Running Head: BODY PROJECT TREATMENT TARGET ENGAGEMENT

**Evidence that a Novel Transdiagnostic Eating Disorder Treatment Reduces Reward Region Response to the Thin Beauty Ideal and High-Calorie Binge Foods**

Eric Stice

Stanford University

Sonja Yokum

Paul Rohde

Jeff Gau

Oregon Research Institute

Heather Shaw

Stanford University

**Supplementary Methods**

#### **Participants and Procedure**

 The project coordinator was solely responsible for allocation and did not know which condition participants would be assigned to until each had completed their pretest assessment (there were 12 exceptions due to needing to assign participants to the waitlist condition in the initial phase of this trial because we could not implement groups during the holiday season; sensitivity analyses confirmed that this departure from full random assignment did not bias tests of intervention effects; Stice et al., 2019). Assessors were not informed of the allocation of participants to condition and baseline assessments were completed before allocation to condition, but 50 of the 138 follow-up assessments were completed by the project coordinator because no other assessor was available at the Texas site. Sensitivity analyses confirmed that this deviation from allocation concealment did not bias the estimates of the intervention effects, in that the parameter estimates of the effects when these 50 participants were excluded were not outside the 95% confidence intervals for the original parameter estimates.

**Non-fMRI Measures**

*Thin-ideal internalization.* The 8-item Thin-Ideal Internalization Scale (TIIS) assessed pursuit of the thin beauty ideal (Stice, Gau, Rohde, & Shaw, 2017)*.* Items were averaged for this and the scales described subsequently. This scale has shown internal consistency (.75), 2-week test-retest reliability (*r*=.80), predictive validity for bulimic symptom onset, and sensitivity to detecting intervention effects (Stice et al., 2019).

*Body dissatisfaction.* The 17-item *Satisfaction and Dissatisfaction with Body Parts Scale* (Berscheid, Walster, & Bohrnstedt, 1973) assessed body dissatisfaction. It has exhibited internal consistency (α=.94), 3-week test-retest reliability (*r*=.90), predictive validity for bulimic symptom onset, and sensitivity to detecting intervention effects (Stice et al., 2019).

 *Negative affect.* Negative affect was assessed with 20 items from the sadness, guilt, and fear/anxiety subscales of the *Positive Affect and Negative Affect Scale-Revised* (PANAS-X; Watson & Clark, 1992). This scale has shown internal consistency (=.95), 3-week test-retest reliability (*r*=.78), convergent validity, predictive validity for bulimic symptom onset, and sensitivity to detecting intervention effects (Stice et al., 2019).

*Food and Model Picture ratings.* Immediately after the scans, participants rated the attractiveness of the models (1=being least attractive to 9 being most attractive) and the palatability (1=being least appetizing to 9 being most appetizing) and monetary value ($1 to $10) of the foods. Attractiveness ratings of thin and average weight models and palatability and monetary ratings of high-calorie and low-calorie food images have shown sensitivity to detecting intervention effects (Stice, Yokum, Veling, Kemps, & Lawrence, 2017; Stice et al., 2015).

**Statistical Methods**

 *MRI acquisition and fMRI data preprocessing.* MRI data were acquired on a Siemens Skyra 3T MRI scanner. Functional scans used a T2\* weighted EPI plus sequence (72 slices, TE=25 ms, TR=2000 ms, flip angle=90°, matrix size=100 x 100, voxel size=2 mm3, axial slices=72, FOV=200, multiband acceleration factor=3). Structural scans were collected using a high-resolution anatomical T1-weighted MP-RAGE scan (TE=3.43 ms, TR=2500 ms, 256 x 256 matrix, voxel size=1 mm3, sagittal slices=176, FOV=256).

 Neuroimaging data were skullstripped using the Brain Extraction Tool in FSL (FMRIB Analysis Group, Oxford, UK) and then preprocessed and analyzed using SPM12 (Wellcome Department of Cognitive Neurology; [http://www.fil.ion. ucl.ac.uk/spm](http://www.fil.ion.ucl.ac.uk/spm)) in Matlab (Mathworks, Inc., Natick, MA). During preprocessing, functional data were preprocessed as follows: (1) adjusted for variation in magnetic field distortion using field maps; (2) realigned to the mean functional from that run and coregistered with the anatomical; and (3) normalized to Montreal Neurological Institute (MNI) space using the DARTEL template and deformation fields output. Functional data were smoothed to 6 mm Gaussian full-width-at-half-maximum (FWHM). A 128 second high-pass filter removed low-frequency noise and signal drift. Head motion greater than 2 mm or degrees in any direction was our *a priori* exclusion criteria. Artifact Detection Toolbox (ART; Gabrieli Laboratory, McGovern Institute for Brain Research, Cambridge MA) was used to detect global mean response spikes and motion outliers. Motion parameters were used as regressors and outlier image volumes (<2 mm) were de-weighted during individual-level model estimation. Anatomical images were coregistered to the mean functional image and segmented into 6 tissue types using unified segmentation approach (Ashburner & Friston, 2005). DARTEL was used to create a group anatomical template, tranformations from which were applied to warp functional data to the ICBM-152 template supplied with SPM12 (Ashburner, 2007).

