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Research report

To eat or not to eat? Availability of food modulates the electrocortical response to food pictures in restrained eaters

Jens Blechert [a,*], Bernd Feige [b], Greg Hajcak [c], Brunna Tuschen-Caffier [a]

[a] Department of Clinical Psychology and Psychotherapy, Institute for Psychology, University of Freiburg, Engelbergerstrasse 41, 79106 Freiburg, Germany
[b] Department of Psychiatry and Psychotherapy, University of Freiburg, Germany
[c] Department of Psychology, Stony Brook University, NY, USA

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ABSTRACT

Restrained eating is a pattern of chronic dietary restriction interspersed with episodes of disinhibited overeating. The present study investigated whether this eating pattern is related to altered electrocortical processing of appetitive food stimuli in two different motivational contexts. Restrained ($n = 19$) and unrestrained eaters ($n = 21$) passively viewed high-caloric food pictures, along with normative emotional pictures in a first block. In a second block, food availability was manipulated: participants were told that half of the food items should later be eaten (available food items), whereas the other half of food items was said to be unavailable. While no group differences were obtained during the first block, restrained eaters' event-related potentials (ERPs) were significantly modulated by the availability manipulation: ERPs for available food cues were significantly less positive than ERPs to unavailable food cues. Restrained eaters might down-regulate their reactivity to available food cues to maintain their dietary rules.

Introduction

In Western cultures people usually have access to an abundance of all types of food, most of which they are able to afford and immediately consume. At the same time, the media mainstream idealizes a thin body shape for women, which has, in part, become the cultural norm. As one consequence, women are faced with having to constantly regulate food consumption—not only for health reasons but also to comply with the socio-cultural ideal of beauty. Additionally, current Western society promotes dieting as a pathway to thinness (e.g., Striegel-Moore, Silberstein, & Rodin, 1986).

According to Herman and Polivy (1980), eating patterns are influenced by the balance between physiological factors prompting the desire for food and efforts to resist that desire. This cognitively mediated effort to combat the urge to eat is termed *restraint*, which can be assessed with a 10-item scale (Herman & Polivy, 1980). A high score on eating restraint is considered a risk factor for eating disorders (e.g., Jacobi, Hayward, de Zwaan, Kraemer, & Agras, 2004; Stice, 2001), especially Bulimia Nervosa (BN) (Stice, 1998, 2001; Stice, Killen, Hayward, & Taylor, 1998), and has therefore received much research attention. Several possible mechanisms linking eating restraint to eating disorders have been proposed.

According to the boundary model (Herman & Polivy, 1984) restrained eaters have a higher tolerance toward hunger and satiety. As a result, they are assumed to be less responsive to *internal* stimuli (signs of satiety or hunger) but more responsive to the availability of *external* stimuli (food stimuli). One frequently used paradigm to study restrained eating is the "pre-load" paradigm: restrained and unrestrained eaters consume a high-caloric pre-load, e.g., a milk-shake, which is followed by a "taste test" during which the amount of food eaten is unobtrusively measured. Typically, restrained eaters consume more food during this taste test with a pre-load compared to without a pre-load, while unrestrained eaters show the opposite pattern (Herman & Polivy, 1980, 1984; Ruderman, 1986). A cognitive explanation for this counter-regulatory eating pattern assumes that restrained eaters hold an "all or nothing" dietary rule. Thus, once the rule is broken, for example by the consumption of a high-caloric pre-load, they become disinhibited and overeat (Herman & Polivy, 1984). An alternative account for the counter-regulatory eating pattern is based on restrained eaters' enhanced sensitivity to external stimuli. The exposure to the food cue (the pre-load), even without its consumption, could trigger stronger craving and preparatory physiological responses in restrained eaters leading to increased

* Corresponding author.
E-mail address: blechert@psychologie.uni-freiburg.de (J. Blechert).

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consumption (Nederkoorn & Jansen, 2002) which might be why their cognitive control of eating sometimes breaks down and they overeat. This sensitivity to external food cues (called *cue reactivity* in the following) has been studied with a number of methodologies.

Klajner and coworkers, for example found increased salivation to food cues in restrained relative to unrestrained eaters (Klajner, Herman, Polivy, & Chhabra, 1981). Measuring event-related potentials (ERPs) Hachel, Hempel, and Pietrowsky (2004) found more positive going ERPs to food-related words *and* control words in restrained compared with unrestrained eaters. Piacentini, Schell, and Vanderweele (1993) found *smaller* electrodermal orienting responses to food odors in restrained compared to unrestrained eaters. Similarly, Nederkoorn and Jansen (2002) found *reduced* salivation and heart rate responses to food cues in restrained eaters and attributed this finding to an automatic down regulation of responses in restrained eaters.

