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Derailing the streetcar named desire. Cognitive distractions reduce individual differences in cravings and unhealthy snacking in response to palatable food

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ABSTRACT

People who are sensitive to food temptations are prone to weight gain and obesity in food-rich environments. Understanding the factors that drive their desire to eat is key to limiting their reactions to available food. This study tested whether individual differences in sensitivity to hedonic food cues are cognitively based and, accordingly, can be regulated by blocking cognitive resources. To this end, one lab study (Study 1; N = 91) and one field study (Study 2; N = 63) measured sensitivity to hedonic food cues using the Power of Food Scale (PFS; Lowe et al., 2009) and assessed participants' appetitive responses to high-calorie food options. To test the role of cognitive elaboration of food cues, participants completed a menu-selection task to induce food cravings and then were free to elaborate those cravings (control group) or were blocked from doing so by cognitive distraction (playing Tetris, solving puzzles; experimental group). Compared to non-sensitive participants, sensitive participants displayed a greater attentional bias to high-calorie food (Study 1), reported stronger cravings (Study 2), and more often chose an unhealthy snack (Studies 1 & 2), but only when they had not been distracted. When distracted, all participants were similarly unresponsive to high-calorie food. This finding suggests that temptation can be effectively controlled by blocking people's cognitive resources, even for people highly sensitive to hedonic food cues.

A dominant approach in explaining hedonic consumption is to assume that controlling cravings requires willpower. Good intentions are hard to achieve in the face of temptation because limited-capacity cognitive control is needed to prevent immediate rewards, desires and emotions driving behavior (Hofmann, Friese, & Strack, 2009; Loewenstein, 1996; Zajonc, 1984). Self-control has thus traditionally been depicted as a struggle between impelling forces and restraining forces that respectively map onto affective reactions on the one side, and cognitive processes on the other side (Hofmann & Van Dillen, 2012). An alternative view is that such a clean distinction cannot be made, because affective reactions themselves are shaped by cognition (Lazarus, 1991; Schachter & Singer, 1962), a view that is supported by accumulating evidence that cognitive loads reduce affective responses (Bishop, 2009; Van Dillen & Koole, 2007; Van Dillen, Van der Wal, & Van den Bos, 2012).

These competing views raise questions about why some people seem more prone to craving and indulging. Do these people have stronger drives, or weaker willpower, or different cognitive processes? To address this question, we focused on the problem of food attractions, because, in modern food-rich societies, people need to regulate their food intake in order to maintain a healthy weight. Individuals differ in their sensitivity to food attractions in the environment and this so-called sensitivity to hedonic food cues is a critical determinant of dietary health (Lowe & Butrin, 2007), as it drives impulsive eating (McManus & Waller, 1995). Individuals high on sensitivity to hedonic food cues moreover experience frequent thoughts, feelings and urges about food in the absence of actual food deprivation (Van Dillen, Papies, & Hofmann, 2013). In one study, for example, baseline differences in sensitivity to hedonic food cues measured by the Power of Food scale (Lowe et al., 2009)

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predicted self-reported cravings as well as subsequent consumption in students given transparent boxes of chocolates to keep with them but not eat for 48 h (Forman et al., 2007). An important question, given the debate on the nature of food cravings, is whether individuals with high sensitivity to hedonic food cues experience a stronger 'visceral' response (Loewenstein, 1996) to food temptations or whether they differ in their cognitive response, with greater attention to and elaboration of hedonic food cues and thoughts than other people, as predicted by Elaboration Intrusion theory (EI theory; Kavanagh, Andrade, & May, 2005; May, Andrade, Kavanagh, & Hetherington, 2012; May, Kavanagh, & Andrade, 2014) and related motivated cognition models (Hofmann & Van Dillen, 2012).

In Elaborated Intrusion theory, limited-capacity cognitive processes create and maintain the desires that drive consumption. Environmental or physiological factors may trigger thoughts about consumption, but those thoughts only become cravings that direct behavior when they are cognitively elaborated (see for a similar perspective Hofmann & Van Dillen; 2012). According to EI theory, we respond to desirable objects and thoughts by imagining the pleasure of indulging (May, Andrade, Panabokke, & Kavanagh, 2004), and strive towards long-term goals by imagining their achievement and mentally contrasting that state with our present state (Oettingen, Mayer, & Thorpe, 2010). Cognitive processes and emotions are thus part of the same, single, embodied motivational system. Unfortunately for good intentions, it is one that favors immediate rewards because imagining the imminent pleasure of indulging immediate temptations is easier than imagining satisfying long-term goals of health or wealth.

If affective responses that drive hedonic consumption are, at least in part, cognitively interpreted, as EI theory suggests, this may have practical implications for the development of interventions that address self-control goals such as maintaining a healthy diet. Rather than strengthening restraining forces, interventions may be directed at weakening impelling forces, for example by disrupting cognitive elaborations in response to an attractive stimulus. A growing number of studies has examined this idea, and has demonstrated that blocking people's mental resources interferes with attention to attractive food options (Van Dillen et al., 2013), as well as (naturally occurring) food cravings (Kemps & Tiggeman, 2010; Skorka-Brown, Andrade, & May, 2015; Skorka-Brown, Andrade, & May, 2014; Skorka-Brown, Andrade, Whalley, & May, 2015; Van Dillen et al., 2013), and, accordingly, with craving-induced consumption choices (Van Dillen et al., 2013). Evidence moreover includes findings that competing visual or olfactory loads are particularly effective (e.g., Kemps & Tiggeman, 2007; Knäuper, Pillay, Lacaille, McCollam, & Kelso, 2011; May, Andrade, Panabokke, & Kavanagh, 2010; Versland & Rosenberg, 2007), that attention diversion also weakens cravings (Hamilton, Fawson, May, Andrade, & Kavanagh, 2013), and high working memory loads do so more than low working memory loads (Van Dillen et al., 2013).

