Electrocortical Processing of Food and Emotional Pictures in Anorexia Nervosa and Bulimia Nervosa

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Objective: To compare the electrocortical processing of food pictures in participants with anorexia nervosa ($n = 21$), bulimia nervosa ($n = 22$), and healthy controls (HCs) ($n = 32$) by measuring the early posterior negativity, an event-related potential that reflects stimulus salience and selective attention. **Methods:** We exposed these three groups to a rapid stream of high- and low-calorie food pictures, as well as standard emotional and neutral pictures. **Results:** Event-related potentials in the time range of 220 milliseconds to 310 milliseconds on posterior electrodes differed between groups: patients with eating disorders showed facilitated processing of both high- and low-calorie food pictures relative to neutral pictures, whereas HC participants did so only for the high-calorie pictures. Subjective palatability of the pictures was rated highest by patients with anorexia nervosa, followed by the HC and bulimia nervosa groups. **Conclusions:** Patients with eating disorders show a generalized attentional bias for food images, regardless of caloric value. This might explain the persistent preoccupation with food in these individuals. **Key words:** anorexia nervosa, bulimia nervosa, early posterior negativity, event-related potentials, food pictures, attentional bias.

ANOVA = analysis of variance; **AN** = anorexia nervosa; **BN** = bulimia nervosa; **EDs** = eating disorders; **DSM-IV** = *Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition*; **EPN** = early posterior negativity; **EEG** = electroencephalography; **ERPs** = event-related potentials; **fMRI** = functional magnetic resonance imaging; **high-cal** = high-calorie; **IAPS** = international affective picture system; **LPP** = late positive potential; **low-cal** = low-calorie; **RSVP** = rapid serial visual presentation.

INTRODUCTION

In Western cultures, people usually have access to an abundance of all types of food, most of which are affordable and readily consumed. At the same time, the mainstream media has idealized a slim body shape for women, which has in part become the cultural norm. In anorexia nervosa (AN) and bulimia nervosa (BN), striving for a lean body shape by restricting food intake has become a superordinate goal. Although most nonpurging type AN patients are highly rigid with respect to food intake, purging type AN patients and BN patients chronically restrain eating but have intermittent binge eating attacks, as described in the *Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition* (DSM-IV). As a result of these abnormal eating patterns, patients with these eating disorders (EDs) experience periods of food deprivation and starvation, interspersed by repletion.

Food is a highly salient biological stimulus category due to its relevance for survival and its inherently rewarding nature. It is, therefore, unsurprising that the brain is specifically geared to process this stimulus class. For example, food deprivation leads to increased visual attention toward food cues (1) and gives rise to increased blood-oxygen dependent levels in inferotemporal regions (amygdala, parahippocampal gyrus, anterior fusiform gyrus), as well as in medial obitofrontal, medial prefrontal, insular, and striatal regions (2,3). In patients with EDs, altered blood-oxygen dependent levels-responses to food pictures were reported in prefrontal and posterior cortical areas (4–6) and, thus, in regions implicated in cognitive control and sensory processing. Patients with EDs also show specific attentional biases in dot-probe tasks: They direct their attention toward high-calorie (high-cal) food items and away from low-calorie (low-cal) food items (7,8).

In sum, convergent evidence suggests that food cues are processed differently in EDs. However, for a functional interpretation of these findings, the time scale of stimulus is important: Attentional capture by motivationally salient stimuli occurs during very brief and particularly early stages of stimulus processing, which poses methodological problems for dot-probe and functional magnetic resonance imaging (fMRI) studies. In general, later phases of stimulus processing might reflect cognitive regulation processes to a higher degree than earlier processes control (9–11). Due to their excellent temporal resolution, event-related potentials (ERPs) can map precisely the temporal dynamics of attentional processes from early through late stages of stimulus processing. To our knowledge, despite their clear relevance to attentional processing of food cues, no study has yet investigated ERPs to food cues in EDs. However, it would be important to know whether the results from attentional bias and fMRI studies generalize to brain electric responses.

