Disorder specific rewarding stimuli in anorexia nervosa

Ann-Kathrin Kogel1 | Stephan Herpertz1 | Sabine Steins-Loeber2 | Martin Diers1

1Department of Psychosomatic Medicine and Psychotherapy, LWL University Hospital, Ruhr University Bochum, Bochum, Germany
2Department of Clinical Psychology and Psychotherapy, Otto-Friedrich-University of Bamberg, Bamberg, Germany

Abstract

Objective: To enhance our understanding of reward stimuli in anorexia nervosa (AN) and to provide a basis for future research on reward processes, disorder specific reward stimuli as well as primary and secondary reinforcers were investigated.

Method: We developed a set of pictures with “disorder specific reward” stimuli, with the six subcategories “sport,” “losing weight,” “healthy food,” “discipline,” “thin bodies,” and “appreciation of others,” and evaluated reward ratings of these “disorder specific reward” stimuli as well as “erotic,” “high caloric,” and “neutral” stimuli in patients with AN and participants in the comparison group (CG).

Results: We found a significant main effect for picture category and a significant interaction. The reward ratings were higher in patients with AN compared with CG for the “disorder specific reward” stimuli. In the reward subcategories, patients with AN had higher reward ratings compared with CG in all categories except for healthy food. The “disorder specific reward” stimuli of the categories “sport,” “losing weight,” and “healthy food” showed higher reward ratings compared with the categories “discipline,” “thin bodies,” and “appreciation of others” in patients with AN.

Discussion: The previously used category “thin bodies” used to investigate the reward system might be less effective compared with stimuli from the categories “sport,” “losing weight,” and “healthy food.”

KEYWORDS
anorexia nervosa, reward system, disorder specific reward, weight loss

1 | INTRODUCTION

Overall, AN ranks among the deadliest mental illnesses (Arcelus, Mitchell, Wales, & Nielsen, 2011; Herpertz et al., 2019; German-S3-Guideline: https://www.awmf.org/leitlinien/detail/ll/051-026. html; August 25, 2020) with high morbidity (Herpertz-Dahlmann, 2009; Zipfel, Giel, Bulik, Hay, & Schmidt, 2015), comorbidity (Herpertz-Dahlmann, 2009; Kaye, Bulik, Thornton, Barbarich, & Masters, 2004; Lewinsohn, Striegel-Moore, & Seeley, 2000; Woodside & Staab, 2006), and mortality (Arcelus et al., 2011; Löwe et al., 2001). Among efforts to identify risk factors and mechanisms underlying the development of AN, increasingly, researchers have focused on the reward system (Haynos, Lavender, Nelson, Crow, & Peterson, 2020; Kaye, Wierenga, Bailer, Simmons, & Bischoff-Grethe, 2013; O’Hara, Campbell, & Schmidt, 2015; Wierenga et al., 2014). However, our knowledge of the specific processes in which these risk factors are involved in the development and maintenance of eating disorders is still limited. For the investigation of the reward system secondary as well as primary reinforcers as money, sex, or food were used (named general rewarding stimuli). In patients with AN, money and tasty food were used (e.g., Bischoff-Grethe et al., 2013) to assess dysfunction in the mesolimbic reward system (Robinson & Berridge, 2008) and a reduced activation in the reward system (e.g., the nucleus
caudatus) was reported (Frank et al., 2005). However, high caloric food is processed aversively-anxiously and leads to inhibitory control (Wierenga et al., 2014). Less is known about the processing of erotic stimuli though some evidence suggests that pictures displaying intimate scenes are rated as less pleasant by individuals with AN compared with controls (Maier et al., 2019). Taken together, these findings suggest that for the activation of the reward system in patients with AN, disorder specific reward stimuli (as female bodies with underweight or sporting pursuit) are necessary (Godier & Park, 2014; O’Hara et al., 2015; Walsh, 2013).

