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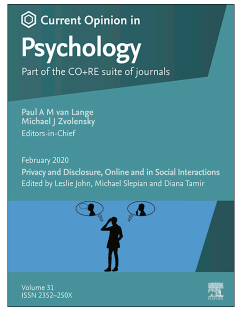

Targeting body image in eating disorders

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Targeting body image in eating disorders

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Abstract

Eating disorders, such as anorexia nervosa (AN), are challenging to treat successfully and have a very high relapse rate. Body image disturbance (BID) is a core component of these eating disorders. It is a predicter of onset, treatment outcome and future relapse. However, recent studies suggest that BID can be improved by an adaptation of cognitive bias training. This does not target the accuracy of body size judgements, but instead focusses on how a body of a particular size is *categorised* by a patient. This recalibration of the categorical boundary at which bodies are judged as over-weight, which challenges a patient's existing preconceptions about which constitutes an acceptable body size, seems to lead to a more general reassessment of eating disordered attitudes and a significant improvement in their psychological profile. These promising findings need further trials to determine the long-term effectiveness of such a targeted intervention, but it potentially provides an important additional treatment option. Additionally, this cognitive bias training may also be effective augmentation to treatment in other conditions which feature BID, such as bulimia nervosa and body dysmorphia.

Key Words: Body Image Disturbance, Cognitive Bias Training, Anorexia Nervosa, Body Image Change

Anorexia nervosa (AN) is a serious mental illness effecting up to 1% of the female population in western societies, where the long-term mortality rate has been estimated to be as high as 10%[1-3]. The highest for any psychiatric disease. A distorted evaluation of personal body size, or body image distortion (BID; *DSM-5*, 2013), is one of the central diagnostic criteria for AN, and is also a key element of psychological models of the disorder[4,5]. BID has been suggested to be a predictor of onset and the effectiveness of treatment and its persistence is a predictor of relapse[6-10] which has been estimated to be as high as 41%[11-12]. BID is so central to AN it has even been suggested that it be renamed as body image disorder[13]. In developing interventions to treat AN, BID provides a potential gateway into treating this most intractable of chronic psychiatric conditions. If BID can be improved, then it is possible that we may also see a more global improvement in symptoms. Therefore, we will first define the nature of BID and then discuss how it can be treated and the impact of this treatment on a patient's psychological profile.

Attitudinal and perceptual body image: same or different?

According to the influential meta-analysis by Cash and Deagle[4], body image comprises two components: (1) perceptual body image represents the accuracy with which a person can judge the physical dimensions of their own body (see also [14,15]), and (2) attitudinal body image captures the feelings that a person has about their body size and shape. Nevertheless, a number of authors have suggested that body size over-estimation in conditions like AN might be explained solely in terms of changes in attitudinal body image[16-18], and tasks that purportedly measure perceptual body image may in fact be visual proxies for estimates of attitudinal body image. Given the severe psychological and physical consequences of eating disorders to sufferers, it is important to decide unambiguously whether there is a separable perceptual component to body image.

To address this problem, Cornelissen et al.[19] used a high-level adaptation paradigm to ask whether perceptual body image measures are really a proxy for attitudinal body image, which is usually assessed psychometrically, or whether these are indeed meaningfully separate, statistically independent constructs. Visual adaptation is a temporary change in perception following prolonged exposure to a new or intense stimulus. It leads to a lingering aftereffect that may continue once the adapting stimulus is removed. High-level adaptation effects result in aftereffects that change in the *same* direction as the adapting stimulus. So if the first model for body image were true (i.e., vision as a proxy for attitude), following the logic of social comparison theory[20], the regression of percentage-error in body size estimation on the strength of an adapting stimulus should show negative slopes, with a linear interaction between the strength of the adapting stimuli and body attitude (See Fig. 1a). If the second, "independence" model were true, a regression of percentage error in body size estimation on the strength of the adapting stimulus should have a positive slope. In addition, the intercept of this regression line should be proportional to attitudinal measures: elevated body image concerns contribute a fixed amount to body size over-estimation (See Fig. 1b). Therefore, plots of the adaptation effect in different observers, each of whom obtains a different score on body attitude, should produce a set of regression lines that have a positive slope and are *parallel* to each other. Cornelissen et al.[19] thus showed clear evidence in support of independence.

Disturbed perceptual body image in anorexia nervosa?