Recent ERP evidence (12,13) suggested that caloric value of food is reflected in the ERP already 120 milliseconds to 160 milliseconds after stimulus onset. Slightly later, in the 200-millisecond to 300-millisecond time range, the early posterior negativity (EPN)—a negative, occipital-parietal deflection of the ERPs—emerges, which is higher for emotional than for neutral pictures (14). An enhanced EPN also emerges for food pictures, and this "food-EPN" has recently been shown to be sensitive to the effect of food deprivation (15). Functionally, the EPN is interpreted as a correlate of attention allocation (14). The EPN is most frequently observed in rapid serial visual presentation (RSVP) tasks: Pictures are presented with high frequency (e.g., three pictures per second) and without perceivable interstimulus interval. It is assumed that this rapid visual stream places a high load on the visual system, which leads to an efficient allocation of processing resources to the

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TABLE 1. Means (SD) of Sample Characteristics

	BN (n = 22)	AN (n = 21)	HC (n = 32)	Statistic F, p	Post Hoc
Age (years)	26.1 ± 7.5	23.2 ± 4.55	26.2 ± 5.02	2.04, .137	
Time of testing (morning, afternoon, evening)	5/9/8	6/5/10	16/8/8	6.47, .167[a]	
Education (low/middle/high)	2/5/15	2/7/12	0/1/31	12.9, .012[a]	AN = BN < HC
Body mass index (kg/m^2)	22.6 ± 3.24	16.6 ± 1.30	20.7 ± 2.41	34.2, <.001	AN < BN = HC
n of calories eaten	490 ± 350	291 ± 301	444 ± 341	2.13, .127	
Subjective feeling of hunger	2.18 ± 1.44	2.52 ± 2.02	3.03 ± 2.09	1.34, .267	
Beck Depression Inventory	17.5 ± 8.30	23.6 ± 11.8	2.94 ± 2.95	46.9, <.001	AN = BN > HC
STAI-state	50.2 ± 5.29	48.5 ± 3.84	45.1 ± 6.34	6.05, .004	AN = BN > HC
EDE-Q restrained	3.34 ± 1.83	3.83 ± 1.96	0.39 ± 0.69	40.8, <.001	AN = BN > HC
EDE-Q eating	3.78 ± 1.36	3.19 ± 1.51	0.12 ± 0.22	86.7, <.001	AN = BN > HC
EDE-Q weight	4.14 ± 1.39	3.71 ± 1.63	0.41 ± 0.52	78.5, <.001	AN = BN > HC
EDE-Q shape	4.69 ± 0.94	4.33 ± 1.42	0.64 ± 0.71	129, <.001	AN = BN > HC

[a] χ^2 (24).
SD = standard deviation; BN = bulimia nervosa; AN = anorexia nervosa; HC = healthy controls; STAI = State-Trait Anxiety Inventory; EDE-Q = Eating Disorder Examination Questionnaire.

motivationally most significant images in the visual stream. The EPN is a very robust phenomenon: It is almost unaffected by habituation (16) or presentation speed in the RSVP task (17). Furthermore, it is maintained despite challenging attentional foreground tasks (18).

Thus, we chose to study the food-EPN because it may reflect early bottom-up aspects of attention to a higher degree than later ERPs, such as the late positive potential (LPP) (19). As food processing is likely under strong cognitive control in patients with AN and BN, the EPN might represent an interesting early window into processing phases that partially precede top-down control. In an RSVP task, we presented AN and BN patients with high-cal and low-cal pictures (7,13), along with normative positive, neutral, and negative pictures of the international affective picture system (IAPS) (20). In addition, palatability was rated for the food pictures, and valence and arousal were rated for IAPS pictures. These data should speak to the following questions: Do patients with EDs show enhanced EPN to food cues? If so, is this the case only for high-cal food or also for low-cal food cues (i.e., a generalized pattern)? Do AN and BN subgroups differ in their attentional processing of high- versus low-cal food? Using neutral IAPS pictures as a baseline, we expected both ED groups to show a higher EPN to high-cal food pictures in comparison to controls based on evidence that high-cal food is perceived as threatening and disgusting by these patients (6,21) and is, therefore, particularly salient. Previous research does not permit hypotheses for differences between AN and BN groups or for low-cal food cues.

METHODS

Participants

The study sample consisted of 21 women diagnosed with AN, 22 with BN, and 32 healthy control (HC) participants. Participants took part in exchange for a remuneration of [euro]50, and they were recruited from the community through newspaper announcements, the department Web site, and from collaborating clinics. Ethical approval for the conduct of this study was granted by the local medical ethics committee. The data collection period extended from October 2007 to December 2008.

