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A high perceptual load task reduces thoughts about chocolate, even while hungry.

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Data for all experiments is available on the open science framework (osf.io/8mep7/)

Abstract

Intrusive thoughts about food can trigger cravings and result in unhealthy eating behaviour. Here we tested whether Load Theory of attention can be applied to the eating behaviour literature and reduce intrusive appetitive-related thoughts. Load Theory predicts that high levels of perceptual load in a task exhaust attentional capacity and so reduces interference from a range of stimuli, including intrusive thoughts. Therefore, this study aimed to test whether perceptual load reduced appetitive-related intrusive thoughts about chocolate. Sixty female participants were first given a chocolate bar to interact with for two minutes, before rating their levels of hunger, craving and liking for chocolate. They were then asked to avoid thinking about chocolate and instead focus attention on a visual search task. Perceptual load was manipulated within-subjects by varying the search set size. Appetitive-related thoughts were measured using both self-caught and probe-caught measures, allowing us to index load effects at varying levels of meta-awareness. Across subjects, the level of appetitive-related thoughts seen in the high load condition was significantly reduced, to less than half the level seen in the low load condition, on both probe and self-caught measures. Furthermore, self-reported hunger, craving and liking for the chocolate were positively correlated with appetitive-related thoughts under low load, but high perceptual load eliminated these state individual differences. Therefore, engaging in perceptually demanding tasks may be a worthwhile strategy for those wanting to disrupt the cycle of craving at the earliest stage.

Keywords: Intrusive thoughts, Food craving, Craving reduction, Perceptual load, Attention.

1. Introduction

Overeating can result in obesity, a costly public health issue causing both physical and psychological harm to the individual. Craving has been argued to play a key role in eating behaviour, often resulting in over-eating (Hetherington & Macdiarmid, 1995), difficultly controlling weight (Meule, Westenhöfer & Kübler, 2011) and triggering binge eating episodes (Waters, Hill, & Waller, 2001). In addition, high levels of craving have been linked to higher BMI (Delahanty, Meigs, Hayden, Williamson, & Nathan, 2002; Rodin, Manuso, Granger, & Nelbach, 1991). Addiction models of craving have argued that cognitive processes, such as attentional bias (enhanced attentional processing of external stimuli) and subjective experience (e.g., substance-related thoughts), contribute towards substance-seeking behaviour (Franken, 2003; Field, Munafò & Franken, 2003). In relation to food, spontaneous intrusive thoughts have been argued to be a crucial trigger in a craving episode (May, Andrade, Kavanagh, & Hetherington, 2012). It has been suggested (Higgs, 2016) that when the initial thought is maintained in working memory, it then increases the salience of internal information (e.g., physiological state and episodic memories) and external information (e.g., food cues in the environment). For example, a person sitting at their desk may spontaneously think about chocolate, which makes them aware of how hungry they are and then increases the likelihood they notice the chocolate bar in their drawer. The latter example relates to attentional bias, which has been suggested to further perpetuate craving and increase the likelihood of consumption (Franken, 2003; Field, Werthmann, Franken, Hofmann, Hogarth & Roefs, 2016). Therefore, the intrusive thought will then continue to cause craving either until it has been satisfied (by consuming the chocolate) or until the cycle is broken. Following the presented logic, we reasoned that one way of breaking the cycle would be by preventing the occurrence of appetitive-related intrusive thoughts.

The current research sought to elucidate the mechanisms underlying the most effective interventions to reduce appetitive-related thoughts, by applying a key theory of selective attention. Load Theory suggests that attention is a limited capacity resource, and that the extent to which task-irrelevant stimuli are selected for further processing depends on the level of perceptual load involved in the current task (Lavie, 2005; 2010). When perceptual demands are low (i.e. there is little information to process, or a very simple perceptual discrimination), this leaves spare capacity which can spill over to allow processing of other, task-irrelevant stimuli (Lavie, Hirst, De Fockert & Viding, 2004). In contrast, when perceptual demands are high (i.e. involving a large amount of information or complex and subtle perceptual discriminations), irrelevant stimuli are filtered out at an early stage and only relevant stimuli are passed on for further processing.

The powerful effects of perceptual load in reducing task-irrelevant processing have been demonstrated with a range of behavioural measures of distractor interference (e.g. Forster & Lavie, 2008) and intentional blindness (e.g. Cartwright-Finch & Lavie, 2006), as well as measures of neural processing (see Lavie, 2005 for review).The majority of research has focused on the visual domain, but perceptual load has also been shown to reduce processing of multisensory stimuli including olfactory (Forster & Spence, 2018), auditory (Macdonald & Lavie, 2011) and tactile (Dalton, Lavie & Spence, 2009). While most research has focused on the role of perceptual load in external tasks, recent research has shown that high perceptual load in mental imagery can have similar effects (Konstantinou & Lavie, 2013; Konstantinou, Beal, King & Lavie, 2014).

Critically, perceptual load has also been shown to reduce internally-generated sources of task-irrelevant processing: Using a thought-probing method, Forster & Lavie (2009) demonstrated that perceptual load reduced the frequency of task-unrelated thoughts (i.e. mind wandering). Perceptual load has also been shown to reduce task-unrelated thoughts in an applied driving setting, using naturalistic manipulations of perceptual load (Geden, Staicu, Feng, 2018). The effect of perceptual load has not been demonstrated, however, with highly salient thoughts such as food. However, perceptual load has been shown to reduce external distraction from both highly salient (Forster & Lavie, 2008) and food images (Morris, Yeomans & Forster, 2018) in an external distraction task. Therefore, we reasoned that perceptual load might have a similar effect on internal distraction in relation to food and have potential usage as a thought-reduction task.

Although intrusive thoughts have been proposed to be key in craving cycle, only one study that we are aware of has directly tested whether intrusive appetitive-related thoughts can be reduced. May, Andrade, Batey, Berry & Kavanagh (2010) tested the effects of visual imagery on appetitive-related intrusive thoughts. Participants either produced self-generated visual imagery about an activity of their choice or followed a guided visual imagery exercise during the subsequent ten-minute period. They responded to intermittent ‘thought probes’ during the experimental period. Fewer appetitive-related intrusive thoughts were reported during both the imagery conditions compared to a control condition. Their findings supported the idea that visual imagery can disrupt the earliest stage of the craving cycle. As visual imagery is known to load perceptual capacity in a similar manner to external perceptual load (Konstantinou & Lavie, 2013; Konstantinou, Beal, King & Lavie, 2014), these prior results appear potentially consistent with our proposals regarding the ability of perceptual load to reduce intrusive thoughts.

Other studies have not directly measured intrusive thoughts during a task but have instead focused on post-task cravings. A variety of external tasks have been found to reduce cravings (Andrade, Pears, May & Kavanagh, 2012; Kemps, Tiggemann, Woods & Soekov, 2004; Kemps, Tiggemann & Hart, 2005; Steel, Kemps & Tiggemann, 2006; Kemps & Tiggemann, 2013; McClelland, Kemps & Tiggemann, 2006; Skorka-Brown, Andrade &

May, 2014; Van Dillen & Andrade, 2016). Interestingly, some of these studies have used external tasks, such as Tetris (a visually demanding computer game), which are also likely to have been high in perceptual demand. However, generally these studies have compared a task to a no-task baseline, rather than systematically varying demand within a task, and as such cannot isolate the underlying mechanism. Without using a controlled manipulation of perceptual load, visually demanding tasks may also be manipulating other aspects of selective attention (e.g., cognitive load, which is argued to have the opposite effect on attention within the framework of Load Theory), as well as motivational factors such as mood and interest.

The primary aim of the current research was to test whether individuals report fewer appetitive-related thoughts under high compared to low perceptual load. To examine this question, we used Forster & Lavie's (2009) visual search paradigm to measure appetitive-related intrusive thoughts under different levels of perceptual load. The advantage of this task is that perceptual load is manipulated by increasing the number of irrelevant stimuli in the search display while all other aspects remain constant. In particular, participants are required to maintain the same target template in working memory across both levels of perceptual load, meaning demand is only increased for perceptual and not cognitive control processes under high perceptual load. Previous research has shown that increasing perceptual load in this way does not impact working memory task performance (Lavie, Hirst, De Fockert & Viding, 2004). We used two measures to detect intrusive thoughts, a probe-caught measure (as in Forster & Lavie, 2009) and a self-caught measure. The former measure involves intermittently prompting participants to report on their current thoughts, while the latter measure required participants to report whenever they notice an intrusive thought by pressing the spacebar. Our use of these two measures allowed us to test the effects of perceptual load on thoughts that reach varying levels of meta-awareness. We predicted that the fewer appetitive-related thoughts (on both self-caught and probe-caught measures) would be reported under high compared to low perceptual load.

The secondary aim of this research was to test for potential interactions between perceptual load and state influences on intrusive thoughts. Multiple studies have found that visuospatial distraction tasks (dynamic visual noise and Tetris) reduced craving in participants, even when they were hungry (Steel, Kemps & Tiggemann, 2006; Van Dillen & Andrade, 2016). We hence examined whether the magnitude of the load effect differed as a function of self-reported state measures of hunger, chocolate craving and chocolate liking. While these differences were expected to positively predict intrusive thoughts under low load, an interesting question was whether perceptual load would be equally effective in reducing thoughts even among very hungry participants, and whether load might even entirely eliminate the influence of individual differences (as has been found in relation to some forms of external distractibility, Forster & Lavie, 2007, although see Forster & Lavie 2016). Finally, we administered six questionnaires measuring trait characteristics which have previously been positively associated with craving (Franken & Muris, 2005; Gay, Schmidt, & Van der Linden, 2011; Hill, Weaver & Blundell, 1991; Meule, Lutz, Vögele & Kübler, 2012; Soetens, Braet, Dejonckheere & Roets, 2006), allowing us to conduct an exploratory analysis of the extent to which our predicted load effects generalise across potential trait influences on appetitive intrusive thoughts.

2. Method

2.1. Participants

Sixty female participants were recruited, aged between 18-35 (*M* = 20.72, *SD* = 1.69) with normal or corrected to normal (e.g., with glasses) vision, either native English speakers or as fluent at both speaking and reading English as a native speaker. The sample was restricted to female participants due to strong gender differences in the experience of craving (Hallam, Boswell, DeVito and Kober, 2016). The study was run as an undergraduate project at the University of Sussex; participants were recruited via study swaps and a £25 prize draw.

The sample was highly powered to detect the primary within-subject effects of interest: a power analysis using G*Power suggested twelve participants were required based on an effect size of .26 (identified from Forster & Lavie, 2008). A sample size of sixty was chosen to power for individual difference analyses, estimated with G*Power using an effect size of .31, the average derived from previous research investigating individual differences in food cravings (Delahanty, Meigs, Hayden, Williamson, & Nathan, 2002; Franken & Muris, 2005; Hill, Weaver & Blundell, 1991; Meule, Lutz, Vogele & Kubler, 2012; Tiggeman & Kemps, 2005).

The study was approved by the University of Sussex Sciences & Technology Cross-Schools Research Ethics Committee. All participants provided informed consent.

2.2. Design

A within subjects 2x2 design was used to assess the frequency of appetitive-related thoughts (either on a self-caught or a probe-caught measure) while participants performed low or high load blocks of the perceptual load task.

2.3. Stimuli and procedure

All stimuli were presented using E-prime 2.0 (Schneider, Eschman & Zuccolotto, 2002) on a 13-inch computer screen. The experiment was presented on a black background and all letter stimuli were grey.

The task was adapted from Forster & Lavie (2009). Participants completed both low and high perceptual load blocks of a visual search task whilst supressing thoughts about chocolate. Each trial started with a central fixation cross displayed for 500 ms, immediately followed by the letter stimuli; the letters appeared for 100 ms, but participants had 2000 ms to respond, after which the display timed-out.

Each stimuli display consisted of six letters arranged in a circle (with a radius subtending 1.6°). Participants searched for a target letter within the circle, either an X or an N, and responded with the corresponding key. Perceptual load was manipulated by varying the setsize of the letter circle. In low perceptual load displays the target letter appeared alongside five small non-target characters (the letter o), which subtended .15°. In high perceptual load displays the non-targets were angular letters selected from the following: H, K, Z, M and W (irrelevant and target letters subtended .6° x .5°).

There were sixteen blocks in total, eight low and eight high perceptual load blocks in the order LHHLLHHL. Each block had 24 trials. Before the experiment participants completed three slowed down example trials and twelve normal speed practice trials for both perceptual load conditions.

Following the practice trials, participants were exposed to chocolate for a two-minute period; they were asked to focus on the chocolate and imagine eating it in as much detail as possible, such as how it would smell and taste. This was done to increase the potential number of thoughts about chocolate, as being exposed to a food item increases craving (Smeets, Roefs & Jansen, 2009). Chocolate was chosen as it is frequently mentioned by participants as a highly craved food (Richard, Meule, Reichenberger & Blechert, 2017). Then participants completed visual analogue measures of hunger, how much they thought they would like the chocolate and how much they craved the chocolate. Each question appeared above a 100 mm horizontal line presented on the computer screen, participants dragged the cursor from the midpoint of the scale to indicate their response. The lower end anchor read 'Not at all' and the upper end anchor read 'Extremely'. Participants were then asked two prompting questions to further encourage appetitive-related thoughts (e.g., How do you think the chocolate would taste?). They responded using a free text-box, but these responses were not included in analysis. Finally, before beginning the task, participants were given simple instructions to attempt to supress any thoughts related to chocolate (no guidance was given on how to do this) and focus on the task.

Intrusive thoughts were measured by self-report and probe-caught methods. Participants pressed the space bar each time they caught themselves thinking about chocolate. The self-caught method is subject to participant awareness of their own thoughts (metacognition) which varies between individuals and does not capture intrusive thoughts that are not consciously noticed (Baird, Smallwood, Fishman, Mrazek & Schooler, 2013). Therefore, at the end of each block a thought probe was used to ask what they were thinking about: the task, the chocolate or something unrelated to both. To avoid any influence in difference of quantification of self caught thoughts and to facilitate comparison with a probe-caught measure, the self-caught thought was defined as the percentage of blocks a thought was reported in rather than number of discrete thoughts.

Finally, participants completed a set of questionnaires measuring trait differences that have previously been linked to craving and self-reported their BMI (Body Mass Index).

2.4. Trait questionnaire measures

2.4.1. Three Factor Eating Questionnaire (TFEQ; Stunkard & Messick, 1985). The 51 item TFEQ is divided into three factors: restraint, disinhibition and hunger. Only restraint and hunger were analysed.

2.4.2. Dutch Eating Behaviour Questionnaire (DEBQ; Van Strien, Frijters, Bergers & Defares, 1986). Only the 10 item external eating subscale of the DEBQ was used in this experiment.

2.4.3. Sensitivity to punishment and reward Questionnaire (SPSRQ; Torrubia, Avila, Moltó, & Caseras, 2001). This 48-item questionnaire is comprised of two subscales, sensitivity to reward (SR), which reflects behavioural activation and sensitivity to punishment which reflects behavioural inhibition. Only the SR was used in analysis.

2.4.4. Baratt Impulsiveness Scale (BIS 11; Patton, et al, 1995). The 30 item BIS 11 measures three dimensions of impulsivity: attentional; motor and non-planning. Only the overall total impulsivity score was used in analysis.

3. Results

All data can be downloaded from the open science framework (osf.io/8mep7/). All analyses were conducted using IBM SPSS Statistics 24. Analyses of reaction time (RT) and percentage error (PE) rates confirmed that the perceptual load task was successful at increasing task difficulty. Only trials to which a correct response was made were included within RT analyses. RT's were significantly slower under high (*M* = 832.62, *SE* = 14.89) than low perceptual load (*M* = 603.68, *SE* = 12.59), t(59) = 20.68, *p* < .001, *d* = 2.15. Percentage error rate was also increased under high (*M* = .19, *SE* = .01) compared to low perceptual load (*M* = .06, *SE* = < .01), *t*(59) = 12.13, *p* < .001, *d* = 1.92. There were also significantly less general task unrelated thoughts under high (*M* = 22.29%, *SE* = 2.88%) compared to low perceptual load (*M* = 35.21%, *SE* = 3.80%), replicating Forster and Lavie's previous findings (2009), *t*(59) = 4.18, *p* < .001, *d* = .50.

To test whether self-caught and probe-caught appetitive-related thoughts were modulated by perceptual load, a 2 x 2 within subject ANOVA was conducted, contrasting perceptual load (low, high) with measure (self-caught, probe-caught). As predicted, fewer appetitive-related thoughts were reported under high compared to low perceptual load, $F(1, 59) = 37.37$, $p < .001$, $N_P^2 = .39$. There was also a significant main effect of measure, $F(1, 59) = 27.21$, $p < .001$, $N_P^2 = .32$, with fewer appetitive-related thoughts being reported on the probe-caught measure. The interaction between perceptual load and measure was also significant, $F(1, 59) = 14.61$, $p < .001$, $N_P^2 = .20$. Figure 1 suggests that the interaction reflects a larger effect of perceptual load on the self-caught compared to the probe-caught measure. However, crucially, follow up *t*-tests showed that perceptual load significantly reduced the percentage of appetitive-related intrusive thoughts for both self-caught, *t*(59) = 6.65, *p* < .001, *d* = .92, and probe-caught measures, *t*(59) = 3.45, *p* = .001, *d* = .44. Mean percentages and standard error are displayed in Figure 1.

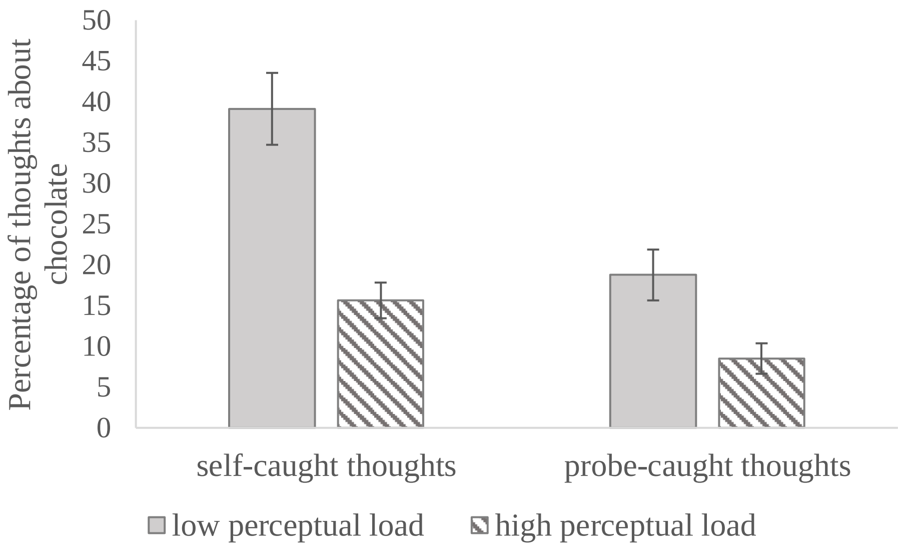

Figure 1: Percentage of self-caught and probe-caught appetitive-related thoughts under low and high perceptual load. Error bars show standard error.

3.1. Individual differences

Sample characteristics have been presented in Table 1. In order to test for potential interaction between load effects and hunger, chocolate craving and chocolate liking, we ran one tailed Pearson correlations between these measures and the load effects on self-caught and probe-caught intrusive thoughts. The purpose of correlating state variables with load effects was to see if the effect of perceptual load generalised across individuals. Load effects were calculated as the difference between intrusive thoughts under low and high perceptual load (i.e., low load intrusive thoughts minus high load intrusive thoughts). As can be seen in Table 2, all three measures correlated significantly for both probe and self-caught thoughts. As correlations between load effects and all three state measures were highly significant, we further broke these relationships by examining the correlations between each of these variables and intrusive thoughts in each load condition. As can be seen in Table 2, hunger, chocolate craving and chocolate liking were all positively associated with the appetitive-related intrusive thoughts in low load. However, these correlations were eliminated in high load.

Exploratory analysis of the trait questionnaire measures did not reveal any significant correlations with intrusive thoughts (on both self-caught and probe-caught measures) and load effects, all *ps* > .175 (see supplementary table S1 for further details). However, we note that as none of the trait measures were associated with thoughts in either load condition (all *ps* > .071) these results are not informative as to how perceptual load modulates trait influences on intrusive thoughts.

Table 1

Sample characteristics: mean (SE in parentheses) and range for measures of both state and trait differences.

	State measures			Trait measures					
	Hunger	Craving	Liking	TFEQ_R	TFEQ_D	BIS 11	SR	DEBQ_E	BMI
Mean (SE)	53.58 (4.12)	60.20 (3.58)	67.60 (3.37)	8.77 (.70)	7.13 (.38)	64.57 (1.13)	11.10 (.54)	3.32 (.08)	20.90 (.47)
Range	0.00 – 100.00	0.00 – 100.00	0.00 – 100.00	0.00 – 21.00	2.00 – 15.00	37.00 – 81.00	3.00 – 21.00	1.90 – 5.00	16.02 – 34.17

Note: TFEQ_R = Three factor eating questionnaire, restraint subscale; TFEQ_D = Three factor eating questionnaire, disinhibition subscale; SR = Sensitivity to punishment and reward Questionnaire, reward subscale; DEBQ_E = Dutch Eating Behaviour Questionnaire, external eating subscale; BMI = Body Mass Index.

Table 2

One tailed Pearson correlations and 95% bootstrapped confidence intervals between state individual differences, load effect on appetitive -related thoughts and frequency of appetitive-related thoughts reported under low and high perceptual load.

		State Hunger	Chocolate craving	Chocolate liking
Load effect	Self-caught	.40**	.34**	.34**
		[.23, .57]	[.15, .54]	[.12, .52]
	Probe-caught	.39**	.32**	.31**
		[.23, .53]	[.26, 60]	[.14, 50]
Low perceptual load	Self-caught	.38**	.36**	.32**
		[.19, .57]	[.17, .54]	[.11, .51]
	Probe-caught	.38**	.44**	.31**
		[.19, .56]	[.26, .62]	[.13, .46]
High perceptual load	Self-caught	.12	.18	.10
		[-.12, .35]	[-.05, .40]	[-.14, .30]
	Probe-caught	.02	.05	.03
		[-.17, .24]	[-.17, .34]	[-.18, .23]

Note: **Correlation is significant at the .01 level

4. Discussion

Our research clearly demonstrates that increasing the level of perceptual load in a task can powerfully reduce appetitive-related intrusive thoughts. There were significantly less thoughts about chocolate when participants were engaged in the high compared to the low perceptual load task. This was evident on both self-caught and probe-caught measures, showing that the effect was not dependent on awareness and/or ability to report the thought. However, the effect was greatest on the self-caught measure, suggesting that the effect of perceptual load increased with higher levels of meta-cognition.

Our results add to the literature on Load Theory by demonstrating that, in addition to reducing awareness of external sensory stimuli and general task unrelated thoughts, perceptual load can reduce the occurrence of even highly salient intrusive appetitive thoughts. An interesting question for future research is whether the effect of perceptual load was primarily on visual intrusive imagery or extended to olfactory imagery (see Kemps & Tiggeman, 2007). Our craving induction method involved participants holding a chocolate bar for two minutes and imagining what it would be like to eat. Whilst internal imagery may have involved multiple senses, the chocolate bar itself was a visual cue. In real world situations where we might encounter appetitive-related cues that might trigger craving episodes, other senses are likely to be involved (e.g., smell). It would be interesting to test whether perceptual load would successfully reduce appetitive-related thoughts in response to multisensory cues (e.g., after tasting the chocolate). Previous research has suggested that perceptual load modulates processing across a variety of sensory domains (olfactory: Forster & Spence, 2018; auditory: Macdonald & Lavie, 2011; and tactile: Dalton, Lavie & Spence, 2009) and processing of external multisensory stimuli (Lunn, Sjoblom, Ward, Soto-Faraco, & Forster, 2019; Spence & Santangelo, 2009). Therefore, it seems likely perceptual load would similarly reduce interference from multisensory intrusive thoughts; however, this is yet to be tested.

Our findings suggest that Load Theory could be used as a framework to predict situations in which people may be susceptible to appetitive-related thoughts. For example, a person sitting at their desk engaged in a perceptually undemanding task (e.g., writing a simple email) would have spare attentional capacity to process an appetitive-related thought. In this context, the appetitive-related thought would be more likely to capture attention, potentially resulting in subsequent craving and ultimately consumption. Therefore, if the same person sitting at their desk wanted to prevent a appetitive-related thought, they could tailor their activity to be more perceptually demanding (e.g., filing, searching a complex spreadsheet or fine tuning the visual details of a presentation); this action would disrupt the process of food craving at the earliest possible stage. Purposefully engaging in high perceptual load tasks may hence be a useful recommendation to reduce interference from appetitive-related thoughts. This could have particular value to individuals trying to prevent themselves indulging in a craving (e.g., those on a diet). We note, however, that in order to isolate the factor of perceptual load our initial demonstration of perceptual load effects on food-related thoughts used a controlled laboratory task. An important next in the application of Load Theory to eating behaviour will be to replicate and translate this laboratory demonstration to real-world tasks varying in perceptual load.

Load Theory carries several theoretical and practical advantages that suggest its application to the eating behaviour literature would be valuable. Firstly, perceptual load is a mechanism which has been argued to operate in a passive and automatic manner (Lavie, 2005; 2010). Therefore, instead of advising individuals to attempt to ignore food cravings at all times, which would place high demands on effortful goal maintenance and inhibitory processes, Load Theory implies that individuals could simply organise their daily tasks in such a way as to passively facilitate beneficial eating behaviours. For example, an individual could purposefully plan to engage in high perceptual load tasks during times of day they know to be at higher risk of snacking and over-eating. In addition, our result suggest that the mechanism of perceptual load is capable of ‘nipping in the bud’ the craving cycle at the earliest stage, of the initial appetitive-related thought, with potential beneficial knock on effects for subsequent cognitive biases (e.g., attentional bias and memory).

Furthermore, adopting the Load Theory framework provides a methodological advantage, in terms of the ability to adopt well-established and robust manipulations of attention (Lavie, 2005; 2010). Previously, the majority of the wider literature investigating attention and eating behaviour has relied upon natural variation in attention (e.g., attentional bias in healthy vs overweight individuals; Castellanos, 2009). Attention has usually only been implied in studies intending to manipulate its effect (e.g., Tetris has been argued to cause visual distraction; Skorka-Brown, Andrade & May, 2014) and, crucially, such studies have not ruled out alternative explanations (e.g., boredom in the no task control condition, motor demand associated with the task or positive mood in response to playing a game). The next step to elucidate the mechanisms of real-world eating behaviour would be to integrate a controlled manipulation of attention with a naturalistic task.

Importantly, our findings suggest that perceptual load was effective in reducing appetitive-related thoughts even for individuals who reported high levels of hunger, chocolate specific craving and liking at the start of the experiment. While these ratings were significantly associated with the number of appetitive-related thoughts under low perceptual load, these individual differences were eliminated under high perceptual load. This finding is in line with previous work on Load Theory showing that perceptual load reduces distraction irrespective of individual differences observed under low perceptual load (Forster & Lavie, 2007). We also extend previous evidence from the eating literature, that a distraction task reduces craving for food in individuals who are hungry (Steel, Kemps & Tiggemann, 2006; Van Dillen & Andrade, 2016). This aspect of our research is important for establishing the usefulness of the task, as in the real world an individual's current state may increase the risk of indulging in an unwanted craving, but our findings suggest a high perceptual load task should still reduce the impact of appetitive-related thoughts.

Exploratory correlations revealed no association between restraint, disinhibition, impulsivity, sensitivity to reward and external eating trait differences in appetitive-related thoughts, even under conditions of low perceptual load. These traits have been shown in previous research to be related to craving (Franken & Muris, 2005; Hill, Weaver & Blundell, 1991; Meule, Lutz, Vögele & Kübler, 2012; Soetens, Braet, Dejonckheere & Roets, 2006). However, while an increase of appetitive-related thoughts is thought to coincide with craving for that food (May, Andrade, Kavanagh, & Hetherington, 2012), none of these trait measures have been shown to be specifically related to increased appetitive-related thoughts. Indeed, it has been suggested that trait measures of individual characteristics may only be related to longer term aspects of craving, and not immediate aspects of craving such as intrusive thoughts (Tiggemann & Kemps, 2005). It is also possible, however, that our ability to detect trait effects was limited by the primarily healthy-weight homogenous student sample recruited in this study.

Given the lack of trait differences in intrusive thoughts in our sample, we were not able to address the issue of how perceptual load might interact with such differences. In future, this research could be extended by investigating whether perceptual load similarly reduces appetitive-related thoughts in more diverse samples, such as those who are currently dieting or even clinical samples. For example, it would be useful to establish whether perceptual load is able to reduce appetitive-related thoughts in overweight and obese populations to the same extent as those with a healthy-weight, as these groups may be a greater risk of experiencing cravings (Delahanty, Meigs, Hayden, Williamson, & Nathan, 2002; Rodin, Manuso, Granger, & Nelbach, 1991). For now, we note promising preliminary evidence that perceptual load was effective at reducing appetitive-related thoughts across individuals, even in those who showed the highest frequency of appetitive-related thoughts.

An advantage of our task is that we were able to directly test whether the number of thoughts produced during the task varied under different levels of perceptual load, rather than relying on a single measure of craving taken after the experiment. However, due to the within subjects design we could not test whether perceptual load had any long term effect on craving or consumption. Van Dillen & Andrade (2016) found that participants choose a healthier snack after playing Tetris, suggesting that a visually distracting task is able to influence actual eating behaviour after completion of the task. As Tetris is also likely to be high in perceptual demand, this implies that a high perceptual load task may also influence subsequent behaviour. In future, it would be useful to test whether perceptual load can reduce unwanted snacking, as this determines whether engaging in tasks high in perceptual load is a worthwhile real-world recommendation.

To summarise, our study clearly shows that perceptual load reduces intrusive appetitive thoughts about chocolate. This suggests Load Theory may be a useful framework to predict the situations in which individuals may be vulnerable to appetitive-related thoughts, which may then result in craving and unwanted consumption. In addition, engaging in high perceptual load tasks may be a valid strategy to reduce the occurrence of appetitive-related thoughts, even when experiencing high levels of hunger, craving or liking for the specific food item.

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Supplementary information

Table S1

Two tailed Pearson correlations and 95% bootstrapped confidence intervals between trait individual differences, load effect on appetitive - related thoughts and frequency of appetitive-related thoughts reported under low and high perceptual load.

		TFEQ_D	TFEQ_R	BIS 11 Total	S Reward	DEBQ_E	BMI
Load effect	Self-caught	-.01	.14	-.04	.10	-.01	-.16
		[-.30, .27]	[-.10, .38]	[-.31, .25]	[-.20, .40]	[-.25, .25]	[-.37, .09]
	Probe-caught	.15	.12	.04	.18	-.02	.02
		[.04, .03]	[-.12, .03]	[-.20, .25]	[-.09, .40]	[-.24, .23]	[-.17, .26]
Low perceptual load	Self-caught	.01	.12	-.06	.02	-.04	-.04
		[-.25, .24]	[-.14, .37]	[-.33, .24]	[-.25, .32]	[-.25, .20]	[-.27, .22]
	Probe-caught	-.00	.07	-.01	.04	-.10	-.12
		[-.22, .21]	[-.18, .31]	[-.23, .19]	[-.21, .28]	[-.29, .10]	[-.30, .11]
High perceptual load	Self-caught	.02	.02	-.06	-.11	-.06	.18
		[-.19, .24]	[-.26, .29]	[-.35, .24]	[-.36, .12]	[-.27, .18]	[-.06, .46]
	Probe-caught	-.23	-.07	-.07	-.21	-.14	-.23
		[-.38, .07]	[-.27, .18]	[-.26, .05]	[-.36, .06]	[-.38, .06]	[-.37, .07]

Note: TFEQ_D = Three factor eating questionnaire, disinhibition subscale; TFEQ_R = Three factor eating questionnaire, restraint subscale; BIS 11 Total = Baratt Impulsivity Questionnaire, total score; S Reward = Sensitivity to punishment and reward Questionnaire, reward subscale; DEBQ_E = Dutch Eating Behaviour Questionnaire, external eating subscale; BMI = Body Mass Index.