However, previous studies of cognitive interference with cravings are usually restricted to measurements of craving itself (e.g., Skorka-Brown et al., 2014), or examine the effects of working memory loads on the attentional capture by attractive food cues (Van Dillen et al., 2013). Where effects on consumption have been measured, findings are mixed and difficult to resolve because the methodologies of these naturalistic studies vary considerably from the laboratory studies that preceded them (Hsu et al., 2014; Kemps & Tiggemann, 2013; Knäuper et al., 2011; Skorka-Brown et al., 2015). Little is known, moreover, about individual variability in these effects. Several important questions remain unanswered. The present study addresses those questions: 1. Are individual differences in cue-provoked craving, or sensitivity to hedonic food cues, mediated by cognitive processes? 2. Do reductions in cue-provoked cravings brought about by cognitive interference lead to reduced consumption? 3. Do laboratory findings generalize to cravings in real-world settings? Thus, the present research sought to explain not only whether cognitive processes underpin the experience of desire, but also whether those processes contribute to individual differences in desire and desire-related behavior and how this extends beyond the laboratory.

We addressed these questions by testing the impact of a high visuospatial cognitive load on responses to food temptations in individuals differing in sensitivity to hedonic food cues, first in the laboratory and then in the field. Study 1 used attentional biases to food cues as an outcome measure, because tempting cues draw attention readily and involuntarily (Kavanagh et al., 2005; Kemps, Tiggemann, & Grigg, 2008; Papies, Stroebe, & Aarts, 2008). Cognitive elaboration maintains a cycle of craving by increasing attentional biases, which in turn increase intrusive thoughts and trigger further elaboration. In drug addiction, neurobiological sensitization to rewarding drug cues (Robinson & Berridge, 2003) is expressed behaviorally as attentional biases to those cues (Franken, 2003). When people are cognitively loaded, moreover, hedonic food cues do not preferentially capture their attention, and no longer result in enhanced cravings and hedonic consumption later on (Van Dillen et al., 2013). Attentional biases can therefore considered a marker of proneness to craving, rather than an index of craving itself. We tested whether individuals high in sensitivity to hedonic food cues would show increased attentional biases towards appetitive food cues following an initial craving induction, and if so, whether these biases were stronger when the working memory processes underpinning willpower and restraint were diminished, or whether they became weaker when they could not be sustained through cognitive elaboration, as EI theory would predict (Kavanagh et al., 2005).

Typical studies of cognitive processes in craving have induced cravings in the laboratory and assessed the impact of cognitive loads on those induced cravings. Rather little research has tested whether cognitive loads also weaken cravings in the field. Skorka-Brown et al. (2014) reported that playing Tetris reduced the strength of naturally occurring cravings in the laboratory, without using a craving induction procedure, and four published studies have tested the effects of cognitive interference on food cravings over extended time periods in the field. Knäuper et al. (2011) and Hsu et al. (2014) showed that neutral visual imagery reduced craving strength, and Kemps and Tiggemann (2013) showed reductions in craving when participants watched a dynamic black and white visual display, and Skorka-Brown et al. (2015) found that playing Tetris for 3 min reduced craving. Findings on food consumption in these studies were mixed: Kemps and Tiggemann reported that visual interference reduced calorie intake, Hsu et al. found that neutral visual imagery reduced unhealthy snacking, but Skorka-Brown et al. and Knauper et al. did not find effects on consumption. One explanation for these mixed findings is that the studies relied on self-report of consumption, which can be unreliable (as Skorka-Brown et al. found).

No field studies to date have tested the impact of cognitive craving interference on food choice directly. Study 2 therefore tested the impact of cognitive distracter tasks on actual snack choice as well as craving of train commuters. It thus extended Study 1 by testing whether individual differences in sensitivity to hedonic food cues are similarly regulated by cognitive distractions in more naturalistic settings, which is an important question for designing effective interventions.

1. Study 1

Study 1 tested the hypothesis that hedonic sensitivity and episodes of craving are both the result of cognitive processing of food cues that can be attenuated by cognitive loads. We tested the prediction that a visuospatial cognitive load would reduce the attentional biases to food that are concomitant with food cravings, and that it would do so most for those participants who were high in hedonic sensitivity and encouraged to think about food. Hedonic sensitivity was treated as a between-participants variable, as were encouragement to think about food and cognitive load: participants underwent a craving induction with or without a subsequent cognitive load, or they were in a control condition with no induction and no load to check that the lab session itself did not induce craving.

1.1. Method

1.1.1. Participants and design

Ninety-one Leiden University students (40 men, average age 19 years) participated in exchange for course credit or money (€3) and were randomly assigned to craving with distraction, craving with no distraction, or control conditions. Dependent variables were response times to pictures of high calorie food items versus objects, and choice of a healthy versus unhealthy snack. Because we wanted participants to choose freely from the provided menu options, people on a diet were excluded from participation. All procedures were approved by the ethical committee of Leiden University.

1.2. Procedure

At the beginning of the experiment, participants were informed that they were to take part in series of unrelated studies that assessed their personal preferences as well as different types of cognitive functioning. Self-reported hunger and sensitivity to hedonic food cues were assessed at the start of the session, followed by an unrelated filler task. Participants indicated to what extent they felt hungry on a nine-point scale, ranging from 1 (not at all) to 9 (very much) and indicated in hours how long ago they had last eaten. Sensitivity to hedonic food cues was assessed by the Power of Food Scale (PFS; Lowe et al., 2009), which measures individual differences in self-reported susceptibility to food temptations in the environment. Participants respond to items such as “If I see or smell a food I like, I get a powerful urge to have some” on a nine-point scale, ranging from 1 (*not at all*) to 9 (*very much*).

