The selective impact of chocolate craving on visuospatial working memory

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Abstract

The present study aimed to extend previous research into cognitive impairments as a consequence of food craving. In particular, the study examined the impact of chocolate craving on the three components of working memory: the phonological loop, the visuospatial sketchpad, and the central executive, assessed by the digit span, corsi blocks, and the double span tasks, respectively. A sample of 96 female undergraduate students were randomly assigned to a craving or control condition. Participants in the craving condition abstained from eating chocolate for 24 hours prior to testing, and performed the cognitive tasks in the presence of chocolate, a manipulation that successfully elicited chocolate cravings. As predicted on the basis of the visual imagery nature of food cravings, participants in the craving condition performed more poorly on the Corsi blocks task than control participants, but the groups did not differ on the digit span or double span measures. These results indicate that chocolate cravings selectively disrupt performance on visuospatial tasks. According to the working memory model, this occurs because food cravings compete for limited visuospatial working memory resources. These findings have practical implications in that visuospatial memory plays an important role in many everyday behaviours.

Key words: food craving; working memory; chocolate craving; visuo-spatial sketch pad
The term ‘craving’ describes a motivational state in which an individual feels compelled to seek and ingest a particular substance (Baker, Morse & Sherman, 1986). Although this definition is usually applied to drugs, it also extends to cravings for other substances such as food. Thus food cravings are defined as an intense desire or urge to eat a specific food (Weingarten & Elston, 1990). It is the intensity and specificity that distinguish a food craving from ordinary eating and hunger (Pelchat, 2002). While such food cravings occur among a large proportion of the general population without any particular problem (Lafay et al., 2001), they can give rise to a range of negative consequences. Specifically, food cravings can trigger possible feelings of guilt and shame if followed by unwanted consumption (Macdiarmid & Hetherington, 1995). In addition, food cravings have been identified as a precursor to binge eating (Gendall, Joyce, Sullivan & Bulik, 1998; McManus & Waller, 1995), and linked to early dropout from weight-loss programs (Sitton, 1991).

More recently, a further negative consequence has been documented. Food cravings also impair cognitive performance. In the initial investigation of the cognitive processes underlying food cravings, Green, Rogers and Elliman (2000) adapted a dual-task paradigm used in cigarette craving research (Cepeda-Benito & Tiffany, 1996). They manipulated food cravings by asking participants to imagine either a food scenario (“Imagine you are eating your favourite food”) or a non-food scenario (“Imagine you are on your favourite holiday”), while performing a simple reaction time task. Green et al. found that current dieters and highly restrained eaters showed slower reaction times when they were instructed to imagine eating their favourite food. They interpreted their findings in terms of Tiffany’s (1990) cognitive model of drug use and craving, in which cravings are the result of a deliberate attempt to inhibit activated drug use or consumption schemas. This requires conscious non-automatic cognitive processing, which uses up limited working memory capacity and
consequently interferes with performance on other tasks that also require non-
automatic processing, such as reaction time. Thus food cravings, like cigarette 
cravings, reduce the resources available for cognitive performance.

Kemps, Tiggemann and Grigg (2008) have extended this study by employing a 
more naturalistic craving induction procedure. They explicitly aroused craving for one 
particular highly desired food, namely chocolate, using a combination of deprivation 
and in vivo exposure to chocolate cues. They were able to successfully replicate Green 
et al.’s (2000) finding of increased reaction time following craving induction 
(Experiment 1). In addition, they also demonstrated reduction in a widely used index of 
limited cognitive resources, namely working memory capacity (Engle, 2001), as 
measured by the operation span task (Experiment 2), particularly in habitual chocolate 
cravers.