Exclusion criteria for all participants were schizophrenia spectrum disorders, bipolar disorder, substance abuse or dependence, or neurological disorders. Exclusion criteria for HC participants included a lifetime diagnosis of any mental disorder according to *Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition* (DSM-IV). Participants with EDs fulfilled the DSM-IV diagnostic criteria of either AN or BN as assessed by the Eating Disorder Examination (22). The Structured Clinical Interview for DSM-IV Axis I Disorders was used for all other psychiatric diagnosis (23). The following comorbid disorders were found in the AN/BN groups: major depression (8/3), dysthymia (2/1), borderline personality disorder (5/2), posttraumatic stress disorder (4/1), and social phobia (2/1). Five patients with AN were taking selective serotonin reuptake inhibitors. Six patients with BN reported a history of AN.

The psychopathology of EDs, as well as anxiety and depressive symptoms, were further assessed with the German version of the Eating Disorder Examination Questionnaire (24), the State-Trait Anxiety Inventory (25), and the Beck Depression Inventory (26). As indicated in Table 1, groups did not differ in age, but patients with AN and BN had lower education. Both ED groups showed higher scores on the Beck Depression Inventory, State-Trait Anxiety Inventory, and Eating Disorder Examination Questionnaire subscales than HCs. Patients with AN had lower body mass indices than the BN and HC groups, which did not differ from each other.

MATERIALS

Participants viewed eight repetitions of a set of 160 pictures from five categories (32 pictures per category). Thirty-two pictures with appetizing high-cal food items and 32 pictures with low-cal food items were matched by visual inspection with respect to complexity (number of food items displayed in one picture), brightness, contrast, viewing distance, and background color (white). Main dishes, as well as desserts and sweets, constituted the high-cal picture set, whereas fruit, rice-bread, vegetables, and salads constituted the low-cal picture set (Fig. 1). High- and low-cal food pictures did not differ in their physical properties (visual complexity, brightness, contrast).[1] Nonfood IAPS control pictures (n = 96) depicted pleasant (e.g., baby animals, human babies with or without parents, erotica, landscapes/sports),

[1] Food pictures had higher brightness than international affective picture system (IAPS) pictures. Contrast did not differ across categories. Visual complexity was analyzed in GIMP by using the "find edges" function (difference of Gaussians), setting a threshold in the black/white image, and quantifying the percentage of black pixels. Visual complexity was significantly higher for neutral IAPS than for all other categories, which did not differ from each other. Results are available from the authors upon request.

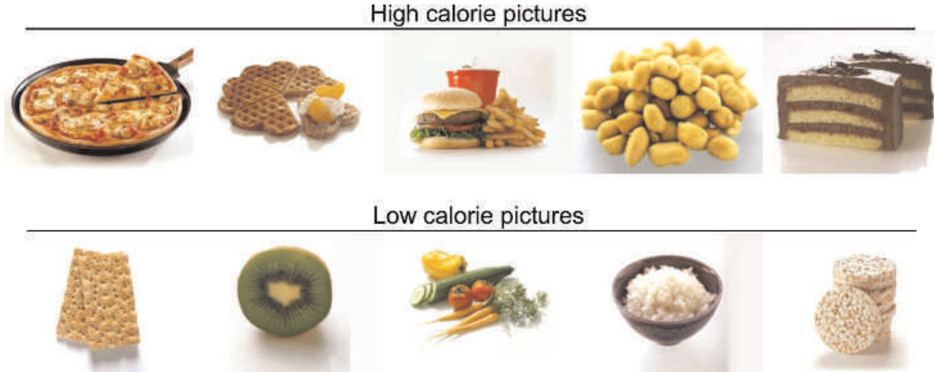

Figure 1. Examples of high- and low-calorie pictures.

neutral (household objects, tools), and unpleasant contents (e.g., angry faces, weapons, mutilations, attacking animals, facial expressions of grief).[2]