Having established the validity of an independent perceptual component to body image, the next clinically important question is whether any differences exist in this attribute when comparing women with AN to healthy controls. Cornelissen et al. [21] re-analysed a previous study in which women with AN and healthy controls were asked to estimate their own body size by manipulating an image of themselves using a body morphing program[22]. The software allowed participants to match their perception of the size of their individual body parts with what they saw on screen by manipulating slider controls. Cornelissen et al.[21] directly compared participants' estimates of their own BMIs with their actual BMIs. As is illustrated in Fig. 2a, they found that: (1) the same regression of estimated BMI on actual BMI captured the data for both AN and the healthy control participants, and (2) the slope of this regression line was less than 1. This implied that inaccuracies in body size estimation across all participants, whether AN or healthy controls, could be explained by a well-known bias in magnitude estimation called contraction bias, which is perfectly normal[23]. Contraction bias arises when one uses a standard reference or template for a particular kind of object against which to estimate the size of other examples of that object. The estimate is most accurate when estimating the size of an object of a similar size to the reference but becomes increasingly inaccurate as the magnitude of the difference between the reference and the object increases. When this happens, the observer estimates that the object is closer in size to the reference than it actually is. As a result, an object smaller in size than the reference will be over-estimated and an object larger will be under-estimated.

The contraction bias explanation predicts that for both healthy controls and women with AN, the accuracy of their body size estimation will be driven by the BMI of the participants, in the same way. While Cornelissen et al.'s[21] re-analysis showed that this was the case, nevertheless the BMI values of the women with AN in the study by Tovée et al.[22] all actually fell within a relatively narrow range 6.9 BMI units (11.5 to 18.4). Most of the variation in BMI in this study was based on the responses of the control participants who ranged in BMI between 14.7 and 36.8 (22.1 BMI units). Therefore, if perceptual body image is indeed normal in AN, a sample of AN women with a much wider BMI range (including recovering patients to expand the range) should mirror the responses of healthy control participants. This is illustrated in Figure 2b, where the gold arrow shows how the regression of estimated BMI on actual BMI in these women should track up along the same regression line as in Fig. 2a. Alternatively, if perceptual body image is disturbed in AN, we should see a very different slope for the regression of estimated BMI on actual BMI, as illustrated in Fig. 2c.

To test this hypothesis, Cornelissen et al.[24] asked women with AN and controls to estimate their body size. In the analysis, they subdivided their groups into those with higher and lower body concerns. For the controls, both high and low concern groups show evidence of contraction bias (Fig. 3). Statistically, the slope of these two lines is the same, so that means that the perceptual component – i.e. the contraction bias effect, is the same for both groups. The difference between the two lines is driven solely by body attitudes. So, this means that whatever your actual BMI is, having negative attitudes to your body increases the size that you think you are. By comparison, women with a history of AN are different. The slope relating estimated size to actual size is much steeper than for controls (Fig. 3). Although, low BMI women with AN are actually quite accurate, as the body weight of anorexics increases, so the tendency for them to over-estimate body size systematically increases as a linear function of their own actual BMI. This is important because persistent body-size over-estimation predicts relapse[6,25], and this over-estimation gets worse as women's BMI increases towards normal and even higher levels.

Can we treat this problem?

Currently, the available treatments for eating disorders are based primarily on specially adapted cognitive-behavioural (CBT) approaches[26,27] and these have shown limited effectiveness[28-30]. A recent systematic review and meta-analysis suggests that once corrections for biases in the data are applied, the effect sizes of these treatments are small and strongly suggest the need for new therapies[31]. The role of BID as a core feature of AN and as a predictor both of onset and relapse suggest the need to develop specific therapies which target distorted body image as part of their treatment [6,25,32].

Recent laboratory evidence has shown that a yes\no forced choice cognitive bias modification (CBM) paradigm that focuses on thin ideals and social comparison processes, leads to reduced concerns about eating (indexed by standardized psychometric assessment) as well as improvements in body image[33,34]. However, systematic Randomized Controlled Studies (RCTs) for these effects in clinical samples are still required. The interventions have used adapted CBM techniques that were originally developed in the field of anxiety[35,36]. Gledhill et al.[33] adapted this paradigm for body size estimation in the light of evidence that individuals show a clear categorical boundary when judging bodies[37]. Using computer generated imagery (CGI) avatars representing a continuum of body sizes from emaciated to obese, Gledhill et al.[33] first identified the baseline measurement of the thin vs fat boundary in individual participants. To do this, the participants locate the point along the continuum which represents their subjective judgement for the transition from a "thin" to a "fat" body (i.e. the categorical boundary). Gledhill et al.[33] then applied the training procedure to shift an individual's categorical boundary towards heavier bodies (see Fig. 4a). They ran this training paradigm in: (1) a sample of adult healthy women with high body image concerns and (2) a sample of women with atypical AN. Participants sat in front of a computer screen on which images of a female CGI body were presented, one at a time. A total of 15 images were used representing the change in BMI from emaciated to obese. On each trial, the participant was asked to classify whether the image on screen was thin or fat. Training was carried out over 4 sessions. Each session comprised: 1) a pre-training baseline measurement, 2) an intervention training or control training, depending on group assignment, 3) a post-training measurement. The pre-training baseline measurement used 45 trials (i.e. 3 presentations of each of the 15 images) and no feedback about a participant's decisions was given. Based on their responses, the baseline thin/fat boundary for that day's session was calculated. During the training phase, participants then carried out a further 6 blocks of 31 trials each, and these include feedback after every trial, e.g. 'Incorrect, that body was thin' or 'Correct, that body was fat'. During the post-training measurement, the same sequence of trials as the baseline measurement was presented, again without feedback. Therefore, on each training session, the extent of any shift in the thin/fat category boundary could be calculated by comparing the post-training measurement with that session's baseline measurement. The key element of the training that appears to cause the shift in the categorical boundary was the confrontational nature of the feedback that participants received in the training phase. In the intervention group, the feedback was "inflationary" and designed to move the boundary towards heavier bodies. For example, if the pre-intervention baseline measurement gave a thin/fat boundary at image 7/15, then the "inflationary" feedback was given as if that boundary was really at image 9/15. Therefore, images that participants had decided were fat during the baseline measurement they now had to accept as thin in order to get a "correct" response. By comparison, in the control group the feedback merely maintained the boundary identified during the baseline measurement (i.e. "maintenance" feedback). So, if the pre-intervention baseline measurement gave a thin/fat boundary at image 7/15, now the "maintenance" feedback was also given for a boundary at image 7/15.

