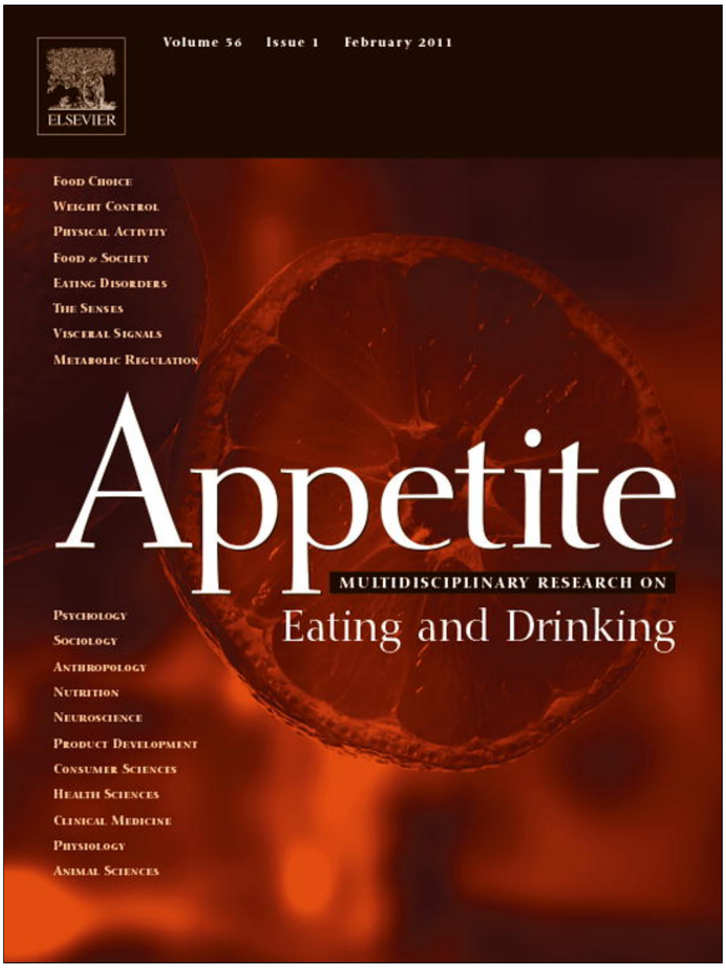

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Research report

Restrained eating is related to accelerated reaction to high caloric foods and cardiac autonomic dysregulation ☆

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ABSTRACT

Cognitive bias to food-cues and cardiac autonomic dysregulation have both been related to disordered eating behavior in previous research. The present study investigated two possible measures of self-regulatory ability in restrained eaters: resistance to distractor interference and vagal-cardiac control. Young women ($N = 47$) performed a flanker task involving high caloric food-cues or neutral pictures. Vagal-cardiac activity was calculated from baseline heart rate recordings at rest. Restrained eaters did not differ from unrestrained eaters in resistance to distractor interference. However, restrained eaters showed shorter reaction times to high-calorie food-cues as compared to neutral pictures than unrestrained eaters. This attentional bias was further related to low dieting success. Moreover, restrained eating was associated with low parasympathetic activation and sympathovagal imbalance, independent of current body mass. Both attentional bias and cardiac autonomic dysregulation were related to self-reported weight fluctuations. Results are discussed in terms of possible adverse consequences of weight cycling in young women and low self-regulatory ability in restrained eaters.

Introduction

Restrained eaters try to cognitively control their eating behavior in order to lose weight or prevent weight gain. Few, if any of those restrained eaters, however, are actually successful in their goal to eat less as restrained eating is not correlated with lower caloric intake (Stice, Cooper, Schoeller, Tappe, & Lowe, 2007; Stice, Fisher, & Lowe, 2004; Stice, Sysko, Roberto, & Allison, 2010). Indeed, restrained eaters are often unsuccessful in maintaining their cognitive control. As a result, restrained eaters tend to have a higher body-mass-index (BMI) and to experience weight cycling (Dinkel, Berth, Exner, Rief, & Balck, 2005; Field, Manson, Taylor, Willett, & Colditz, 2004). One explanation for this association could be that restrained eaters are only temporarily able to maintain their cognitive restriction over their eating behavior and often indulge in overeating. For instance, restrained eaters – especially those categorized using the *Restraint Scale* (Herman & Polivy, 1980) – have been found to be rather unsuccessful in their attempt to lose weight and to show disinhibited food intake in a variety of experimental situations involving food exposure or other manipulations that limit self-regulatory resources (see Stroebe, 2008 for a review).