Procedure

After the first session during which the diagnostic interviews were conducted, participants attended two experimental sessions approximately 1 week apart. The present investigation was always scheduled at the second experimental session. Because it could be expected that groups differed in their food consumption and hunger has been shown to influence the ERPs to food pictures (15), we asked participants to eat a "normal" meal before Session 2 (we provided specific tips as to what to eat). To enhance the commitment to comply with this instruction and to report honestly the quantity of food eaten, the experimenter announced a saliva test in Session 2; the test allegedly measured the amount of food eaten on that day and participants would be asked to eat at the session, should they fail to do so before. After welcoming the participants to Session 2, the experimenter familiarized them with the electroencephalography (EEG) laboratory and the upcoming procedures and conducted the mock saliva test by asking them to chew on a salivette for 2 minutes (a postsession interview confirmed that none of the participants questioned the validity of this saliva test). Participants then listed all food consumed on the study day and rated their present feeling with regard to hunger (on a 1–9 scale, ranging from "not hungry at all" to "extremely hungry"). As shown in Table 1, groups were successfully matched according to the number of calories, hunger, and testing time.[3] After the fitting of the electrode cap, participants were guided to a dimly lit, electrically shielded, sound-proof 2.5 × 3 m recording cabin.

During the RSVP paradigm 8.3 × 6.25 inch, 600 × 450 pixel pictures were presented as a continuous stream without any perceivable interstimulus gap on a 17-inch monitor at 1-m viewing distance, with each picture shown for 333 milliseconds (three pictures per second) (15). Pictures were shown in pseudorandom order with no more than two repetitions of the same category (high-cal, low caloric, positive/negative/neutral IAPS pictures). The pseudorandom order ensured that potential baseline shifts due to carry-over effects from the previous picture were equally distributed across the five categories (27). Additional control analyses of baseline levels (the last 40 ms of the previous picture) were unaffected by the category of the previous picture, $F < 1.00$ (evaluated relative to its own baseline) (27).

After picture viewing, all electrodes were detached, and participants left the cabin and completed a questionnaire displaying all color pictures along with visual analog scales. IAPS pictures were rated on valence and arousal (1–9). The high- and low-cal food pictures were rated on palatability (from 1 representing "not appetizing" to 9 representing "very appetizing").

EEG Recording

The EEG was digitally recorded with SynAmps amplifiers and Scan 4.0 software (Neuro-Scan, Inc., Sterling, Virginia) and Ag/AgCl electrodes, using an extended 10- to 20-System electrode cap (EasyCap, Falk Minow Services, Herrsching-Breitbrunn, Germany), with midline sites Fz, Cz, and on each side F3/F4, F7/F8, FC5/FC6, FT7/FT8, T7/T8, C3/C4, CP1/CP2, CP5/CP6, TP9/TP10, P3/P4, P7/P8, O1/O2. The ground electrode was positioned on the midline at AFz, and Pz was used as the online reference. The vertical electrooculogram was recorded from above and below the eyes, and the horizontal electrooculogram was recorded from the outer canthi of each eye. The sampling rate was 500 Hz, and online filtering occurred at 0.1 Hz to 100 Hz. Electrode impedance was kept <5 kΩ.

Offline analyses were performed, using AVG-Q (28) involving conversion to the common average reference, low-pass filtering at 30 Hz (15), and artifact rejection (i.e., base-to-peak amplitude exceeding 80 μV on any channel). Electromagnetic Encaphalography Software (29) was used to generate the figures, based on the average waveforms calculated in AVG-Q. The number of valid trials (approximately 83%) did not differ between conditions or groups, $F < 1.00$. ERPs were constructed by separately averaging baseline-subtracted (40 milliseconds) epochs for each category, sensor, and participant.

Statistical Analysis

Similar to the findings of Stockburger et al. (15), the first set of analyses were based on single-sensor waveform analyses. In these analyses, analyses of variance (ANOVAs) containing the within-subjects factors Category and the between-subjects factor Group were calculated for each time point after picture onset and separately for each individual sensor. To guard against chance findings, we considered significant effects meaningful only when the effects were observed for at least 12 continuous data points (24 milliseconds) and two neighboring sensors (15,30).

