$

One-tailed planned comparisons were used to test prespecified hypotheses. Missing data were handled by listwise deletion.

Shapiro-Wilk tests and data plots were used to assess normality. Levene's test was used to assess homogeneity of variance. Where this test indicated heteroskedasticity, *Welch's F* was computed (Field, 2009). Mauchly's test was conducted for all mixed ANOVAs. Where this test indicated violation of the sphericity assumption, the Greenhouse-Geisser correction was used for epsilons ranging .50 – .75, otherwise the Huynh-Feldt correction was used (Field, 2009).

2.5.2 Additional analysis

In addition to our planned analyses, we fit linear mixed-effects models (LMMs) to model distance estimation and confidence at the trial level. These analyses were performed on account of the large degree of individual variation observed within the dataset, and to mitigate loss of information due to listwise deletion of missing data. In order to replicate the structure of our planned ANOVAs, random effects were limited to by-participant random intercepts (more complex models are included in the supplementary materials). The key advantages of this approach over traditional ANOVA are (1) increased power on account of trial-level estimation and (2) 'partial-pooling' of information across individual and group terms. Together, these innovations improve the accuracy and reliability of parameter estimates (Gelman & Hill, 2006).

LMM analyses were conducted in *R* (v3.6.2; R Core Team, 2019) with *RStudio* (v1.2.5033; RStudio Team, 2015). LMMs were fit using the package *lme4* (Bates et al., 2015).

Diagnostic plots revealed no evidence of violated assumptions. Although distance can be construed as a random effect, the low number of sampled levels led us to include it as an ordered factor (polynomial contrasts); all remaining factors were unordered and sum-to-zero contrast-coded. Main effect and interaction terms were assessed using Kenward-Roger F tests (Satterthwaite degrees of freedom) from Type-II ANOVA tables obtained from the *car* package (Fox & Weisberg, 2018a). Planned (Bonferroni-corrected) and post-hoc (Tukey-corrected) comparisons were evaluated using the *emmeans* package (Lenth, 2020). *Effects* (Fox & Weisberg, 2018a, 2018b) and *ggplot2* (Wickham, 2016) were used to visualise model predictions (visualisations of response distributions are included in the supplementary materials).

3. RESULTS

3.1 Planned analysis

3.1.1 EDE-Q

A mixed ANOVA showed significant between-group effects for global EDE-Q score, $F(2,87)=26.20, p<.001, \eta^2=.37$. Significant differences were also found for all subscales: Restraint, *Welch's* $F(2,55.42)=25.09, p<.001, \omega=.30$; Eating Concern, *Welch's* $F(2,55.83)=21.81, p<.001, \omega=.30$; Shape Concern, $F(2,87)=18.49, p<.001, \eta^2=.30$; Weight Concern, $F(2,87)=17.04, p<.001, \eta^2=.28$. Post-hoc comparisons indicate that our AN sample demonstrated a higher level of ED psychopathology than the REC and HC groups, which is consistent with the self-reported diagnosis. For means, standard deviations and post-hoc comparisons, see Table 1.

3.1.2 BAT

A mixed ANOVA showed significant between-group differences for total BAT score, $F(2,87)=24.54, p<.001, \eta^2=.36$. Significant differences were also found for all subscales: Negative appreciation with one's own body size, $F(2,87)=18.06, p<.001, \eta^2=.29$; Lack of familiarity with one's own body, $F(2,87)=26.40, p<.001, \eta^2=.38$; General body dissatisfaction, $F(2,87)=12.19, p<.001, \eta^2=.22$. Post-hoc comparisons indicate that, overall, AN and REC patients have more negative body attitudes than HC, and that negative body attitudes (apart from negative appreciation) are higher in AN patients than REC patients. For means, standard deviations and post-hoc comparisons see Table 1.

Table 1.

Demographics, clinical assessment, EDE-Q and BAT scores.