Participants were then informed that they would engage in a pilot study about people's food/holiday preferences (depending on the condition) and were randomly assigned to distraction ($N = 30$), no distraction ($N = 30$) or control ($N = 31$) conditions. To induce craving, participants composed their favorite meal from a menu that included items such as ‘Onion soup au gratin with old Beemster cheese and sour dough bread with fresh butter’ (translated from Dutch). Participants in the control condition selected their favorite holiday destination from a list (see Supplementary materials 1). The craving induction was followed by distraction or no distraction. Participants in the distraction condition played Tetris for 3 min. Tetris has a high visuospatial working memory load and is a validated tool to interfere with the visual imagery that may contribute to food craving (Holmes, James, Coode-Bate, & Deeprose, 2009; May et al., 2012; Skorka-Brown et al., 2014; 2015; Van Dillen et al., 2012). The object of the game is to move and rotate blocks of various shapes to create a horizontal line of blocks without gaps. In the no-distraction condition, participants were told that the computers in the lab were old and that they may have to wait before the experiment would continue (Van Dillen et al., 2012). They simply viewed a blank computer screen for 3 min, as did participants in the control (holiday) condition.

Next, all participants performed a probe classification task (Papies et al., 2008). Two pictures were presented simultaneously on the screen, followed by a small arrow pointing either upwards or downwards. On half of the critical trials, the probe appeared in the same location as a food picture (food trials), and in the other trials, the probe appeared in the location of an object picture (object trials). Participants indicated as fast and as accurately as possible whether the arrow was pointing upwards or downwards, using the “2” and “8” keys on the numerical keypad. Each trial started with a fixation cross for 500 ms, followed by the picture pair for 500 ms and then by the probe that remained on the screen until a response was given. Twenty food-object picture pairs and 20 filler object–object picture pairs were each presented four times: twice on each side of the screen, twice in each probe condition (food, object) to give 160 trials presented in random order. Pictures were taken from a validated dataset (Van Dillen et al., 2013) and presented objects or food centered on screen against a white background and of a standard dimension of 200 by 200 pixels. Forty pictures depicted everyday objects such as a telephone, or a vase, half of which were paired with food pictures to form the experimental trials, and half of which were used for the filler trials. Ten food pictures showed high calorie foods (brownies, fries) and ten showed low calorie foods (whole-wheat bread, radishes) which pilot data ($N = 97$) confirmed were rated as less tasty ($M = 5.40$, $SD = 1.17$) than the high calorie foods ($M = 6.40$, $SD = 1.18$, $t(96) = 6.09$, $p < .001$) on a Likert-type scale from 1 (*not at all tasty*) to 9 (*very tasty*).

At the end of the experiment participants were invited to choose a snack ‘left over’ from the departmental Sinterklaas celebration[1] from a selection of healthy (tangerines, apples) and unhealthy snacks (chocolates, marzipan). Choices were unobtrusively recorded by the experimenter. At the end of the experiment, participants were debriefed, paid, and thanked.

1.3. Results

1.3.1. Individual differences

Self-reported hunger ($M = 3.62$, $SD = 1.64$, range 1–7), last time eaten ($M = 1.25$ h, $SD = 1$ h, range 0–5), and power of food scores ($M = 54$, $SD = 13$, range 23–99) did not differ between conditions (all $ps > .350$).

1.3.2. Selective attention to tempting food

In accordance with Papies et al. (2008), attentional bias scores were obtained by subtracting reaction times (RTs) on food trials from reaction times on object trials, computed separately for high calorie food pictures and low calorie food pictures for each participant. The reaction time differences provide an index of relative attention to (attractive) food, with positive differences indicating an attention bias to food pictures and with negative differences suggesting a bias to object pictures. RTs on trials with errors and RTs <100 ms or >1500 ms were excluded from the analyses (2.4%; Townshend & Duka, 2001). An overview of the estimated mean RTs and standard errors can be found in Table 1.

We first conducted a full-factorial GLM analysis of participants' attentional bias to both high calorie food pictures and low calorie food pictures, with elaboration (distraction, wait, control) as between subjects factor, and standardized PFS scores (Cronbach's $\alpha = .89$) and hunger scores (averaged across the two items, Cronbach's $\alpha = .84$) as continuous variables between-subjects.

The GLM is a multivariate regression model that allows for the

[1] Sinterklaas is a traditional Winter holiday figure in the Netherlands, Belgium, Aruba, Suriname, Curacao, Bonaire, and Indonesia; he is celebrated annually on Saint Nicholas' eve (5 December) or, in Belgium, on the morning of 6 December. Retrieved from http://en.wikipedia.org/wiki/Sinterklaas-2011-01.

Table 1
Response times (Mean RTs, SEs) to pictures of high-calorie food, low-calorie food and objects as a function of condition (distraction, no distraction, control) and Power of Food (PFS; estimated for respectively −/+ 1 SD from the overall mean PFS score).