Gledhill et al.[33] showed that the increase in the size of a body that was classified as "fat", as a result of training, occurred for those participants who received inflationary feedback, but not for those who received maintenance feedback (Fig. 4b&c). This change in the way bodies were categorised was accompanied by a significant reduction of the participants' own concerns about body shape/weight and eating (Fig. 4d&e). When tested at 1-month follow-up, these reductions were retained. In a similar study, Szostak[38] also used the same training paradigm to manipulate participants' interpretation of body size, and to encourage their interpretation of thinness over heaviness in normal-sized bodies, in women with heightened body shape, weight and eating concerns. The training successfully shifted the categorical boundary towards a heavier body, and the shift was retained at a 2-week follow-up. Most recently Irvine et al.[34] replicated the Gledhill et al.[33] study, but this time using longer stimulus presentations presented in a virtual reality environment. In sum, two key outcomes resulted from these laboratory studies: Inflationary feedback succeeded in changing participants' judgements about other people's body size. Avatars that participants would have described as "fat" before training were later categorized as "thin" after training. The second key outcome was the one that is clinically most important: all these studies found a significant change in participants' attitudes about their own body. Specifically, psychological concerns they may have had about their own body shape and weight, as well as their own eating habits, were significantly reduced. This effect persisted for around one-month post-training.

Conclusions

BID is a key component of AN and a predicter of onset, treatment outcome and future relapse post-treatment. BID can be modified by targeted interventions which do not alter accuracy of body size judgements, instead change how a body of a particular size is categorised. This recalibration of the categorical boundary, challenging the participant's existing perceptions about themselves, seems to lead to a more global reassessment of eating disordered attitudes and a significant improvement in psychological profile. These promising findings obviously need further trials to determine the intervention's long-term effectiveness, but it potentially provides a tool to treat a particularly intractable chronic condition. Although, the application of this intervention has been focussed on women with AN, it may also be effective in other conditions which feature BID, most obviously bulimia nervosa and body dysmorphia disorder.

References

Papers of particular interest, published within the period of review, have been highlighted as: **

1) Berkman, N. D., Lohr, K. N., & Bulik, C. M. (2007). Outcomes of eating disorders: A systematic review of the literature. International Journal of Eating Disorders, 40, 293–309. Doi: 10.1002/eat.20369
2) Fichter, M. M., & Quadflieg, N. (2016). Mortality in eating disorders—Results of a large prospective clinical longitudinal study. International Journal of Eating Disorders., 49, 391–401. https://doi.org/10.1002/eat.22501
3) Khalsa, S. S., Portnoff, L. C., McCurdy□McKinnon, D., & Feusner, J. D. (2017). What happens after treatment? A systematic review of relapse, remission, and recovery in anorexia nervosa. Journal of Eating Disorders, 5(1), 1–12. https://doi.org/10.1186/s40337-017-0145-3
4) 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, 107-126. Doi: 10.1002/(SICI)1098-108X(199709)22:2%3C107::AID-EAT1%3E3.0.CO;2-J
5) Fairburn, C. G., Cooper, Z., & Shafran, R. (2003). Cognitive behaviour therapy for eating disorders: A “transdiagnostic” theory and treatment. Behaviour Research and Therapy, 41, 509–528. Doi:10.1016/s0005-7967(02)00088-8
6) **Junne, F., Wild, B., Resmark, G., Giel, K.E., Teufel, M. Martus, P., et al. (2019) The importance of body image disturbances for the outcome of outpatient psychotherapy in patients with anorexia nervosa: Results of the ANTOP□study. European Eating Disorders Review, 27(1), 49-58. Doi: 10.1002/erv.2623
   This study tests whether body image predicts the outcome of treatment in an out-patient cohort of 148 women with AN. Path analysis shows that negative body image at the beginning of treatment predicts stress during treatment, which in turn predicts negative mood at the end of treatment, which turn predicts BMI and score on the eating Disorder inventory at 12 months post-treatment.
7) Bluett, E. J., Lee, E. B., Simone, M., Lockhart, G., Twohig, M. P., Lensegrav□Benson, T., & Quakenbush□Roberts, B. (2016). The role of body image psychological flexibility on the treatment of eating disorders in a residential facility. Eating Behaviors, 23, 150–155. https://doi.org/10.1016/j.eatbeh.2016.10.002
8) Calugi, S. & Dalle Grave, R. (2019) Body image concern and treatment outcomes in adolescents with anorexia nervosa. International Journal of Eating Disorders 52, 582-585 DOI: 10.1002/eat.23031
9) **Lee, E. B., Ong, C. W., Twohig, M. P., Lensegrav□Benson, T., & Quakenbush□Roberts, B. (2018). Increasing body image flexibility in a residential eating disorder facility: Correlates with symptom improvement. Eating Disorders, 26(2), 185–199. https://doi.org/10.1080/10640266.2017.13662
   This study measured body image concerns and flexibility as predictors of treatment outcome in 103 female in-patients with an eating disorder. Changes in body image predicted changes in a range of measurements in psychological profile (controlling for BMI, depression and anxiety) and researchers conclude that their results show that body image is an important target for treatment.
10) Pellizzer, M.L., Waller, G. & Wade, T.D. (2018). Body image flexibility: A predictor and moderator of outcome in transdiagnostic outpatient eating disorder treatment. International Journal of Eating Disorders 51, 368-372. DOI: 10.1002/eat.22842
11) Berends, T., Boonstra, N., & van Elburg, A. (2018). Relapse in anorexia nervosa: A systematic review and meta-analysis. Current Opinion in Psychiatry, 31, 445-455. Doi: 10.1097/YCO.0000000000000453