Cognitive bias to food-cues

Cognitive bias to food stimuli has been closely associated with disordered eating behavior, but also restrained eating (Brooks, Prince, Stahl, Campbell, & Treasure, 2011). The presence of food-cues influences performance on a variety of cognitive tasks in these groups, which may be related to increased incentive salience of such cues (Brooks et al., 2011). For instance, restrained eaters are faster to recognize and detect food-related words compared to neutral words (Boon, Vogelzang, & Jansen, 2000; Hollitt, Kemps, Tiggemann, Smeets, & Mills, 2010) or show increased Stroop interference for such words (Francis, Stewart, & Hounsell, 1997; Green & Rogers, 1993). Behavioral disinhibition was especially pronounced in response to food-related words in a sample of bulimic patients (Mobbs, van der Linden, d'Acremont, & Perroud, 2008). In contrast, we found even better behavioral inhibition in restrained than in unrestrained eaters and, in addition, slower reactions to pictorial food-cues in restrained eaters compared to unrestrained eaters (Meule, Lukito, Vögele, & Kübler, 2011). Similarly, conflicting

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results for attentional bias or reward sensitivity to food-cues in restrained eaters have also been reported (Ahern, Field, Yokum, Bohon, & Stice, 2010).

Cardiac autonomic regulation

Heart rate variability (HRV) refers to the variation of heart beat intervals and is influenced by sympathetic and parasympathetic input to the sino-atrial node of the heart. Increased high-frequent parasympathetically (or vagally) mediated modulations increase HRV while increased low-frequent sympathetic activation (or sympathovagal imbalance) decreases HRV (Task Force of The European Society of Cardiology and The North American Society of Pacing and Electrophysiology, 1996). Accordingly, time domain measures of HRV, such as the root mean square of successive differences, are positively correlated with indices of vagal-cardiac control (high frequency power, see Methods) and negatively correlated with the ratio between low frequency and high frequency power (Task Force of The European Society of Cardiology and The North American Society of Pacing and Electrophysiology, 1996). A higher vagal-cardiac control or higher HRV, respectively, reflects a higher flexibility of the cardiovascular system. This enables an organism to quickly adapt to changing environmental requirements (Thayer & Lane, 2009). Accordingly, HRV is associated with health-status and several physical conditions (Britton & Hemingway, 2004; Thayer, Yamamoto, & Brosschot, 2010). For instance, being overweight or obese is related to low HRV (Britton & Hemingway, 2004; Karason, Molgaard, Wikstrand, & Sjostrom, 1999; Latchman, Mathur, Bartels, Axtell, & De Meersman, 2011). Consequently, frequent exercise or weight loss increases HRV (Britton & Hemingway, 2004; Karason et al., 1999; Thayer et al., 2010).

In addition to the empirical observation of an association between HRV and physical conditions, the model of neurovisceral integration (Thayer & Lane, 2009) provides a theoretical framework for HRV reflecting self-regulatory strength. This model provides a link between prefrontal and subcortical brain structures and the autonomic regulation of cardiac activity (*central autonomic network* (CAN)). The output of the CAN is directly linked to HRV and particularly high-frequent, parasympathetic mediated tonic HRV has been found to covary with the activity of the prefrontal cortex (Thayer, Hansen, Saus-Rose, & Johnsen, 2009). Accordingly, HRV is associated with processes that are involved in self-regulation, e.g. emotion regulation and executive functioning (Appelhans & Luecken, 2006; Thayer et al., 2009). For example, positive associations have been found between resting levels of vagally mediated HRV and performance in working memory tasks and the continuous performance test (Hansen, Johnsen, & Thayer, 2003) or longer persistence in an unsolvable anagram task (Segerstrom & Nes, 2007).