Stimulus	Low PFS			High PFS		
	Distraction	No distraction	Control	Distraction	No distraction	Control
High-calorie food	671 (40)	512 (40)	649 (42)	621 (41)	530 (41)	618 (43)
Low-calorie food	628 (42)	521 (41)	623 (42)	609 (42)	592 (42)	603 (43)
Object	649 (42)	511 (43)	604 (43)	680 (44)	594 (43)	624 (44)

assessment of the influence of categorical and continuous predictor variables and their interactions as in a multivariate ANOVA, while retaining the continuous character of individual difference variables, such as PFS scores (see Tabachnick & Fidell, 2001, pp. 901–903; see also Papies et al., 2008). This analysis yielded significant interactions of food type and elaboration; $F(2, 79) = 4.25$; $p = .018$, $\eta_p^2 = .097$, and of PFS and elaboration; $F(2, 79) = 5.64$; $p = .005$, $\eta_p^2 = .125$. To further examine these interactions, we analyzed the effects of elaboration and PFS separately for participants' attentional biases to high calorie food and to low calorie food.

For the attentional bias to high calorie foods, a GLM analysis with elaboration (distraction, no distraction, control) as between subjects factor, and standardized PFS scores and hunger scores as continuous variables between-subjects, yielded main effects for both PFS; $F(2, 88) = 7.38$; $p = .008$, $\eta_p^2 = .081$ and elaboration, $F(2, 88) = 11.29$; $p < .001$, $\eta_p^2 = .212$. Participants displayed a greater attentional bias towards high calorie food pictures with increasing PFS scores and a greater bias in the no-distraction condition ($M = 33$ms, $SD = 53$ms) than in both the distraction condition ($M = -31$ms, $SD = 70$ms; $p = .001$) or control condition ($M = -19$ms, $SD = 46$ms; $p < .001$), whereas the latter two conditions did not differ ($p = .360$).

There was moreover an interaction between elaboration and PFS: $F(2,88) = 35.71$, $p = .005$, $\eta_p^2 = .120$ (Fig. 1). A regression analysis revealed a highly significant effect of PFS on selective attention to high-calorie food items in the no-distraction condition; $\beta = .65$, $t(28) = 4.25$, $p < .001$, with higher PFS scores relating to greater selective attention to high-calorie food pictures. There was no relationship between PFS and attentional bias in the distraction condition, $\beta = -.104$, $t(28) = -.523$, $p = .605$, and only a marginally significant effect in the control condition, $\beta = .338$, $t(29) = 1.77$, $p = .091$.

To further understand the interaction of elaboration and PFS, we next analyzed the effects of elaboration separately for participants scoring high or low on the PFS (by comparing the estimated means for one standard deviation above or below the standardized mean PFS score, respectively; see Cohen, Cohen, West, & Aiken, 2003; for this procedure). For participants scoring relatively high on the PFS, these comparisons yielded a significant effect of elaboration; $F(2,84) = 15.29$, $p < .001$, $\eta_p^2 = .267$, with participants displaying a significantly greater attention bias in the no-distraction condition ($M = 64$ms, $SE = 17$ms) than in both the distraction condition ($M = -41$ms, $SE = 14$ms; $p < .001$) and the control condition ($M = 6$ms, $SE = 16$ms; $p = .005$), with the latter two conditions differing significantly as well ($p = .025$). For participants scoring relatively low on the PFS, these comparisons yielded no significant differences between the no-distraction condition ($M = -1$ms, $SE = 13$ms) and the distraction condition ($M = -22$ms, $SE = 13$ms; $p = .255$), or between the distraction condition and the control condition ($M = -44$ms, $SE = 15$ms; $p = .291$). There was however a significant difference between the attentional bias observed in the no-distraction condition and the control condition, $p = .039$. See Fig. 1 for a depiction of relevant means and standard errors.

A similar GLM analysis of selective attention to low calorie food pictures yielded no significant main effects or interactions (all $ps > .500$), with no differences between attention biases in the no-distraction condition ($M = -2$ms, $SD = 40$ms), the distraction condition ($M = 0$ms, $SD = 79$ms), or control condition ($M = -3$ms, $SD = 74$ms; $ps > .625$).

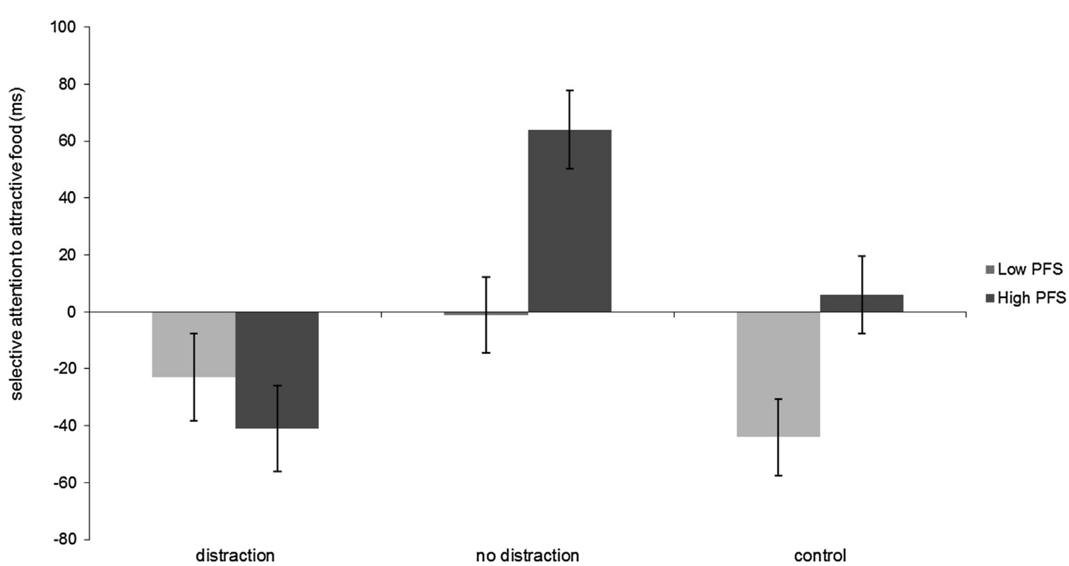

Fig. 1. Selective attention scores to high-calorie food pictures in response to the menu selection task of Study 1 and as a function of elaboration (distraction, no distraction) and power of food (PFS), compared with a condition without craving induction (control). PFS values represent plus (PFS + 1) or minus one (PFS − 1) standard deviation from the respective means. Selective attention scores were obtained by subtracting reaction times on food trials from reaction times on object trials. Error bars reflect standard errors.