12) Carter JC, Blackmore E, Sutandar-Pinnock K, Woodside DB. (2004). Relapse in anorexia nervosa: a survival analysis. Psychological Medicine 34:671–9. DOI: 10.1017/S0033291703001168
13) Phillipou A, Castle DJ, Rossell SL. (2018). Anorexia nervosa: Eating disorder or body image disorder? Australian & NZ Journal of Psychiatry 52:13–4. DOI: 10.1177/0004867417722640
14) Gardner, R. M., & Brown, D. L. (2014). Body size estimation in anorexia nervosa: A brief review of findings from 2003 through 2013. Psychiatry Research, 219, 407-410. Doi: 10.1016/j.psychres.2014.06.029
15) Skrzypek, S., Wehmeier, P. M., & Remschmidt, H. (2001). Body image assessment using body size estimation in recent studies on anorexia nervosa. A brief review. European Child & Adolescent Psychiatry, 10, 215-221. Doi: 10.1007/s007870170010
16) **Mölbert, S. C., Thaler, A., Mohler, B. J., Streuber, S., Romero, J., Black, M. J., . . . Giel, K. E. (2018). Assessing body image in anorexia nervosa using biometric self-avatars in virtual reality: attitudinal components rather than visual body size estimation are distorted. Psychological Medicine, 48, 642–653. Doi: 10.1017/S0033291717002008
This interesting study uses 3D scans of its participants to effectively create a 3D "photograph" of each of them, to which the investigators then applied a morph to simulate an increase or decrease in weight by up to 20%. Although this range of weight change is limited at this stage, the application of this kind of personalised, highly realistic stimuli is a clear pointer to the future of body perception research.
17) Mergen, J., Keizer, A., Koelkebeck, K., van den Heuvel, M. R. C., & Wagner, H. (2018). Women with anorexia nervosa do not show altered tactile localization compared to healthy controls. Psychiatry Research, 267, 446-454. Doi: 10.1016/j.psychres.2018.06.007
18) 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. Doi: 10.1002/(SICI)1099-0968(199706)5:2<75::AID-ERV190>3.0.CO;2-A.
19) Cornelissen, KK, Widrington, H, McCarty, K, Pollet, TV, Tovée, MJ. & Cornelissen, PL (2019) Are attitudinal and perceptual body image the same or different? Evidence from high-level adaptation. Body Image, 31, 35-47. DOI: 10.1016/j.bodyim.2019.08.001
20) Festinger, L. (1954). A theory of social comparison processes. Human Relations, 7, 117-140. Doi: 10.1177%2F001872675400700202
21) Cornelissen P.L., Johns, A. and Tovée, M.J. (2013) Body size over-estimation in women with anorexic nervosa is not qualitatively different from female controls. Body Image, 10(1), 103-111. DOI: 10.1038/s41598-017-15339-z
22) Tovée, M. J., Benson, P. J., Emery, J. L., Mason, S. M., & Cohen-Tovée, E. M. (2003). Measurement of body size and shape perception in eating-disordered and control observers using body shape software. British Journal of Psychology, 94, 501–516. DOI: 10.1348/000712603322503060
23) Poulton, E. C. (1989). Bias in quantifying judgements. Hove, UK: Erlbaum.
24) Cornelissen KK, Bester A, Cairns P, Tovee MJ and Cornelissen PL (2015) The influence of personal BMI on body size estimations and sensitivity to body size change in anorexia spectrum disorders. Body Image, 13, 75-85.
25) Liechty JM. (2010). Body image distortion and three types of weight loss behaviors among non-overweight girls in the United States. Journal of Adolescent Health, 47, 176–182. DOI: 10.1016/j.jadohealth.2010.01.004
26) Fairburn, C. G., Bailey-Straebler, S., Basden, S., Doll, H.A., Jones, R., Murphy, R. et a'. (2015) A transdiagnostic comparison of enhanced cognitive behaviour therapy (CBT-E) and interpersonal psychotherapy in the treatment of eating disorders. Behaviour Research Therapy, 70, 64-71. Doi: 10.1016/j.brat.2015.04.010
27) Hay, P. J., Claudino, A. M., Touyz, S., & Abd Elbaky, G. (2015). Individual psychological therapy in the outpatient treatment of adults with anorexia nervosa. The Cochrane Library.
28) Murray, S. B., Quintana, D. S., Loeb, K. L., Griffiths, S., & Le Grange, D. (2019). Treatment outcomes for anorexia nervosa: A systematic review and meta-analysis of randomized controlled trials. Psychological Medicine, 49, 535-544. Doi: 10.1017/s0033291718002088