Applying the neurovisceral integration model to restrained eating behavior would imply that persons with high self-regulatory capacity, i.e. those who restrict their food intake successfully, to have high HRV while those with low self-regulatory capacity would show low HRV. Indeed, the majority of studies point to parasympathetic dominance and decreased sympathetic modulation in anorectic patients (see Mazurak, Enck, Muth, Teufel, & Zipfel, 2011 for review) while the opposite is true for obese patients (Karason et al., 1999; Latchman et al., 2011). However, these differences in cardiac autonomic activity may reflect physiological changes and differences in BMI due to malnourishment and lifestyle factors rather than variations in self-regulatory capacity. Sustained extreme weight loss has been found to be related to autonomic dysregulation in anorectic patients (Wu, Nozaki, Inamitsu, & Kubo, 2004). Therefore, investigation of HRV as a marker of self-regulation needs to take into account such differences, particularly in BMI. In a sample of bulimic patients, we found dissociation between fasting and non-fasting bulimic patients such that only fasting women showed increased parasympathetic modulations compared to controls whereas non-fasting subjects displayed sympathetic dominance (Coles, Vögele, Hilbert, & Tuschen-Caffier, 2005; Vögele, Hilbert, & Tuschen-Caffier, 2009). Groups did not differ in BMI. Therefore, current fasting status with accompanying parasympathetic dominance could be an index of successful eating-related self-regulation. Another study compared HRV between obese patients with binge eating disorder (BED) and those without BED (Friederich et al., 2006). Although there was no baseline difference in HRV between groups, an augmented reduction of parasympathetic HRV was observed in obese binge eaters as a result of mental challenge. This change was linked to binge eating frequency. In a sample of normal-weight volunteers, Rodríguez-Ruiz and colleagues (2009) investigated HRV in trait chocolate cravers. Chocolate cravers with low HRV had high scores on the *Eating Attitudes Test* while no such association was present in the low craving group (Rodríguez-Ruiz et al., 2009). They interpreted their results such that low vagally mediated HRV was a marker of inadequate emotion regulation that was associated with food cravings and uncontrolled eating behavior.

Hypotheses

In the current study, we used a behavioral and a physiological measure of self-regulatory ability. At the behavioral level, we investigated how well participants resisted interference by a distractor which has been found to be closely related to response inhibition (Friedman & Miyake, 2004). The experimental paradigms to assess resistance to distractor interference are derived from the Eriksen flanker task (Eriksen & Eriksen, 1974), which requires participants to respond to a target that is flanked by either congruent or incongruent distractors. Incongruent distractors interfere with the required target response leading to increased reaction times. We hypothesized that the self-regulatory deficits of restrained eaters should manifest in high distractor interference, i.e. longer reaction times in incongruent trials. Additionally, we predicted that an attentional bias for high-calorie food-cues should lead to even higher distractor interference in a flanker task involving such cues. More precisely, we expected restrained eaters to show increased reaction times in incongruent neutral trials, i.e. when neutral targets are flanked by food-cues.

To our knowledge, no study has investigated HRV under resting conditions in restrained eaters, as yet. Since restrained eaters are rather unsuccessful in their attempt to restrict their food intake, we expected them to show lower levels of parasympathetic activity compared to unrestrained eaters as an index of lowered self-regulatory capacity.

In summary, we hypothesized restrained eaters (1) to show higher distractor interference in a flanker task as compared to unrestrained eaters, (2) further to show higher distractor interference when neutral targets are flanked by food-cues, and (3) to present with lower vagal-cardiac activity as compared to unrestrained eaters.

Methods

Participants

Female psychology students, who were in their introductory study period, were recruited from the University of Würzburg, Germany ($N = 47$). Average age was $M = 23.7$ years ($SD \pm 3.4$), and the mean BMI was $M = 22.4$ kg/m^2 ($SD \pm 2.8$). Participants received course credits for participation.

Heart rate recording

Heart rate was monitored at the beginning of each experimental session with the Polar watch RS800CX (Polar Electro Oy, Kempele, Finland), using a sampling rate of 1000 Hz. After attaching the chest strap, participants were seated in a quiet room. Subsequently, the experimenter instructed participants to close their eyes and relax and left the room for ten minutes.