Thus, although some evidence exists for elevated cue reactivity, restrained eaters might down-regulate their responses to food under some circumstances. To address the present inconsistencies in the cue reactivity literature the present study sought to examine *under which conditions* enhanced cue reactivity or down-regulation of appetitive responses to high-energy food cues might occur. The pre-load literature suggests that actual consumption of high-calorie food disinhibits subsequent eating. Thus, when pictures are only passively viewed, without exposure to a pre-load, they might not be motivationally significant enough to trigger altered cue responses or give rise to inconsistent response patterns. Interestingly, Ruderman, Belzer, and Halperin (1985) showed that even the announcement the consumption of a high-caloric food during a subsequent taste test could trigger disinhibited eating just as would be expected after the consumption of a pre-load. Thus, the perceived availability and requirement to eat food in restrained eaters might lead to differential processing of food pictures.

In sum, the present study aimed to disentangle the motivational contexts that lead to enhanced cue reactivity from those that lead to down-regulation of appetitive responses by manipulating the perceived availability of the food items displayed during picture viewing. In a first "passive viewing block" food pictures were passively viewed along with normative emotional pictures. During this block, the motivational context was unspecified and restrained eaters might not differ from controls at all. In a second "availability block", pictures were arranged in two separate "menus" and participants were instructed that they would be required to "taste" items from one of the menus (the "available" menu) after picture viewing but not from the other menu (the "unavailable" menu). We assumed that the announcement of the subsequent taste test would challenge the dietary rules of restraint eaters. In this context, restrained eaters might down-regulate any appetitive motivational tendencies elicited by these highly salient food stimuli to foster behavioral control on the taste test. Alternatively, they could "let go" of their usual restriction and show disinhibited appetitive responses.

To index the motivational significance of food stimuli we measured the late positive potential (LPP), a positive ERP around 300–700 ms after stimulus presentation which is larger for emotional and motivational significant stimuli than to neutral stimuli (Schupp, Junghofer, Weike, & Hamm, 2003; Schupp, Flaisch, Stockburger, & Junghofer, 2006). Thus, enhanced reactivity to food cues should be associated with an increased LPP. Importantly, recent evidence indicates that the LPP is also sensitive to the effects of emotion regulation: various instructions to down-regulate the emotional impact of a picture have been found to decrease the LPP (Foti & Hajcak, 2008; Hajcak, Moser, & Simons, 2006; Hajcak & Nieuwenhuis, 2006; Krompinger, Moser, & Simons, 2008; Moser, Hajcak, Bukay, & Simons, 2006). Thus, in restrained eaters, the LPP to available relative to unavailable pictures might indicate whether cue reactivity is enhanced (i.e., larger LPPs) or decreased (i.e., smaller LPPs). Unrestrained eaters' LPP, by contrast should not be modulated by the availability manipulation.

Methods

Participants

Participants were female students selected on the basis of their score on the Restraint Scale (Dinkel, Berth, Exner, Rief, & Balck, 2005a; Dinkel, Berth, Exner, Rief, & Balck, 2005b; Herman & Polivy, 1980) which was administered as part of an online screening ($N = 128$) 8–12 weeks before the study. From this sample, participants with a score within the lowest or highest three deciles of the restraint scale were invited to take part in a study of implicit self-esteem ($N = 80$, Hoffmeister et al., in press). Out of this group 19 restrained eaters (RES group) and 21 unrestrained eaters (UNRES) were willing to participate in the current investigation in exchange for either course credit or 20€. The RES group scored in the range 16–23 whereas the UNRES group scored 1–10, which is concordant with established cut-offs for restrained eating (Dinkel et al., 2005b). Eating disorder psychopathology as well as anxiety and depressive symptoms were assessed with the German versions of the EDE-Q (Hilbert, Tuschen-Caffier, Karwautz, Niederhofer, & Munsch, 2007), the State-Trait Anxiety Inventory (STAI, Laux, Glanzmann, Schaffner, & Spielberger, 1981), and the Beck Depression Inventory (BDI, Hautzinger, Bailer, Worall, & Keller, 1994). As indicated in Table 1, groups did not differ on age, anxiety symptoms, education (all were university students), and feelings of

Table 1
Means (SD) of sample characteristics.