In a second set of analysis, these effects were explored by conventional ANOVAs on the basis of mean activity in selected sensor clusters and time windows. Only posterior sensor regions are reported. Mean amplitudes from a large posterior sensor cluster (O1, O2, Pz, P3, P4, P7, P8),[4] identified by both visual inspection and waveform analyses, were averaged for a time interval from 220 milliseconds to 310 milliseconds. Not shown here for reasons of brevity are analyses of earlier time intervals (100–120 milliseconds), frontal electrode sites (posterior effects were mirrored with opposite polarity over frontal sites), and laterality effects, none of which reached significance. An initial 3 × 5, Group (AN, BN, HC) × Category (low-cal, high-cal, pleasant, neutral, unpleasant) ANOVA with repeated measures on Category (Greenhouse-Geiser correction) tested for global Group × Category interactions. The following comparisons were planned to follow up on such a global interaction. Using the neutral IAPS category as a general reference category (6,21,31), two 3 × 3, Group × Category ANOVAs compared food and emotional pictures separately with the neutral

[2] International affective picture system positive pictures: 1440, 1463, 1540, 1710, 1722, 2070, 2080, 2160, 2165, 2311, 2540, 2550, 4250, 4534, 4607, 4608, 4610, 4611, 4641, 4653, 4658, 4659, 4660, 4669, 4700, 5621, 5623, 5830, 8080, 8161, 8370, 8400; neutral pictures: 6150, 7000, 7002, 7010, 7020, 7030, 7031, 7034, 7040, 7050, 7060, 7090, 7100, 7110, 7130, 7140, 7150, 7170, 7175, 7190, 7211, 7217, 7224, 7234, 7500, 7510, 7560, 7590, 7595, 7705, 7950, 7950; negative pictures: 1050, 1052, 1120, 1280, 1300, 1302, 1930, 1931, 2205, 2700, 2800, 2900, 2053, 6570, 3110, 2120, 6211, 6230, 3550, 6250, 6260, 6350, 6370, 6510, 6550, 6560, 6821, 9000, 9001, 9140, 9220, 9570.

[3] To explore whether groups differed in their consumption of low-calorie versus high-calorie food on the study day, we reviewed the eating logs and classified the consumed food items as either containing high-calorie food items of the types (like chocolate, butter, nuts) we presented during our task or not containing those. Groups did not differ on this index, χ^2 (2) = .552, p = .759.

[4] Similar results were obtained with a more confined sensor group (O1, O2).

category. Significant Group × Category interactions were then followed by t tests within each group.

RESULTS

ERPs

The global, 3 × 5, Group × Category ANOVA revealed a significant Group × Category interaction, $F(8,288) = 2.32$, $p = .036$, $\eta^2 = 6.07$, in addition to a main effect of Category, $F(4,288) = 18.5$, $p < .001$, $\eta^2 = 20.4$. The main effect of Group was not significant, $F < 1.00$.

For the contrast between food pictures and neutral IAPS pictures in a 3 × 3, Group × Category (high-cal, low-cal, neutral) ANOVA, a significant Group × Category interaction was obtained, $F(4,144) = 5.57$, $p < .001$, in addition to a strong main effect of Category, $F(2,144) = 83.8$, $p < .001$, $\eta^2 = 53.3$, $\eta^2 = 13.4$. No main effect of Group was found, $F < 1.00$. Figure 2*A* illustrates the temporal-spatial location of this interaction, as revealed by single sensor analysis. Figure 2*B* displays the averaged ERPs in high-cal, low-cal, and neutral IAPS conditions separately for the three groups. Follow-up within participant t tests revealed that BN patients' EPNs were higher for the high-cal and low-cal pictures compared with neutral IAPS, BN: t (21) = 7.64, $p < .001$, $d = 3.57$; t (21) = 6.12, $p < .001$, $d = 1.47$, but high- and low-cal categories did not differ from each other, t (21) = 0.73, $p = .473$, $d = 0.21$. In AN, all categories differed significantly from each other with high-cal pictures being followed by low-cal pictures, t (31) = 2.61, $p = .017$, $d = 0.57$, and low-cal pictures being followed by neutral pictures, t (20) = 5.91, $p < .001$, $d = 1.68$. In HC, by contrast, EPNs were enhanced for high-cal relative to low-cal and neutral pictures, t (31 = 4.15, $p < .001$, $d = 0.58$, t (31) = 5.28, $p < .001$, $d = 0.99$, but the low-cal/neutral contrast did not reach significance, t (31) = 1.95, $p = .066$, $d = 0.44$.