The aim of the present study was to go one step further in a more detailed 
analysis of the locus of performance decrements resulting from food cravings. The 
most commonly adopted model of working memory is that proposed by Baddeley 
(2000; Baddeley & Hitch, 1974). According to this tripartite model, working memory 
comprises a supervisory system, the central executive, and two slave systems, the 
phonological loop and the visuo-spatial sketch pad. The central executive is an 
attentional control system, responsible for updating information, focusing and 
switching attention, and the coordination of two simultaneous tasks (Baddeley, 1986). 
The phonological loop is responsible for maintaining and manipulating auditory and 
verbal material. The visuo-spatial sketch pad performs a similar function for visual and 
spatial information and is involved in visual imagery. Because these slave systems 
have limited storage capacity, concurrent verbal (or visual) processing will interfere 
with the content of the phonological loop (visuo-spatial sketch pad) by competing for 
verbal (visual) processing resources (Baddeley & Andrade, 2000).
Several lines of evidence from current investigations of the cognitive underpinnings of food craving point to mental imagery, particularly visual imagery, as playing a key role in cravings. First, surveys of everyday cravings for various substances including alcohol, tobacco and food have corroborated previous anecdotal reports of desire-related images in naturalistic craving experiences (Salkovskis & Reynolds, 1994). Second, these desire-related images appear to involve substantial visual, but little auditory, content (May, Andrade, Panabokke & Kavanagh, 2004; Tiggemann & Kemps, 2005). Third, Harvey, Kemps and Tiggemann (2005) reported a positive correlation between participants’ vividness ratings of an imagined food scenario and their craving intensity, indicating that stronger food cravings are associated with more vivid images. Finally, a number of studies have demonstrated that visual processing tasks reduce food cravings in a way that auditory tasks do not (Kemps, Tiggemann, Woods & Soekov, 2004; Kemps, Tiggemann & Hart, 2005; Kemps & Tiggemann, 2007). Together, these lines of evidence lead to the conclusion that the imaginal component of food cravings is predominantly visual rather than auditory or verbal in nature.

To the extent that food cravings are indeed visual in nature, the working memory model would argue that the associated craving-related images will engage the visuo-spatial sketch pad. As a consequence of the limited capacity of this sub-system, the model would further predict specific decrements in performance on tasks which require the use of the visuo-spatial sketch pad. The present experiment tested this prediction by examining the selective effect of chocolate cravings on three well-established cognitive measures designed to tap the three specific components (phonological loop, visuo-spatial sketch pad, central executive) of working memory. Chocolate was chosen as the target food because it is the most commonly and intensely craved food in Western cultures (Hetherington & Macdiarmid, 1993).
Method

Participants

Participants were 96 female undergraduate students at Flinders University, aged between 18 and 29 years, who took part for course credit. Only women were recruited, because food cravings are more prevalent in women than in men (Weingarten & Elston, 1990).

Design

The study employed a mixed 2 x 3 experimental design. The between-subjects factor was condition (craving, control), and the repeated-measures factor was working memory task (digit span, Corsi blocks, double span). Participants were randomly allocated (subject to equal ns) to the craving or control condition. Those assigned to the craving condition were instructed to abstain from eating chocolate for 24 hours prior to the testing session. All participants reported having complied with this instruction.

Materials

Phonological loop task: Digit span

The digit span task is a commonly used and validated measure of phonological loop capacity (Baddeley, Gathercole & Papagno, 1998). For each trial of this task, a sequence of digits (numbers) was displayed successively in the centre of the computer screen at a rate of one digit per 1.5 seconds, with an inter-stimulus interval of 0.5 seconds. Following presentation of the last digit, participants were required to recall out loud the sequence of digits in correct serial order. A score of 1 was awarded if all digits were recalled in correct order; a score of 0 was given if there was any mistake.
In the standard form of this task, a total of 24 trials are presented, with digit sequences ranging from 2 to 9 digits. Because the effect of craving on cognition has been reported as relatively brief (Madden & Zwaan, 2001), tasks needed to be of short duration. Here only sequences of 6 and 7 digits were used, deemed to be of intermediate length and maximal responsiveness by Kemps et al. (2005). There were three trials for each of these sequence lengths, and hence potential scores ranged from 0 to 6.