	RES $n = 18$	UNRES $n = 21$	Statistic t(df), p	Direction
Age (years)	22.6 (3.27)	23.6 (5.03)	0.73(37), .471	RES = UNRES
Body mass index (kg/m^2)	24.1 (3.80)	20.1 (2.25)	4.03(37), <.001	RES > UNRES
Restraint scale	19.1 (2.22)	6.95 (2.56)	15.7(37), <.001	RES > UNRES
BDI	7.56 (4.36)	4.14 (5.05)	2.24(37), .032	RES > UNRES
STAI-state	37.9 (10.8)	34.5 (6.90)	1.20(37), .241	RES = UNRES
EDE-Q restrained	1.82 (1.21)	0.39 (0.55)	4.63(23.0), <.001	RES > UNRES
EDE-Q eating concerns	1.28 (1.08)	0.24 (0.53)	3.72(23.9), <.001	RES > UNRES
EDE-Q weight concerns	2.52 (1.02)	0.54 (0.63)	7.15(27.3), <.001	RES > UNRES
EDE-Q shape concerns	2.86 (1.16)	1.04 (0.99)	5.28(37), <.001	RES > UNRES
Time of testing (morning, noon, afternoon, evening, %)	27.8, 27.8, 16.7, 27.8	23.8, 23.8, 19.0, 33.3	$\chi^2(3) = 0.25$, .977	RES = UNRES
Hunger rating	5.11 (2.08)	5.00 (1.87)	0.18(37), .864	RES = UNRES
Mood rating	6.83 (1.43)	6.76 (1.09)	0.18(37), .865	RES = UNRES

Note: RES, restraint group; UNRES, unrestrained group; BDI, Beck Depression Inventory; STAI-State, State-Trait Anxiety Inventory; EDE-Q, Eating Disorder Examination Questionnaire.

hunger at the beginning of the testing session. Further, groups were matched regarding the time of testing. As expected, groups differed on the restraint scale, but also on BDI-depression, and BMI (body mass index, the ratio of weight to squared height in kg/m^2) which is a prevalent difference between restrained and unrestrained eaters (e.g., Dinkel et al., 2005b; Meijboom, Jansen, Kampman, & Schouten, 1999). As could be expected, the RES group evidenced higher scores on all subscales of the EDE-Q.

Materials

Participants viewed 160 different pictures from 4 categories (40 pictures per category). Forty pictures with appetizing high-caloric food items (mainly snacks: fast food, sweets, deserts[1]) were collected from various sources on the Internet, and edited to be homogeneous with respect to complexity (number of food items displayed in one picture) brightness, contrast, viewing distance and background color. Food pictures were selected to resemble "binge food", i.e., food that eating disordered patients frequently report to consume during binge eating episodes. Non-food control pictures ($n = 120$) were selected from the International Affective Picture System (IAPS, Lang, Bradley, & Cuthbert, 1997) including pleasant, neutral, and unpleasant contents.[2] The three IAPS categories differed on normative ratings of valence (pleasant: $M = 7.07$, SD = 1.68; neutral: $M = 5.07$, SD = 1.24; unpleasant: $M = 2.42$, SD = 1.58); and arousal (pleasant: $M = 5.42$, SD = 2.23; neutral: $M = 2.80$, SD = 1.99, unpleasant: $M = 6.19$, SD = 2.21).

Procedure

Food deprivation has been shown to influence ERPs to food pictures (Stockburger, Weike, Hamm, & Schupp, 2008). To reduce between subject variance in deprivation, all participants were asked not to eat anything in the 3 h proceeding the testing session. To further enhance the commitment to comply with this instruction and to honestly report the quantity of food eaten before the session, the experimenter announced a saliva test allegedly being sensitive to recent food consumption (see Drobes et al., 2001 and Stockburger et al., 2008, for a similar procedure). After welcoming the participant, the experimenter familiarized the participant with the electroencephalography (EEG) laboratory and the upcoming procedures, and conducted the bogus saliva test by asking participants to chew on a salivette for 2 min. Participants then completed a questionnaire containing questions regarding consumption of food on the study day and the present feeling of hunger (on a 1–9 scale, not hungry at all to extremely hungry). Groups did not differ on that scale assuring comparable satiety (Table 1). Logs of participants' food consumption indicated good compliance (90.3%) with the instructions not to eat anything in the previous 3 h.[3]

After the fitting of the electrode cap, participants were guided to the dimly lit, electrically shielded and sound-proof 2.5 m $\times$ 3 m EEG chamber. Unrelated to the present investigation, and prior to the picture viewing paradigm reported here, all participants underwent a quiet sitting baseline (4 min), viewed a sadness inducing film (3 min, followed by a 6 min recovery period), and read self-referent sentences (12 min).