The reward-centered-model of AN postulates that disorder specific stimuli are perceived as rewarding whereas food-associated stimuli are perceived as aversive (O’Hara et al., 2015). At present, there are only few studies using disorder specific reward stimuli. The presentation of underweight bodies was perceived as more rewarding compared with normal weight bodies in patients with AN, a finding reversed in controls leading to an activation of the ventral striatum (Fladung et al., 2010; Fladung, Schulze, Schöll, Bauer, & Grön, 2013). These findings were replicated with peripheral physiological measures (Clarke, Ramoz, Fladung, & Gorwood, 2016). Patients with AN show an attention bias to underweight female bodies (Horndasch, Kratz, et al., 2018) and to sporting pursuit (Giel et al., 2013), are processing underweight female bodies as positive (O’Hara, Keyes, Renwick, Giel, et al., 2016), and evaluate physical activity as rewarding (O’Hara, Keyes, Renwick, Leyton, et al., 2016). In a go/no-go task with physical activity cues patients with AN displayed increased prefrontal cortex activation compared with controls (Kullmann et al., 2014).

Until now, there has been no systematic investigation on disorder specific reward stimuli, unlike for other disorders, especially addictive behavior. For example, in smokers, differential effects for smoking stimuli are observed depending on their stage in the smoking ritual (Mucha, Pauli, Weber, & Winkler, 2008; Stippkeohl et al., 2010). In addition, apart from proximal cues, which are closely related to the substance itself (e.g., displaying a cigarette or a cigarette package), distal cues (e.g., the environment in which smoking takes place), are also able to induce cue-reactivity (Conklin, Robin, Perkins, Salkeld, & McClemont, 2008). Regarding AN and taking into account the complexity of the psychopathology, underweight bodies, and physical activity might be only two relevant stimulus categories with other categories of relevant stimuli remaining unexplored. To enhance our understanding of reward system deficiency in AN, it is therefore important to systematically assess the subjective evaluation of disorder specific reward stimuli to provide a valid basis to further investigate mechanisms that may contribute to the development and maintenance of AN in future research. Hence, the aim of the present study was the identification and evaluation of specific reward stimuli for patients with AN. For the evaluation of this developed stimulus category we compared reward ratings of these stimuli with ratings of neutral stimuli and high caloric food stimuli, and we explored ratings regarding erotic stimuli as a less investigated type of a primary reinforcer. We expected that patients with AN would rate disorder specific reward stimuli as more rewarding than the comparison group (CG) and as more rewarding than the other categories.

## Methods

### Participants and clinical assessment

Derived from the effect size of Fladung et al. (2013) and taking into account that our reward stimuli were newly developed and expand the stimulus material of Fladung et al., we chose an effect size of 0.2 for the power calculation. This suggests a sample size of n = 46 for a MANOVA, an alpha error of .05 and a beta error of .90. To allow for a normal attrition rate of 10% we tested 50 female participants, 25 patients with AN and 25 CP matched for age. All participants (AN and CP) were aged over 18 years. The participants with AN were recruited from the Department of Psychosomatic Medicine and Psychotherapy, LWL University Hospital, Ruhr University Bochum (RUB). The CP were recruited via advertisements; exclusion criteria were a current or past eating disorder diagnosis and an Eating Disorder Examination Questionnaire (EDE-Q, Fairburn & Beglin, 1994) score ≥ 2.3 (Hilbert, de Zwaan, & Braehler, 2012; Mond, Hay, Rodgers, Owen, & Beumont, 2004). Informed consent was obtained and the study was approved by the ethics committee of the faculty of medicine at the RUB and adhered to the Declaration of Helsinki.

In addition to the demographic and clinical data, the German Version of the EDE-Q, the German Version of the Body Shape Questionnaire (BSQ/FFB; Pook, Brähler, & Tuschen-Caflisch, 2009), and the German Version of the Sociocultural Attitudes Toward Appearance Questionnaires (SATAQ-G; Knauss, Paxton, & Alaker, 2007) were assessed.

### Determination of rewarding categories

To identify possible categories of reward stimuli we applied a two-stage process. At stage one we used open qualitative interviews in five patients with AN to identify disorder specific reward situations, events or emotions. From this information, we then constructed a structured/semi structured questionnaire (see Supplementary Material) which was in stage two assessed in an independent sample of 26 patients with AN and 40 participants in the CG. In the structured part, we assessed positive emotions [visual analog scale (VAS) ratings 0–10] in response to 45 specific rewarding situations in patients with AN and CG. In the semi structured part, we described five specific scenarios (e.g., “Imagine that you have finally reached your goal of wearing a special skinny jeans”) and asked in patients with AN and CG to describe up to three emotions induced by these scenarios and to elaborate on why these emotions are experienced. In addition, patients with AN and the CG rated their positive emotions to these scenarios on the VAS. Lastly, patients with AN were asked open questions regarding whether there are positive emotions or happiness elicited by the disorder, rewarding or motivating aspects, description of a perfect day, and reasons for not stopping starvation. The analysis of this questionnaire revealed six sub-categories of rewarding situations: “sport,” “losing weight,” “healthy food,” “discipline,” “thin bodies,” and “appreciation of others.” For these categories we compiled visual stimuli.
2.3 Visual stimuli and ratings