IAPS pictures were analyzed in a 3 × 3, Group × Category (pleasant, neutral, unpleasant) ANOVA. A Category effect emerged, $F(2,144) = 8.22$, $p < .001$, $\eta^2 = 10.1$, but no main effect or interaction of Group, $F < 2.37$, $p > .128$. Category effects replicated previous findings of stronger EPN to both negative and positive compared with neutral IAPS pictures, $t > 3.2$, $p < .002$, but positive and negative IAPS did not differ from each other, $t < 1.00$.

Subjective Ratings

A univariate ANOVA for palatability ratings for the high-cal food yielded a strong between group effect, $F(2,69) = 9.61$, $p > .001$, $\eta^2 = 22.4$. Tukey post hoc tests showed that patients with BN gave lower palatability ratings than the HC group ($p = .039$) and the AN group ($p < .001$). Patients with AN tended to give higher ratings than the HC group, $p = .081$ (Fig. 2*C*). Palatability ratings for low-cal pictures were not modulated by Group, $F(2,69) = 1.12$, $p = .33$, $\eta^2 = 3.30$.

Valence and arousal ratings of the IAPS pictures were submitted to a 2 × 3 × 3, Scale (valence, arousal) × Group (AN, BN, HC) × Category (positive, neutral, negative) ANOVA. Main effects for Category and Scale were found, $F > 116$, $p < .001$, but no main effects or interactions of Group, all $F < 2.21$, $p > .087$. As could be expected, valence ratings confirmed the classification of IAPS picture (negative < neutral < positive), and arousal of both negative and positive pictures was rated higher compared with the neutral category (results available from the authors on request).

DISCUSSION

To our knowledge, this is the first investigation of ERPs to high- and low-cal food cues in patients with AN and BN. In line with previous findings (13), healthy participants showed higher EPN to high-cal pictures compared with low-cal or neutral IAPS pictures, whereas the latter two categories did not differ. Thus, the EPN proved sensitive to the caloric content of food. In the patient groups, by contrast, both food categories (high-cal, low-cal) gave rise to an enhanced EPN compared with neutral IAPS pictures, illustrating an enhanced processing of both food categories and partially confirming our hypothesis (we had expected enhanced EPN only for the high-cal condition in ED groups). Interestingly, although less marked, there seemed to be a slight difference between the patients groups in EPN amplitude: Patients with AN even differentiated between high- and low-cal pictures, whereas patients with BN did not. In addition, patients with AN and BN differed in their subjective palatability ratings for high-cal pictures: Patients with BN gave lower ratings than controls, whereas patients with AN tended to give higher ratings than controls. Importantly, subjective ratings and ERPs for standard positive and negative IAPS pictures did not differ between groups, thereby excluding low-level perceptual deficits in patient groups or general differences in emotional reactivity.

ED patients' EPNs were enhanced to food pictures, regardless of caloric content. This is unexpected because high-cal food included typical "forbidden food," which was rated as disgusting and threatening/anxiety provoking in previous studies (6,21) and could have consequentially captured visual attention. Low-cal food, by contrast, included "good" food, that is, food which these patients typically consume and which might therefore be expected to be less salient. Contrary to what one might expect from previous disgust/threat ratings, palatability for high-cal food was rated higher in AN (trend) and lower in BN relative to controls. Differences in the scales (palatability/anxiety/disgust) might account for this inconsistency. Alternatively, one could speculate that group differences in palatability ratings reflect the degree of control patients with AN and BN exert over their eating behaviors: Patients with BN fear the occurrence of the next episode of binge eating, whereas patients with restrictive AN usually do not avoid confrontation with palatable high-cal food (32). Thus, palatability ratings might reflect top-down cognitive processes to a higher degree than the EPN results. Yet, another possibility to explain the discrepancy between EPN (elevated in both ED groups compared with controls) and palatability ratings (AN higher, BN lower than controls) bears on incentive sensitization theory (33,34). This theory proposed a dissociation of motivational

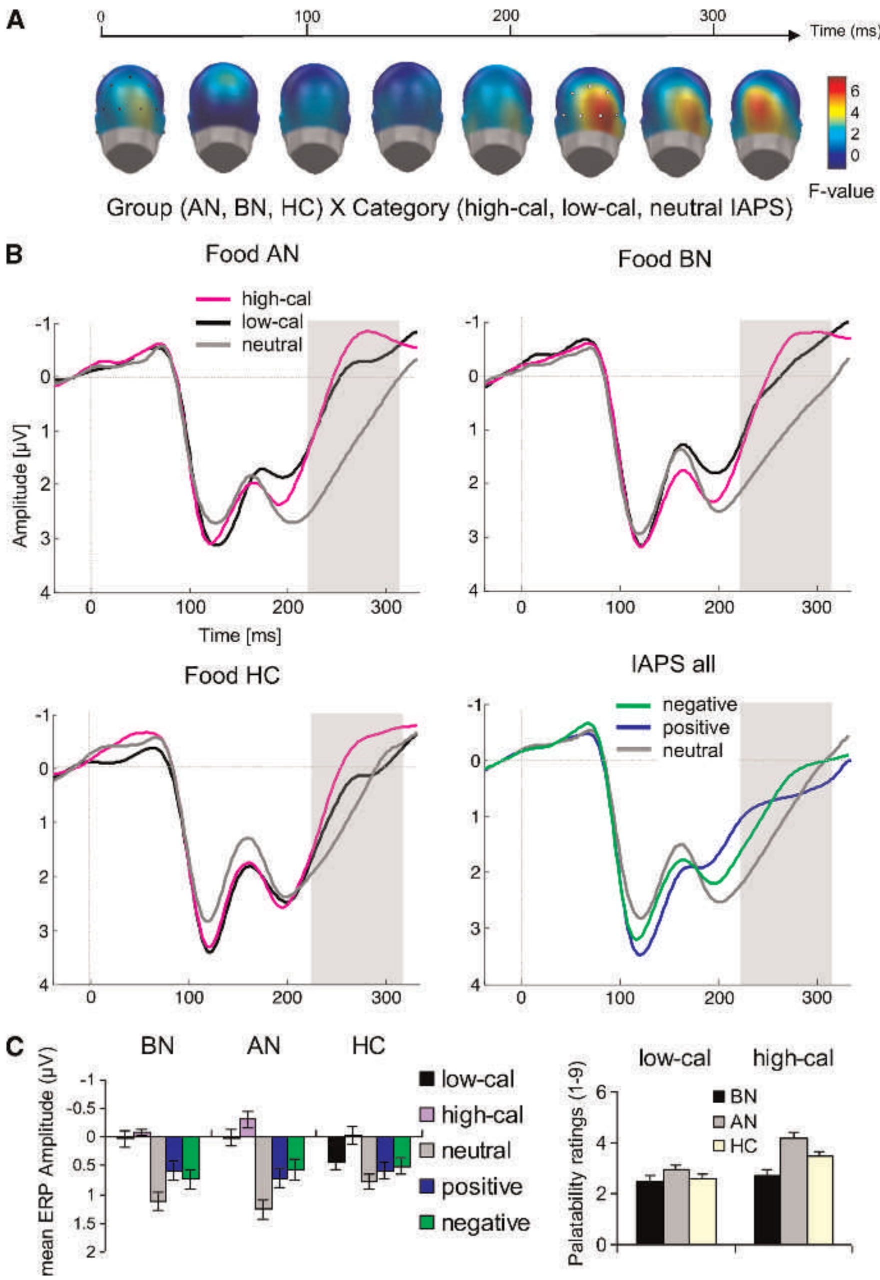

Figure 2. *A*) Scalp potential maps illustrating the *F* value of the Category (high-calorie food, low-calorie food, neutral IAPS) × Group (AN, BN, HC) interaction (back view of model head, each head representing the mean of 40 s, 1 s gab). Sensors selected for statistical analysis and averaged for the plots in *B* and *C* are displayed in white (O1, O2, P3, P4, P7, P8, Pz). *B*) ERPs to the neutral IAPS and to the high- and low-calorie food pictures in each group. ERPs to the positive, negative, and neutral IAPS, collapsed across groups (*lower right*). *C*) Mean voltages of ERPs in the 220- to 310-millisecond time range in all conditions (*left side*). Palatability ratings across groups (*right side*). IAPS = international affective picture system; AN = anorexia nervosa; BN = bulimia nervosa; HC = healthy control ; high-cal = high calorie; low-cal = low calorie; ERPs = event-related potentials.