	HC <i>N</i> = 31	REC <i>N</i> = 29	AN <i>N</i> = 30
Demographics			
Age	22.55 ± 3.79	22.76 ± 3.99	22.17 ± 4.14
Age range	19 - 34	19 - 35	18 - 32
BMI	21.06 ± 3.42	21.60 ± 2.74	19.55 ± 3.21
BMI range	16.23 – 32.37	17.26 – 30.11	14.15 – 26.27
Right - Handedness	27	26	28
Reported diagnosis			
AN – Restrictive	--	18	28
AN – Binge/Purge	--	10	1
OSFED	--	1	1
Other diagnoses	--	27	28
OSFED	--	1	1
Other diagnoses	--	27	28
Age: symptom onset	--	13.90 ± 2.58	13.97 ± 3.10
Age: AN diagnosis	--	16.14 ± 2.52	17.23 ± 2.98
Age: start of treatment	--	14.72 ± 5.74	14.47 ± 8.18
Duration treatment	--	2.48 ± 2.79	3.77 ± 3.78
EDE-Q			
Global Score	1.17 ± 0.99	1.86 ± 1.22	3.33 ± 1.35
Restraint	0.80 ± 1.03	1.26 ± 1.19	3.16 ± 1.79
Eating Concern	0.62 ± 1.02	1.38 ± 1.22	2.78 ± 1.59
Shape Concern	1.83 ± 1.26	2.55 ± 1.54	3.94 ± 1.33
Weight Concern	1.41 ± 1.32	2.25 ± 1.38	3.45 ± 1.42
BAT			
Total score	23.00 ± 16.83	35.93 ± 13.90	47.40 ± 13.33
Negative appreciation	7.32 ± 6.19	13.14 ± 6.09	16.80 ± 6.36
Lack of familiarity	7.68 ± 4.52	12.28 ± 5.12	17.53 ± 6.15
General dissatisfaction	8.00 ± 4.16	10.52 ± 4.19	13.07 ± 3.65

Note. Other diagnoses are other lifetime diagnosis; for a full overview see Table S.1. Duration of treatment is in years ($\pm$ *SD*). Boldface indicates significant difference from corresponding estimate in the preceding column.

3.1.3 TDE-Q

A mixed ANOVA showed significant between-group differences for evaluation of arm size, $F(2,87)=3.88, p<.05, \eta^2=.08$. Post-hoc comparisons revealed that AN patients evaluate their arm as more fat ($M=60.30, SD=22.09$) compared to HC ($M=46.90, SD=5.77$) ($p<.05$). No differences were found between AN and REC patients ($M=56.07, SD=19.83$) ($p=1.0$), or REC patients and HC ($p=.21$).

Significant differences were also found for change in evaluation of arm size during the day, *Welch's* $F(2,51.93)=4.72, p<.05, \omega=.07$. AN patients ($M=33.47, SD=38.15$) report more fluctuation during the day compared to HC ($M=11.74, SD=16.73$) ($p<.05$). No significant differences were found between AN and REC patients ($M=18.72, SD=25.47$) ($p=.14$), or REC patients and HC ($p=1.0$).

Significant differences were also found for change in evaluation of abdomen size during the day, $F(2,87)=13.65, p<.001, \eta^2=.24$. AN patients ($M=79.10, SD=28.47$) and REC patients ($M=65.59, SD=26.98$) report more fluctuation compared to HC ($M=42.74, SD=27.03$; $p<.001$ and $<.05$, respectively). No differences were found between AN and REC patients ($p=.19$).

No significant differences were found for evaluation of abdomen size, $F(2,87)=2.82, p=.065$.

Taken together, these results imply that AN patients rate their arm as fatter compared to REC patients and HC. AN patients also report more change in their evaluation of arm and abdomen size compared to HC. The latter was also apparent in REC patients compared to HC.

3.1.4 TDE-D

Two participants were excluded from analysis due to missing data (technical error). The full ANOVA table is presented in Table 2 (see Table S.2 for descriptive statistics).

AN patients' performance on the TDE-D during the Salient condition did not significantly differ as a function of Response-delay compared to REC patients and HC, $F(1,85)=1.104, p=.296$. REC patients and HC also showed no significant difference in estimation accuracy on this contrast, $F(1,85)=1.950, p=.166$. TDE-D did not significantly differ between groups, $F(1,85)=1.968, p=.164$.

3.1.5 Confidence Ratings

Eight participants were excluded from analysis due to missing data (technical error). The full ANOVA table is presented in Table 2 (see Table S.3 for descriptive statistics).