**Visuo-spatial sketch pad task: Corsi blocks**

Visuospatial memory span was assessed using a computerised version of the Corsi blocks task. This task was explicitly designed as a visuospatial analogue of the digit span task (Milner, 1971), and has been validated as an index of visuo-spatial sketch pad capacity (Hanley, Young & Pearson, 1991). Nine 3 x 3 cm black squares were positioned in a quasi-random pattern on a 24 x 20 cm blue background in the centre of the screen. In each trial, sequences of squares were highlighted by changing from black to white for 1.5 seconds, with an inter-stimulus interval of 0.5 seconds. Following presentation of the last square in each sequence, participants were cued to replicate the sequence by touching the squares on the touch screen in the same order in which they were highlighted. A score of 1 was given for a totally correct sequence.

In its original form, this task consists of 24 trials of sequences of 2 to 9 squares. In the present study, three trials each of sequences of 5 or 6 highlighted squares (intermediate length) were presented. Thus potential scores ranged 0 - 6.

**Central executive task: Double span**

The double span memory task of Martein, Kemps and Vandierendonck (1999) was designed to tap the central executive by requiring the coordination of responses to
concurrent visuospatial and phonological information. The authors report validation by a dual-task paradigm in which an attentional (central executive) suppression task resulted in poorer combined recall of words and spatial locations (Martein et al., 1999). On each trial, common nouns (e.g., arrow, saw, boot) appeared one by one at random locations on a 4 x 4 grid, at a rate of one word per 1.5 seconds, with an inter-stimulus interval of 0.5 seconds. At the end of each sequence, participants were cued to recall the sequence by repeating the words aloud, while touching the corresponding grid locations in which they appeared, in their correct order of presentation. To score 1 both words and locations needed to be recalled in correct order.

In its original form, the task consists of 15 trials with sequences of 2 to 6 words and locations. Here only sequences of 4 and 5 items were used, with three trials of each. Thus possible scores again ranged 0 – 6.

Trait chocolate craving

Trait chocolate craving was assessed by the Craving Subscale of the Attitudes to Chocolate Questionnaire (Benton, Greenfield & Morgan, 1998). This scale consists of 10 statements about thoughts, feelings and behaviours relating to chocolate. Participants rate how well each item (e.g., “My desire for chocolate often seems overpowering”) describes them on a 7-point scale from (1 = ‘not at all like me’, to 7 = ‘very much like me’). Higher scores indicate higher levels of trait chocolate craving, with a possible range of 10 to 70. In the present sample, the Craving Scale had high internal consistency (Cronbach’s α = .89).

Procedure

Participants were tested individually in a quiet room in the Applied Cognitive Psychology laboratory in a session of approximately 30 min duration. As cravings
occur more frequently after midday (Hill et al., 1991), participants were tested only in the afternoon (between 1 and 5 pm). Upon arrival, after indicating their consent, participants filled in background information about their age, the last time they ate, their current level of hunger, as well as their height and weight to enable calculation of their BMI.

Following the craving induction protocol developed by Kemps and Tiggemann (2007), all participants were seated approximately 45 cm from a 17 inch computer touch screen. In the craving condition, a basket of small, wrapped chocolates was placed on the left hand side of the computer keyboard. The basket contained two mini-sized bars of each of eight popular chocolates: Mars, Snickers, Cherry Ripe, Crunchie, Timeout, Flake, Picnic and Twix. As evidence concerning cigarette cravings indicates that cue exposure is maximally effective if the participant interacts with the craving induction stimulus (Baxter & Hinson, 2001), participants were instructed to actively engage with the chocolate. Specifically, they were asked to choose their favourite chocolate bar, to unwrap it, and then to place the wrapper and the chocolate bar on a tray on top of the computer hard drive. Next participants were asked to write down which chocolate bar they had chosen, and to indicate how much they liked the chocolate on a 100 mm visual analogue scale, ranging from 0 ‘not at all’ to 100 ‘very much’.