View block

In the first block, participants viewed the 40 food pictures along with the 40 pleasant, 40 unpleasant, 40 neutral IAPS pictures in a random order with the restriction of no more than two repetitions per category. Participants were instructed to view the pictures naturally. The 8.3 $\times$ 6.25 in. pictures were presented on a 17 in. monitor at 1 m viewing distance for 1000 ms, followed by a 500-ms intertrial interval (ITI). Picture presentation was controlled by a Presentation program (Neurobehavioral Systems, Inc.; Albany, CA).

Availability block

To make the motivational context more explicit and to effectively manipulate the availability of some food items without making the study aim too obvious, the following procedure was used. Written instruction informed participants that they would subsequently see the food pictures again, however, arranged in two "menus", and that they would be asked to eat from the items in both menus later. Then, however, just prior to the presentation of food pictures, the experimenter entered the EEG-cabin and gave the following instruction: "unfortunately we could not obtain the items for menu 1 today, so only menu 2 is available for eating later". By disguising the availability manipulation as an error of the experimenter we intended to enhance its credibility.[4] Participants were then presented with two sets of 20 food pictures each (menus 1 and 2), roughly matched in caloric content. Each set was preceded by written instructions: "menu 1: you will now see a set of food items. We have prepared some of them for you and would later ask you to taste them. While viewing the pictures, please imagine you would eat of them". The identical instruction was used for menu 2. The two picture sets were run in alternating order four times each. Timing of picture presentation and ITI were identical to Block 1. The assignment of picture sets to the available condition (menu 1: not available, menu 2: available) as well as whether the first menu was menu 1 or menu 2 was counterbalanced across participants to exclude possible picture set or order effects. Thus each participant viewed 80 presentations of the available food items and 80 presentations of the unavailable food items.

EEG recording and data analysis

The EEG was digitally recorded with SynAmps amplifiers and Scan 4.0 software (Neuro-Scan, Inc., Sterling, VA, USA) from Ag/AgCl electrodes, using an extended 10–20-system electrode cap (EasyCap, Falk Minow Services, Herrsching-Breitbrunn, Germany), from midline sites Fz, Cz, Pz and on each side F3/F4, F7/F8, T7/T8, C3/C4, CP1/CP2, CP5/CP6, FT9/FT10, 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 electro-oculogram (VEOG) was recorded from above and below the right and left eye and the horizontal electro-oculogram (HEOG) was recorded from the outer canthi of each eye. Online filtering occurred between 0.1 and 100 Hz and sampling rate was 500 Hz. Electrode impedance was kept below 5 kΩ (10 kΩ for VEOG and HEOG).

[1] The food pictures displayed the following items: potato chips, candy, mars bar, chocolate, smarties, muffins, cakes, ice cream, cheese, butter, pralines, hot dog, nuts, lollies, pasta, pizza, donut, etc.

[2] IAPS: positive pictures: 1440, 1463, 1540, 1710, 1722, 1750, 2000, 2057, 2070, 2080, 2160, 2165, 2311, 2530, 2540, 2550, 2660, 4250, 4520, 4531, 4534, 4607, 4608, 4610, 4611, 4641, 4653, 4658, 4659, 4660, 4669, 4687, 4700, 5621, 5623, 5830, 8080, 8161, 8370, 8400; neutral pictures: 5300, 5395, 5455, 5535, 5891, 6150, 7000, 7002, 7004, 7010, 7020, 7030, 7031, 7034, 7040, 7050, 7060, 7090, 7095, 7096, 7100, 7110, 7130, 7140, 7150, 7170, 7175, 7190, 7211, 7217, 7224, 7234, 7235, 7500, 7510, 7560, 7590, 7595, 7705, 7950; negative pictures 1050, 1052, 1120, 1280, 1300, 1302, 1930, 1931, 2053, 2110, 2120, 2205, 2700, 2730, 2800, 2900, 3022, 3110, 3120, 3181, 3230, 3300, 3350, 3550, 6211, 6230, 6250, 6260, 6350, 6370, 6510, 6550, 6560, 6570, 6821, 9000, 9001, 9140, 9220, 9570.