TDE-D confidence ratings did not significantly differ between AN patients and REC patients or HC ($F(1,79)=2.758, p=.101$), nor REC patients and HC ($F(1,79)=0.055, p=.815$). As predicted, AN participants' confidence ratings declined significantly from the Direct to the Delay condition, $F(1,79)=4.194, p<.05$. However, Response-delay did not significantly modulate confidence ratings in HC, $F(1,79)=1.574, p=.213$.

Table 2.

Planned analysis: ANOVAs for TDE-D and Confidence Ratings

Source	<i>df</i>	<i>F</i>	<i>p</i>	<i>partial</i> <i>η</i> ²
<u>TDE-D</u>				
Body-part	1, 85	10.68	.002	.11
Response-delay	1, 85	14.63	< .001	.15
Distance	1.46, 170¹	26.83	< .001	.24
Group	1, 85	2.09	.13	
Group*Distance	4, 85	4.30	.002	.09
Group*Body-part	2, 85	1.77	.18	
Group*Response-delay	2, 85	1.64	.20	
Body-part*Response-delay	1, 85	.84	.36	
Body-part*Distance	2, 170	1.81	.17	
Response-delay*Distance	1.90, 170 ²	2.76	.07	
Body-part*Response-delay*Group	2, 85	.53	.59	
Body-part*Distance*Group	2, 85	.55	.70	
Response-delay*Distance*Group	4, 85	.52	.72	
Body-part*Response-delay*Distance	1.91, 170 ²	.42	.65	
Body-part*Response-delay*Distance*Group	8, 85	.42	.80	
<u>Confidence Ratings</u>				
Distance	1,79	13.66	< .001	.15
Body-part	1, 79	.024	.876	
Response-delay	1, 79	3.00	.087	
Group	1, 79	1.40	.254	
Distance*Group	4, 158	3.16	.016	.07
Distance*Body-part	1.93, 152.48²	4.94	.009	.06
Group*Body-part	2, 79	.012	.989	
Group*Response-delay	2, 79	2.12	.127	
Body-part*Response-delay	1, 79	.481	.490	

Response-delay*Distance	1.84, 145.15 ²	.69	.49
Body-part*Response-delay*Distance	1.95, 153.9 ²	1.72	.183
Body-part*Response-delay*Group	2, 79	.25	.777
Body-part*Distance*Group	4, 158	1.86	.120
Response-delay*Distance*Group	4, 158	1.97	.101
Body-part*Response-delay*Distance*Group	4, 158	.87	.486

Note. ¹Greenhouse-Geisser correction, ²Huynh-Feldt correction

3.2 Additional analysis

3.2.1 TDE-D

The ANOVA table from the random-intercepts LMM of TDE-D estimates is presented in Table 3 (see Table S.4 for model summary).

TDE-D in AN did not significantly interact with Response-delay and Body-part, $t(5210)=1.04, p=.650$. In the Salient condition, delay-induced changes in estimation performance did not significantly differ between AN and REC patients, $t(5210)=0.40, p=1$, but did significantly differ between REC patients and HC, $t(5210)=6.45, p=.008$. No differences were found in the Non-Salient condition ($ps>.09$). Modelling Group as a linear trend supported the hypothesis that TDE-D estimates were largest for AN and smallest for HC, $t(93.54)=2.01, p=.048$.

The LMM further revealed significant two-way interactions between Group*Body-part, Group*Response-delay, and Group*Distance. Post-hoc contrasts showed that AN patients and HC underestimated distances less on the abdomen compared to the arm (both $ps<.001$; see figure 2A). AN and REC patients both estimated distances as larger in the delayed condition compared to the direct condition ($ps<.001$; see figure 2B), while their distance estimates in the 50mm condition differed significantly from those in the 60mm and 70mm condition (all $ps<.001$; see figure 2C).

3.1.2 Confidence Ratings

The ANOVA table from the random-intercepts LMM of confidence ratings is presented in Table 3 (see Table S.5 for model summary).

TDE-D confidence ratings did not significantly differ between AN and REC patients, $t(85.9)=1.12, p=.265$, nor REC patients and HC, $t(86)=0.60, p=.553$. As predicted, AN patients reported lower confidence after a delayed response, $t(5038)=5.26, p<.001$. By contrast, HC showed no significant difference in confidence ratings between Direct and Delayed trials, $t(5044)=0.16, p=.44$ (see figure 2E).