 *fMRI data analysis.* At the subject level, BOLD signal was modeled in a fixed effects analysis with separate regressors modeling each condition of interest for each task for pretest and posttest separately. T-maps were constructed for comparisons of activation within participants for the following contrasts: model picture paradigm: thin models versus average-weight models; food picture paradigm: high-calorie binge foods versus low-calorie foods. We also performed *a priori* regions-of-interest (ROI) analyses within the caudate and ventromedial prefrontal cortex (vmPFC) to test for significant pre-post changes within these regions. Morphology-based regions of interests (ROIs) were generated using the Montreal Neurological Institute (MNI) average adult MRI template. For the caudate, we created an ROI that included bilateral caudate. Peak activity was considered significant at a peak level of *p*<0.05 FWE corrected across the total number of voxels across the ROI. For the vmPFC, we used a spherical ROI (10-mm diameter spheres) centered at peak coordinates from published papers (Hare, Camerer, & Rangel, 2009; Smith, Hayden, Truong, Song, Platt, & Huettel, 2010; Winston, O'Doherty, Kilner, Perrett, & Dolan, 2007). Peak activity with *p*-values ≤0.05 corrected using voxel-level familywise error rate (pFWE) over the 10 mm sphere were considered significant.

**Supplementary Results**

**Relations of pre-post changes in neural response to thin models and high-calorie foods to pre-post changes in other outcomes**

We tested if pre-post BOLD response changes correlated with pre-post changes in self-reported outcomes. Although correlations did not survive adjustment for multiple comparisons, the uncorrected associations are considered. Pre-post changes in right caudate response (MNI coordinates: 12, 17, -1) to the contrast thin > average-weight models correlated negatively with pre-post attractiveness ratings of average-weight models (*r*=-0.25, *p*=0.01), suggesting that the change in right caudate activation to thin models was related to increased perceived attractiveness of average-weight models. Pre-post changes in left vlPFC response to the contrast high-calorie > low-calorie foods correlated negatively with pre-post change in monetary value of low-calorie foods (*r*=-0.21, *p*=0.03), suggesting that a pre-post reduction in left vlPFC activation to high-calorie binge foods is related with an increase in monetary value of low-calorie foods.

Table 1S

Comparison of Condition, Demographics and Baseline Outcomes by Participants who Completed Baseline and Posttest Assessments versus Participants who Dropped Out at Posttest.

|  |  |  |  |
| --- | --- | --- | --- |
|  | Completed Baseline and Posttest (*n*=125) | Completed Baseline Only(*n*=3) | Test Statistics |
| Condition (%) |  |  |  |  |  |
| Waitlist control |  | 41.9 |  | 23.1 | *χ*2[2,138]=2.47, *p*=.291 |
| Early symptom BPT  |  | 36.8 |  | 38.5 |  |
| Original BPT  |  | 21.6 |  | 38.5 |  |
| Age [*Mean*, (*SD*)] | 21.9 | (3.4) | 22.6 | (3.3) | *t*[136]=0.67, *p*=504 |
| Hispanic (%) |  | 15.4 |  | 0.0 | *χ*2[1,135]=2.16, *p*=.142 |
| Race (%) |  |  |  |  | *χ*2[4,135]=0.66, *p*=.956 |
| Asian |  | 15.6 |  | 15.4 |  |
| Black or African American |  | 4.1 |  | 7.7 |  |
| American Indian/Alaskan Native |  | 1.6 |  | 0.0 |  |
| Caucasian |  | 77.9 |  | 76.9 |  |
| Other |  | 0.8 |  | 0.0 |  |
| Maximum parental education (%) |  |  |  |  |  |
| Some high school |  | 4.8 |  | 0.0 | *χ*2[4,138]=1.67, *p*=.799 |
| High school graduate  |  | 5.6 |  | 0.0 |  |
| Some college |  | 15.2 |  | 15.4 |  |
| College graduate |  | 31.2 |  | 30.8 |  |
| Advanced degree |  | 43.2 |  | 53.8 |  |
| Baseline outcomes [*Mean*, (*SD*)] |  |  |  |  |  |
| Eating disorder symptoms | 42.0 | (23.4) | 42.8 | (20.6) | *t*[136]=0.12, *p*=906 |
| Thin-ideal internalization | 3.7 | (0.4) | 3.7 | (0.4) | *t*[134]=0.48, *p*=.635 |
| Body dissatisfaction | 4.1 | (0.7) | 4.0 | (0.5) | *t*[136]=-0.39, *p*=.698 |
| Negative affect | 3.4 | (0.8) | 3.5 | (0.6) | *t*[136]=0.31, *p*=.759 |
| Palatability high calorie foods | 5.7 | (1.4) | 6.4 | (1.0) | *t*[122]=1.56, *p*=.121 |
| Palatability low calorie foods | 5.2 | (1.2) | 4.7 | (1.1) | *t*[122]=-1.19, *p*=.233 |
| Monetary value high-calorie foods | 4.1 | (1.6) | 5.1 | (1.5) | *t*[134]=2.07, *p*=.041 |
| Monetary value low-calorie foods | 4.3 | (1.3) | 4.5 | (1.4) | *t*[134]=0.72, *p*=.471 |
| Attractiveness thin models | 6.4 | (1.4) | 6.6 | (0.9) | *t*[134]=0.40, *p*=.688 |
| Attractiveness average-weight models | 4.9 | (1.5) | 5.2 | (1.8) | *t*[120]=0.59, *p*=.571 |
| Abstinence from binges, vomiting, and laxative/diuretic use (*%*) |  | 7.2 |  | 0.0 | *χ*2[1,138]=1.00, *p*=.317 |