"wanting" and subjective hedonic "liking" of a primary reinforcer. Thus, the EPN might index the further aspect, whereas palatability ratings might reflex the latter. Future research should target this interesting dissociation more specifically by using a broader set of self-report measures and an assessment of actual eating.

Our finding of enhanced EPN to food pictures in EDs is generally in line with the work of Stockburger et al. (15), who showed that food deprivation modulated the food-EPN. However, Stockburger and co-workers found more positive ERPs in the EPN time range, whereas we found the more typical negative deflection. Several study differences could account for this (sample composition, EEG montage, within subject design) but, more interestingly, chronic deprivation as characteristic for EDs could have a different neural signature than short-term deprivation in healthy volunteers. Similar to patients with anxiety disorders, the ED patient might have developed enduring attentional biases for food, and our results indicate that these biases are not confined to high-cal food but extend to low-cal food. Unfortunately, the present RSVP task does not allow inferences about attentional direction, i.e., attention toward versus away from high- versus low-cal food (7), limiting the comparability to research using dot-probe tasks.

But what does an enhanced EPN mean? Enhanced EPN is also reported for phobic images in other disorders, such as in spider phobia (35,36). Interestingly, in these studies, pictures that elicited an enhanced EPN also gave rise to a later LPP, which is consistent with an interpretation of the EPN indexes a selection of salient targets for later in-depth processing as indexed by the LPP or P300. It has also been suggested that the EPN reflects motivated attention and, hence, a motivational guidance of attention in line with the organisms goals (37). Thus, patients with AN and BN might "scan" their environment for food cues, regardless of caloric value, possibly with the implicit goal of controlling their exposure to these stimuli to maintain their dietary restraint.

Previous fMRI studies in food-deprived (2,3,38) and ED individuals (4,39) have outlined a widespread neural network supporting food processing encompassing regions implicated in cognitive control (prefrontal cortex), reward (orbitofrontal cortex and striatum), and emotion/arousal (insula, amygdala, fusiform gyrus). We chose to measure the EPN, as opposed to later ERP components, because it provides us with a window into early attentional processing and thus a processing stage, which can be considered as less heavily influenced by cognitive top-down control processes. On a neural level, the typical posterior location of the EPN might reflect activations in the visual cortex (15,16,18,40), which receives input from the amygdala (41,42). Thus, a rapid interplay of amygdala and visual cortex might be involved in a preferential processing of food cues in EDs. An interesting question would be if structures implicated in cognitive control, such as (pre-)frontal areas, come online only later during food-cue processing and are thus not reflected in the EPN. However, more research is clearly needed on how brief brain-electric activations, such as the EPN, map onto neural structures as identified by fMRI. In addition, an integration of findings across different measures of attentional bias (e.g., dot-probe tasks) is desirable (31).

In sum, we believe that an enhanced EPN for high- and low-cal food pictures in EDs speaks to a generalized attentional bias to food in these individuals, which might be only partially cognitively represented. Functionally, this would explain the persistent preoccupation with food in these individuals in an environment rich with food cues. Enhanced detection of these cues can influence later information-processing stages like explicit stimulus evaluation, memory encoding, and decision making. This food-biased information processing might explain why patients with EDs constantly monitor and regulate their attentional foci and behavioral tendencies. This might maintain their fear of binge eating and weight gain. Future research should explore whether this early attentional bias remits with treatment (43) and how the food-EPN relates to other measures of attentional bias (7,31).

Some study limitations should be considered. First, our instruction to participants to eat "normally" —although successfully matching groups—does not reflect their habitual eating patterns, and we did not objectively measure actual nutritional status. A more controlled approach would compare the three groups studied here in both a food-deprived and a satiated state (3), which might be achieved in an inpatient setting. In addition, neutral pictures had a higher visual complexity than food pictures, which might have contributed to the higher EPN for the latter. Although this is a potential confound for the category differences (44), it should not have affected group differences or group $\times$ category interactions because all participants saw the same pictures. Still, future research might profit from a closer matching of picture properties in EPN tasks. In addition, it would be useful to study ERPs in entirely medication-free AN patients and to compare restrictive and purging AN subtypes. Finally, our limited set of dependent variables did not permit a more comprehensive exploration of how early attentional biases translate into subjective experience and actual eating behavior, which would be a fruitful direction for future research.

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