[3] Three unrestrained eaters reported having eaten a small amount of food (one bread, piece of chocolate, gummy bears) while one unrestrained eater had eaten lunch 1 h prior to the investigation. Exclusion of this latter person, however, did not alter the pattern of results.

[4] The experimenter had placed some food items on the desks in the room used for electrode setup suggesting the factual availability of food.

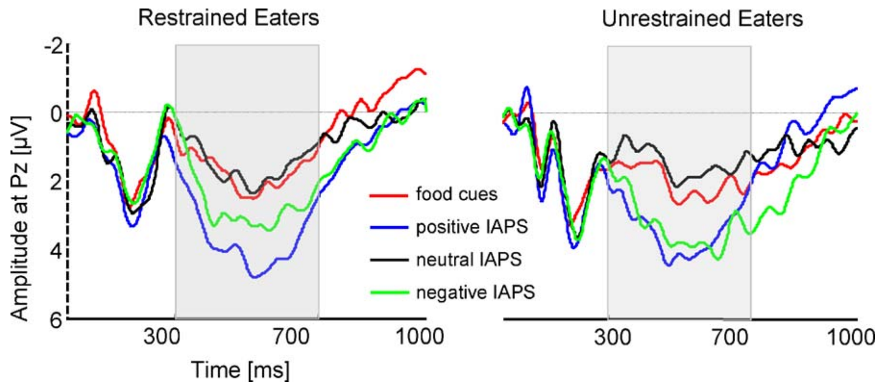

Fig. 1. Event-related potentials to food pictures during the viewing block in the restrained and unrestrained group at Pz. Statistical analysis was carried out in the time range 300–700 ms.

Offline analyses were performed using AvgQ[5] (Feige, 1999) during which each trial was corrected for vertical EOG artifacts using the method developed by Gratton, Coles, and Donchin (1983), re-referenced to the average reference, and low-pass filtered at 20 Hz. Trials were rejected if there was excessive physiological artifact (i.e., base-to-peak amplitude exceeding 120 μV on any channel). Number of valid trials was high (96%) and did not differ between conditions or groups.

ERPs were constructed by separately averaging baseline-subtracted (200 ms pre-stimulus) food trials as well as pleasant, unpleasant, and neutral IAPS trials in Block 1. Separate averages were also created for menu 1 (not available) and menu 2 (available) during Block 2. The LPP was scored by averaging mean amplitude in a time range between 300 and 700 ms based on previous research on the impact of cognitive appraisal strategies on the LPP (Hajcak et al., 2006).

Results

Block 1: view condition

Previous research indicated that the LPP is maximal at Pz (e.g., Hajcak et al., 2006; Hajcak & Nieuwenhuis, 2006). Fig. 1 displays the grand averages for restrained and unrestrained eaters in the food, neutral and emotional conditions at Pz. Visual inspection suggests group differences with regard to a stronger N2 in the unrestrained eaters which, however, did not prove statistically reliable (p's > .3). In both groups, a strong modulation of the LPP for emotional compared to neutral and food pictures was evident, while the latter two conditions did not differ. A 4 (Condition: positive, neutral, negative IAPS, food) X 2 (Group: RES, UNRES) ANOVA yielded a significant Condition effect, $F(3,111) = 24.5$, $p < .001$, $\eta^2 = 39.9\%$ but no main effect or interaction of Group (p's > .37). To follow up on the Condition effect, separate t-tests contrasted the positive and negative IAPS pictures as well as the food pictures with the neutral IAPS pictures. For negative vs. neutral and positive vs. neutral, these t-test were highly significant, $t(38) = 5.64$, $p < .001$, $d = 0.55$, and $t(38) = 6.79$, $p < .001$, $d = 0.73$, respectively. Food pictures, by contrast, did not elicit a LPP: The t-test contrasting food pictures with neutral pictures yielded a non-significant Condition effect, $t(38) = 1.50$, $p = .143$, $d = 0.14$.