The LMM revealed additional significant interactions between Body-part*Distance and Group*Distance. Post-hoc analysis of the Distance*Body-part interaction revealed that participants were more confident about their estimation accuracy on the arm for 70mm compared to 50mm ($p=.005$). On the abdomen, participants were more confident at 70mm compared to 50mm ($p<.001$) and at 70 mm compared to 60mm ($p<.001$; see figure 2D). Contrasts for the Group*Distance interaction revealed that HC were more confident in distance estimates at 70mm compared to 60 mm ($p=.005$), 70mm compared to 50mm ($p<.001$), and 60mm compared to 50mm ($p=.016$; See figure 2F).

Figure 2. Significant interactions from TDE-D (left column) and Confidence Ratings (right column) LMMs. (A) Group*Body-Part interaction. (B) Group*Delay interaction. (C) Group*Distance interaction. (D) Distance*Body-part interaction. (E) Group*Delay interaction. (F) Group*Distance interaction. *** = $p < .001$, ** = $p < .01$, * = $p < .05$, error bars depict S.E.

Table 3.

Additional analysis: LMMs for TDE-D and Confidence Ratings

Source	<i>df</i>	<i>F</i>	<i>p</i>
<u>TDE-D</u>			
Body-part	1, 5210.6	103.32	< .001
Response-delay	1, 5210.6	54.98	< .001
Distance	2, 5210.0	50.79	< .001
Group	2, 87	2.12	0.126
Group*Body-part	2, 5210.6	18.40	< .001
Group*Response-delay	2, 5210.6	7.03	< .001
Group*Distance	4, 5210.0	6.59	< .001
Body-part*Response-delay	1, 5210.7	1.61	0.205
Body-part*Distance	2, 5210.0	1.65	0.192
Response-delay*Distance	2, 5210.0	2.74	0.064
Group*Body-part*Response-delay	2, 5210.0	0.94	0.39
Group*Body-part*Distance	4, 5210.0	0.57	0.68
Group*Response-delay*Distance	4, 5210.0	0.60	0.66
Body-part*Response-delay*Distance	2, 5210.0	0.38	0.68
Group*Body-part*Response-delay*Distance	4, 5210.0	0.19	0.94
<u>Confidence Ratings</u>			
Distance	2, 5037	26.44	< .001
Response-delay	1, 5039.7	15.96	< .001
Body-part	1, 5041.4	0.46	.497
Group	2, 86.0	1.57	.215
Body-part*Distance	2, 5037	4.55	.011
Group*Response-delay	2, 5039.8	7.52	< .001
Group*Distance	4, 5037	4.33	< .001
Group*Body-part	2, 5041.4	0.74	.477
Body-part*Response-delay	1, 5039.8	0.23	.633
Response-delay*Distance	2, 5037	1.87	.155

Group*Body-part*Response-delay	2, 5039.8	0.05	.949
Group*Body-part*Distance	4, 5037	0.99	.410
Group*Response-delay*Distance	4, 5037	1.28	.277
Body-part*Response-delay*Distance	2, 5037	0.82	.441
Group*Body-part*Response-delay*Distance	4, 5037	0.60	.665

Finally, distance estimates and confidence ratings were correlated with clinical variables: symptom onset, illness duration, duration of treatment and BMI. No significant results survived Bonferroni correction ($\alpha = .003$). This indicates that the clinical variables and BMI do not influence our outcome measure.

4. DISCUSSION

A much-debated issue in AN research is whether overestimation of body size reflects a difference in perceptual processing, or stems from non-perceptual factors, such as the cognitive and affective attitudes patients hold towards their own bodies (Smeets, 1997). This study aimed to investigate the comparative influence of perceptual and non-perceptual factors on tactile size estimation in AN and REC patients, by manipulating response delay. Here, a delayed response allowed participants to deliberate, increasing the influence of non-perceptual factors (e.g. attitudes and emotions) on their final estimation, while a direct response did not include this deliberation period, more directly reflecting their perception of the distance. Additionally, we investigated if this response delay affects confidence in the accuracy of these judgments.