1.3.3. Food choice

A binary logistic regression of participants' food choices with elaboration, PFS, their interaction, and self-reported hunger as predictors yielded a significant effect of elaboration (Wald(2) = 4.64, p = . 034), with 70 percent of the participants in the no-distraction condition choosing an unhealthy snack compared to 46 percent of the participants in the distraction condition (B = −1.28, SE = .58, Wald(1) = 5.35, p = . 021), and 47 percent in the control condition (B = −1.21, SE = .59, Wald(1) = 4.83, p = . 028). When participants had the capacity to elaborate following the menu selection task, they were thus more likely to select an unhealthy snack instead of a healthy snack than when they had been distracted by a cognitive task.

We also observed the expected interaction between condition and PFS; B = .79, SE = .37, Wald(2) = 4.03, p = . 045. We further analyzed this interaction by probing the effect of PFS within each condition, following Hayes and Matthes (2009). The probed logistic regression analysis revealed a significant effect of PFS in the no-distraction condition; B = 2.91, SE = .31, Wald(1) = 5.17, p = . 023, but not in the distraction condition; B = .597, SE = .53, Wald(1) = 1.85, p = .174, or the control condition; B = −.018, SE = .41, Wald(1) = .002, p = .967. Participants in the no-distraction condition, who had the capacity to elaborate on the menu selection task, were more likely to opt for a sweet treat rather than a piece of fruit, the higher their PFS scores (i.e. the higher their hedonic sensitivity to attractive food options).

1.4. Discussion

Study 1 found that a craving induction (a menu selection task) enhanced people's attentional biases to high-calorie foods and their tendency to select an unhealthy snack over a healthy snack only when people were not distracted by a cognitive task following the menu task. Individual differences in sensitivity to hedonic food cues, as measured by the Power of Food Scale (PFS; Loewe et al., 2009), were highly predictive of the strength of this attentional bias and actual food choice. However, when cognitive resources were loaded by playing Tetris, people with a high sensitivity to hedonic food cues were no longer attracted by high-calorie foods, behaving like the low sensitivity participants and those who had not experienced the craving induction.

These findings can be explained by EI theory's emphasis on the cognitive elaboration of any intrusive thoughts that occur as a result of attention to food-related cues (Kavanagh et al., 2005). In EI theory, this affectively-charged cognitive elaboration *is* craving. Individuals with high sensitivity to hedonic food cues appear to be more likely to respond to high-calorie food by elaborating thoughts about food, when cognitive resources are available to do so. This elaboration increases selective attention to and desire for the food and influences behavioral choices.

Somewhat unexpectedly, for participants in the distraction condition and the control condition, we observed, on average, attentional biases for objects instead of high-calorie foods. Whereas we can only speculate about the underlying mechanisms, one possibility is that because more object pictures than food pictures were being displayed, participants focused on the object pictures as a default strategy, a strategy that was overruled by our craving induction in the no distraction condition. Importantly, in the no distraction condition, participants did display an attention bias to high-calorie food, but not to low-calorie, neutral food, and this bias was positively associated with individual differences in sensitivity to hedonic food cues.

Study 1 thus extended previous research on cognitive processes in craving by showing that cognitive processes mediate individual differences in measures associated with food craving, and that cognitive loads reduce attentional biases to palatable foods and effectively decreased high calorie snack choices prompted by a craving induction. Perhaps most important, the findings of Study 1 provided first evidence that engaging in a cognitive task can be an effective self-regulation strategy, particularly for people highly sensitive to hedonic food cues in their environment.

2. Study 2

Study 2 extended Study 1 to a naturalistic setting, testing whether cognitive processes mediate individual differences in craving and high-calorie snack choice in the field. It was predicted that the impact of food attractions on cravings would be selective for individuals with high sensitivity to hedonic food cues, and that a cognitive load would reduce this impact for those individuals and decrease the number choosing a high calorie snack over a non-food gift.

2.1. Methods

2.1.1. Participants and design

A total of 63 participants (34 men; aged 18–67 years with mean age 29 years) who were commuting between Amsterdam and Arnhem (both cities in the Netherlands) volunteered to take part. The study took place in the afternoon, when people are known to experience strong desires for tasty snacks (Hofmann, Vohs, & Baumeister, 2012). Participants were invited to take part in a study ostensibly aimed to examine individual preferences and cognitive functioning. They were randomly assigned to distraction (N = 31) or no distraction (N = 32) conditions. Self-reported hunger and PFS were measured as continuous variables, with self-reported cravings as the dependent measure, similarly as in Study 1. Food choice was measured surreptitiously by offering participants a choice between a pen and a chocolate to thank them for their participation. People on a diet were informed that they could not participate. All procedures were approved by the ethical committee of Utrecht University.

2.2. Procedure

In a paper-and-pencil task, participants selected their favorite option for each course on a menu. Between courses, those in the no distraction condition copied their option of choice. Participants in the distraction condition performed short cognitive tasks: using a code to convert numbers into letters spelling a word, erasing the letters ‘c’ and ‘s’ in a letter grid, and making words from a selection of letters provided.

As a measure of craving, participants then rated on a nine-point scale ranging from 1 (*not at all*) to 9 (*very much*) to what extent they, at this moment, 1) felt an appetite, 2) were thinking about tasty food, 3) felt the urge to eat something, and 4) felt like snacking (Van Dillen et al., 2013). Participants next indicated on a nine-point scale (ranging from 1 *not at all*, to 9 *very much*) to what degree they were hungry, and how long ago they had eaten (in hours). Next, they filled out the PFS and demographic information (height, weight, sex, and age), were thanked for their efforts and offered a chocolate (Celebrations©) or a ballpoint pen and were then debriefed.

2.3. Results

2.3.1. Individual differences

Body Mass Index (BMI) was computed for each participant by dividing their weight in kilograms by the square of their length in meters. BMI (M = 23, SD = 3.4, range 16–37), self-reported hunger (M = 3,11 SD = 1.79, range 1–7), last time eaten (M = 1.13 h, SD = 1.01 h, range 0–5), and power of food scores (M = 55, SD = 13, range 22–84) did not differ between the two conditions (all $Fs < 1.86$, $ps > .177$).

2.3.2. Cravings

We conducted a full-factorial GLM analysis of participants' average cravings scores (Cronbach's $\alpha = .85$), with elaboration (distraction, no distraction) as between subjects factor and standardized PFS scores (Cronbach's $\alpha = .82$) and standardized hunger scores (averaged across the two items, Cronbach's $\alpha = .86$) as continuous variables between-subjects.

This analysis yielded a main effect of PFS ($F(1, 62) = 36.62$; $p < .001$, $\eta_p^2 = .400$), such that participants with higher PFS scores experienced stronger cravings. The analysis also revealed a significant main effect of hunger, $F(1, 62) = 10.155$; $p = .002$, $\eta_p^2 = .156$, such that with increasing hunger, cravings increased as well. Finally, there was a main effect of elaboration; $F(1, 62) = 20.09$; $p < .001$, $\eta_p^2 = .268$ – participants who were not distracted following the menu-selection task reported stronger cravings ($M = 5.05$, $SD = 1.81$) than participants who were distracted ($M = 3.98$, $SD = .79$).[2]

There moreover was the predicted two-way interaction between elaboration and power of food ($F(1, 62) = 31.22$; $p < .001$, $\eta_p^2 = .362$). As in Study 1, we examined this interaction by analyzing the effects of elaboration for participants with relatively high versus low PFS scores and the effects of PFS on cravings within each condition (Cohen et al., 2003). For participants with relatively low PFS scores (one standard deviation below the mean), we observed no main effect of elaboration ($F(1, 62) = 1.46$, $p = .232$, $\eta_p^2 = .026$), with participants reporting similar cravings in the distraction condition $M = 3.93$, $SE = .25$ and the copy condition $M = 3.51$, $SE = .25$. For participants with relatively high PFS scores (one standard deviation above the mean), we observed a significant effect of elaboration ($F(1, 62) = 48.40$, $p < .001$, $\eta_p^2 = .468$), with participants reporting less intense cravings in the distraction condition $M = 4.05$, $SE = .29$ than in the copy condition $M = 6.65$, $SE = .24$. Subsequent analyses of variance of the effect of PFS within each condition moreover yielded an effect of sensitivity to hedonic food cues for participants who were not distracted, $F(1, 31) = 51.47$; $p < .001$, with higher PFS scores associated with stronger cravings. There was no effect of PFS on cravings for participants who were distracted following the menu items, $F(1, 30) < 1$; $p > .400$, such that the distracter task reduced cravings for high PFS participants down to levels experienced by low PFS participants (Fig. 2).

2.3.3. Food choice

All participants chose either the pen or the chocolate. A binary logistic regression (Hayes & Matthes, 2009) of participants'choices, with elaboration, PFS, and their interaction as predictors, and self-reported hunger as covariate, yielded a significant effect of elaboration; B = 6.27, $SE = 2.03$, Wald(1) = 9.56, $p = .002$, such that in the no distraction condition 78 percent of the participants chose a chocolate, against only 20 percent in the distraction condition. We observed a marginally significant main effect of hunger, B = .89, $SE = .47$, Wald(1) = 3.51, $p = .061$, such that participants scoring high compared to low on self-reported hunger were more likely to choose a chocolate rather than a pen as reward for participation.

The regression analysis also yielded the predicted interaction between elaboration and PFS; B = 5.67, $SE = 2.17$, Wald(1) = 6.83, $p = .009$. There was a significant effect of PFS in the no-distraction condition; B = 5.02, $SE = 2.06$, Wald(1) = 5.94, $p = .015$, such that participants with higher PFS scores were more likely to opt for a chocolate. With distraction, participants were less likely to choose chocolate and there was no effect of PFS on choice; B = −.64, $SE = .49$, Wald(1) = 1.76, $p = .185$.

2.4. Discussion

Even in a naturalistic setting, cognitive distraction reduced the desire to snack, extending the literature on cognitive interference with craving to real-world conditions. As anticipated from Study 1, the effect was most pronounced for those participants with high levels of sensitivity to hedonic food cues (as measured by the PFS; Lowe et al., 2009); cognitive distraction reduced their craving scores to the level seen in participants relatively low in sensitivity to hedonic food cues. This finding was mirrored in the behavioral data: distraction reduced the likelihood of highly sensitive participants selecting chocolate over a pen to the level observed in participants with low sensitivity to hedonic food cues. In sum, individual differences in sensitivity to hedonic food cues only affected people's cravings and craving-induced choices when they could elaborate on the attractive menu options.

3. General discussion

This research addressed to what extent individual differences in

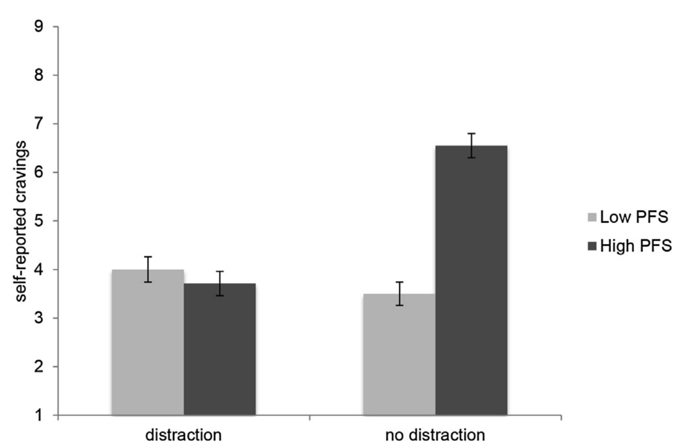

Fig. 2. Self-reported cravings (1 = very low to 9 = very high) in response to the menu selection task of Study 2 and as a function of elaboration (distraction, no distraction) and sensitivity to hedonic food cues (power of food; PFS). PFS values represent plus (PFS + 1) or minus one (PFS − 1) standard deviation from the respective means. Error bars represent standard errors.

[2] Note that we used a different control condition in Study 2 than in Study 1. Instead of having people wait in between the menu selection tasks, we instructed them to copy their menu option of choice, to be able to control the timing of the different conditions in a field setting. One possibility though, is that any craving differences we observed were the result of greater elaboration on the menu items in the copy condition rather than reduced elaboration in our distraction condition, as we propose. To rule out this alternative hypothesis, we conducted an online MTurk study to establish that cue-induced cravings would be reduced by the cognitive distraction (i.e., the problem solving tasks) in comparison to both the no distraction condition of Study 1 (wait) and the control condition of Study 2 (copy). One hundred thirty US based volunteers (73 females, $M_{age} = 35$ years, ranging from 19 to 67 years) participated in exchange for payment of $1. Participants were randomly assigned to the distraction ($N = 39$; comparable to Study 2 experimental) wait ($N = 45$ comparable to Study 1 control), or copy ($N = 45$ comparable to Study 2 control) conditions. The timing of the three conditions was held constant at 100 s. We measured participants' self-reported cravings using the same four items as in Study 2 (Cronbach's $\alpha = .94$). An analysis of variance of the effect of condition on self-reported cravings while controlling for self-reported hunger (Cronbach's $\alpha = .89$) and BMI revealed a marginal main effect of condition; $F(122,2) = 2.75$, $p = .068$, $\eta_p^2 = .045$. Most importantly, pairwise comparisons showed that participants reported significantly weaker cravings in the distraction condition ($M = 4.59$, $SE = .46$) compared to both the wait condition ($M = 6.24$, $SE = .38$, $p = .030$) and the copy condition ($M = 5.85$, $SE = .26$, $p = .025$), whereas the two control conditions did not differ, $p = .384$, thus confirming the effectiveness of the experimental design of Study 2.

hedonic sensitivity (Lowe et al., 2007) reflect differences in the cognitive elaboration of food cues, and to what extent cognitive distractions can interrupt these elaborations and subsequent food choices. By testing the proposed theoretical framework in different settings (in the lab, and on the train), with different samples (students, commuters), and with different interventions (Tetris, puzzles) and measures (attentional bias, self-reported cravings, and choice behavior), we moreover demonstrated the generalizability of our effects.

Following a food craving induction, we varied the presence of a cognitive distraction and then assessed participants' appetitive responses to palatable food. We observed that, after a menu selection task intended to induce desire for attractive food options, people only attended preferentially to palatable food pictures (Study 1) and experienced cravings for food (Study 2) when they had the opportunity to elaborate on the appetizing menu items while waiting or copying the items,[2] but not when they were intermittently distracted by a cognitive task. Both studies showed that, when they had the opportunity to elaborate, people were more inclined to choose sweets instead of healthier options, but they were more likely to choose a pen or fruit when distracted by a cognitive task.

People with high sensitivity to hedonic food cues, those who are habitually easily swayed by palatable food, showed attentional biases towards high calorie foods (Study 1), craved palatable food after choosing items from a menu (Study 2), and were more likely than people with low sensitivity to choose high calorie sweet snacks than fruit or a pen (Studies 1 and 2). These individual differences were entirely removed (Studies 1 and 2) by brief cognitive distractions between the craving induction and outcome measures, such as playing Tetris (Study 1) or solving puzzles (Study 2), suggesting that individual differences in hedonic sensitivity reflect differences in allocation of cognitive resources in response to food cues, that is, differences in individuals' tendency to elaborate craving thoughts or images. It is interesting, moreover, to note that the effectiveness of the distraction intervention appeared to be independent of participants' BMI (Study 2), even though BMI scores ranged from (slightly under) normal weight to extremely overweight.

Our findings fit well with observations that food consumption is to a large extent driven by non-homeostatic processes such as the perceived hedonic value of food cues (Lowe & Butrin, 2007), which may explain the high prevalence of obesity in food-rich environments. Whereas (self-reported) hunger predicted cravings in Study 2, people's cravings were also driven by both individual differences in sensitivity to attractive food cues, and the availability of cognitive resources. The present findings demonstrate the effortful nature of food cravings, and the role that the allocation or diversion of attentional resources may play in their regulation (see also Mann & Ward, 2007; Van Dillen et al., 2013). More broadly, our findings support theories like EI theory (Kavanagh et al., 2005) that argue that desires are cognitive states – albeit affectively charged – rather than pure expressions of basic physiological or emotional responses.

The findings extend existing research showing that visuospatial loads reduce craving (e.g., Andrade, Pears, May, & Kavanagh, 2012; Kemps & Tiggeman, 2007; 2010; Skorka-Brown et al., 2014) by showing that cognitive loads also reduce attentional biases that are triggered by appetitive food cues, and that are associated with craving and the behaviors that result from craving. EI theory views attentional biases as precursors of cravings, which increase the likelihood of experiencing an intrusive thought about the target of desire that may then be cognitively elaborated. Once a craving has begun, cognitive resources are increasingly focused on the desire object or idea, and this increases attentional biases towards related cues in the environment. Vice versa, cravings less likely arise, when selective attention to hedonic information is blocked. The present findings are therefore consistent with this hypothesized association between attentional biases and cravings, and offer hope that cognitive interventions that dampen cravings will help break this vicious cycle by reducing the attentional biases that help feed it.

By showing that cognitive loads weaken cravings selectively for individuals most prone to experiencing and acting on them, and by showing that this effect occurs in a field setting as well as in the laboratory, this study paves the way for developing interventions targeted more directly at the cognitive mechanisms underlying individual differences in cravings and craving-induced consumption. Cognitive distracters such as those used here may be helpful and widely available tools for coping with cravings when they occur (and indeed are one component of a current online treatment for alcohol dependence; www.ontrack.org.au). Testing the (long term) effectiveness of such interventions in applied settings can provide important insights in both the nature of people's cravings (i.e. in relation to specific contexts, time of day, etc.) and how cognitive distractions can best be used to fight them.

An important question is how the current findings relate to research showing an actual increase in impulsive eating as a consequence of resource depletion (Baumeister, Bratslavsky, Muraven, & Tice, 1998; see for a similar discussion, Van Dillen et al., 2013), or high cognitive load (e.g., Hofmann, Gschwendner, Friese, Wiers, & Schmitt, 2008; Papies et al., 2008; Ward & Mann, 2000). For example, dieters consume more "forbidden food" when under task load than otherwise (e.g., Ward & Mann, 2000). A common feature of these studies is the activation of a self-control goal that promotes dieting, such as the suppression of desire-related thoughts among restrained eaters (Papies et al., 2008). Research suggests that suppression becomes problematic under reduced capacity conditions, because the to-be-suppressed information is part of the attentional task-set. Ironically, this may give this information an accessibility advantage in the competition over attentional resources, such that when suppression is impeded due to additional task load, further intrusions are the result (for a review, see Wegner, 1994). Possibly then, the effects of task load are twofold: reducing cravings and impulsive food consumption in the absence of an explicit self-control goal, while producing rebound effects when people try to actively suppress their cravings (Erskine, 2008) and are unaware of the possible benefits of distraction. Future research should examine this hypothesis further.

Note that we observed variable effects of hunger on cravings and snack choice, with no effects in Study 1, but more cravings and unhealthy snack choice with increasing hunger in Study 2. This variability could not be attributed to different levels of hunger reported between the studies. However, contrary to our lab study, in our train study, people reported their hunger immediately after their cravings (and right before their choice between a chocolate and a pen). Accordingly, responses on the craving items could have influenced responses on the hunger items, which may explain the main effects we observed. It is notable that hunger did not further differentiate the effects of load or hedonic sensitivity on cravings or snack choice, providing further evidence to the notion that cognitive elaborations influence impulsive eating relatively independent of homeostatic variables. Note though, that the sample sizes of our current samples preclude strong conclusions about the effects of self-reported hunger, something that could be addressed in future studies.

Our approach is consistent with a dynamic model of desire (e.g., Hofmann & Van Dillen, 2012) that underlines the interplay of three elements: (a) impulsive cues such as automatic affective reactions or deprivation cues, (b) reflective processes such as cognitive elaborations of those cues, and (c) situational (e.g., cognitive load) and dispositional (e.g., sensitivity to hedonic food cues) boundary variables that shift the relative influence of reflective versus impulsive processes on desire-related behavior. In line with this, when no cognitive distracter was present, people high compared to low in sensitivity to hedonic food cues were more likely to respond to and elaborate on a craving induction, and accordingly, to succumb to attractive food, providing evidence for dispositional variations in both reflective and impulsive responses to palatable food cues. What is striking, however, is that cognitive distractions eliminated these individual differences in craving-induced behavior (see also Van Dillen et al., 2013), suggesting that even – indeed, especially – people more 'predisposed' to be attracted by palatable foods, could profit from interventions like the currently used cognitive distractions.

In conclusion, the current study demonstrated that individual differences in cue-provoked affective responses that drive hedonic consumption are, at least in part, cognitively interpreted, which may have practical implications for the development of interventions that address self-control goals such as maintaining a healthy diet. Rather than strengthening restraining forces, the findings suggest that interventions may be directed at weakening impelling forces, for example by disrupting cognitive elaborations in response to attractive food cues. The cognitive tasks we used to reduce food cravings are available to a wide audience, such as computer games and simple problem solving tasks. By taking these tasks into the field (or rather, onto the train), we demonstrated that people from various backgrounds have at their disposal effective tools to fight cravings in everyday 'temptation prone' situations, such as while at home behind their computer, when waiting for an appointment or during the train ride home from work. The effectiveness of relatively brief and accessible tasks in limiting the impact of food attractions may provide a promising starting point for developing new interventions promoting healthy dietary behavior.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.appet.2015.09.013.

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