Block 2: effects of availability of food

Visual inspection of the ERP waveforms revealed the modulation of the ERP over frontal regions as a function of Group and condition (see Fig. 2B for selected sensors). In addition a Group (RES, UNRES) × Condition (available vs. unavailable) ANOVA was calculated for each sensor in the time range 300–700 ms (cf. Schupp et al., 2003). Fig. 2C illustrates the topography of the Group × Condition interaction, by mapping its F-value on the scalp using spherical spline interpolation (Junghofer, Elbert, Leiderer, Berg, & Rockstroh, 1997). A slightly left sided focus of the interaction did not prove statistically significant. Thus, for the statistical analysis, we collapsed the sensors F3, F4, and Fz into a frontal score, C3, Cz, and C4 in to a central score, and P3, Pz, and P4 into a parietal score for each condition and group (Fig. 2A) and Bonferroni-adjusted our α-level. Cohen's d and eta-squared are reported as effect size measures.

On the frontal score the magnitude of the ERP in the unavailable and available condition in the RES group was −1.77 μV (SD = 1.38) and −2.20 μV (SD = 1.26), respectively. In the UNRES group the magnitude of the ERP in the unavailable and available condition was −1.96 μV (SD = 1.70) and −1.82 μV (SD = 1.72). The Group × Con- Condition ANOVA yielded a significant Condition × Group interaction, $F(1,37) = 6.31$, $p = .016$, $\eta^2 = 14.7\%$. The main effects of Group and Condition were not significant ($ps > .24$). Post hoc t-tests indicated that the interaction was mainly due to less positive LPPs to available food cues relative to unavailable food cues in the RES group, $t(17) = 2.47$, $p = .024$, $d = 0.325$, while there was no difference in the UNRES group, $p = .328$, $d = 0.08$. Because groups differed in BMI and BDI, these variables were added in two separate Group - × Condition analyses of covariance. Neither BMI nor BDI reached significance as covariates, $ps > .123$ and the Group × Condition interaction remained significant in both cases $ps < .042$.

Despite uniform instructions not to eat in the 3 h preceding the experiment and generally good compliance with these instructions, participants varied considerably on hunger ratings. The individual ratings ranged 1–8 on the 1–9 scale, without systematic group differences. Since previous studies suggested altered ERPs to food pictures in hungry compared to satiated individuals (Carretie, Mercado, & Tapia, 2000; Stockburger et al., 2008) we correlated the ERP-difference score described above with hunger ratings. This correlation was not significant, $r(39) = -0.02$. Mean LPPs across both conditions were also uncorrelated with hunger ratings $r(39) = -0.14$. Similarly, previous research suggested that negative mood states could disinhibit restrained eaters when confronted with food (e.g., Ruderman, 1985). Correlations of the BDI and the 1-item mood ratings with the ERP-difference score were not significant, both $rs < 0.17$.

Discussion

To our knowledge this is the first study of ERPs to food pictures in restrained and unrestrained eaters. Our design featured two

[5] EMEGS (Junghofer & Peyk, 2004) was used to generate the figures, based on the average waveforms calculated in AVG-Q.