Participants in the control condition underwent an analogous procedure. In this case a basket containing 16 coloured blocks of approximately the same size and shape replaced the basket of chocolate bars. There were two blocks of each of eight colours (black, red, orange, yellow, blue, green, purple and brown). This protocol was used to control for the possibility that merely interacting with an object may lead to variation in working memory performance (Sayette & Hufford, 1994). Control participants were asked to select their favourite coloured block, place it on a tray on the computer hard
drive, write down the colour of the block they had chosen and rate how much they liked that colour on a 100 mm visual analogue scale.

Participants then completed the three working memory tasks: digit span, Corsi blocks, and double span. The order of presentation was counterbalanced across participants and conditions according to a Latin square. Because cravings may be short-lived (Madden & Zwaan, 2001), the craving induction procedure was repeated before each of the working memory tasks.

Upon completion of the three working memory tasks, participants were asked to indicate their level of craving on a series of five 100 mm visual analogue scales. Participants indicated their current level of chocolate craving, as well as reporting retrospectively on their level of craving when they first arrived at the psychology laboratory, and after selecting the first, second and third chocolate bars or coloured blocks. Scale values ranged from 0 ‘no desire or urge to eat chocolate’ to 100 ‘extremely strong desire or urge to eat chocolate’. Measures were taken retrospectively to minimise the likelihood of inadvertently inducing chocolate cravings in the control group during the experiment (Madden & Zwaan, 2001). These rating scales were used as a manipulation check to ensure that the craving condition elicited consistently higher levels of chocolate craving than the control condition throughout the experimental session.

Finally, participants were asked to complete the Attitudes to Chocolate Questionnaire (Benton et al., 1998).

Results

Preliminary analysis

A series of independent samples t-tests confirmed that random assignment to condition had produced two equivalent groups. Specifically, the craving and control
groups did not initially differ on any of BMI, $t(94) = 0.71, p > .05$, trait craving, $t(94) = 1.12, p > .05$, or level of hunger, $t(94) = 0.96, p > .05$.

*Chocolate craving induction*

In order to determine the success of the craving manipulation, retrospective chocolate craving ratings at each time point were analysed by a series of independent samples t-tests. As indicated in Table 1, the craving group did not differ from the control group upon arrival in the laboratory, $t(94) = 0.42, p > .05$, but did at every subsequent time point (Block 1, $t(94) = 3.13, p < .01, d = .65$; Block 2, $t(94) = 5.10, d = 1.05, p < .001$; Block 3, $t(94) = 6.16, p < .001, d = 1.27$; End, $t(94) = 3.14, p < .01, d = .65$). Thus, at each time point after the craving induction, craving participants experienced higher chocolate cravings than the control group.

[Table 1 about here]

*Effect on cognitive performance*

To investigate the effect of chocolate craving on cognitive performance, a 2 (condition: craving, control) x 3 (task: digit span, Corsi blocks, double span) mixed model ANOVA was conducted. There was no main effect of craving condition, $F(1,94) = 0.58, p > .05$, but importantly, there was a significant condition x task interaction, $F(2, 93) = 4.32, p < .05, d = .61$, indicating that the craving and control groups differed in performance across the tasks. Means are graphically depicted in Figure 1.

[Figure 1 about here]

Follow-up univariate analyses (with Bonferroni adjustment for multiple comparisons) indicated that the craving group performed significantly more poorly on the Corsi blocks task than did the control group, $t(94) = 2.59, p < .017, d = .53$. There
clearly was no significant difference on the digit span, $t(94) = 0.06, p>.05$, or double span tasks, $t(94) = 0.68, p>.05$.

**Moderating role of trait chocolate craving**

To test whether the obtained effects of induced chocolate craving are moderated by trait level of craving, a series of hierarchical multiple regression analyses was conducted. For each working memory task, condition (craving, control) and centred chocolate craving scores were entered in Step 1 of the regression, and the product term representing the interaction in Step 2, following the procedure outlined by Aiken and West (1991).