We used pictures of four categories, 24 “neutral”, 24 “high caloric”, 24 “erotic”, and 24 “disorder specific reward” pictures. The disorder specific reward category consists of the six subcategories named above with four pictures for each subcategory. “High caloric” food pictures (e.g., cream cake, muffin, burger, lasagna) and “neutral” pictures (e.g., chair, dresser, stones) were used from the “Food-Pics” database (Blechert, Meule, Busch, & Ohla, 2014). The “erotic” pictures (e.g., scantily dressed couples kissing) were selected via Google picture search. We chose pictures similar to the International Affective Picture System (IAPS, Lang, Bradley, & Cuthbert, 2008), but did not use the original IAPS pictures as the resolution was lower than pictures of food. The “disorder specific reward” pictures (e.g., for “sport”: jogging, abdominal muscle training; for “losing weight”: measuring the body girth or weight; oversized clothing; for “healthy food”: apples, broccoli; for “discipline”: women rejecting high caloric food or choosing healthy food; for “thin bodies”: female underweight bodies; for “appreciation of others”: female models posing) were also selected via Google picture search. All pictures and their sources can be found in Table S4 in the Supplementary Material. For all categories, the objects were presented on a white background (600 × 450 pixel). Pictures were matched for object size, intensity (brightness), complexity (number of pixels at the object border), and norm-complexity (ratio of number of pixels at the object border to enclosed pixels; Blechert et al., 2014). To compare the picture attributes, a general linear model was used. We did not find significant differences between the categories for object size [F(3,92) = 2.484, p = .066, partial η² = 0.075], intensity [F(3,92) = 0.230, p = .875, partial η² = 0.007], complexity [F(3,92) = 1.151, p = .333, partial η² = 0.036], and norm-complexity [F(3,92) = 0.010, p = .999, partial η² = 0.000].

In total, we had 96 pictures divided into 24 sets of four pictures comprised of one picture of each category presented in a randomized order. Randomization was done with www.randomizer.org (last requested on October 20, 2020). We assured that the picture category of the fourth picture of a set was never the same as the first picture in the following set. Each category was presented five to seven times on every position. Participants were instructed to look at the picture and then answer to the questions. They had to rate how rewarding they perceived the picture (“How rewarding is this picture for you?”)—on an 11-point numerical rating scale (0 = not at all to 10 = very). We also assessed valence (“How positive are your emotions when looking at this picture?”), and arousal ratings (“How aroused are you when looking at this picture”; Bradley & Lang, 1994) for each picture. These ratings are not related to the present research question, but might be interesting for researchers who want to match pictures of different categories regarding valence and arousal. Therefore, descriptive data are presented in Table S4.

2.4 Data analysis

For group comparisons on the demographic and clinical variables, two-tailed two sample t-tests after testing for normal distribution were applied. Comparisons of ratings of the four picture categories between the two groups were done with a mixed-between-within ANOVA and post hoc pair wise comparisons with the four picture categories as within factor and group as between factor. To compare the reward rating in the six subcategories between the two groups we also computed a mixed between-within ANOVA with post hoc pair wise comparisons with the six reward subcategories as within factor and group as between factor. We performed a correlation analysis using Pearson’s coefficient (r) to test the association between the eating-disorder psychopathology and the reward ratings of the six “disorder specific reward” pictures.

The level of significance was set at p < .05. Cohen’s d effect size and the 95% Confidence Interval are reported. There were no missing data. Statistical analysis was conducted with IBM SPSS Statistics 26 (Chicago, Illinois).

2.5 Availability of data

All data presented in this article can be accessed via: https://doi.org/10.17605/OSF.IO/4YVUN.