We expected a longer response time would increase tactile distance estimates in AN patients, especially in salient body parts. We also expected REC patients to estimate distances as larger than HC, but smaller than AN patients. While our planned analyses indicated that tactile distance estimation varied as a function of both body-part and response-delay, group-level interactions were only revealed when we modelled participant responses on the trial-level, using linear mixed-effects modelling (LMM). The results of this additional analysis revealed that AN and REC patients, but not HC, judge distances as larger when responding after a 5s delay period. Further, tactile distances were judged as larger on the forearm compared to the abdomen in AN patients and HC (but not REC). Contrary to our expectations, response-delay did not interact with body part salience.

In terms of estimation confidence, we expected AN patients to report lower confidence than HC and REC. Additionally, we expected AN patients to be less confident in the delayed, compared to the direct condition, while we expected the opposite for HC. Although our ANOVA failed to provide statistical evidence of these effects, the additional sensitivity afforded by the LMM furnished partial support: AN patients reported lower confidence in their estimation accuracy in the delayed condition, compared to the direct condition. Contrary to our expectations, we did not see an influence of response-delay on confidence ratings in REC or HC.

Our findings are consistent with the claim that increased tactile distance estimations in AN patients (relative to HC) is due to non-perceptual factors. In other words, AN patients estimate tactile distances as larger not because they perceive them as larger, but due to processes that occur after the perceptual experience. Previous research suggested that either attitudes about body size (e.g. beliefs about being overweight) or demand characteristics (beliefs about what the experimenter expects) may cause AN patients to overestimate their bodies. Such explanations predict that AN patients would only increase their estimates (when given more time to respond) in the salient (abdomen, medio-lateral) as opposed to non-salient (arm, proximo-distal) condition. This is because patients do not hold false beliefs about their arm length and would not assume the experimenter expected them to misestimate those dimensions. Our results contradict this prediction, as when looking at the AN group, there is no delay*body-part interaction (see: fig. S.7). Given this finding, whichever non-perceptual factors drive misestimation, they must affect both body-part conditions. Explanations of this finding may refer to changes in the memory of the touch experience (Williamson et al., 2004); or judgment biases driven by time to reflect on anxiety (Øverås et al., 2014) or task difficulty (Waller & Hodgson, 1996). While our data cannot distinguish between the various possibilities, this represents a promising avenue for future research.

Another novel finding of the study stems from our use of the TDE-Q, designed to measure fluctuations in bodily attitudes. The results of this questionnaire suggest AN patients show a higher fluctuation in their evaluative attitudes towards their arms and abdomens, compared to HC. Interestingly, this measure also discovered that REC patients' evaluation of their own abdomen size fluctuates significantly more compared to HC. These daily fluctuations in evaluation of body size are additional indicators of uncertainty in the body size attitudes of AN and REC patients (Espeset et al., 2011).

In further support of a difference in confidence between AN, REC, and HC—we found that while HC were more confident for larger compared to smaller distances, this was not the case for AN and REC, who exhibited no between-distance differences in confidence ratings. The results from our HC group can be explained with reference to perceptual ambiguity: smaller tactile distances are closer to the 2-point discrimination threshold and are thus more perceptually ambiguous, causing participants to be less confident in such judgments. While it is not clear how to explain the homogeneity of confidence judgments in AN and REC patients, future research might clarify this issue by using more precise confidence measures (Matthews et al., 2020).

These findings bear significant theoretical relevance, especially related to ongoing debates regarding models of body representation. Such debates focus on the number of body representations, their functional relationships with one another, and the kinds of behavioural capacities they underpin (de Vignemont, 2017; Gadsby, 2018; 2019; Longo, 2015; Pitron & de Vignemont, 2018; Pitron et al., 2018). One proposal within these debates is that multiple body representations (including those that underpin tactile size perception) all derive their spatial content from a shared representation (Gadsby, 2017). This finding is largely motivated by evidence that, in the case of AN, each representation is distorted (as evident in visual size estimate, affordance processing, and tactile distance estimation tasks). However, the finding that overestimation of tactile distances by AN patients (compared to HC) may reflect non-perceptual disturbances undermines this justification for the model.

Although our findings might be taken to suggest that targeting cognitive-evaluative attitudes is more clinically effective than targeting bodily perception, it is too early to draw such a conclusion. First, the attitudinal influence present in our delayed condition is still situated within a perceptual context—patients’ deliberations are directly prompted by a bodily experience. This is important, as “perceptual” interventions are usually targeted at attitudinal responses to perceptual experience (Delinsky & Wilson, 2006; Keizer et al., 2019). Second, we only measured tactile perception in this study, while perceptual training usually targets other aspects of perception (visual perception, affordance perception). Further research should explore whether errors in perception are present in these domains.