Step 1 was not significant for digit span, $F(2,93) = 2.10, p>.05$, or double span, $F(2,93) = 1.45, p>.05$. It was significant for the Corsi blocks task, $F(2,93) = 4.08, p<.05$, with condition ($\beta = .24, p<.05$) carrying the effect, mirroring the earlier ANOVA result. More importantly, in no case did the product term (Step 2) offer additional prediction over and above that offered by the main effects, as indicated by non-significant $R^2_{change}$ values (digit span, $R^2_{change} = .015, F(1,92)_{change} = 1.44, p>.05$; Corsi blocks, $R^2_{change} = .024, F(1,92)_{change} = 2.43, p>.05$; double span, $R^2_{change} = .016, F(1,92)_{change} = 1.56, p>.05$). This indicates that there was no interaction between condition and trait chocolate craving on any measure.

**Discussion**

The major findings of the present experiment are clear. In line with our prediction, experimentally induced chocolate cravings decreased performance on the Corsi blocks, a well-established measure of the visuo-spatial sketch pad component of working memory. The general working memory decrement is consistent with that found in cigarette smokers following smoking induction (Madden & Zwaan, 2001;
Zwaan, Stanfield & Madden, 2000; Zwaan & Truitt, 1998), and in habitual cravers following food craving induction (Kemps et al., 2008). However, the present experiment goes further in locating the deficit in the visuo-spatial sketch pad component of working memory. In so doing, the findings support both the proposal that food cravings are primarily visual in nature, and the application of the working memory model to food cravings. In working memory terms, food cravings compete for the limited resources of the visuo-spatial sketch pad and thereby disrupt performance on cognitive tasks that load on the visuo-spatial sketch pad. Future research should similarly seek to locate more precisely the effects of cigarette craving.

It is perhaps somewhat surprising that the induced chocolate craving disrupted visuo-spatial memory, as measured by the Corsi blocks task, but did not affect performance of the double span task, which also involves recall of spatial locations. One possibility is that the verbal labels of the words in the double span task facilitated the recall of their corresponding locations. Indeed, it is well-documented that the availability of verbal codes can improve spatial memory for locations (e.g., Pezdek & Evans, 1979). Another explanation is that the number of items in the double span sequences was smaller than that of the Corsi blocks sequences. This was done deliberately to ensure sequences of intermediate length for each task (Kemps et al., 2005). Consequently, the sequences of to-be-remembered locations in the double span task may not have been sufficiently long to have been affected by the craving manipulation.

The obtained difference between groups on visual memory span was not moderated by trait chocolate craving. That is, performance in the craving condition was poorer than in the control condition, irrespective of underlying level of trait craving. This is in contrast to the finding of Kemps et al. (2008), where the effects of the craving induction were largely limited to high trait cravers. They interpreted their
finding in terms of Tiffany’s (1990) model, whereby individuals who habitually crave chocolate (high trait cravers) would have more well-developed and elaborate chocolate acquisition and consumption schemas. However, Kemps, Tiggemann and Hart (2005) were able to use a visuospatial task to induce and reduce chocolate cravings in both self-identified (high trait) chocolate cravers and non-cravers (low trait chocolate cravers). In terms of Tiffany’s (1990) model, it is likely that in Western cultures most people have acquisition and consumption schemas related to chocolate. Taken together, the results suggest that the state experience of chocolate craving selectively loads the resources of the visuo-spatial sketch pad, independent of a person’s habitual trait craving level.

In some ways, this finding sits curiously against a parallel body of literature on the cognitive deficits associated with weight-loss dieting. This has demonstrated decrements on both phonological loop (Green & Rogers, 1998; Shaw & Tiggemann, 2004) and central executive (Green & Rogers, 1998; Green et al., 2003; Kemps & Tiggemann, 2005; Kemps, Tiggemann & Marshall, 2005; Vreugdenburg, Bryan & Kemps, 2003) components of working memory, but never on the visuo-spatial component. Green, Elliman and Rogers (1997) reasoned that these selective working memory impairments are a function of diet-related preoccupying cognitions about food, weight and body shape which are primarily verbal in nature. Interestingly, while a number of studies have found an association between dietary restraint and food craving (Fedoroff, Polivy & Herman, 1997; Overduin & Jansen, 1996; Warren & Cooper, 1988), others have not (Harvey, Wing & Mullen, 1993; Hill, Weaver & Blundell, 1991; Rodin, Mancuso, Granger & Nelbach, 1991). Tiggemann and Kemps (2005) have suggested that dietary restraint will be related to global or aggregate (trait) measures of food craving, but not to the intensity of single episodes. Only the latter is expected to load the visuo-spatial sketch pad. Thus we tentatively propose that dieting
provides an underlying continuing disruption of cognitive tasks, whereas episodes of cravings selectively interfere with visuospatial performance. Future research could usefully select self-identified dieters and non-dieters to undergo the craving induction procedure.