29) Khalsa, S.S., Portnoff, L.C., McCurdy-McKinnon, D. & Feusner, J.D. (2017). What happens after treatment? A systematic review of relapse, remission, and recovery in anorexia nervosa. Journal of Eating Disorders, 5, 20. DOI:10.1186/s40337-017-0145-3
30) Zipfel, S., Giel, K.E., Bulik, C.M., Hay, P. & Schmidt, U. (2015). Anorexia nervosa: Aetiology, assessment, and treatment. The Lancet Psychiatry, 2, 1099-1111. DOI: 10.1016/S2215-0366(15)00356-9
31) van den Berg, E., Houtzager, L., de Vos, J., Daemen, I., Katsaragaki, G., Karyotaki, E., Cuijpers, P., & Dekker, J. (2019). Meta-analysis on the efficacy of psychological treatments of anorexia nervosa. European Eating Disorder Review, 27, 331-351. Doi: 10.1002/erv.2683
32) Castro J, Gila A, Puig J, Rodriguez S, Toro J. (2004). Predictors of rehospitalization after total weight recovery in adolescents with anorexia nervosa. International Journal of Eating Disorders, 36:22–30. DOI:10.1002/eat.20340
33) **Gledhill LJ, Cornelissen KK, Cornelissen PL, Penton-Voak IS, Munafo MR & Tovée MJ (2016) An interactive training programme to treat body image disturbance. British Journal of Health Psychology. Doi: 10.1111/bjhp.12217.
This paper details the application of a cognitive bias program to recalibrate how participants categorize body weight. In the first study they reported a 2-arm RCT in which women with high body image concerns were randomly allocated into intervention and control conditions. The cohort that received the active intervention showed not only significant improvement in body image, but also a general improvement in psychological profile. In a second study this positive outcome is replicated in a cohort of women with atypical AN.
34) Irvine, KR, Irvine, A, Maalin, N, McCarty, K, Cornelissen, KK, Toveé, MJ, & Cornelissen, PL (2020) Using immersive virtual reality to modify body image. Body Image, 33, 232-234. Doi: 10.1016/j.bodyim.2020.03.007
35) Penton-Voak, I. S., Thomas, J., Gage, S. H., McMurran, M., McDonald, S., & Munafò, M. R. (2013). Increasing recognition of happiness in ambiguous facial expressions reduces anger and aggressive behaviour. Psychological Science, 24, 688–697. Doi: 10.1177/0956797612459657
36) Hakamata, Y., Lissek, S., Bar-Haim, Y., Britton, J.C., Fox, N.A., Leibenluft, E., et al. (2010) Attention bias modification treatment: a meta-analysis toward the establishment of novel treatment for anxiety. Biological Psychiatry, 68(11), 982-990. Doi: 10.1016/j.biopsych.2010.07.021
37) Tovée, M. J., Edmonds, L., & Vuong, Q. C. (2012). Categorical perception of human female physical attractiveness and health. Evolution and Human Behavior, 33, 85-93. Doi: 10.1016/j.evolhumbehav.2011.05.008
38) Szostak, N. M. (2018). Negative body image and cognitive biases to body size. (Doctoral thesis). Retrieved from: https://hydra.hull.ac.uk/resources/hull:16444