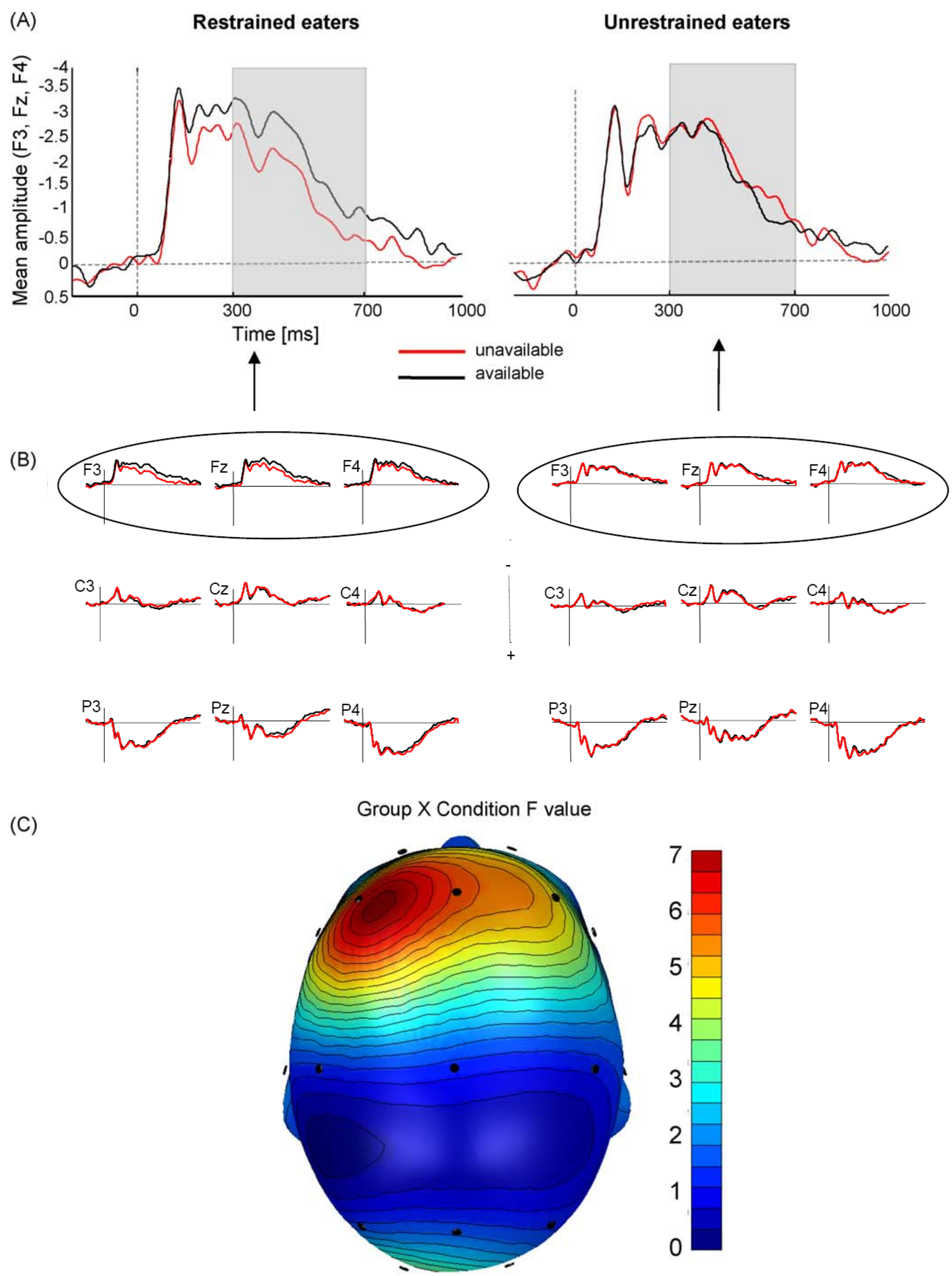

Fig. 2. Results from the availability block. (A) ERP waveforms averaged over frontal sensors (F3, F4, Fz), (B) grand mean waveforms for selected frontal, central, and parietal sensors and (C) mapping of the Condition × Group ANOVA *F*-value, 300–700 ms.

separate blocks to specify under which conditions restrained eaters might show enhanced or reduced cue reactivity to high-calorie food pictures. The results of the *view block*, during which pictures of high-caloric food items were passively viewed along with standard positive, neutral and negative IAPS pictures, can be summarized as follows. Well in line with previous research, both groups showed an enhanced LPP to emotional (positive, negative) compared to neutral IAPS pictures (see Schupp et al., 2006, for review). However, both groups had comparable ERP responses to food items, which indicated that cue reactivity during passive viewing might not differ between restrained and unrestrained eaters in this motivational context. Also previous ERP research failed to demonstrate a selective alteration of ERPs to food cues. Hachel et al. (2004) found no differences in ERPs to food and non-food words in restrained and unrestrained eaters but ERPs were generally more positive going in restrained eaters. Behavioral and psychophysiological studies provided inconsistent results with increased reactivity (Klajner et al., 1981), decreased reactivity (Nederkoorn & Jansen, 2002; Piacentini et al., 1993) or unaltered reactivity (Bulik, Lawson, & Carter, 1996) in restrained relative to unrestrained eaters. In a passive viewing context, food pictures might not be particularly arousing, which might be why ERPs to food pictures did not differ from ERPs to neutral IAPS pictures in the present study. Without a more explicit motivational context, restrained eaters might indeed be characterized by normal reactivity to food cues.

The results from the availability block provided more insight into restrained eaters' processing style. We had expected a modulation of LPPs by the availability manipulations in restrained eaters but not in unrestrained eaters due to increased regulation efforts in the former group as a results of an anticipated break of dietary rules (i.e., participants were expecting to eat the available food items after picture viewing). Results showed that restrained eaters' LPPs to the available food set were *reduced* (i.e., weaker in positive amplitude, suggesting less motivational salience) relative to the LPP to the unavailable food, while unrestrained eaters' LPPs were not modulated by availability. This could speak to a successful down-regulation of the salience of the available food cues in restrained eaters. This is consistent with previous studies reporting smaller psychophysiological responses to food cues in restrained eaters (Nederkoorn & Jansen, 2002) under conditions that allow later food consumption and suggests that restrained eaters, in line with their general restricted eating behavior, exerted cognitive control over their motivational tendencies, thereby reducing cue reactivity. The present finding suggests that such down-regulation depends heavily on the motivational context: Restrained eaters apparently employ down-regulation selectively, i.e., under conditions of expected in vivo exposure but not to all food cues they see (e.g., in advertisements, television). It is interesting to note that smaller cue reactivity has also sometimes been reported for eating disordered individuals (Bulik et al., 1996; Karhunen, Lappalainen, Tammela, Turpeinen, & Uusitupa, 1997). Similar contextual influences might in deed exist in clinical patients: cue reactivity in bulimic patients differs strongly before and after in vivo food exposure (Mauler, Hamm, Weike, & Tuschen-Caffier, 2006).

Several study limitations have to be considered. First, it is possible that the announcement of a taste test did not disinhibit appetitive responses of restrained eaters to a similar degree as a pre-load would have. Thus, the obtained reduced reactivity to the available food set might not be representative for contexts that would typically result in a breakdown of cognitive control and disinhibited eating in restrained eaters and we did not assess behaviorally (i.e., by means of a actual taste test) or subjectively (i.e., by means of verbal ratings) whether eating or desire to eat was inhibited or disinhibited. Instead, we inferred inhibition/down-regulation from LPP amplitudes. Although there is now ample evidence that the LPP to emotional pictures is reduced by several down-regulatory mechanisms (Foti & Hajcak, 2008; Hajcak et al., 2006; Hajcak & Nieuwenhuis, 2006; Krompinger et al., 2008; Moser et al., 2006) it not considered a genuinely inhibitory ERP component like, for example, the anterior N2 in oddball tasks (see Folstein & Van Petten, 2008, for review).

Second, our interpretations rest on findings regarding the posterior LPP but the more frontal location and the absence of a marked positivity – possibly also related to our average reference calculations – indicated that other neural generators might contribute to ERP modulation in the current study as well. Recent evidence points to a more frontal location of the LPP in tasks involving the change of stimulus meaning (MacNamara et al., 2009). Although speculative at this point, prefrontal generators would be consistent with an enhanced recruitment of the prefrontal cortices which inhibit subcortical, emotion-generative centers, particularly during cognitive down-regulation strategies like reappraisal (Ochsner & Gross, 2005), and which show altered activity during viewing of food pictures in eating disordered individuals (Uher et al., 2004). Further, the prefrontal and the orbitofrontal cortices are implicated in encoding the motivational value of food (Siep et al., 2008). Reference independent, high density ERP studies and functional magnetic resonance imaging studies might provide more insight into the neural generators of inhibitory control during picture viewing.

Third, there is at least one alternative account of the present findings. There is recent evidence that cognitive performance of restrained eaters and dieters is impaired during cognitive tasks due to interference from thoughts and preoccupation about food (Jones & Rogers, 2003; Kemps & Tiggemann, 2005). It might thus be possible that restrained eaters allocated less attention to the food pictures in the availability block due to interference of this kind. Reduced attention to the motivational content of pictures has been shown to reduce LPP amplitude (Hajcak et al., 2006; Hajcak & Nieuwenhuis, 2006). Fourth, although our participants generally adhered to the instructions not to eat in the 3 h prior to the study, hunger ratings indicated considerable variance across participants. Even though no correlation was found with the LPP-modulation, we were not able to disentangle the effect of long-term dietary restraint from short-term deprivation. A full crossing of these two factors (high and low restrained participants under deprived and non-deprived conditions) would provide more insight here (see, for example, Piacentini et al., 1993). Finally, our modest effect sizes obtained in Block 2 call for a replication of this result, possibly with increased participant and trial numbers.

With these limitations in mind we draw the following conclusions. Restrained eaters do not appear to generally differ from unrestrained eaters in their electrocortical responses to high-caloric food cues during passive viewing. However, they respond less strongly to food cues which they expect to eat subsequently than to food cues which they do not expect to eat—a difference that was not evident in non-restrained eaters. This modulation could be due to cognitive down-regulation of reactions to highly salient stimuli which they expect to be confronted with.

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