Flanker task

The flanker task was presented after heart rate recording was completed. The experiment ran on a PC using E-prime 2.0 (Psychology Software Tools Inc., Pittsburgh, PA). Participants were instructed to respond to the target stimulus by pressing a left or right response button if the target was a food or a neutral item (mapping was counterbalanced across participants). In our version of the flanker task, the central targets were pictures of either high-calorie foods or neutral objects, which were flanked by pictures either from the same category (congruent condition) or distractors from the other category (incongruent condition). Food items were pictures of high caloric sweet or savory foods. Neutral pictures were common household items. All pictures were taken from a set previously used in one of our studies (Meule et al., 2011) and edited to be homogeneous with respect to background color (Fig. 1). The procedure of the task was adapted from von Geusau and colleagues where a rectangle was presented for 500 ms accompanied by the flankers (von Geusau, Stalenhoef, Huizinga, Snel, & Ridderinkhof, 2004). After the target appeared in the rectangle, it remained on the screen until a response was detected. Maximum possible reaction time (RT) was 1500 ms. The inter-trial interval was fixed at 1000 ms. During the inter-trial interval, the screen was either blank or, in case of a false reaction, feedback was provided. The task included a total of 360 trials divided in six blocks.

Questionnaires

Participant characteristics

Participants reported their age, height, weight and hours since the last meal. They also indicated their habitual level of physical activity ("How often do you exercise per week for at least 15 min?"). Response categories on a 4-point scale ranged between *never* to *more than 5 times*.

Restrained eating

Participants completed the German version of the *Restraint Scale* (Dinkel et al., 2005; Herman & Polivy, 1980) at the end of the session. The *Restraint Scale* consists of two subscales that measure *concern for dieting* (RS-CD) and *weight fluctuations* (RS-WF; Blanchard & Frost, 1983; Dinkel et al., 2005). The German version of the *Restraint Scale* has an internal consistency of $\alpha = .83$ (RS-CD: $\alpha = .82$, RS-WF: $\alpha = .69$; Dinkel et al., 2005).

Current food cravings

The state version of the *Food Cravings Questionnaires* (FCQ-S; Cepeda-Benito, Gleaves, Williams, & Erath, 2000; Meule, Lutz, Vögele, & Kübler, 2012) was administered. The FCQ-S measures current food cravings as a multi-dimensional construct consisting of psychological (*intense desire to eat*, *anticipation of positive reinforcement* or *relief from negative states that may result from eating*), behavioral (*lack of control over eating*), and physiological (*hunger*) aspects (Cepeda-Benito et al., 2000). The German version of the FCQ-S has an internal consistency of $\alpha = .92$ ($\alpha = .87–.89$ for the subscales; Meule et al., 2012).

Impulsivity

Subjects' self-reported impulsivity was assessed with the short version of the *Barratt Impulsiveness Scale* (BIS-15; Meule, Vögele, & Kübler, 2011; Spinella, 2007). It consists of the subscales *motor*, *attentional*, and *non-planning impulsivity*. The German version of the BIS-15 has an internal consistency of $\alpha = .81$ ($\alpha = .68–.82$ for the subscales; Meule, Vögele et al., 2011).

Perceived self-regulatory success in dieting

The *Perceived Self-Regulatory Success in Dieting Scale* (PSRS) consists of three questions asking participants to indicate on a 7-point scale how successful they are in losing weight, watching their weight, and how difficult they find it to stay in shape (Fishbach, Friedman, & Kruglanski, 2003). The scale was translated into German by the first author taking both the English (Fishbach