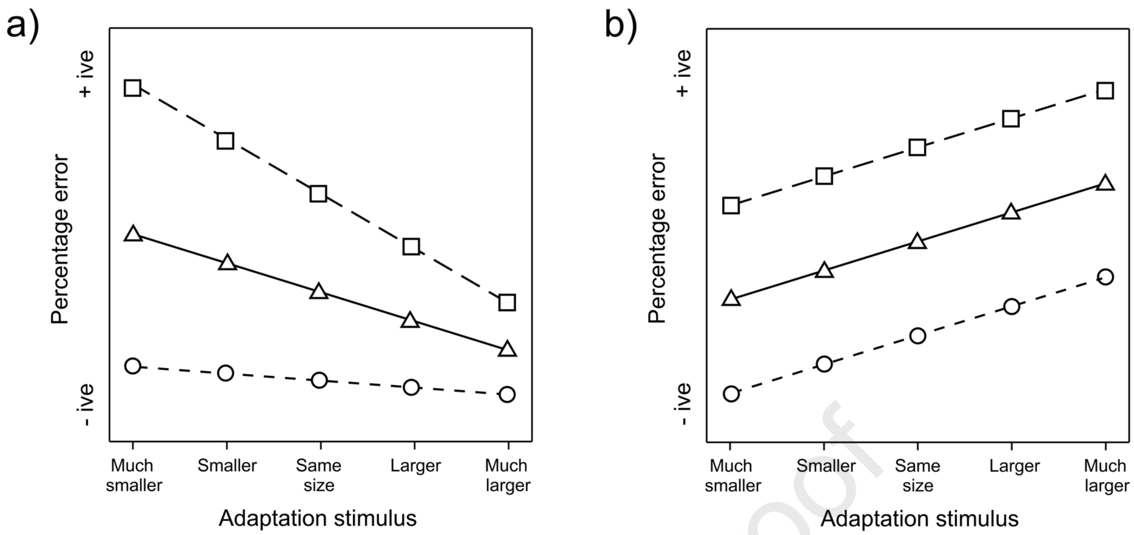
Figure Legends

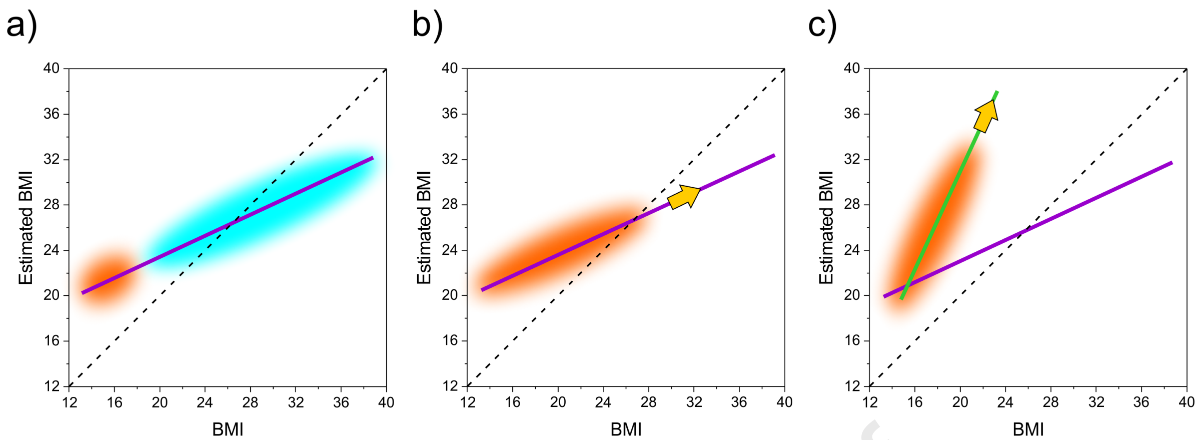
Figure 1: a) Sketch graph to show predicted effects of adaptation for the “perception as proxy for attitude” hypothesis. The y-axis represents percentage error in post-adaptation body-size estimation. Negative values represent under-estimation and positive values over-estimation. The x-axis corresponds to the size of the adapting stimulus relative to the body size of the observer. b) Sketch graph to show predicted effects of adaptation for the “independence” hypothesis. For Sketch graphs a) and b), the adaptation effects are shown separately for low (circles), medium (triangles), and high (squares) body image concerns.

Figure 2: a) Schematic representation of the results from Cornelissen et al. (2013) with women with AN in orange and healthy controls in cyan; b) The pattern of body size estimation predicted by the contraction bias model in women with AN, or recovering from AN, who have a wider range of BMI; c) The pattern of body size over estimation in women with AN whose perceptual body image is distorted, and follows a different trajectory from that predicted by contraction bias. In a), b), and c) the dashed line represents veridical performance, where body size estimates are perfectly accurate.

Figure 3: shows the relationship between participants' BMI (x-axis) and their subjective estimate of body size (PSE) separately for women with a history of AN (white) and healthy controls (black). The dotted black line represents the line of equality, where PSE matches BMI perfectly. The impact of psychometric performance on these relationships is illustrated by the separate lines for each group: i.e., the data are plotted for PSYCH (a latent variable derived from a principal components analysis of questionnaires assessing attitudes to body shape, eating, depression and self-esteem) at + 1 SD, dashed lines, and – 1 SD, solid lines.)