In order to test and replicate previous findings, we adopted a TDE paradigm employed in (Keizer et al., 2011; Keizer et al., 2012; Engel & Keizer, 2017). This introduces an important caveat to our interpretation. While our results suggest that AN and REC overestimate due to

non-perceptual factors, this interpretation may be specific to the paradigm used here. For example, in visual body size estimate research, the type of measure employed has been found to modulate body size estimates (Cornelissen et al., 2017). Some studies which found differences in TDE between AN and HC used alternative methods (Risso et al., 2020; Spitoni et al., 2015), and these methods may be more suited to capturing perceptual differences between these groups (see also: Tosi & Romano, 2020). Accordingly, future research should further investigate these claims, employing various methods of assessing tactile size perception.

Another caveat to note is that, in increasing their estimates of tactile distances (in the delayed condition), AN and RAN were in fact estimating distances more accurately. This finding is consistent with results from previous research, which show that AN groups are often more accurate than HC in their body size estimates, in virtue of underestimating less (Bowden, et al., 1989; Meermann, 1983; Lindholm & Wilson, 1988; for review and discussion, see Farrell et al., 2005). In the literature on eating disorders, the focus is on the differences in estimates provided by the different groups (AN, REC, HC), not the accuracy of those estimates (Keizer et al., 2011; 2012). The important difference between these groups (body image disturbance) provides theoretical reason to assume that AN and REC would estimate distances as larger than HC (Gadsby, 2017). In contrast, there is no clear, theoretically supported reason for why AN and REC would exhibit greater accuracy in their tactile size estimates. Nevertheless, there may still be some explanation for why AN and RAN would become more accurate in their estimates, compared to HC, when given more time to respond. Providing such an explanation is, however, beyond the scope of this discussion.

We acknowledge that the critical interactions between group and response-time were uncovered in the unplanned component of our analysis. While such findings are usually caveated with the need for cautious interpretation, it should be stressed that our LMMs aimed to emulate the ANOVAs specified in our preregistered analysis with greater power and precision. Although LMMs are commonly regarded in psychology as more complex and difficult to interpret than traditional methods (Meteyard & Davies, 2020), our findings showcase the advantages of such techniques in the context of substantial individual variation and unbalanced data—common occurrences in clinical research settings.

One limitation of our study is that our participant groups do not significantly differ in terms of BMI. Our mean BMI for AN patients is higher than cut-off scores for diagnosis. One

possible explanation is that AN patients already started their ED treatment and were already in the process of regaining their lost weight, as weight regain is one of the main focusses in AN treatment (Noordenbos & Elburg, 2018). However, gaining weight does not necessarily resolve BID—in many cases, it worsens them (Cornelissen et al. 2017—, nor the attitudes towards gaining weight. That problematic eating behaviours and attitudes are still problematic, despite weight gain, is reflected in the results of the EDE-Q, where AN patients scored significantly higher than REC patients and HC on ED psychopathy. These results indicate that core symptoms of AN are still very much present even though their BMI is not significantly different than those of REC patients and HC. Furthermore, we did not find a correlation between BMI and our TDE scores. In our past studies using the TDE (where we also included clinical samples, where BMI did fall under the weight cut-off for the diagnosis), we found no correlation between BMI and the outcome measures (e.g. Keizer et al, 2011; 2012, Engel & Keizer, 2017). This is also consistent with other findings of no correlation between low BMI and body image disturbances (using both attitudinal and perceptual measures) (Molbert et al., 2018; Ben-Tovim et al., 1990). This indicates that BMI is not a factor of influence when it comes to overestimation, as opposed to attitudes towards the body (as suggested by our results).

In summary, we showed that allowing AN and REC patients more time to respond during tactile distance estimation causes them to make larger distance estimates. This finding lends support for a non-perceptual explanation of tactile distance overestimation in AN, suggesting that previous findings that AN patients estimate tactile distances as larger than HC may be due to non- perceptual, differences. We also discovered that, in contrast to HC and REC, AN patients became less confident when given more time to respond, contributing of differences in confidence associated with the disorder.

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