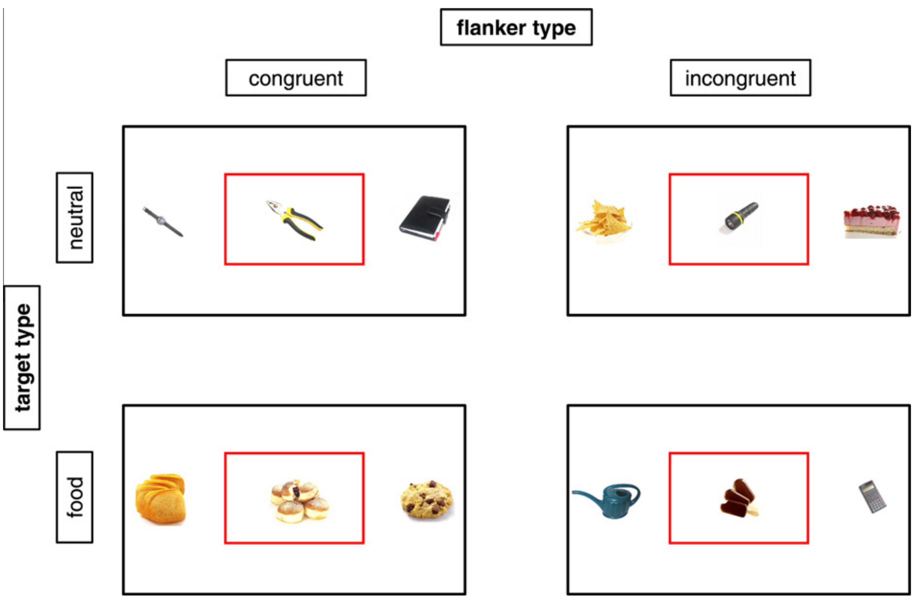

Fig. 1. Representative screen displays of the flanker task with congruent and incongruent trials with either a neutral or a food target. A red rectangle flanked by two distractors was presented on the screen for 500 ms. Participants had to push a right or left response button when food or neutral targets appeared in the rectangle. Intertrial interval was 1000 ms. (For interpretation of the references in colour in this figure legend, the reader is referred to the web version of this article.)

et al., 2003) and Dutch version (Papies, Stroebe, & Aarts, 2008a) into account. The PSRS has previously been found to correlate negatively with BMI and has an internal consistency of $\alpha = .66–.72$ (Fishbach et al., 2003; van Koningsbruggen, Stroebe, & Aarts, 2011).

Data analysis

R–R-recordings were analyzed using Kubios HRV 2.0 software (Tarvainen, Niskanen, Lipponen, Ranta-Aho, & Karjalainen, 2009). Interbeat interval series were corrected for artifacts with the default settings of the program. Trend components were removed with the smoothness priors detrending method ($\lambda = 500$). Only the last five minutes of the collected data were used for calculation of autonomic parameters (Task Force of The European Society of Cardiology and The North American Society of Pacing and Electrophysiology, 1996). Spectral power was obtained for high frequency (HF: 0.15–0.4 Hz) and low frequency (LF: 0.04–0.15 Hz) components by Fast Fourier Transformation. HF power, expressed in normalized units (HF n.u. = HF ms^2/(total power ms^2 – very low frequency ms^2)) is an index of vagal-cardiac control and LF/HF power ratio a marker of sympathovagal balance (Task Force of The European Society of Cardiology and The North American Society of Pacing and Electrophysiology, 1996). LF/HF was log-transformed due to skewed distribution of data.

Participants were categorized as high versus low restrained eaters using a median split on the *Restraint Scale*. Participants scoring exactly on the median ($Mdn = 14$, $n = 3$) were included in the high restraint group ($n = 25$), as the common European median of the *Restraint Scale* is usually lower (Dinkel et al., 2005). RTs in the flanker task with less than 150 ms, reflecting anticipation, were removed from analyses. A repeated measures ANOVA was performed with RT as dependent variable and picture type and congruence as within-subject factors. Post-hoc *t*-tests were Bonferroni-adjusted. Univariate ANOVAs were run to compare questionnaire variables between groups. To follow up the effect of dieting success on task performance and physiological variables, we ran regression analyses with restraint, dieting success, the interaction restraint × dieting success, and BMI as *z*-standardized predictors. These analyses were also run for the subscales of the *Restraint Scale* separately.

Results

Questionnaire data

Groups did not differ in age, hours since the last meal, current food cravings, habitual physical activity, or impulsivity (Table 1). Restrained eaters had a higher BMI and dietary restraint score, but reported less perceived self-regulatory success in dieting (Table 1).

Task performance

ANOVA for repeated measures yielded significant interactions between picture type × congruence ($F_{(1,\ 45)} = 4.12$, $p < .05$, $\eta_p^2 = .08$) and picture type × restraint status ($F_{(1,\ 45)} = 7.46$, $p < .01$, $\eta_p^2 = .14$) while there was no interaction between congruence × restraint status ($F_{(1,\ 45)} = .002$, ns) and no main effects (picture type ($F_{(1,\ 45)} = .94$, ns), congruence ($F_{(1,\ 45)} = 2.98$, ns) and restraint status ($F_{(1,\ 45)} = .4$, ns)). Post hoc *t*-tests indicated that RTs in incongruent trials were slower than in congruent trials only when the target was a food picture ($M_{(congruent)} = 437.7$ ms ($SE \pm 6.9$), $M_{(incongruent)} = 443.3$ ms ($SE \pm 6.3$), $t_{(46)} = -2.6$, $p < .02$). The significant picture type × restraint status interaction indicated a differential reaction of low restrained and high restrained eaters to pictures of food and neutral objects. Post hoc *t*-tests revealed that restrained eaters responded faster to food targets ($M = 440.33$ ms, $SE \pm 9.3$) compared to neutral targets ($M = 451.51$ ms, $SE \pm 8.6$, $t_{(24)} = -2.5$, $p < .02$). Reaction times did not differ between target types in unrestrained eaters ($t_{(21)} = 1.2$, ns). No three-way interaction picture type × congruence × restraint status ($F_{(1,\ 45)} = .008$, ns) was observed.

To further explore the influence of dieting success on reaction times, we calculated a variable for attentional bias ($RT_{neutral} - RT_{food}$) and used this in subsequent regression analyses. The overall model including the total restraint score was significant ($F_{(4,42)} = 4.01$, $p < .01$). Dieting success negatively predicted attentional bias while restraint was a marginal significant predictor of attentional bias (Table 2). The overall model including concern for dieting was also significant ($F_{(4,42)} = 2.97$, $p < .05$). Dieting success was the only significant predictor of attentional bias (Table 2). The overall model including weight fluctuations was also significant ($F_{(4,42)} = 5.12$, $p < .01$). Dieting success and weight fluctuations were significant predictors of attentional bias while the influence of BMI was marginally significant (Table 2).

Cardiac autonomic regulation

The overall model including the total restraint score as predictor of vagal-cardiac control was marginally significant ($F_{(4,42)} = 2.11$, $p < .10$). Restraint negatively predicted vagal-cardiac control (Table 3). The overall model including concern for dieting was not significant ($F_{(4,42)} = .88$, ns) while the model including weight fluctuations was marginally significant ($F_{(4,42)} = 2.32$, $p < .08$). Weight fluctuations negatively predicted vagal-cardiac control (Table 3). Similar results were obtained for sympathovagal balance. The overall models including the total restraint score ($F_{(4,42)} = 2.68$, $p < .05$) or weight fluctuations ($F_{(4,42)} = 3.27$, $p < .05$) were significant while the model including concern for dieting was not ($F_{(4,42)} = 1.01$, ns). Total restraint score and weight fluctuations positively predicted LF/HF, suggesting sympathovagal imbalance with increasing restraint scores (Table 4).

Discussion

The present study aimed at investigating the relationship between restrained eating behavior, resistance to distractor interference when exposed to food cues, and cardiac autonomic regulation. The results revealed that restrained eating was associated

Table 1
Group differences between restrained and unrestrained eaters in questionnaire data.

	Unrestrained eaters ($n = 22$) *M* (*SD*)	Restrained eaters ($n = 25$) *M* (*SD*)	Test statistics
Age	23.5 (3.2)	23.9 (3.7)	$F_{(1,45)} = 0.2$, ns
Body-mass-index	21.4 (2.3)	23.2 (2.9)	$F_{(1,45)} = 5.5$, $p < .05$
Last meal (hours)	4.8 (3.5)	6.2 (5.5)	$F_{(1,45)} = 1.1$, ns
Physical activity (self-report)	0.9 (0.6)	1.0 (0.5)	$F_{(1,45)} = 1.2$, ns
Food Cravings Questionnaire – state	36.5 (11.9)	38.0 (11.6)	$F_{(1,45)} = 0.2$, ns
Restraint Scale	9.8 (2.4)	17.7 (2.9)	$F_{(1,45)} = 100.9$, $p < .001$
Perceived Self-regulatory Success in Dieting Scale	13.4 (2.9)	11.1 (4.0)	$F_{(1,45)} = 5.2$, $p < .05$
Barratt Impulsiveness Scale	31.9 (6.2)	31.8 (7.6)	$F_{(1,45)} = 0.0$, ns

Table 2
Regression analyses investigating attentional bias as a function of restraint and dieting success.

Predictors	β	t	p
Restraint Scale – total score			
BMI	−.27	−1.57	ns
Restraint	.28	1.87	<.07
Dieting success	−.48	−2.81	<.01
Restraint × dieting success[a]	−.05	−.35	ns
Restraint Scale – concern for dieting			
BMI	−.21	−1.19	ns
Concern for dieting	.10	.63	ns
Dieting success	−.52	−2.87	<.01
Concern for dieting × dieting success	−.00	−.03	ns
Restraint Scale – weight fluctuations			
BMI	−.29	−1.75	<.09
Weight fluctuations	.35	2.60	<.05
Dieting success	−.51	−3.15	<.01
Weight fluctuations × dieting success	−.11	−.88	ns

[a] Although there was no significant interaction between restraint and dieting success, the relationship between attentional bias and dieting success was stronger in restrained eaters ($r = -.44$, $p < .05$) than in unrestrained eaters ($r = -.24$, ns).