Figure 4: a) The middle row shows part of the body sequence varying in BMI. The top row illustrates the results from a baseline assessment and the position of the categorical boundary prior to training. The bottom row illustrates the results from the post-training test session, showing that the categorical boundary has shifted relative to the pre-training result. b) A plot of the mean value of BMI at the categorical boundary (predicted from the statistical modelling) as a function of measurement day. Magenta and red circles represent control group (Con) pre- and post-training thresholds respectively. Cyan and blue circles represent intervention group (Int) pre- and post-training thresholds respectively. c) A plot of the predicted differences between pre- and post-training categorical threshold, with 95% CIs, as a function of training day. Confidence intervals that straddle zero are not significant at $p < .05$. Blue circles represent the intervention group and red circles the control group. d) A plot of predicted global EDE-Q scores (reported as z-scores) as a function of measurement day. Blue circles represent the intervention group and red circles the control group. e) A plot of the predicted differences in global EDE-Q z-scores between the control and training groups as a function of measurement day, with 95% CIs, as a function of training day. Confidence intervals that straddle zero are not significant at $p < .05$.


a)
+ ive
Percentage error
- ive
Much smaller
Smaller
Same size
Larger
Much larger
Adaptation stimulus
b)
+ ive
Percentage error
- ive
Much smaller
Smaller
Same size
Larger
Much larger
Adaptation stimulus



a)
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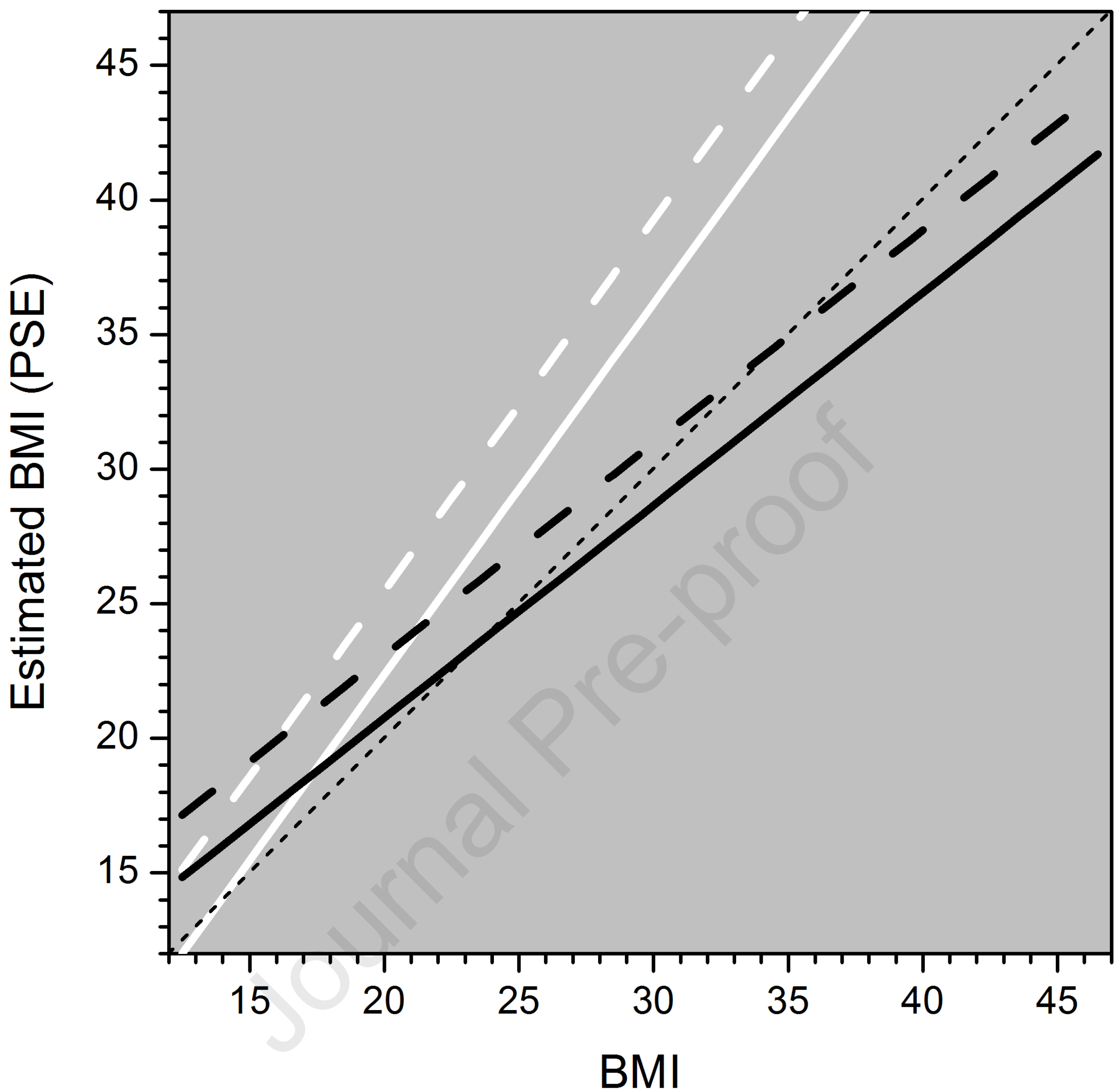
c)
Estimated BMI
BMI
40
36
32
28
24
20
16
12