3 RESULTS

Mean age of the AN group (restricting type n = 18, binge eating/purging type n = 7) was 26.80 (±7.94) years, mean body mass index (BMI) was 16.12 (±2.11) kg/m². Mean age of the CG was 23.88 (±5.87) years, mean BMI was 22.64 (±5.11) kg/m² (see Table 1). Both groups were not significantly different for age [t(48) = 1.478, p = .146, d = 0.418, 95%CI (−1.051, 6.891)]. The main effect of group was not significant [F(1,48) = 2.951 to 0.118], and BMI was significantly lower [t(48) = −5.904, p < .001, d = 1.668, 95%CI (−8.776, 4.273)] in the patients with AN compared with the CG.

3.1 Comparison of the four categories: Disorder specific reward, erotic, high caloric, and neutral

We found a significant main effect for picture category [F(3,144) = 20.714, p < .001, partial η² = 0.301] which was qualified by a significant category by group interaction effect [F(3,144) = 7.336, p < .001, partial η² = 0.133]. The main effect of group was not significant [F(1,48) ≤ 0.001, p = .987, partial η² ≤ 0.001]. To specify the significant interaction effect the four picture categories were first compared between groups. Only “reward” was rated as significantly more rewarding in the patients with AN compared with the CG [t(48) = 4.040, p ≤ .001, d = 1.649, 95% CI(0.986 to 2.940)]. In contrast, “erotic” [t(48) = 0.004, p = .997, d = 0.002, 95% CI(−1.686 to 1.693)], “high caloric” [t(48) = −1.856, p = .070, d = −0.758, 95% CI (−2.951 to 0.118)], and “neutral” [t(48) = −1.891, p = .065, d = −0.772, 95% CI(−1.193 to 0.364)] were not significantly different between groups. In the patients with AN, “disorder specific reward” had higher ratings than “high caloric” and “neutral,” while “erotic,” and “high caloric” had also higher ratings than “neutral.” In the CG “disorder specific reward,” “high caloric,” and “erotic” had higher ratings than “neutral,” but “disorder specific reward” had lower ratings.
than “high caloric” and “erotic.” All other comparisons were not significantly different (see Figure 1 and Table 2).

### 3.2 Comparison of reward ratings in the reward subcategories

We found a significant main effect for reward subcategory \[F(5,240) = 18.693, p < .001, \text{partial } \eta^2 = 0.280\] and a significant group effect \[F(1,48) = 16.321, p < .001, \text{partial } \eta^2 = 0.254\]. However, the interaction was not significant \[F(5,240) = 1.729, p = .129, \text{partial } \eta^2 = 0.035\]. To specify the significant group effect the six reward subcategories were compared between groups. The subcategory “sport” \[t(48) = 2.527, p = .015, d_j = 0.0, 95\% \text{ CI}(0.460 \text{ to } 4.040)\], “losing weight” \[t(48) = 3.909, p < .001, d_j = 0.0, 95\% \text{ CI}(1.515 \text{ to } 4.725)\], “discipline” \[t(48) = 2.350, p = .023, d_j = 0.0, 95\% \text{ CI}(0.182 \text{ to } 2.338)\], “thin bodies” \[t(48) = 2.847, p < .001, d_j = 0.0, 95\% \text{ CI}(0.218 \text{ to } 2.862)\] were rated significantly higher in the patients with AN compared with the CG, “healthy food” \[t(48) = 1.814, p = .076, d_j = 0.0, 95\% \text{ CI}(0.141 \text{ to } 2.741)\] was not significantly different between groups. In the patients with AN, “sport” had higher ratings than “discipline,” “thin bodies,” and “appreciation of others”; “losing weight” had higher ratings than “discipline,” “thin bodies,” and “appreciation of others”; “healthy food” had higher ratings than “discipline,” “thin bodies,” and “appreciation of others.” In the CG “sport” had higher