Table 3
Regression analyses investigating vagal-cardiac control as a function of restraint and dieting success.

Predictors	β	t	p
Restraint Scale – total score			
BMI	.22	1.19	ns
Restraint	−.44	−2.77	<.01
Dieting success	−.10	−.57	ns
Restraint × dieting success	.08	.53	ns
Restraint Scale – weight fluctuations			
BMI	.22	1.19	ns
Weight fluctuations	−.43	−2.90	<.01
Dieting success	−.04	−.23	ns
Weight fluctuations × dieting success	.13	.92	ns

Table 4
Regression analyses investigating sympathovagal balance as a function of restraint and dieting success.

Predictors	β	t	p
Restraint Scale – total score			
BMI	−.29	−1.62	ns
Restraint	.47	3.02	<.01
Dieting success	.11	.60	ns
Restraint × dieting success	−.07	−.52	ns
Restraint Scale – weight fluctuations			
BMI	−.30	−1.70	<.10
Weight fluctuations	.49	3.39	<.01
Dieting success	.04	.22	ns
Weight fluctuations × dieting success	−.12	−.85	ns

with faster reaction times in response to high caloric food-cues as compared to neutral cues, independent of resistance to distractor interference. Furthermore, accelerated reactions to food-cues were associated with low dieting success. Finally, restrained eating was linked to cardiac autonomic dysregulation after controlling for differences in BMI.

Accelerated detection of pictorial food stimuli is in line with better detection of food-related words in restrained eaters (Boon et al., 2000; Hollitt et al., 2010). This finding is in contrast with results of a previous study, where we observed slowed reactions of restrained eaters in response to food-cues in a related task (Meule et al., 2011). Smeets and colleagues (2009) investigated attentional bias in chocolate cravers and found dissociation between attentional bias in a food-exposure condition and a non-exposure condition. In the food-exposure condition, high chocolate cravers detected chocolate pictures faster than low chocolate cravers, but this accelerated detection did not correlate with self-reported craving. However, chocolate cravers in the exposure condition showed increased distraction by chocolate pictures in comparison to low chocolate cravers and this distraction was correlated with self-reported craving. In line with this, we would argue that in cognitive tasks that involve simple reactions, pre-exposure to food and thereby induced craving leads to slowed reactions (i.e. distraction) to food-cues in populations like restrained eaters or high cravers (Green, Rogers, & Elliman, 2000; Kemps, Tiggemann, & Grigg, 2008; Meule et al., 2011; Smeets et al., 2009), similar to slowed reactions after drug exposure and drug craving (Baxter & Hinson, 2001; Cepeda-Benito & Tiffany, 1996; Sayette & Hufford, 1994; Sayette et al., 1994). On the other hand, when no pre-exposure occurred or when no craving was experienced like in the present study, these groups show accelerated reactions to high-calorie food-cues (Boon et al., 2000; Hollitt et al., 2010; Smeets et al., 2009). Smeets and colleagues interpreted their results such that faster detection of food stimuli occurred because high-calorie food-cues have incentive salience in chocolate cravers (incentive-sensitization theory, Robinson & Berridge, 1993). Accordingly, it has been suggested previously that greater incentive salience and anticipation of reward from food intake might foster weight gain and attempts to restrict food intake in restrained eaters (Lowe & Kral, 2006; Stice et al., 2010). Accelerated responses could be explained by these appetitive motivational characteristics of food-cues which make them more salient and attention-grabbing than other stimuli. Accordingly, attentional bias to food-cues increased with perceived hedonic ratings of those foods in restrained eaters (Papies, Stroebe, & Aarts, 2008b). However, it cannot be inferred from our results if these fast reactions indeed represent a speeded detection of food-cues because of their incentive salience or rather an attempt to rapidly avoid those potentially threatening stimuli.