Estimated BMI (PSE)
45
40
35
30
25
20
15
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35
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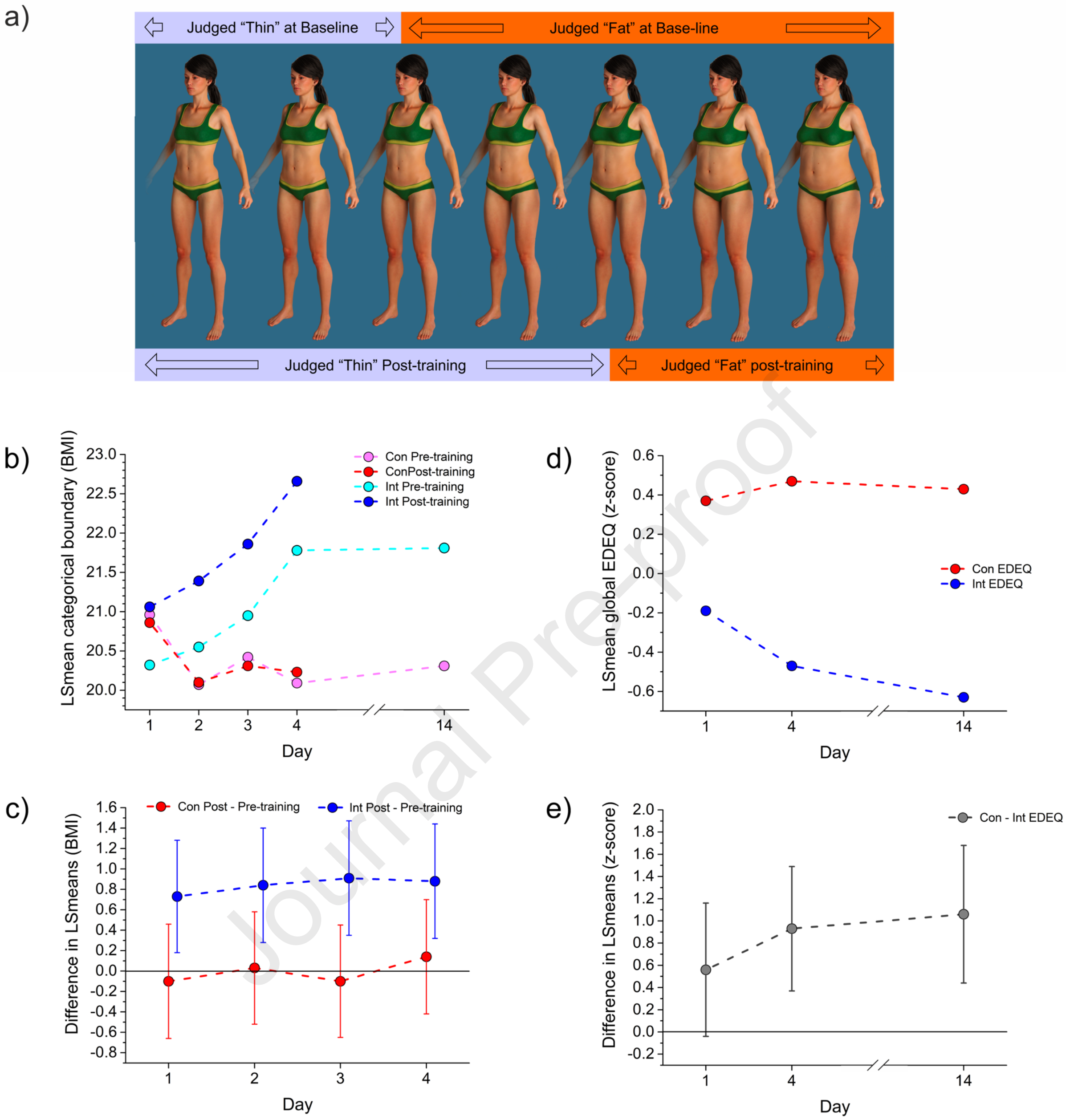
45
BMI


a)
Judged "Thin" at Baseline
Judged "Fat" at Base-line
Judged "Thin" Post-training
Judged "Fat" post-training
b)
LSmean categorical boundary (BMI)
Con Pre-training
ConPost-training
Int Pre-training
Int Post-training
Day
d)
LSmean global EDEQ (z-score)
Con EDEQ
Int EDEQ
Day
c)
Difference in LSmeans (BMI)
Con Post - Pre-training
Int Post - Pre-training
Day
e)
Difference in LSmeans (z-score)
Con - Int EDEQ
Day

Declaration of interests

☒ The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

☐The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: