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Turning a Blind Eye to Temptation: How Cognitive Load Can Facilitate Self-Regulation

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The present research shows in 4 studies that cognitive load can reduce the impact of temptations on cognition and behavior and, thus, challenges the proposition that distraction always hampers self-regulation. Participants performed different speeded categorization tasks with pictures of attractive and neutral food items (Studies 1–3) and attractive and unattractive female faces (Study 4), while we assessed their reaction times as an indicator of selective attention (Studies 1, 3, and 4) or as an indicator of hedonic thoughts about food (Study 2). Cognitive load was manipulated by a concurrent digit span task. Results show that participants displayed greater attention to tempting stimuli (Studies 1, 3, and 4) and activated hedonic thoughts in response to palatable food (Study 2), but high cognitive load completely eliminated these effects. Moreover, cognitive load during the exposure to attractive food reduced food cravings (Study 1) and increased healthy food choices (Study 3). Finally, individual differences in sensitivity to food temptations (Study 3) and interest in alternative relationship partners (Study 4) predicted selective attention to attractive stimuli, but again, only when cognitive load was low. Our findings suggest that recognizing the tempting value of attractive stimuli in our living environment requires cognitive resources. This has the important implication that, contrary to traditional views, performing a concurrent demanding task may actually diminish the captivating power of temptation and thus facilitate self-regulation.

Keywords: self-regulation, cognitive load, attention, motivation, food choice

> Temptation rarely comes in working hours. It is in their leisure time that men are made or marred.
>
> —W. N. Taylor

In our daily lives, we are constantly confronted with temptations that distract us from the pursuit of our long-term objectives. From billboards, magazines, and television screens, a continuous stream of images of desirable objects and activities is broadcasted into our world. Indeed, the repeated exposure to such cues in the environment can increase the likelihood that people indulge themselves. In the domain of eating, for instance, dieters are more likely to overeat after having been exposed to the sight, smell, or taste of highly palatable foods (Fedoroff, Polivy, & Herman, 1997, 2003; Herman & Mack, 1975; Jansen & van den Hout, 1991; Papies & Hamstra, 2010; for a review, see Stroebe, van Koningsbruggen, Papies, & Aarts, in press). Similarly, the repeated exposure to attractive females has been found to enhance males' perception of women as lust objects (Cikara, Eberhardt, & Fiske, 2011) and to lead them to devalue their current relationship (Miller, 1997; Rusbult, 1983). It is not surprising then, that the omnipresence of tempting cues of food and sex in our living environment are increasingly being blamed for the development of the current "obesity epidemic" or the "pornification" of society.

To date, self-regulation research has suggested that tempting cues are especially likely to lead people astray when mental capacity is low, for example when they are distracted such that they do not have cognitive resources available to regulate the impact of temptations on their behavior (e.g., Baumeister, Bratslavsky, Muraven, & Tice, 1998; Vohs & Heatherton, 2000). This way, cognitive load has been shown to disinhibit dieters' eating behavior (Ward & Mann, 2000) and promote unhealthy choices (Shiv & Feodorikhin, 2002), and these effects may occur by increasing people's reliance on impulsive tendencies (Friese, Hofmann, & Wänke, 2008; Hofmann, Friese, & Strack, 2009).

In the current research, however, we provide evidence that cognitive load can also have beneficial effects on self-regulation. At first sight, this idea may seem counterintuitive, as traditional

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models of impulse control have always stressed the negative impact of cognitive load on self-regulation success (Baumeister, Heatherton, & Tice, 1994; Shiv & Feodorikhin, 2002; Ward & Mann, 2000; Wegner, 1994). However, this work has primarily focused on the effect of cognitive load on the willful *suppression* of one's impulse to give in to temptations—objects that have already elicited a sense of craving or desire—rather than on the effect of cognitive load on the attentional *capture* of potentially tempting stimuli in the first place (i.e., objects that may not yet have elicited a strong sense of craving but may have the potential to do so). In other words, previous research has shown that cognitive load can interfere with the down-regulation of one's impulses once these have been triggered by a tempting stimulus, but has not addressed whether load can affect whether this stimulus is seen as tempting in the first place. For example, resisting the lure of a tempting dessert at a hotel buffet may be difficult for the regular holiday tourist when attention has already been caught by the sensory appeals of the food; however, the conference visitor next to him, engaged in a lively scientific discussion with a colleague or rehearsing tomorrow's presentation, may look at that same dessert without even noticing its appeal.

In the present article, we propose a conceptual framework for the effects of cognitive load on (selective) attention to temptation, and we test its implications for self-regulation across the domains of eating behavior and interpersonal relationships. Our idea is based on attention theories (Knudsen, 2007; Pessoa & Adolphs, 2010) that focus on the role of working memory in selecting information that is most relevant for the task at hand. When cognitive load increases, selection becomes more stringent, such that the motivational significance of task-irrelevant features is no longer assessed, even though attention to these features is normally prioritized due to their biological significance.

How Potential Temptations Affect Self-Regulation

How do appealing objects affect our behavior? A potential temptation, such as a tasty food, an attractive person, a glass of beer, or a cigarette, may activate in perceivers hedonic thoughts and associations of pleasure and reward (e.g., Ferguson & Bargh, 2004; Hofmann, Rauch, & Gawronski, 2007; Papies, Stroebe, & Aarts, 2007). The activation of such a hedonic motivation is associated with biases in attention toward temptation cues (Gable & Harmon-Jones, 2010; Papies, Stroebe, & Aarts, 2008a), which lead perceivers to process temptation cues preferentially over other cues in the environment (see Field, Munafo, & Franken, 2009, for a review). For example, dieters have thus been found to display selective attention for attractive food items (Papies et al., 2008a), smokers for smoking-related cues (e.g., Mogg, Bradley, Field, & de Houwer, 2003), and heavy drinkers toward alcohol-related cues (e.g., Townshend & Duka, 2001). In addition, when this hedonic motivation has been activated, relevant items, such as a glass of water or a tasty muffin, look bigger in size, reflecting the same processing bias (van Koningsbruggen, Stroebe, & Aarts, 2011; Veltkamp, Aarts, & Custers, 2008).

Once desirable targets thus capture attention, they trigger cognitive elaborations, which enhance the motivation of attaining the desired target (Gable & Harmon-Jones, 2011), and which are reflected in the conscious, subjective quality of cravings (Berridge, 2009; Kavanagh, Andrade, & May, 2005; Robinson & Berridge, 2003). Indeed, the preferential attention for appetitive cues has been found to relate to the experience of cravings. Intense cravings, in turn, influence consumption of the desired substance and have been identified as a major factor underlying self-control failures in addiction such as relapse (e.g., Field & Eastwood, 2005; Mischel, Ebbesen, & Zeiss, 1972; see Franken, 2003, for an overview). Numerous studies have thus shown that attention to attractive cues can enhance the likelihood that people give in to temptations. In a recent study on the effects of food advertising on automatic snacking (Harris, Bargh, & Brownell, 2009), both children and adults consumed more unhealthy snack foods following exposure to snack food advertising compared to the other conditions. Interestingly, in these studies, food advertising increased consumption of products not in the presented advertisements. It thus appears that attention to attractive cues may not just trigger an approach motivation to the items initially displayed, but also to other rewards (see also Wadhwa, Shiv, & Nowlis, 2008).

Does this mean that we will experience temptation each time we are exposed to desirable items? We think not. We suggest that the more cognitive resources are devoted to processing desirable objects, the more cravings "build up" (in working memory) such that, all else being equal, their power over subsequent behavior increases (Hofmann & Van Dillen, 2012). Accordingly, the development of cravings may be thwarted when people's cognitive resources are absorbed by a demanding task while they are exposed to potential temptations. Specifically, when under high cognitive load, people may not recognize the hedonic relevance of attractive stimuli, and accordingly, do not devote special attention to them. This in turn prevents elaborations on these stimuli that build up cravings, and that may result in (possibly unhealthy) impulsive behavioral decisions (Kavanagh et al., 2005). We thus propose that the development of motivation for temptations is resource-dependent, and therefore, that cognitive load can lead to what we call a "blind eye" to temptation in that cognitive load may impact the hedonic appraisal of desirable targets and thus prevents the motivational "pull" of temptation that would otherwise ensue.

No Representation With Taxation: How Cognitive Load Can Prevent Selective Attention and Craving

According to the framework of the development of motivation outlined above, people first need to recognize a desirable target's hedonic value for it to trigger craving-related elaborations. A process we propose is highly contingent on the availability of cognitive resources. Our sweet tooth alone does not make us inclined to snack, nor does the mere presence of an attractive potential mate turn us into a disloyal partner: Temptations need to be mentally represented as such and desire needs to be nourished, just like a spark needs the right conditions to develop into a flame. Like other cognitive processes, desire, too, may be subject to the constraints of the human information processing system.

In itself, this idea is not completely new, as Gilbert and Hixon (1991) have tested a similar assumption in the domain of stereotype activation. In their seminal work, Gilbert and Hixon showed that the automaticity of stereotype activation is conditional, in that it only comes to mind when people are not placed under significant cognitive load during exposure to the stereotype object. However, no research to date has extended this idea to the self-regulation domain. Thus, no studies so far have examined the influence of cognitive load on the strength of attentional capture exerted by tempting stimuli, and related to this, on the emergence of experienced cravings and desires. In the present article, we attempt to fill this gap and demonstrate the potential benefits of cognitive load for self-regulation.

Conceptual support for our proposition that a cognitively taxing task may prevent people from feeling tempted comes from emotion research. Recent studies have shown that attention to emotional targets is automatic in the sense of being fast and involuntary, but that it is also resource-dependent (Erthal et al., 2005; Okon-Singer, Tzelgov, & Henik, 2007; Van Dillen & Koole, 2009). In one study, for example, participants were slower to categorize the gender of angry faces than of happy faces (an index of selective attention to threatening information) while they mentally rehearsed a one-digit number (low cognitive load), but not when they rehearsed an eight-digit number (high cognitive load; Van Dillen & Koole, 2009). Similar findings have been reported in the domain of affective neuroscience in which cognitive load has been found to reduce neural responses to both positive and negative pictures (Erk, Kleczar, & Walter, 2007; Pessoa, McKenna, Gutierrez, & Ungerleider, 2002; Van Dillen & Derks, 2012; Van Dillen, Heslenfeld, & Koole, 2009) and even painful stimuli (Bantick et al., 2002).

By putting considerable strain on attentional resources, then, cognitive load can override selective attention to the emotional aspects of targets and subsequent elaborations on these aspects (Van Dillen & Derks, 2012; Van Dillen, Van der Wal, & Van den Bos, 2012). In the present research, we suggest that cognitive load may reduce attention to attractive targets in a similar way, hence controlling desire before it can take full swing. To the extent that it prevents the development of desire in the first place, cognitive load may thus provide an efficient buffer against a variety of temptations in our living environment.

Overview of the Present Research

We conducted four studies that examined the effect of cognitive load on the preferential processing of desirable targets. We presented participants with attractive stimuli, that is, images of tasty foods (Studies 1–3) and pictures of attractive opposite-sex faces (Study 4), and examined their impact on participants' attention and motivation to give into temptation under either low or high cognitive load. We hypothesized that attractive stimuli capture people's attention (compared to neutral or unattractive targets) under low load, when cognitive resources are available to extract their hedonic value. Thus, if ample cognitive resources are available, attractive targets will receive preferential attention, and cravings and desires for these targets as well as similar temptations may emerge. On the other hand, if fewer cognitive resources are available due to increased load of a competing task, attractive targets will not receive attentional priority because their hedonic relevance is not processed, and cravings and desires are less likely to develop.

In three studies (Studies 1, 3, and 4), we assessed reaction time differences on categorization tasks with attractive and neutral stimuli as an index of prioritized processing of tempting cues, and in one study (Study 2), we assessed the accessibility of specific hedonic thoughts after tempting primes. Study 1 was designed to demonstrate our basic premise that cognitive load disrupts attentional capture by attractive food stimuli. To this end, we compared response times to pictures of attractive foods with response times to neutral food pictures on a spatial categorization task while we concurrently varied cognitive load. We reasoned that high cognitive load would prevent attentional capture of tempting stimuli, as evidenced by an absence of response time differences between the two types of pictures under high cognitive load. In addition, this study was set up to provide a first indication that preventing the full processing of attractive food stimuli interferes with the development of cravings for food. We argued that when participants are exposed to attractive food while under cognitive load, they develop less intense cravings for food relative to participants not under load. Thus, the motivational impact of attractive food is reduced when cognitive resources are compromised during food exposure.

In Study 2, we used a lexical decision task that assesses spontaneous thoughts about eating enjoyment when exposed to tempting food cues (Papies et al., 2007). This way, we aimed to demonstrate more directly that cognitive load prevents the activation of hedonic thoughts in response to attractive (food) items. In this task, participants decide quickly and accurately whether a given stimulus is an existing word or not. Before participants had to make a lexical decision, we exposed them to cues signaling tempting food or not, such that each word was preceded by either an attractive food picture, or a neutral food picture. The critical comparison consists of participants' reaction times to words that reflect an eating enjoyment goal (e.g., tasty). We reasoned that when participants are under cognitive load, they cannot extract the hedonic relevance of the food pictures they are presented with. Hence, we predicted attractive food pictures to speed up participants' lexical decisions of hedonic food words, but only when cognitive load is low and not when cognitive load is high.

In Study 3, participants again categorized pictures of tasty and neutral food items, as well as non-food objects. This time, however, we used a food categorization task such that participants categorized the objects as edible or inedible (Toepel, Knebel, Hudry, le Coutre, & Murray, 2009). We expected greater attention to attractive food pictures under low load, as reflected in faster responses to these pictures compared to neutral food pictures. Again, we predicted this effect to be eliminated by high cognitive load, because participants who are under high cognitive load may not extract the hedonic relevance of the tasty foods and therefore may not be able to categorize these faster than neutral foods. In addition, we assessed participants' actual food choice, when they were presented with the choice between tasty and neutral food items. This way, we could assess whether the effects of cognitive load would extend to actual behavior, and would prevent the influence of exposure to tasty, but unhealthy foods on people's snack choice. Furthermore, we hypothesized that the effects of cognitive load on attention to attractive stimuli may be especially pronounced for people who are susceptible to the motivational pull of attractive temptations. To address this issue, we included a measure of individual differences in sensitivity to tempting food cues in the environment (Power of Food Scale [PFS]; Lowe et al., 2009) as a potential moderator of attention to attractive food stimuli and food choice behavior. Because cognitive load may short-circuit the processing of reward, we hypothesized that participants who score high on the measure of Power of Food would allocate more attention to attractive food and would display a stronger tendency to select tasty foods, but not when they are under cognitive load.

In Study 4, we extended our cognitive load hypothesis into the domain of interpersonal attraction and desire. Here, male participants performed the spatial categorization task used in Study 1 with attractive and unattractive female faces as targets. We expected participants to attend more strongly to attractive compared to unattractive female faces, as evidenced by slower categorizations of attractive faces, but again, only when cognitive load is low. As in Study 3, we investigated a conceptually similar moderator effect of individual susceptibility to attractive stimuli in the domain of interpersonal attraction. Specifically, we suggest that heterosexual males without a committed relationship may be less discriminating than males in a relationship, when it comes to the physical attractiveness of potential female partners (Lydon, Meana, Sepinwall, Richards, & Mayman, 1999; Simpson, Gangestad, & Lerma, 1990). However, those who are in a relationship may be tempted more specifically by the possibility of extra-relationship interactions with highly attractive members of the opposite sex to the extent that they perceive high quality alternatives to their current relationship (DeWall et al., 2011; Rusbult, Martz, & Agnew, 1998; Rusbult & Van Lange, 2003). In order to test these hypotheses, we included both relationship status as well as interest in alternatives (Rusbult et al., 1998) as potential moderators of attentional capture by attractive female faces. Importantly, we again predicted individual differences in attention to these faces to be eliminated by high cognitive load.

Study 1: Attention Allocation to Tempting Stimuli

Study 1 was designed to show that participants allocate more attention to pictures of attractive compared to neutral food, but that this effect disappears when under cognitive load. In addition, this study was set up to examine whether cognitive load can disrupt the development of cravings when participants have been repeatedly exposed to potentially tempting stimuli.

In a speeded categorization task of attractive and neutral food pictures, we tested whether cognitive load moderates attention to desirable food items. Participants were asked to indicate, as quickly as possible and with a response window of 2 s, whether each picture appeared on the left or right side of the screen. In this task, the picture content bears no relation to the categorization that participants are required to make. However, because object-based attention is prioritized over location-based attention (Vecera & Farah, 1994), people still extract the hedonic relevance of the images, and, as a consequence, allocate more attention to pictures of attractive foods than of neutral foods (Toepel et al., 2009). This attentional capture, in turn, will slow down the categorization on their spatial location of attractive food targets compared to neutral food targets. Hence, we used a spatial categorization task as a means of assessing attention to the hedonic nature of attractive versus neutral food targets.

We varied cognitive load by means of a digit span manipulation (Sternberg, 1969), such that while performing the categorization task, participants had to rehearse either a one-digit number (low load) or an eight-digit number (high load). Our central hypothesis was that recognizing the hedonic relevance of the attractive food pictures, and thus allocating more attention to them, is contingent on the availability of cognitive resources. Therefore, we expected that the slowdown in categorization of attractive compared to neutral food items would not occur when participants are under high cognitive load, since cognitive load will prevent the processing of the hedonic relevance of the attractive food stimuli.

Following the categorization task, we also assessed participants' food cravings. We expected that by preventing full (hedonic) processing of the food stimuli, high cognitive load would reduce the experience of food cravings, which may otherwise develop by the exposure to attractive food pictures during the categorization task (see Kavanagh et al., 2005). Therefore, participants that performed the categorization task while under high cognitive load should experience less food cravings after this task than participants who did the task under low cognitive load.

Method

Participants and design. Ninety-four paid volunteers at Utrecht University (57 women; mean age 21 years) took part in the experiment. The experimental design was 2 (food type: attractive vs. neutral; within participants) $\times$ 2 (cognitive load: high vs. low; between participants), and participants' response latencies in the categorization task, as well as their food cravings after the task, served as dependent variables.

Procedure. Upon arrival at the laboratory, participants were seated in individual cubicles containing a desktop computer. All materials and instructions were presented on the computer.

The spatial categorization task consisted of 30 trials. A picture appeared on screen of which participants had to decide as quickly as possible, and within 2 s, by a keyboard response (*a* and *b* keys), whether it appeared on the left or right side of the screen. We selected 15 pictures of attractive, high calorie foods, such as brownies and French fries, and 15 pictures of neutral, low calorie foods, such as whole-wheat bread and radishes. Pilot ratings of the material ($N = 98$) on a Likert-type scale ranging from 1 (*not tasty*) to 9 (*very tasty*) confirmed that the high-calorie food items were perceived to be significantly tastier ($M = 6.58$, $SD = 1.37$) than the low-calorie food items ($M = 5.23$, $SD = 1.24$), $t(97) = 7.54$, $p < .001$.

We varied cognitive load (low vs. high) between participants by manipulating the digit span of a number that participants retained during the spatial categorization task, such that participants memorized one digit in the low load condition and eight digits in the high load condition (Sternberg, 1969). Following the row of asterisks that announced the beginning of a trial, participants first viewed for 2 s the number that they had to retain during the remainder of the trial. Then, the food picture appeared on the screen. When participants had provided their response to the location of the food picture, a number was again presented on the screen, and participants had 2 s to judge whether it was the same number as they had retained. In half of the trials, this was the same number as participants had seen previously, whereas in the remaining half, one of the digits was different. In the high-load condition, we varied the position of the digit that differed such that participants had to retain the full number in order to arrive at the correct answer.

After participants had completed all 30 trials of the categorization task, they reported their food cravings by answering four questions on a Likert-type scale ranging from 1 (*not at all*) to 9 (*very much*). The four questions were as follows: At this moment,

. . . how much do you desire to eat?; . . . how much appetite do you feel?; . . . how much do you feel the urge to eat?; and . . . how much do you feel like snacking? (Cronbach's α = .94). Finally, participants were thanked for their efforts, debriefed, and paid by the experimenter.

Results

Digit span performance. A one-way analysis of variance (ANOVA) of participants accuracy on the digit span task with cognitive load (one digit vs. eight digits) as an independent variable revealed a significant effect, $F(1, 93) = 345.81$, $p < .001$, $\eta^2 = .790$. As intended, participants were less accurate in the high load condition (M = 58%, SD = 9%) than in the low load condition (M = 93%, SD = 10%). We also observed an effect of cognitive load on response times, $F(1, 93) = 267.24$, $p < .001$, $\eta^2 = .738$, as participants were faster to respond to the one-digit numbers (M = 1,119 ms, SD = 342 ms) than to the eight-digit numbers (M = 2,249 ms, SD = 333 ms).

Spatial categorization task. To analyze participants' response times on the categorization task, we conducted a full factorial repeated measures ANOVA, with food type and cognitive load as within- and between-subjects factors, respectively. We excluded response latencies larger than 1,800 ms and smaller than 200 ms (5% of the data points) from subsequent analyses in order to reduce the influence of outliers. This ANOVA revealed the predicted two-way interaction between food type and cognitive load, $F(1, 92) = 4.68$, $p = .033$, $\eta^2 = .050$. As can be seen in Figure 1, and in line with our hypothesis, pairwise comparisons showed that under low load, participants were slower to respond to attractive food items (M = 788, SD = 245) than to neutral food pictures (M = 731, SD = 228), $F(1, 92) = 4.69$, $p = .033$, $\eta^2 = .051$. However, under high cognitive load, participants responded equally fast to attractive and neutral food pictures (respectively, M = 711, SD = 201, and M = 720, SD = 210; $F < 1$). Likewise, when we compared the effects of load for attractive and neutral food pictures, we observed a marginally significant effect of load on response latencies to attractive pictures, $F(1, 92) = 2.77$, $p = .098$, $\eta^2 = .029$, but not to neutral pictures ($F < 1$). Thus, cognitive load prevented selective attention to the attractive food pictures in the categorization task.

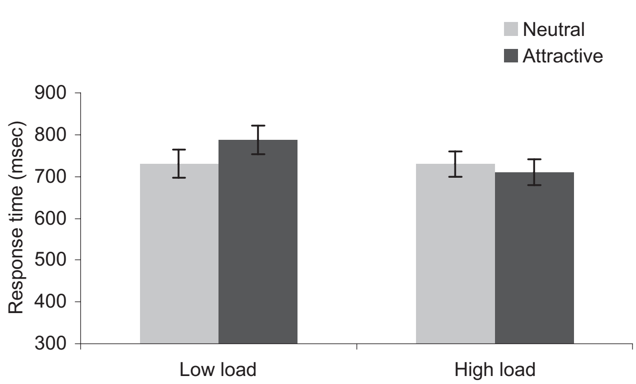

Figure 1. Average response times in milliseconds on the spatial categorization task of Study 1 to attractive and neutral food pictures as a function of cognitive load (low; high). Greater response times to attractive compared to unattractive female faces reflect greater selective attention to attractive female faces. Error bars represent the standard error of the mean.

Cravings. To examine participants' cravings following the categorization task, we conducted an analysis of variance with cognitive load as independent variable. As predicted, this revealed an effect of load, $F(1, 92) = 3.95$, $p = .052$, $\eta^2 = .041$, albeit only marginally significant. Participants reported more intense cravings in the low load condition (M = 5.81, SD = 2.10) than in the high load condition (M = 4.97, SD = 2.04).

Discussion

Using a spatial categorization task, Study 1 showed that participants under low cognitive load allocated more attention toward tempting than to neutral stimuli, as evidenced by slower spatial categorizations of attractive food pictures compared to neutral food pictures. However, this effect disappeared for participants under high cognitive load: Here, participants were equally fast to respond to tasty and neutral food items. This suggests that they may not have assessed the hedonic relevance of the attractive food items when cognitive load was high. Our load manipulation similarly affected participants' snack cravings following the categorization task: When participants had been under high load during the exposure to attractive food pictures in the categorization task, they experienced less intense cravings after the task than in the low load condition. Hence, the desire to consume attractive food temptations may only develop to the extent that people have ample resources to assess their hedonic value.

Study 2: Hedonic Processing of Temptation

Study 1 suggested that participants allocated more attention to attractive compared to neutral food pictures, but that cognitive load eliminated this effect. However, while these findings suggest that when participants are under cognitive load, they cannot extract the hedonic relevance of the food pictures, this explanation was not tested directly. Therefore, Study 1 may still leave room for alternative interpretations. As an example, one could argue that perhaps participants did assess the hedonic relevance of attractive food cues during the long digit span task (i.e., the high load condition), but quickly responded to the left-right position of these cues in order to prevent interference with performance on the digit span task. The attractive pictures displayed during the categorization task, in contrast, presumably were less likely to interfere with the short digit span task (i.e., the low load condition); therefore, participants may have "allowed" themselves to devote more attention to the attractive food pictures and, hence, to take longer to indicate their position during the short digit span task.

Study 2 was designed to rule out such accounts by showing more directly that load prevents processing of the hedonic relevance of attractive food cues. To do so, we decided to measure the activation of hedonic thoughts in response to food temptations. We employed a modified version of a primed lexical decision task that has been used previously in research on dieting (Papies et al., 2007). This task was designed to assess the cognitive accessibility of words related to desire and enjoyment of food (e.g., delicious, tasty, enjoying). We expected participants to spontaneously activate hedonic thoughts in response to attractive food pictures, but not to neutral food pictures. This should be reflected in shorter reaction times to hedonic words in the lexical decision task, due to their increased accessibility. Reaction times to neutral, non-hedonic target words should not be affected by these attractive primes.

As our critical manipulation, we concurrently varied cognitive load, such that it was either absent, moderate, or high. Importantly, we expected faster recognition of hedonic words after the display of attractive food pictures than after neutral food pictures, but only when sufficient cognitive resources are available, that is, in the absence of a high concurrent cognitive load. When cognitive load was high, we expected that food temptations would not trigger any hedonic thoughts and as a consequence, we expected no effect of food type on the recognition of hedonic targets.

In this study, we also included an additional condition in which participants did not receive a concurrent task, in order to get a more fine-grained insight into the effects of cognitive load on hedonic processing. By comparing a no load condition with a moderate load and a high load condition, we wished to disentangle whether the differences between conditions found in Study 1 were due to the mere presence of a secondary task, or to the reduction of cognitive capacity due to the digit span manipulation. We hypothesized hedonic processing to be blocked only when processing resources are strongly absorbed by a demanding concurrent task (the high load condition; see Vytal, Cornwell, Arkin, & Grillon, 2012, for a similar account of the effects of cognitive load). Thus, we expect hedonic reactions to food to be activated in the no load and the moderate load condition, but no longer in the high load condition.

Method

Participants and design. One hundred and seven paid volunteers at Leiden University (59 women; average age 21 years) took part in the experiment. We used a 2 (prime: attractive food vs. neutral food pictures; within participants) $\times$ 2 (target: hedonic vs. neutral words; within participants) $\times$ 3 (cognitive load: no vs. moderate vs. high; between participants) experimental design.

Procedure. Upon arrival at the laboratory, participants were seated in individual cubicles containing a desktop computer. All materials and instructions were presented on the computer. Participants were told that they would be presented with pictures and words. They instructed to view each picture carefully, and to respond to the target words as quickly and accurately as possible by pressing the clearly labeled "yes" or "no" keys to indicate whether the word was an existing Dutch word or not. The lexical decision task began with 10 practice trials. Each trial consisted of a row of asterisks presented in the center of the screen for 1,000 ms, followed by the picture prime for 450 ms and followed by a blank screen for 250 ms. Subsequently, a letter string was presented between four asterisks on each side, signaling to participants that this was the target word requiring a lexical decision. The target remained on the screen until the participant responded or for a maximum of 2 s. The next trial started after an interval of 1,000 ms.

We selected as primes 15 pictures of attractive foods, and 15 pictures of neutral foods. The pictures were taken from the same stimulus set as used in Study 1. In addition, 30 nonfood pictures, such as pictures of a telephone and a lamp, were presented to mask the actual purpose of the experiment. All objects (food, nonfood) were displayed in equal size and were centrally positioned against a white background.

Following the practice trials, participants proceeded with the actual lexical decision task, which consisted of 60 trials. Half of these trials presented words as targets, and half presented non-words, such that the probability that a word or a non-word target would appear was the same. Of the 30 word-trials, our 20 critical trials consisted of 10 hedonic and 10 neutral word targets (see the Appendix). These were equally often preceded by either an attractive or a neutral food picture. In addition, there were 10 food-unrelated filler trials containing a non-food object as a prime and a neutral word as target.

Of the 30 non-word trials, 10 were preceded by either an attractive food prime or a neutral food prime in order to preclude participants' expectancy that food primes would invariably be followed by a word-target. The remaining 20 non-word trials contained pictures of non-food objects as primes. All trials were presented in random order.

Cognitive load during the lexical decision task was varied between participants, using the same digit span manipulation as in Study 1. Participants were randomly assigned to one of three conditions. In the no load condition, participants simply performed the primed lexical decision task. In the moderate load condition, following the row of asterisks that announced the beginning of a trial, participants first viewed a five-digit number for 2 s (e.g., "46385") that they had to retain during the remaining of the trial (Sternberg, 1969). In the high load condition, this was an eight-digit number (e.g., "25371906"). After participants had provided their response on a trial of the lexical decision task, they were again presented with a number, and indicated within a 2-s time window whether or not this was the same number as they had memorized.

At the end of the study and after an unrelated task, participants were debriefed, paid, and thanked.

Results

Digit span performance. An ANOVA of participants' accuracy rates on the digit span task with cognitive load (moderate vs. high) as an independent variable yielded a significant effect of cognitive load, $F(1, 64) = 64.53$, $p < .001$, $\eta^2 = .506$. Response latencies on the digit span task were not affected by load, $F(1, 64) < 1$. Participants in the high load condition successfully retrieved on average 76% of the eight-digit numbers ($SD = 10\%$) and took 1,550 ms to respond ($SD = 348$ ms). Participants in the moderate load condition successfully retrieved on average 91% of the five-digit numbers ($SD = 5\%$) with an average response latency of 1,486 ms ($SD = 324$ ms). No effects of prime or target in the lexical decision task on digit retrieval rates were observed (all ps $> .200$).

Primed lexical decision task. The main dependent variable was participants' average response latency for indicating that the hedonic and neutral target words were existing Dutch words. There were no incorrect responses. Response latencies larger than 1,800 ms and smaller than 200 ms (4% of the data points) were excluded from subsequent analyses in order to reduce the influence of outliers.

Response latencies were analyzed in a 2 (prime: attractive vs. neutral food picture) $\times$ 2 (target: hedonic vs. neutral word) $\times$ 3 (cognitive load: no, moderate, high) full-factorial ANOVA. There was a main effect of cognitive load, $F(2, 104) = 22.19$, $p < .001$, $\eta^2 = .299$. Pairwise comparisons (adjusted for multiple comparisons) showed that, compared to the no load condition ($M = 588$ ms, $SD = 184$ ms), participants were significantly slower to respond on the lexical decision task when concurrently memorizing five digits (moderate load; $M = 764$ ms, $SD = 231$ ms; $p < .001$) or eight digits (high load; $M = 809$ ms, $SD = 284$ ms; $p < .001$). We also observed a main effect of target, $F(1, 105) = 16.29$, $p < .001$, $\eta^2 = .135$. Participants were generally faster to recognize neutral words ($M = 705$, $SD = 195$) than hedonic words ($M = 736$, $SD = 195$).[1]

The analysis further revealed the predicted three-way interaction between prime, target, and cognitive load, $F(2, 104) = 3.33$, $p = .040$, $\eta^2 = .060$. To examine this interaction, we analyzed the effects of prime and target for the three cognitive load conditions separately. In line with our hypotheses, we found an interaction effect of prime and target in the no load condition, $F(1, 41) = 5.92$, $p = .019$, $\eta^2 = .126$. As displayed in Figure 2, participants were faster to recognize hedonic words primed by attractive food pictures ($M = 580$, $SD = 112$) than hedonic words primed by neutral food pictures ($M = 617$, $SD = 119$), $F(1, 41) = 7.85$, $p = .008$, $\eta^2 = .161$. However, the type of prime did not affect the response latencies for neutral words ($p > .35$).

In the moderate load condition, we observed a similar interaction of prime and target, $F(1, 34) = 5.38$, $p < .001$, $\eta^2 = .318$. Although participants were generally slower than in the no load condition, they were still faster to recognize hedonic words primed by attractive food pictures ($M = 749$, $SD = 198$) than by neutral food pictures ($M = 821$, $SD = 213$), $F(1, 34) = 12.47$, $p = .001$, $\eta^2 = .268$. As in the no load condition, participants in the moderate load condition were about equally fast in recognizing neutral words primed by high attractive food pictures as by neutral food pictures ($p = .091$).

Importantly, in the high load condition, we did not observe an interaction between prime and target, $F(1, 29) < 1$, $p > .95$. In line with our predictions, participants' response latencies to both hedonic and neutral target words were unaffected by whether these were preceded by attractive or neutral food pictures. These results are displayed in Figure 2.

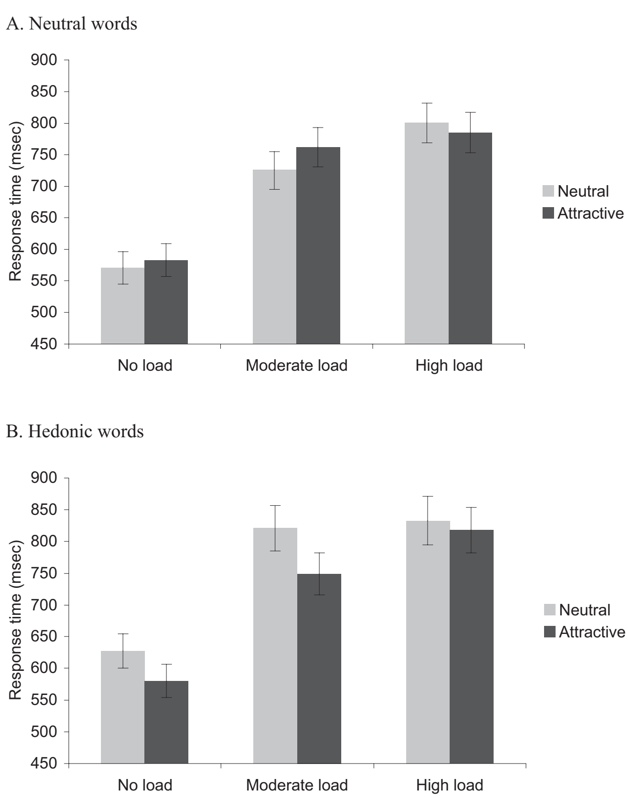

Figure 2. Average response times in milliseconds to neutral words (Panel A) and hedonic words (Panel B) on the lexical decision task of Study 2 as a function of cognitive load (no; moderate; high) and neutral and attractive food pictures as primes. Error bars represent the standard error of the mean.

Discussion

Study 2 confirmed our hypotheses concerning the effects of cognitive load on the hedonic responses to attractive food stimuli. Under no load or moderate load, participants were faster to recognize hedonic target words when these were preceded by attractive food pictures compared to neutral food pictures. High cognitive load, however, completely eliminated the priming effect of attractive food pictures on the accessibility of hedonic words. These findings suggest that the activation of hedonic thoughts in response to tempting food items is resource dependent, such that their activation is prevented only when concurrent task load is sufficiently high, and not under any dual task conditions. Thus, high concurrent task load, but not low, or even moderate task load, appears to occupy the very cognitive resources involved in the processing of the hedonic relevance of stimuli.

Study 3: Unhealthy Snack Choice

The results of Studies 1 and 2 provide first evidence that high cognitive load prevents the processing of the hedonic properties of food temptations and their impact on motivation and, thus, may actually reduce the need for self-control. In other words, if one does not recognize the temptation, there is little need to down-regulate one's cravings for food in an effortful manner, and making healthy choices should be much easier.

In Study 3, we tested the effects of cognitive load on temptation by looking at healthy eating behavior more directly. Rather than assessing the experience of food cravings after the exposure to attractive food pictures with or without high cognitive load, we extended our test to actual food choice. In this study, participants again categorized pictures of attractive and neutral foods, and we then assessed their subsequent choice between desirable and neutral snacks at the end of the experiment.

This time, the categorization task required participants to categorize the objects in the pictures as edible or inedible (Toepel et al., 2009), while we again varied cognitive load. We reasoned that

[1] Although we tried to match for word length, the faster reaction time to neutral words may be due to the fact that these words might be more familiar than the hedonic words we used. Important for our current analysis, this pattern of findings was consistent across load conditions, which implies that it probably did not reflect any differences in hedonic processing of the target words as the result of varying task load.

when participants categorize pictures as edible or inedible, their responses would be facilitated when the pictures represented attractive foods compared to neutral foods because the hedonic content of the pictures is related to the activated category in a meaningful way and attention to this content will therefore speed up categorization (Barsalou, 1985; Burnett, Medin, Ross, & Blok, 2005). Thus, contrary to Study 1, attention to the hedonic relevance of attractive food would be reflected in faster, rather than slower, responses to attractive compared to neutral foods. This way, we aimed to show that the effects of cognitive load would extend across different experimental tasks and independent of whether attention to the hedonic aspects of attractive foods would either slow down or speed up responses on the categorization task.

In order to examine whether cognitive load also helps to reduce the hedonic effects of attractive food items for people who are particularly sensitive to the allure of food in their environment, we moreover included an individual difference measure of participants' psychological susceptibility to desirable food items (Power of Food Scale [PFS]; Lowe et al., 2009). This scale measures self-reported sensitivity to food temptations in different situations by means of 21 questions, such as when food is available, when food is merely present, or when one has tasted some of food available (e.g., "If I see or smell a food I like, I get a powerful urge to have some"; "It seems like I have food on my mind a lot"). Thus, the PFS assesses the experienced effect of tempting food that arises from psychological sensitivity to its hedonic qualities, rather than from actual physiological deprivation. This is particularly relevant in food rich societies, and the expected reward from the consumption of highly palatable foods has been found to be at least as predictive of food (over)consumption as actual food deprivation (Appelhans et al., 2011; Lowe & Butryn, 2007; Pinel, Assanand, & Lehman, 2000; Schultes, Ernst, Wilms, Thurnheer, & Hallschmid, 2010; Stroebe, Papies, & Aarts, 2008). The PFS has earlier been demonstrated to have adequate internal consistency and test–retest reliability (Lowe et al., 2009).

We predicted participants scoring high on the PFS to display greater differences in categorization speed between attractive and neutral foods than participants with low PFS scores, because they are more likely to attend to the attractive food's hedonic qualities. In line with previous studies (Bishop, 2009; Vytal et al., 2012), we expected this difference to be reduced by cognitive load. In addition, we expected an effect of PFS on food choice, such that participants with higher PFS scores would more likely make unhealthy, hedonic food choices after being exposed to attractive food in the categorization task, but again only when cognitive resources had been available to process the hedonic quality of the food pictures. In other words, we expected that cognitive load would eliminate the effects of individual variations in sensitivity to food rewards by preventing the hedonic processing of tempting food cues and, accordingly, their impact on attention and subsequent food choices.

Method

Participants and design. Forty-nine paid volunteers at Leiden University (36 women; average age 21 years) took part in the experiment. The study had a 2 (food type: attractive vs. neutral; within participants) $\times$ 2 (cognitive load: no vs. high; between participants) design with participants' response times on the food categorization task, as well as their subsequent snack choice as dependent variables.

Procedure. Upon arrival, participants were led to individual cubicles with a personal computer, on which all further instructions were provided. We first asked participants to complete the Power of Food Scale (PFS; Lowe et al., 2009; $\alpha = .89$) using a 9-point scale ranging from 1 (*not at all*) to 9 (*very much*), after which they first proceeded to an unrelated study, which served as a filler task for the current study.

After the filler task and a brief introduction, participants performed the speeded categorization task in which they viewed pictures of food items and food-unrelated objects. Cognitive load was again varied by means of a digit span manipulation such that participants concurrently either rehearsed no digits (no load), or eight digits (high load). From the same set as used in the previous studies, we selected 18 pictures of attractive foods, such as brownies and French fries, and six pictures of neutral foods, such as whole-wheat bread and radishes. In addition, six nonfood pictures, such as pictures of a telephone and a lamp, were presented to mask the actual purpose of the experiment. We displayed significantly more attractive food items than neutral food or nonfood items in order to induce stronger cravings (Kavanagh et al., 2005).

Accordingly, the categorization task consisted of 30 trials. In the high load condition, each trial started with the display of an eight-digit number (e.g., "25371906") for 2 s, which participants had to retain during the trial. Next, a picture appeared, of which participants had to decide as quickly as possible, and within 2 s, by a keyboard response (*a* and *b* keys, counterbalanced) whether it was a food (edible) or a nonfood item (inedible). Next, a number again appeared on the screen, and participants had 2 s to judge whether it was the same number as they had retained. In the no load condition, participants did not memorize any digits during the categorization task.

At the end of the study, participants were thanked for their efforts, and the experimenter explained that the snacks stalled in the experimenter room were leftovers from the departmental Sinterklaas celebration[2] and that the participants were free to take one snack. The foods were tangerines and apples (healthy snacks) as well as chocolates and marzipan (unhealthy snacks). The experimenter unobtrusively recorded participants' food choices. Finally, participants were debriefed and paid by the experimenter.

Results

Digit span performance. Participants on average successfully retrieved 71% of the eight-digit numbers ($SD = 18\%$) and took 1,878 ms on average to respond ($SD = 650$ ms).

Food categorization task. To reduce the influence of outliers, response latencies under 200 ms and over 1,800 ms were first removed (3% of the data points). Due to a technical failure, we did not record the response latencies of three participants, who were thus excluded from all subsequent analyses.

We analyzed participants' response times on the categorization task in a multivariate regression analysis in the general linear

[2] 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 (December 5th) or, in Belgium, on the morning of December 6th ("Sinterklaas," n.d.).

model (GLM; full factorial), with food type and cognitive load as categorical predictors, and PFS scores as a continuous predictor, while including all main and interaction effects. The GLM is a multivariate regression model that allows the 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 & Hamstra, 2010).

This analysis revealed a highly significant main effect of load, $F(1, 45) = 65.89$, $p < .001$, $\eta^2 = .61$, such that participants were slower to respond under high cognitive load ($M = 756$, $SD = 142$) compared to no cognitive load ($M = 448$, $SD = 126$). More importantly, we again found the predicted two-way interaction between food type and cognitive load, $F(1, 45) = 10.68$, $p = .002$, $\eta^2 = .20$. In line with our hypotheses, planned comparisons showed that in the absence of cognitive load, participants were faster to categorize attractive food items ($M = 438$, $SD = 120$) than neutral food items ($M = 461$, $SD = 133$), $F(1, 48) = 9.99$, $p = .003$, $\eta^2 = .192$, whereas participants responded equally fast to attractive and neutral food items when they were under high cognitive load (respectively, $M = 763$, $SD = 134$, and $M = 749$, $SD = 149$; $F < 1$).

We also observed a three-way interaction between food type, cognitive load, and PFS scores, $F(1, 45) = 6.71$, $p = .01$, $\eta^2 = .14$, which is displayed in Figure 3. To further examine this interaction, we next analyzed the effects of cognitive load and food type separately, for participants scoring high or low on the PFS (one standard deviation above or below the mean, respectively; see Cohen, Cohen, West, & Aiken, 2003, for this procedure). For participants scoring high on the PFS, this analysis revealed a significant interaction between cognitive load and food type, $F(1, 45) = 16.55$, $p < .001$, $\eta^2 = .283$. Without load, these participants were significantly faster to categorize attractive than neutral food items, $F(1, 45) = 28.55$, $p < .001$, $\eta^2 = .405$, but under high load, there was no effect of food type on categorization latencies, $F(1, 45) = 2.27$, $p = .140$, $\eta^2 = .051$. For participants scoring low on the PFS, we did not observe an interaction between cognitive load and food type, $F(1, 45) < 1$.

Snack choice. Next, we analyzed the percentage of participants who chose an unhealthy snack (unhealthy = 1, healthy = 0) after the study by means of a multiple binary logistic regression (following the recommendations by Hayes & Matthes, 2009), with PFS scores, cognitive load, and their interaction as predictors. Because all participants chose to take a snack of some kind (unhealthy or healthy), there were no missing values for the analysis of snack choice. The analysis yielded a main effect of PFS scores, $B = –3.59$, $SE = 1.42$, Wald(1) = 6.42, $p = .010$; a marginally significant effect of load, $B = 1.48$, $SE = 0.76$, Wald(1) = 3.79, $p = .053$; and a significant interaction between

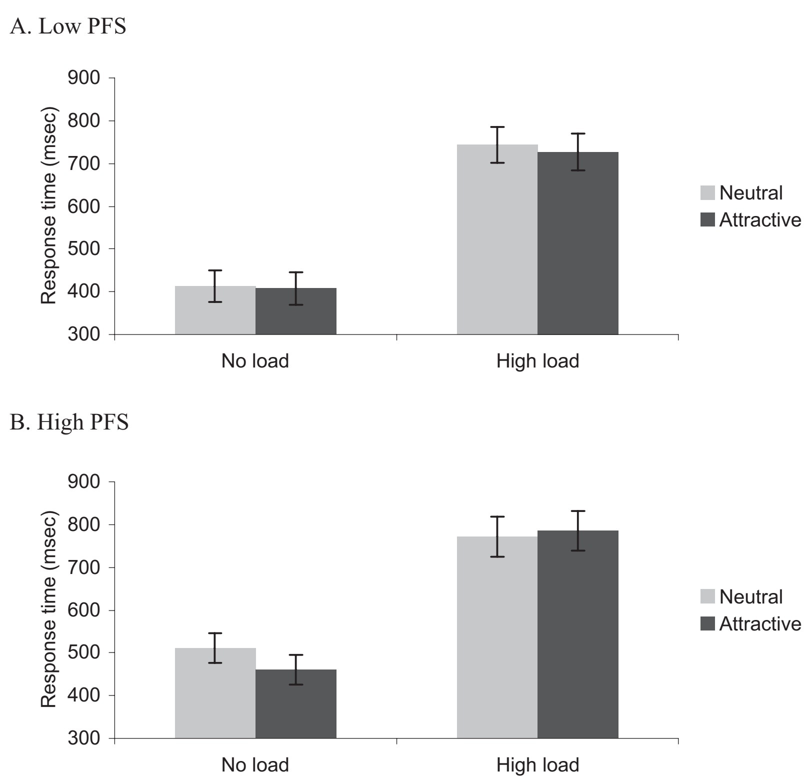

Figure 3. Estimated response times in milliseconds on the food categorization task of Study 3 to neutral and attractive food pictures as a function of cognitive load (no; high) and low (Panel A) and high (Panel B) scores on the Power of Food Scale (PFS). Low and high PFS values represent ±1 *SD* from the respective means. Smaller response times to attractive versus neutral food pictures reflect greater selective attention to attractive food. Error bars represent the standard error of the mean.

cognitive load and PFS scores, $B = 2.68$, $SE = 0.97$, Wald(1) = 7.63, $p = .006$. To further analyze this interaction and test our specific hypotheses, we probed the effects of cognitive load within high or low power of food (±1 *SD*). As illustrated in Figure 4, there was no effect of cognitive load for participants low on PFS, $B = -1.12$, $SE = 1.00$, Wald(1) = 1.26, $p = .26$. For participants high on PFS, however, and similar to the results on the food categorization task, there was a significant effect of cognitive load on snack choice, $B = 4.08$, $SE = 1.39$, Wald(1) = 8.65, $p = .003$, such that these participants were more likely to select an unhealthy snack after performing the categorization task without cognitive load rather than with high cognitive load.

Discussion

Replicating the findings of Study 1 with a different categorization task, Study 3 showed that cognitive load blocks attention to the hedonic properties of tasty food cues. Here, participants were faster to categorize tasty high-calorie foods than low-calorie foods as edible, but not when their cognitive resources were taxed by a demanding concurrent task. This processing bias was most pronounced for individuals highly sensitive to food temptations, but again, only when cognitive load was absent and not when cognitive load was high. High cognitive load also resulted in a general slowdown of responses to the food categorization task. This slowdown was likely due to the increased attentional demands of the high-load task (Barrouillet, Bernardin, Portrat, Vergauwe, & Camos, 2007; for a similar finding, see Van Dillen & Koole, 2009).

In addition, we extended the effect of blocking cognitive resources from cravings to actual food choice. As the interaction between load and PFS revealed, participants high in sensitivity to tempting food, compared to those low in sensitivity to tempting food, were much more likely to choose an unhealthy snack when they were not under cognitive load. In contrast, under high load, however, participants' snack choice was not affected by their sensitivity to food temptations. These results suggest that cognitive load prevented the translation of participants' psychological vulnerability to the tempting value of attractive food into actual unhealthy food choice. Based on Studies 1 and 2, we can assume that participants under load did not process the hedonic relevance of the tasty foods and therefore may have developed considerably lower motivational impetus to choose and consume otherwise tempting food. As a result, it was easier for them to refrain from choosing the attractive, unhealthy snacks.

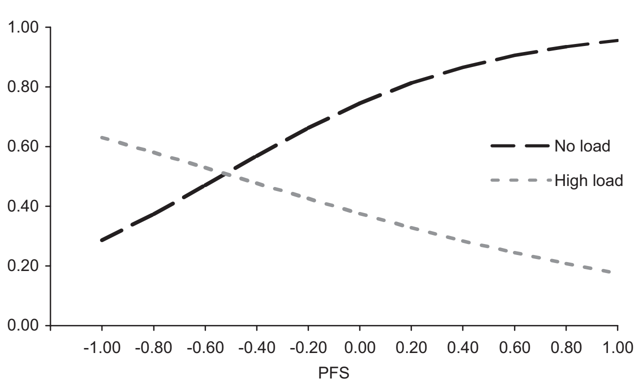

Figure 4. Unhealthy snack choice (probabilities) in Study 3 as a function of cognitive load (no; high) and standardized scores on the Power of Food Scale (PFS). High and low PFS values represent ±1 *SD* from the respective means.

Study 4: Interpersonal Attraction

Study 4 was designed to replicate and extend the findings of Studies 1–3 in a different domain. Our studies so far have demonstrated that cognitive load can reduce attention to the hedonic properties of attractive food stimuli, prevent food cravings which otherwise develop during the exposure to attractive food pictures, and facilitate healthier choices. In Study 4, we examined these self-regulatory benefits of cognitive load in the domain of interpersonal behavior. Thus, rather than examining the effects of load on the processing bias for tasty food items, this study examined its effects on male participants' attention to attractive female faces.

Because people in an intimate relationship perceive attractive members of the opposite sex differently (Maner, Gailliot, & Miller, 2009), we expected that participants' processing of attractive others as potential partners could be influenced by their relationship status. Thus, we included this variable in our experimental design. In order to get a more fine-grained understanding of participants' motivation with respect to attractive others, we also measured the extent to which participants in a relationship still perceived alternatives to their current relationship partner (Rusbult et al., 1998). We reasoned that, compared to participants with low interest, participants with high interest in alternatives would allocate relatively more attention to pictures of attractive females than of unattractive females, even though they are currently in a relationship (see also DeWall et al., 2011).

Method

Participants and design. Eighty-eight paid volunteers at Utrecht University (all men; all heterosexual; average age 21 years) took part in the experiment. The experimental design was a 2 (target attractiveness: attractive vs. unattractive; within participants) × 2 (cognitive load: high vs. low; between participants) × 2 (relationship status: in a relationship vs. single; between-participants) design. Forty-five participants were in a relationship, and 39 reported to be single. Due to technical problems, the computer did not record response latencies of four participants, and the attractiveness ratings as well as interest in alternatives of another seven participants, leaving 84 participants, 77 participants, and 31 participants, respectively, for the analyses of these dependent variables.

Procedure and equipment. Participants performed the same speeded categorization task used in Study 1 and indicated the spatial location of attractive versus unattractive female faces on the screen. In addition, we added filler trials with male faces to disguise the purpose of the experiment. The total stimulus set thus consisted of 60 pictures: 15 attractive female faces, 15 unattractive female faces, and 30 male faces. All faces were drawn from a database developed by van Leeuwen and Macrae (2004).

Cognitive load was again varied between participants by means of the same digit span manipulation used in the previous studies. That is, at the beginning of each trial of the categorization task, participants rehearsed either one-digit (low cognitive load) or eight-digit (high cognitive load) numbers and indicated at the end of each trial whether or not the rehearsed number matched a target number displayed on the screen.

Following the categorization task, participants indicated whether they were currently in a romantic relationship. In case participants confirmed this, we asked them to fill out the Interest in Alternatives scale, a five-item measure of people's perceptions of the potential alternatives to their relationship from Rusbult et al. (1998; e.g., "The people other than my partner with whom I might become involved are very appealing"; 1 = *strongly disagree*, 7 = *strongly agree*; Cronbach's $\alpha = .90$). If participants indicated they were single, they proceeded to the next part of the experiment.

We then again presented all participants with each of the faces used in the categorization task and asked them to indicate on a 9-point scale (1 = *not at all*, 9 = *very*) how attractive they found these faces. At the end of the study, participants were thanked for their efforts, debriefed, and paid by the experimenter.

Results

Digit span performance. A one-way ANOVA of participants' accuracy on the digit span task with cognitive load (one digit vs. eight digits) as an independent variable revealed an effect of load, $F(1, 87) = 145.25$, $p < .001$, $\eta^2 = .520$. Participants were less accurate in the high load condition ($M = 66\%$, $SD = 8\%$) than in the low load condition ($M = 92\%$, $SD = 9\%$).

Attractiveness ratings. Analyses of participants' attractiveness ratings confirmed that they found the attractive female faces ($M = 6.70$, $SD = 1.41$) more attractive than the unattractive female faces ($M = 3.06$, $SD = 1.54$), $F(1, 76) = 239$, $p < .001$, $\eta^2 = .750$. We also observed a main effect of relationship status, $F(1, 76) = 8.70$, $p = .004$, $\eta^2 = .112$, such that, compared to males in a relationship ($M = 4.49$, $SD = 1.38$), single males rated all female faces as more attractive ($M = 5.11$, $SD = 1.48$). Cognitive load and interest in alternatives had no interaction effect on participants' attractiveness ratings ($F < 1$).

Spatial categorization task. We first analyzed participants' response times on the categorization task in an ANOVA with attractiveness, cognitive load, and relationship status as independent variables. To reduce the influence of outliers on the analysis, response latencies below 200 ms and above 1,800 ms were first removed (6% of the data points). The analysis yielded a two-way interaction between attractiveness and relationship status, $F(1, 83) = 3.98$, $p = .049$, $\eta^2 = .05$, which was qualified by a three-way interaction of attractiveness, load, and relationship status, $F(1, 80) = 4.79$, $p = .031$, $\eta^2 = .06$. To decompose this three-way interaction, we proceeded with analyzing the effects of attractiveness and load separately for single participants and participants in a relationship.

Somewhat surprisingly, for single participants, there were no effects of either attractiveness or cognitive load ($F \leq 1$). Thus, regardless of concurrent task load, single males did not take any longer to categorize attractive female faces than unattractive female faces (see Discussion for possible explanations). For males in a relationship, however, we observed the expected interaction between attractiveness and load, $F(1, 37) = 4.28$, $p = .046$, $\eta^2 = .11$. These findings are displayed in Figure 5. Under low cognitive load, males in a relationship were slower to indicate the position of attractive compared to unattractive female faces, $F(1, 37) = 5.10$, $p = .030$, $\eta^2 = .12$, indicating selective attention to the attractive faces. Under high load, however, they did not differ in their response times to attractive versus unattractive female faces ($F < 1$).

Next, in order to examine whether high interest in alternatives related to greater attention to attractive compared to unattractive female faces and, critically, whether this effect was again moderated by cognitive load, we investigated the role of Interest in Alternatives (Rusbult et al., 1998) as an additional, continuous predictor among participants in a relationship. We conducted a multivariate regression analysis in the GLM (full factorial) with attractiveness and load as categorical predictors, and standardized Interest in Alternatives scores as a continuous predictor (see Study 3 for this statistical technique). This analysis yielded a significant three-way interaction between attractiveness, load, and Interest in Alternatives, $F(1, 28) = 6.53$, $p = .005$, $\eta^2 = .32$. We next analyzed the effects of attractiveness and load for participants high (+1 *SD*) and low (−1 *SD*) Interest in Alternatives. For participants with high Interest in Alternatives, the crucial interaction between attractiveness and load emerged, $F(1, 28) = 5.48$, $p = .010$, $\eta^2 = .281$. As can be seen from Figure 6, highly interested participants were significantly slower to categorize attractive than unattractive female faces when under low cognitive load, $F(1, 28) = 12.06$, $p = .002$, $\eta^2 = .301$. Under high cognitive load, however, there was no effect of attractiveness on their categorization latencies, $F(1, 28) = 2.06$, $p = .144$, $\eta^2 = .075$. For participants scoring low on the Interest in alternatives scale, there was no interaction between attractiveness and load, $F(1, 28) < 1$ (see Figure 6).[3]

Discussion

In this fourth, and final study, we tested whether cognitive load reduces selective attention to temptation cues in a different domain. The findings we obtained were conceptually similar to those of Studies 1–3: Cognitive load reduced male participants' attention to the attractive female faces they perceived, as evidenced in smaller response time differences on the categorization task to these faces and unattractive female faces.

Somewhat unexpectedly, the effects of Study 4 only held for male participants in a relationship, and more specifically, who reported interest in alternative dating partners. We had predicted that being single might reflect the motivation to look out for (attractive) women, so that single men, too, would pay more attention to attractive females than unattractive females. However, reality may be somewhat more complicated. For one, there may be many reasons to be single, other than not being able to find a suitable mate: One may have just gotten out of a relationship or be too involved with study or work, which may be reasons to show

[3] Whereas we observed no significant interaction between attractiveness and cognitive load, $F(2, 28) < 1$, pairwise comparisons showed that in the low load condition, participants low in interest in alternatives displayed the opposite pattern to participants high in interest, with marginally significantly *longer* response latencies to unattractive than to attractive female faces, $F(2, 28) = 3.91$, $p = .058$, $\eta^2 = .123$. This is in line with previous research showing that being in a steady relationship may actually form a buffer against attractive alternative partners (e.g., Maner et al., 2009). Importantly, when under high load, there was again no effect of attractiveness on low interested participants' response times. See also Figure 6.

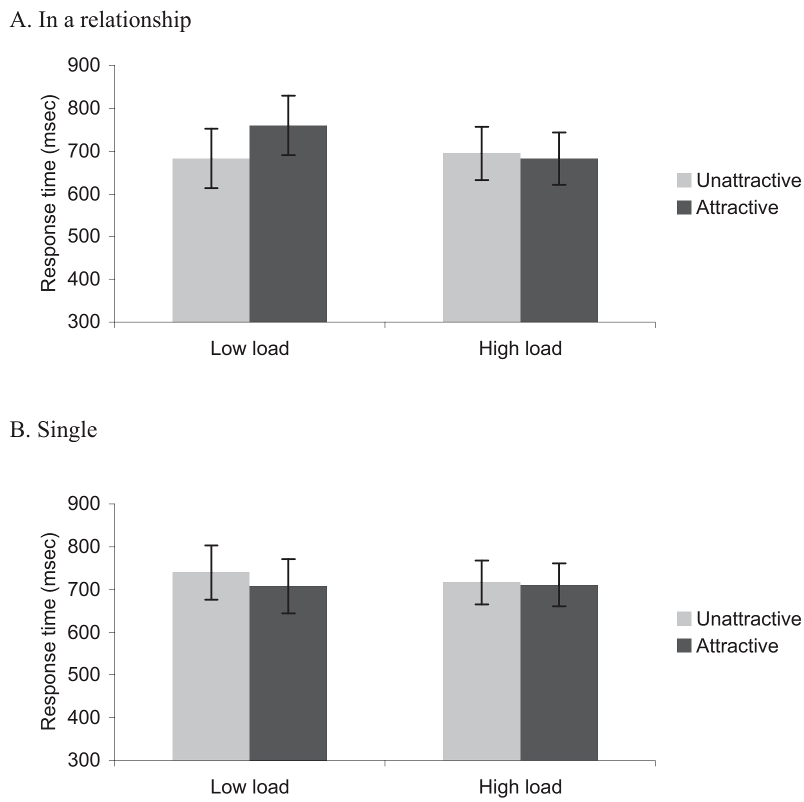

Figure 5. Average response times in milliseconds on the spatial categorization task of Study 4 to attractive and unattractive female faces as a function of cognitive load (low; high) and relationship status (in a relationship, Panel A; single, Panel B). Greater response times to attractive compared to unattractive female faces reflect greater selective attention to attractive female faces. Error bars represent the standard error of the mean.

little interest in attractive opposite sex individuals. Future studies could take such motivational differences into account when studying motivational processes in the domain of interpersonal attraction. Moreover, a recent study (Maner et al., 2009) demonstrated that single participants displayed greater selective attention to attractive opposite-sex targets than participants in a relationship, but only when participants had been primed with the concept of mating before the attention task. Perhaps then, single males pay relatively more attention to attractive women only when the context signals a mating opportunity.

Another explanation is that single males may be less selective in their attention to women. In support, single men rated the female faces overall as more attractive than men in a relationship, consistent with prior research (Lydon et al., 1999; Simpson et al., 1990). Conversely, being in a relationship does not necessarily imply that one has no interest in attractive women (especially when the sample under investigation consists of young college students without children). Whereas there is ample research showing the buffering effects of being in a relationship (e.g., Maner et al., 2009), men in a relationship may still pay attention to attractive opposite-sex individuals (Miller, 1997), especially when they feel that the quality of alternatives to their partner is high (Rusbult & Van Lange, 2003). Indeed, we found that interest in alternatives (Rusbult et al., 1998) further qualified the results for men in a relationship, such that only men with a high interest in alternatives displayed selective attention to attractive female faces to begin with. This moderator finding further supports our notion that the categorization task taps into motivational effects on attention due to the processing of hedonic relevance.

In sum, there may be other motivational factors at play in addition to relationship status per se, which affect the motivation to look out for attractive mates, such as the perceived quality of alternatives. Clearly, future research is needed to further examine which factors may be most decisive. Most important for our current analysis though, cognitive load moderated attention to attractive female faces for males in a relationship who reported interest in alternative dating partners, providing further evidence for our idea that hedonic responses to tempting cues are dependent on cognitive resources.

General Discussion

Four studies investigated the idea that the hedonic processing of temptation is resource dependent. On the background of recent thinking about the role of cognitive resources in emotional processing (Van Dillen & Koole, 2009) and the role of working memory processes in the elaboration of desire (Hofmann & Van Dillen, 2012; Kavanagh et al., 2005), we hypothesized that desirable targets grab people's attention and impact people's cravings and subsequent behaviors, only to the degree that cognitive re-

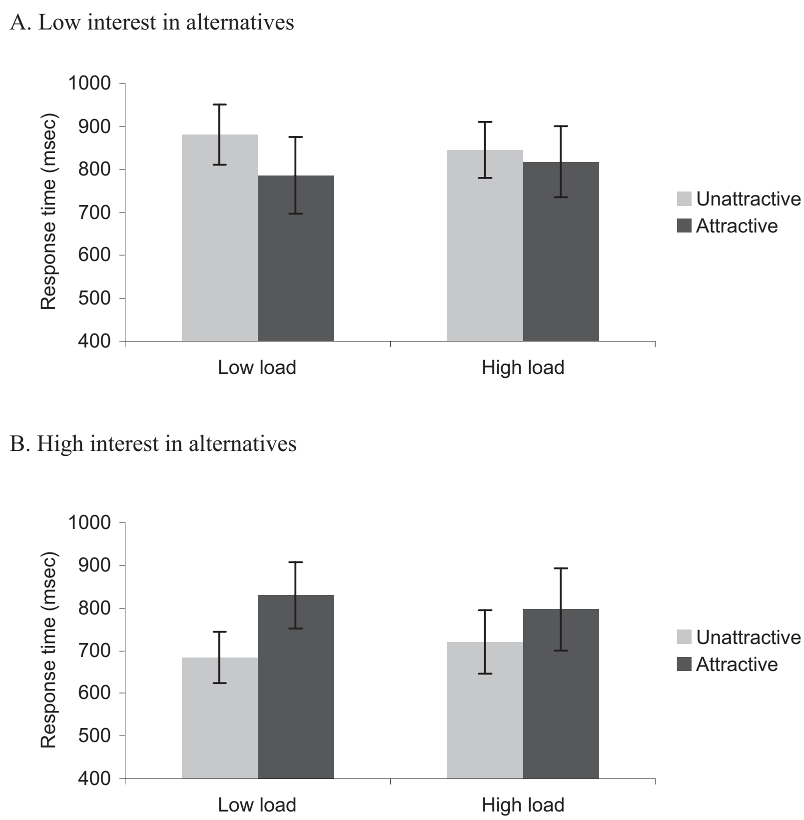

Figure 6. Estimated response times in milliseconds on the spatial categorization task of Study 4 to attractive and unattractive female faces as a function of cognitive load (low; high) and interest in alternatives (low interest, Panel A; high interest, Panel B). Low and high interest values represent ± 1 *SD* from the respective means. Greater response times to attractive compared to unattractive female faces reflect greater selective attention to attractive female faces. Error bars represent the standard error of the mean.

sources are available to extract the hedonic relevance of (potentially) tempting stimuli. To test the idea of a "blind eye" to temptation, participants categorized attractive and neutral stimuli (Studies 1, 3, and 4) and performed a lexical decision task that assesses spontaneous thoughts about eating enjoyment (Study 2) under varying cognitive load, after which we assessed cravings (Study 1) and craving-induced choices (Study 3). In support of our hypothesis, participants displayed greater attention to attractive compared to neutral food items (Studies 1 and 3), greater activation of hedonic thoughts (Study 2), and greater attention to attractive compared to unattractive female faces (Study 4) under low, or moderate cognitive load, but not under high cognitive load. Moreover, high cognitive load reduced participants' cravings for food (Study 1) and their choices for tasty but unhealthy snacks (Study 3).

In addition, we observed individual differences in the sensitivity to food temptations, as measured by the Power of Food Scale (Lowe et al., 2009) to influence participants' appetitive responses to food only when cognitive load was low (Study 3). Under low cognitive load, but not under high cognitive load, highly sensitive participants displayed a larger processing bias for tasty food pictures and a greater preference for unhealthy snacks than mildly sensitive participants. Similarly, we observed individual differences in interest in alternatives (Study 4; Rusbult et al., 1998) to influence greater attention to attractive versus unattractive female faces for male participants in a relationship, but again, under low cognitive load but not under high load.

Importantly, in all three studies that used a categorization task, the desirable targets were the objects to be categorized. Thus, participants could always clearly *perceive* the targets (i.e., they were not literary "blind" to the targets). Yet, when concurrent cognitive load was high, participants did not seem to process their tempting qualities. Moreover, we varied the meaningful relationship between targets and categorization task, such that participants categorized the target as being displayed on the left or right side of the screen (Studies 1 and 4), or as edible or inedible (Study 3). Regardless of whether attention to the tempting qualities of the stimuli facilitated or interfered with performance on the categorization task, the biasing impact of stimulus attractiveness was always reduced by high concurrent cognitive load. This suggests that the effects of cognitive load extend beyond a simple "out of sight, out of mind" principle and reduce desire by restricting what features people attend to, even if these would normally automatically capture attention, and trigger hedonic associations. As such, the present findings are in line with recent evidence that changing the actual meaning of appetitive items in more neutral terms that does not focus on their hedonic qualities so much effectively reduces people's cravings for these items (Hofmann, Deutsch, Lancaster, & Banaji, 2010).

By examining the robustness of the findings across different experimental set-ups and different domains, we aimed to demonstrate the general validity of our predictions. Hence, our findings may not be restricted to food or interpersonal attraction. Rather, we propose that the development of any type of desire may ultimately be restricted by people's momentary cognitive capacity. Thus, cognitive load should similarly prevent cravings for cigarettes, alcohol, or gambling. Indeed, recent evidence suggests that abstaining smokers could effectively control cigarette cravings by engaging in a taxing visual imagery task (May, Andrade, Panabokke, & Kavanagh, 2010; see also Kemps, Tiggeman, & Hart, 2005).

Timing Is Everything: Distinct Effects of Load in the Self-Control Process

At first sight, the present findings may seem counterintuitive, given earlier demonstrations of how the regulation of cravings and desires may decline under high cognitive load (e.g., Hofmann, Gschwendner, Friese, Wiers, & Schmitt, 2008a; Ward & Mann, 2000). In studies on eating behavior, for example, a common finding is that people consume more "forbidden food" when under cognitive load than otherwise, and that this effect is particularly pronounced for dieters, who are especially sensitive to the tempting qualities of high-calorie food (e.g., Bellisle & Dalix, 2001; Boon, Stroebe, Schut, & Ijntema, 2002; Ward & Mann, 2000). The present findings suggest, however, that rather than actively suppressing one's behavioral tendencies toward objects that have already elicited a sense of craving or desire, preventing one's attention to be grasped by temptation in the first place, for example by engaging in an involving task, should circumvent the problem of the willful control of desire identified in prior research.

This reasoning is in line with the work of Gilbert and Hixon (1991), who showed that whereas cognitive load prevented the activation of stereotypical knowledge when confronted with a stereotype object, cognitive load facilitated stereotype application once it had already been activated (see also Macrae, Hewstone, & Griffiths, 1993). Along similar lines, Baumeister et al. (1994, p. 26) seem to have predicted the possibility that mental load may have different effects depending on the timing in the self-regulation process:

> The importance of managing attention leads to a seemingly paradoxical prediction, namely that being preoccupied can have opposite effects on self-regulation. On the one hand, if the person is seriously preoccupied with thinking about certain things, he or she may be less likely to notice tempting or threatening stimuli, and so there will be less difficulty resulting from conflicting impulses that need to be controlled. On the other hand, if such impulses do arise, being preoccupied may make it more difficult for the person to control them.

In most studies on cognitive load in self-regulation, people had ample resources available to develop cravings, but had little resources available once they had to control them. In contrast, in the present research we induced cognitive load before confronting people with tempting stimuli, such that the attractive features of these stimuli were most likely not attended to, and then, not elaborated upon. Indeed, our findings show that thus occupying one's mind effectively prevents the development of cravings in the first place. Hence, whereas earlier studies have shown that the hedonic qualities of tempting stimuli play a crucial role in the psychological processes leading to self-regulatory failures (e.g., Hofmann et al., 2008a; Papies & Hamstra, 2010; Papies et al., 2007), the current findings indicate that identifying these hedonic qualities in the first place depends on the cognitive resources available to process them. Future studies may systematically examine the effects of introducing cognitive load at different stages in a situation potentially presenting a self-regulation challenge.

Relation to Ego Depletion and to Implicit Self-Control

The current findings raise the question whether cognitive load may have similar or distinct effects from those of ego-depletion (i.e., the idea that self-control or willpower is an exhaustible resource; Baumeister et al., 1998), another widely studied topic in self-regulation. More specifically, the effects of resource depletion established in the literature clearly go beyond the cognitive processing effects studied here as they rather appear to include a strong motivational component that may render people less "willing" to exert self-control. For instance, Muraven, Shmueli, and Burkley (2006) have argued that ego depletion may make participants less willing to spend self-regulatory efforts on a subsequent task because they may want to conserve available resources. Such an impact of motivational processes also becomes apparent from findings showing that beliefs about willpower affect subsequent performance (Job, Dweck, & Walton, 2010; Martijn, Tenbült, Merckelbach, Dreezens, & de Vries, 2002). Furthermore, recent findings suggest that ego depletion may *intensify* rather than dampen emotional processing and thus may have quite distinct effects from cognitive load. In a functional magnetic resonance imaging (fMRI) investigation, Wagner and Heatherton (in press) observed that depleted participants showed increased amygdala reactivity to negative emotional scenes. In a related vein, Vohs et al. (2012) found that participants who were depleted at an earlier time point subsequently reported stronger emotional reactions to pleasant and unpleasant images and film clips, intensified pain in a cold pressor task, and an increased urge to eat cookies presented during a taste and rate test. Taken together, these results suggest that concurrent cognitive load and prior ego depletion have opposite effects regarding simultaneous versus subsequent emotional processing, respectively, including the appraisal of hedonic relevance studied in the present research.

Moreover, a number of recent studies have shown that, in some instances, temptation cues not only lead to hedonic processing and to subsequent failures in self-regulation, but can also activate long-term goals and regulatory processes. This pattern of temptation-elicited goal activation has in turn been linked to better long-term self-regulatory success. Successful dieters, for example, have been shown to spontaneously activate the goal of dieting in response to attractive food cues (Fishbach, Friedman, & Kruglanski, 2003; Papies, Stroebe, & Aarts, 2008b), and it has been argued that this "implicit self-control" is particularly effective because it does not rely on conscious intentions and is therefore independent of cognitive resources (Fishbach & Shah, 2006). In light of the present findings, it is conceivable, however, that the activation of such counter-active self-regulatory processes may depend on whether the perceiver actually recognizes the tempting value of an attractive stimulus; if a stimulus is not categorized as desirable and therefore potentially threatening to one's long-term goals, it may not activate processes to counter this temptation either (Hofmann & Van Dillen, 2012). Future research should examine this hypothesis and thus test whether the activation of counteractive control depends on the identification of temptation (and perhaps also its associated conflict, see Myrseth & Fishbach, 2009), and can therefore be considered a resource-dependent phenomenon or whether implicit self-control operates even in the absence of stimulus categorization.

Conclusion

In modern societies, people are confronted with temptation on a daily basis. In order not to be swayed by its captivating power, people need to regulate temptation's impact on thoughts, feelings, and behavior. In the present research, we demonstrated that the capture of potentially tempting stimuli is contingent on cognitive resources and that, somewhat counter intuitively, the emergence of desire can be prevented by taxing people's cognitive resources to process the hedonic relevance of tempting stimuli. Accordingly, cognitive load may sometimes benefit self-regulation by turning a blind eye to temptation, which has important implications both for theories of motivation and desire as well as for applications to facilitate self-regulation in daily life.

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Appendix

Hedonic and Neutral Word Targets

Hedonic Target Words (Translated From Dutch)

delicious, tasty, yummy, enjoying, indulging, scrumptious, delectable, snacking, savoring, bite

Neutral Target Words (Translated From Dutch)

interesting, easy, cozy, clean, clear, drawing, living, outside, measuring, book

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