### TABLE 1

Demographic and clinical characteristics

|                      | AN \((n = 25)\) \(M \pm SD\) | CG \((n = 25)\) \(M \pm SD\) | \(t\) | df | \(p\) | \(d\) | 95\% CI          |
|----------------------|-----------------------------|-----------------------------|-----|----|-----|-----|----------------|
| Age \(\text{years}\) | 26.80 ± 7.94                | 23.88 ± 5.87                | 1.478 | 48 | .146 | 0.418 | –1.051 to 6.891 |
| BMI \(\text{kg/cm}^2\) | 16.12 ± 2.11               | 22.64 ± 5.11               | –5.904 | 31.957 | <.001 | 1.668 | –8.776 to 4.273 |
| EDE-Q                |                             |                             |      |    |     |     |                |
| Restraint eating     | 4.63 ± 2.04                 | 1.73 ± 0.73                 | 6.711 | 30.107 | <.001 | 1.893 | 2.020 to 3.788  |
| Weight concern       | 3.26 ± 1.48                 | 1.55 ± 0.42                 | 5.527 | 27.776 | <.001 | 1.572 | 1.072 to 2.336  |
| Shape concern        | 3.87 ± 1.46                 | 1.94 ± 0.54                 | 6.208 | 30.402 | <.001 | 1.753 | 1.299 to 2.571  |
| Eating concern       | 3.53 ± 1.74                 | 1.18 ± 0.19                 | 6.679 | 24.574 | <.001 | 1.899 | 1.621 to 3.067  |
| Total score          | 3.82 ± 1.59                 | 1.60 ± 0.39                 | 6.775 | 26.819 | <.001 | 1.918 | 1.549 to 2.895  |
| BSQ/FFB              | 119.12 ± 47.09              | 55.16 ± 17.08               | 6.384 | 30.206 | <.001 | 1.806 | 43.506 to 84.414 |
| SATAQ-G              |                             |                             |      |    |     |     |                |
| Internalization      | 19.88 ± 5.86                | 13.40 ± 5.80                | 3.928 | 48 | <.001 | 1.111 | 3.163 to 9.797  |
| Pressure             | 16.24 ± 5.76                | 12.00 ± 5.88                | 2.575 | 48 | .013 | 0.728 | 0.930 to 7.550  |
| Awareness            | 18.44 ± 3.95                | 14.60 ± 3.91                | 3.457 | 48 | .001 | 0.977 | 1.607 to 6.073  |

Abbreviations: 95\% CI, 95\% confidence interval; AN, anorexia nervosa; BMI, body mass index; BSQ/FFB, Body Shape Questionnaire (Pook et al., 2009); CG, comparison group; \(d\), Cohen’s \(d\); EDE-Q, Eating Disorder Examination Questionnaire (Fairburn & Beglin, 1994); M, mean value; SATAQ-G, Sociocultural Attitudes Toward Appearance Questionnaires (Knauss et al., 2007).

### FIGURE 1

Reward ratings \(0–10\) for patients with anorexia nervosa (AN, orange) and the comparison group (CG, blue) for the four different categories: neutral; erotic; high caloric; disorder specific reward [Color figure can be viewed at wileyonlinelibrary.com]
ratings than “losing weight,” “discipline,” “thin bodies,” and “appreciation of others”; “losing weight” had lower ratings than “healthy food” and higher ratings than “thin bodies,” and “appreciation of others”; “healthy food” had higher ratings than “discipline,” “thin bodies,” and “appreciation of others,” “discipline” had higher ratings than “thin bodies,” and “appreciation of others.” All other comparisons were not significant different (see Figure 2 and Table 3).

### Correlations of reward ratings and eating-disorder psychopathology in patients with anorexia nervosa

We found significant positive correlations between the reward subcategory “losing weight,” and “thin bodies” and the EDE-Q indicating that with increasing severity of eating disorder psychopathology these categories were rated as more rewarding (see Table 4). All other reward subcategories had no significant correlations with the EDE-Q or BMI.

### 4 | DISCUSSION

The aim of the study was the evaluation of disorder specific reward stimuli for patients with AN to provide a valid basis to further investigate reward mechanisms in future research. Therefore, we developed a set of pictures with “disorder specific reward” stimuli which was administered along with high-caloric food stimuli, neutral stimuli, and erotic stimuli to patients with AN and CG and rated for reward. Our main finding is that the “disorder specific reward” stimuli are rated as significantly more rewarding in the patient group compared with CG while no significant differences were observed for the other

### TABLE 2

Comparisons of the reward ratings for the four picture categories within groups

| Group   | Comparison                  | df  | t       | p       | d₂   | 95% CI     |
|---------|-----------------------------|-----|---------|---------|------|------------|
| AN      | Neutral vs. erotic          | 24  | –4.507  | <0.001  | –1.840 | –4.442 to –1.652 |
|         | Neutral vs. high caloric    | 24  | –2.775  | 0.011   | –1.133 | –3.153 to –0.464 |
|         | Neutral vs. d.s. reward     | 24  | –8.278  | <0.001  | –3.379 | –4.108 to –2.468 |
|         | Erotic vs. high caloric      | 24  | 1.746   | 0.094   | 0.713  | –0.226 to 2.702  |
|         | Erotic vs. d.s. reward       | 24  | –0.362  | 0.720   | –0.148 | –1.618 to 1.135  |
|         | High caloric vs. d.s. reward| 24  | –2.080  | 0.048   | –0.849 | –2.949 to –0.012  |
| CG      | Neutral vs. erotic          | 24  | –4.771  | <0.001  | –1.948 | –3.531 to –1.399  |
|         | Neutral vs. high caloric    | 24  | –6.201  | <0.001  | –2.532 | –3.528 to –1.766  |
|         | Neutral vs. d.s. reward     | 24  | –3.630  | <0.001  | –1.482 | –1.171 to –0.322  |
|         | Erotic vs. high caloric      | 24  | –0.474  | 0.640   | –0.194 | –0.972 to 0.609   |
|         | Erotic vs. d.s. reward       | 24  | 4.520   | <0.001  | 1.845  | 0.934 to 2.503    |
|         | High caloric vs. d.s. reward| 24  | 5.935   | <0.001  | 2.423  | 1.239 to 2.561    |

Note: Ratings were conducted on an 11-point numerical rating scale (0 = not at all to 10 = very). Abbreviations: 95% CI, 95% confidence interval; AN, anorexia nervosa; CG, comparison group; d₂, Cohen’s d for paired tests.
categories. In addition, patients with AN rated the disorder-specific stimuli as significantly more rewarding than high-caloric or neutral stimuli. These findings underline the assumption that disorder-specific stimuli are an important category when investigating reward mechanisms in AN. From our six subcategories of the “disorder specific reward” stimuli, the categories “sport,” “losing weight,” and “healthy food” showed higher reward ratings compared with the categories “discipline,” “thin bodies,” and “appreciation of others.” Although this pattern was similar in patients with AN and the CG, ratings were overall significantly higher for patients with AN compared with CG suggesting that these may be important reward subcategories for future research. Interestingly, measures of eating disorder

| Group   | Comparison                      | df | t   | p    | dz  | 95% CI           |
|---------|---------------------------------|----|-----|------|-----|-----------------|
| AN      | Sport vs. losing weight         | 24 | 0.366 | .717 | 0.149 | −1.343 to 1.923 |
| AN      | Sport vs. healthy food          | 24 | 0.569 | .574 | 0.232 | −1.339 to 2.359 |
| AN      | Sport vs. discipline            | 24 | 3.186 | .004 | 1.301 | −0.814 to 3.806 |
| AN      | Sport vs. thin bodies           | 24 | 3.670 | .001 | 1.498 | 1.111 to 3.969  |
| AN      | Sport vs. appreciation of others| 24 | 3.301 | .003 | 1.348 | 1.105 to 4.795  |
| AN      | Losing weight vs. healthy food   | 24 | 0.313 | .757 | 0.128 | −1.231 to 1.671 |
| AN      | Losing weight vs. discipline     | 24 | 3.267 | .003 | 1.334 | 0.744 to 3.296  |
| AN      | Losing weight vs. thin bodies    | 24 | 6.119 | <.001| 2.498 | 1.491 to 3.009  |
| AN      | Losing weight vs. appreciation of others | 24 | 3.971 | .001 | 1.621 | 1.277 to 4.0425 |
| AN      | Healthy food vs. discipline      | 24 | 3.618 | .001 | 1.477 | 0.773 to 2.827  |
| AN      | Healthy food vs. thin bodies     | 24 | 3.342 | .003 | 1.364 | 0.776 to 3.284  |
| AN      | Healthy food vs. appreciation of others | 24 | 4.057 | <.001| 1.656 | 1.199 to 3.681  |
| AN      | Discipline vs. thin bodies      | 24 | 0.467 | .644 | 0.191 | −0.785 to 1.245 |
| AN      | Discipline vs. appreciation of others | 24 | 1.100 | .282 | 0.449 | −0.560 to 1.841 |
| AN      | Thin bodies vs. appreciation of others | 24 | 0.886 | .385 | 0.362 | −0.546 to 1.366 |
| CG      | Sport vs. losing weight         | 24 | 3.075 | .005 | 1.255 | 0.382 to 1.938  |
| CG      | Sport vs. healthy food          | 24 | −0.785 | .440 | −0.320 | −1.597 to 0.717 |
| CG      | Sport vs. discipline            | 24 | 2.560 | .017 | 1.045 | 0.256 to 2.384  |
| CG      | Sport vs. thin bodies           | 24 | 4.708 | <.001| 1.922 | 1.460 to 3.740  |
| CG      | Sport vs. appreciation of others | 24 | 4.051 | <.001| 1.654 | 1.099 to 3.381  |
| CG      | Losing weight vs. healthy food   | 24 | −3.364 | .003 | −1.373 | −2.582 to −0.618 |
| CG      | Losing weight vs. discipline     | 24 | 0.438 | .665 | 0.179 | −0.594 to 0.914 |
| CG      | Losing weight vs. thin bodies    | 24 | 3.628 | .001 | 1.481 | 0.621 to 2.259  |
| CG      | Losing weight vs. appreciation of others | 24 | 3.071 | .005 | 1.254 | 0.354 to 1.806  |
| CG      | Healthy food vs. discipline      | 24 | 4.766 | <.001| 1.946 | 0.998 to 2.522  |
| CG      | Healthy food vs. thin bodies     | 24 | 6.638 | <.001| 2.710 | 2.095 to 3.985  |
| CG      | Healthy food vs. appreciation of others | 24 | 6.222 | <.001| 2.540 | 1.791 to 3.569  |
| CG      | Discipline vs. thin bodies      | 24 | 4.315 | <.001| 1.762 | 0.668 to 1.892  |
| CG      | Discipline vs. appreciation of others | 24 | 3.006 | .006| 1.227 | 0.288 to 1.552  |
| CG      | Thin bodies vs. appreciation of others | 24 | −1.472 | .154 | −0.601 | −0.865 to 0.145 |

Note: Ratings were conducted on an 11-point numerical rating scale (0 = not at all to 10 = very).
Abbreviations: 95% CI, 95% confidence interval; AN, anorexia nervosa; CG, comparison group; dz, Cohen’s d for paired tests.

| EDE-Q  | Losing weight | Healthy food | Discipliner | Thin bodies | Appreciation of others |
|--------|---------------|--------------|-------------|-------------|------------------------|
| 0.155, .459 | 0.839, <.001 | 0.259, .212 | 0.285, .168 | 0.625, .001 | 0.305, .138 |

| BMI    | Losing weight | Healthy food | Discipliner | Thin bodies | Appreciation of others |
|--------|---------------|--------------|-------------|-------------|------------------------|
| 0.186, .372 | −0.216, .300 | −0.223, .284 | 0.037, .859 | −0.017, .937 | −0.319, .120 |

Note: Ratings were conducted on an 11-point numerical rating scale (0 = not at all to 10 = very).
Abbreviations: BMI = body mass index; EDE-Q = Eating Disorder Examination Questionnaire (Fairburn & Beglin, 1994).
psychopathology were positively correlated with higher ratings of the “disorder specific reward” subcategories “losing weight” and “thin bodies,” but not “sport” and “healthy food.” This suggests that the reward value of the subcategories “losing weight” and “thin bodies” increases with increasing psychopathology. However, this finding also suggests that present questionnaire measures on eating disorder psychopathology may not cover all relevant aspects of psychopathology.

Disorder specific stimuli have been used in previous studies. Similar to our “thin bodies,” previous studies used underweight bodies as visual stimuli and reported more positive feelings in patients with AN compared with controls (Clarke et al., 2016; Fladung et al., 2010, 2013; Horndasch, Roesch, et al., 2018; O’Hara, Keyes, Renwick, Giel, et al., 2016). Fewer studies used “physical activity” stimuli (similar to our category “sport”) which were evaluated as rewarding (O’Hara, Keyes, Renwick, Giel, et al., 2016; O’Hara, Keyes, Renwick, Leyton, et al., 2016). Additionally, patients with AN showed an attention bias to underweight female bodies (Horndasch, Kratz, et al., 2018) and to sporting pursuit (Giel et al., 2013). In accordance with the reward-centered-model of AN, disorder specific stimuli should be perceived as rewarding and processed in the mesolimbic reward system (O’Hara et al., 2015). An increased activation of the ventral striatum in patients with AN compared with controls was found for underweight bodies (Fladung et al., 2010, 2013). As our category “thin bodies” had the second lowest reward ratings, it can be assumed that the presentation of stimuli related to our categories “sport,” “losing weight,” and “healthy food” may lead to an even stronger activation in the ventral striatal reward system. Indeed, identifying the specific kind of stimuli necessary to elicit differences between patients with AN and the CG in the reward system might be important. For example, monetary reward (Bischoff-Grethe et al., 2013; Ehrlich et al., 2015; King et al., 2016) or food stimuli (Boehm et al., 2018) are not leading to an increased activation of the reward system in patients with AN, whereas low-calorie food items are associated with reactions consistent with reward (Foerde, Steinglass, Shohamy, & Walsh, 2015; Holsen, Lawson, Christensen, Klibanski, & Goldstein, 2014; Scaife, Godier, Reinecke, Harmer, & Park, 2016). In line with our finding that high caloric pictures were rated less rewarding than disorder specific reward pictures, pictures of high calorie food items were rated more negatively (Horndasch, Roesch, et al., 2018), and less appetizing (Holsen et al., 2012) by patients with AN compared with a CG. However, it should be acknowledged that in the present study no significant group differences regarding reward ratings of high caloric food stimuli were found. On a brain level, patients with AN showed food motivation circuitry hypervigilation (Holsen et al., 2012). These areas are also related to the processing of appetite and food intake regulation, but also to stressful stimuli and anxiety disorders (Holsen et al., 2012). Interestingly, in recovered individuals with AN, the pleasant taste of chocolate activates the ventral striatum as part of the reward system, whereas the pleasant sight of chocolate only activates the occipital cortex (Cowdrey, Park, Harmer, & McCabe, 2011). Thus, methodological differences to previous studies might explain why no group differences were observed.

We found no significant group differences regarding the “erotic” pictures which were rated from patients with AN comparable to the “disorder specific reward” pictures. This finding is in contrast to previous results that indicated that pictures of intimate scenes had lower valence ratings in individuals with AN compared with controls (Maier et al., 2019). In addition, the hypothalamic–pituitary–gonadal axis disturbance leads to a reduced libido (Zeeck et al., 2011) which would suggest lower ratings for erotic pictures in patients with AN. However, our study used pictures with more explicitly erotic content and it is possible that erotic situations are still perceived as rewarding in spite of a reduced libido. Nevertheless, given the lack of research on reactivity of patients with AN to erotic stimuli future studies are warranted to elucidate this finding.

A limitation of our study is that we cannot rule out that our ratings are influenced by social desirability, lacking subjective awareness of a deficiency in the brain reward system, or even confounded by automatic unconscious reactions to disorder-specific stimuli (Leins et al., 2021). This might also explain why reward ratings were in general rather low. Thus, future research should objectively assess reward reactivity to disorder specific reward stimuli and the functioning of the brain reward system in general, for example by implementing a cue-reactivity paradigm in which psychophysiological or brain responses to stimuli are assessed or by assessing the speed of response of the ratings or using a forced choice between stimuli. It also would be interesting to investigate the association between subjective and objective measures. In addition, we did not differentiate between different subtypes of AN, and we cannot rule out potential differences regarding the rewarding nature of the various stimulus categories. Finally, only women were included in this study, and male patients with AN might experience different rewarding aspects.

5 | CONCLUSION

Patients with AN reported higher reward ratings of “disorder specific reward” stimuli compared with the CG while no significant group differences were observed regarding high caloric, erotic, and neutral stimuli. This suggests that disorder specific stimuli are important to incorporate in future studies on the reward system in patients with AN. Within the disorder specific reward category, the subcategory “sport” and the newly developed subcategories “losing weight” and “healthy food” were perceived as rewarding. Compared with these categories, the previously used category “thin bodies” as well as the categories “discipline,” and “appreciation of others” were rated less rewarding. Future research investigating the reward system might use the pictures of our categories sport, losing weight and healthy food or the individual pictures with the highest reward ratings in patients with AN (see Table S4).

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CONFLICT OF INTEREST

The authors declare no conflicts of interest.
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SUPPORTING INFORMATION

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