In addition to the theoretical implications, the results have important practical consequences for everyday cognitive functioning. The contemporary environment is saturated with food cues (e.g., advertisements on television or bill-boards) that are likely to induce food cravings in vulnerable individuals. Individuals who are exposed to such cues in situations where they cannot respond to their cravings and have to perform a cognitive task may suffer decrements in visuospatial performance. Although such decrements are liable to be small, there are a number of situations where split-second responses are crucial, for example, when manoeuvring through dense traffic, or responding to a visual probe in real-world vigilance tasks, such as monitoring a radar screen or inspecting items on an industrial production line (Baddeley, 1990). Thus a reduction in visuospatial resources arising from exposure to craving cues has the potential to compromise the ability of people to perform their jobs and everyday cognitive tasks to an optimal level.

Like all studies, the present experiment carries a number of limitations. The sample consisted of university students, and so results may not generalize to other groups. Quite likely reductions in performance would be greater in a sample of self-identified chocolate cravers (‘chocoholics’) or other individuals for whom food cravings are problematic, e.g., binge eaters and overweight or obese individuals who are trying to lose weight (Gendall et al., 1998; McManus & Waller, 1995; Sitton, 1991). In addition, although we adopted a more naturalistic and ecologically valid protocol than some previous studies, chocolate cravings were still induced experimentally in a laboratory setting. Future research needs to replicate the present
laboratory findings for naturally occurring chocolate cravings, as well as cravings for other foods. Finally, the craving ratings could only be obtained retrospectively at the end of the session, in order to not confound the experimental manipulation.

Despite these limitations, the present experiment makes a useful and timely contribution to the growing literature on craving. In support of conceptions of food cravings as largely visual in nature, we have demonstrated that chocolate cravings can impair visuospatial cognitive performance. In so doing, we have also demonstrated the applicability of the working memory model to food cravings. Future research should seek similarly to establish the locus of cravings for other substances such as cigarettes, alcohol or other drugs.
References


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**Table 1**
Mean (standard deviations in parentheses) chocolate craving ratings over time.

<table>
<thead>
<tr>
<th>Time points</th>
<th>Craving group</th>
<th>Control group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arrival at lab</td>
<td>26.52</td>
<td>28.54</td>
</tr>
<tr>
<td></td>
<td>(22.00)</td>
<td>(24.80)</td>
</tr>
<tr>
<td>Chocolate/Block 1</td>
<td>45.60</td>
<td>30.15</td>
</tr>
<tr>
<td></td>
<td>(24.29)</td>
<td>(24.15)</td>
</tr>
<tr>
<td>Chocolate/Block 2</td>
<td>54.40</td>
<td>28.02</td>
</tr>
<tr>
<td></td>
<td>(25.18)</td>
<td>(25.54)</td>
</tr>
<tr>
<td>Chocolate/Block 3</td>
<td>63.67</td>
<td>28.58</td>
</tr>
<tr>
<td></td>
<td>(28.49)</td>
<td>(27.33)</td>
</tr>
<tr>
<td>Completion of tasks</td>
<td>63.52</td>
<td>43.58</td>
</tr>
<tr>
<td></td>
<td>(31.55)</td>
<td>(30.85)</td>
</tr>
</tbody>
</table>

*p < .01*
Figure 1
Mean working memory task performance (with within standard error bars)