Our hypothesis of increased distractor interference in restrained eaters could not be confirmed. Likewise, restrained eaters did not differ in self-reported impulsivity, supporting the notion that restrained eaters do not display a general inhibitory deficit (Meule et al., 2011). Furthermore, restrained eaters did not show the expected increase in distractor interference in incongruent neutral trials. Hence, it is possible that although food distractors might have attracted the attention of restrained eaters, they were able to easily disengage from food-cues (Hollitt et al., 2010; Meule, Lukito et al., 2011). However, in both groups a significant picture type × congruence interaction indicated that the expected flanker-effect was absent when targets were neutral pictures. A possible explanation might be that food pictures are stronger related to one another than neutral pictures. The latter only have in common that they are no food pictures, but may be differently located within a semantic network. Therefore, food pictures as flankers could be easily discriminated from neutral target pictures in incongruent neutral trials whereas neutral pictures as flankers for food pictures were more distracting in incongruent trials. Another possible explanation could be that emotional valence might have influenced flanker effects (Fenske & Eastwood, 2003). It has been shown that ignoring or inhibiting otherwise neutral visual stimuli during the performance of a task has a negative affective impact (Fenske & Raymond, 2006). Thus, ignoring neutral pictures could have rendered them negative thereby making them more emotionally salient and distracting.

Our hypothesis of low vagal-cardiac activity in restrained eaters was confirmed in that restrained eating was associated with sympathetic dominance and decreased parasympathetic modulation after controlling for differences in BMI. This result is in accordance with prior findings in non-fasting patients with bulimia nervosa or chocolate cravers with eating disorder symptoms (Coles et al., 2005; Rodríguez-Ruiz et al., 2009; Vögele et al., 2009). Restrained eaters were rather unsuccessful in their dietary restriction as they had a higher BMI and lower perceived self-regulatory success in dieting as compared to unrestrained eaters. Groups did not differ in self-reported physical activity or hunger levels. Therefore, these low parasympathetic heart rate modulations, which were independent of BMI, may reflect self-regulatory deficiencies of restrained eaters. However, two limitations to this interpretation have to be noted. Firstly, cardiac autonomic regulation was unrelated to self-perceived dieting success. Secondly, although sympathovagal imbalance was found in restrained eaters independent of actual body weight, it might still be caused by physical changes and not reflect self-regulation. Cardiac autonomic regulation was especially related to the weight fluctuations subscale of the *Restraint Scale*. Weight cycling has been found to have potentially adverse physiological effects, especially in normal-weight women (Kajioka, Tsuzuku, Shimokata, & Sato, 2002; Roybal, 2005) and could therefore be contributing to autonomic dysregulation. Accordingly, parasympathetic reactivity has been found to be negatively associated with self-reported weight fluctuations in a sample of bulimic patients (Vögele et al., 2009). On the other hand, weight fluctuations were based on subjective self-report. Future studies should replicate these findings using objective and prospective measures of weight fluctuations instead of retrospective self-report instruments.

The current results showed that restrained eaters display heightened reactivity to pictorial food-cues in terms of accelerated reactions that were also inversely related to dieting success. Moreover, they were also characterized by sympathovagal imbalance such that they showed sympathetic dominance at rest. These results have two practical implications. Firstly, exposing restrained eaters to high caloric food stimuli while concomitantly inhibiting responses could decrease reactivity to such cues thereby preventing binge eating. Indeed, recent evidence suggests that inhibiting responses to tempting stimuli decreases chocolate consumption in chocolate cravers (Houben & Jansen, 2011) and alcohol consumption in heavy drinkers (Houben, Nederkoorn, Wiers, & Jansen, 2011). In those studies, motor responses to relevant stimuli (e.g. chocolate) have to be withheld in a Go/No-Go-paradigm. This inhibition is thought to lead to a devaluation of those stimuli (Veling, Holland, & van Knippenberg, 2008), which may be a mechanism leading to decreased food intake (Houben & Jansen, 2011). Secondly, future studies may investigate if cardiac autonomic dysregulation of restrained eaters can be normalized by increasing HRV, e.g. by means of biofeedback (Lehrer, Vaschillo, & Vaschillo, 2000). This procedure has already been found to decrease substance cravings in patients with post-traumatic stress disorder (Zucker, Samuelson, Muench, Greenberg, & Gevirtz, 2009). Therefore, modulation of physiological parameters might also increase self-regulatory abilities of restrained eaters, thereby decreasing loss of control elicited by food-cues.

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