Table 2S

*Results of Condition × Time × Baseline Eating Disorder Symptoms Effects from Mixed Effects Growth Models Comparing Combined BPT (n=83) and Waitlist Control Participants (n=55)*

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Outcome | Estimate | *SE* | *t*-value | *p*-value |
| Eating disorder symptoms | 0.12 | 0.12 | 1.03 | .305 |
| Thin-ideal internalization | -0.01 | 0.07 | -0.09 | .926 |
| Body dissatisfaction | 0.11 | 0.14 | 0.81 | .416 |
| Negative affect | -0.10 | 0.14 | -0.69 | .488 |
| Palatability high calorie foods | 0.01 | 0.27 | 0.04 | .965 |
| Palatability low calorie foods | -0.06 | 0.21 | -0.28 | .787 |
| Monetary value high-calorie foods | -0.07 | 0.24 | -0.31 | .759 |
| Monetary value low-calorie foods  | -0.15 | 0.22 | -0.69 | .491 |
| Attractiveness thin models  | -0.14 | 0.23 | -0.61 | .545 |
| Attractiveness average-weight models | -0.17 | 0.24 | -0.73 | .467 |
| *SE*=standard error. Note. The waitlist control is the reference category (i.e., dummy coded 0) |

**Supplemental References**

Ashburner, J. (2007). A fast diffeomorphic image registration algorithm. *NeuroImage, 38*(1), 95-113.

Ashburner, J., & Friston, K. J. (2005). Unified segmentation. *NeuroImage, 26*(3), 839-851.

Hare, T. A., Camerer, C. F., & Rangel, A. (2009). Self-control in decision-making involves modulation of the vmPFC valuation system. *Science, 324*(5927), 646-648.

Smith, D. V., Hayden, B. Y., Truong, T. K., Song, A. W., Platt, M. L., & Huettel, S. A. (2010). Distinct value signals in anterior and posterior ventromedial prefrontal cortex. *Journal of Neuroscience, 30*(7), 2490-2495.

Stice, E., Gau, J. M., Rohde, P., & Shaw, H. (2017). Risk factors that predict future onset of each DSM-5 eating disorder: Predictive specificity in high-risk adolescent females. *Journal of Abnormal Psychology, 126*(1), 38-51.

Stice, E., Yokum, S., Rohde, P., Shaw, H., Gau, J. M., Johnson, S., & Johns, A. (2019). Randomized trial of a dissonance-based transdiagnostic group treatment for eating disorders: An evaluation of target engagement. *Journal of Consulting and Clinical Psychology, 87*(9), 772-786.

Stice, E., Yokum, S., & Waters, A. (2015). Dissonance-Based Eating Disorder Prevention Program Reduces Reward Region Response to Thin Models; How Actions Shape Valuation. *PLoS One, 10*(12), e0144530.

Watson, D., & Clark, L. . (1992). Affects separable and inseparable: On the hierarchical arrangement of the negative affects. *Journal of Personality and Social Psychology, 62*(3), 489-505.

Winston, J. S., O'Doherty, J., Kilner, J. M., Perrett, D. I., & Dolan, R. J. (2007). Brain systems for assessing facial attractiveness. *Neuropsychologia, 45*(1), 195-206.