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Abstract

Elaborated Intrusion theory (EI theory; Kavanagh, Andrade & May, 2005) posits two main cognitive components in craving: associative processes that lead to intrusive thoughts about the craved substance or activity, and elaborative processes supporting mental imagery of the substance or activity. We used a novel visuospatial task to test the hypothesis that visual imagery plays a key role in craving. Experiment 1 showed that spending 10 minutes constructing shapes from modeling clay (plasticine) reduced participants' craving for chocolate compared with spending 10 minutes 'letting your mind wander'. Increasing the load on verbal working memory using a mental arithmetic task (counting backwards by threes) did not reduce craving further. Experiment 2 compared effects on craving of a simpler verbal task (counting by ones) and clay modeling. Clay modeling reduced overall craving strength and strength of craving imagery, and reduced the frequency of thoughts about chocolate. The results are consistent with EI theory, showing that craving is reduced by loading the visuospatial sketchpad of working memory but not by loading the phonological loop. Clay modeling might be a useful self-help tool to help manage craving for chocolate, snacks and other foods.

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Use of a clay modeling task to reduce chocolate craving

Craving for food is a cognitive-emotional appetitive state distinct from physiological states such as nutritional status (Pelchat & Schaefer, 2000) or hunger (Lafay et al, 2001), and which plays an important role in the development of obesity (Schlundt, Virts, Sbrocco, & Pope-Cordle, 1993). Craving is associated with binge eating (Gendall, Joyce, Sullivan & Bulik, 1998) and early dropout from weight-loss programs (Sitton, 1991). Even if it is resisted, craving can be distressing and distracting (Green, Rogers & Elliman, 2000). Self-report data suggest that the phenomenology of craving for food is similar to craving for addictive drugs, and involves mental images of consumption (Kavanagh, May & Andrade, 2009; May, Andrade, Kavanagh & Penfound, 2008; May, Panabokke, Andrade & Kavanagh, 2004). The present study tests whether a novel technique for blocking imagery can reduce craving for a commonly-craved food, namely chocolate.

A recent theory of the psychological processes involved in craving, the Elaborated Intrusion or EI theory (Kavanagh, Andrade & May, 2005), gives mental images of consumption a key role in craving. The core of EI theory is the interplay between associative and elaborative cognitive processes. Craving episodes are triggered by environmental and internal cues, including physiological changes, retrieved memories, and associated thoughts and images. Through automatic, associative processes, these cues result in apparently spontaneous intrusive thoughts about desired substances or activities.

Depending on the extent of deficit and whether competing cognitive tasks are present, the intrusive thought may then be elaborated. This cognitive elaboration is the heart of craving, drawing cognitive resources away from other tasks, inducing changes in emotion and enhancing or maintaining motivation to acquire and consume the substance. Elaboration may involve generating expectancies about consummation, or planning how to acquire the substance, but most commonly it involves the construction, maintenance, and manipulation of sensory images of the desired target.

For example, someone might imagine selecting a chocolate from a box, taking a bite and feeling the chocolate melt in their mouth, and feeling the pleasure of having their hunger or desire for something sweet satisfied. These sensory images, because they mimic the actual experience, are immediately pleasurable. However, they trigger further substance-related thoughts and increase awareness of the perceived deficit, and so are ultimately aversive, leading the person into a vicious circle of momentarily pleasant imagery that then impairs mood and sucks more resources into creating an even better, more realistic, more pleasurable image, which then increases awareness of deficit and negative affect even further.

There is already evidence for the role of sensory imagery in craving for addictive substances, such as alcohol and nicotine, and in more everyday desires for food, drink, and physical activity. Visual images are commonly reported during episodes of craving for food, drinks, cigarettes, and even during craving for sport (May et al., 2004; May et al., 2008). Sensory imagery predicts the intensity and frequency of craving within and across episodes, and across participants (May et al., 2008; Kavanagh, May & Andrade, 2009; Statham, Connor, Kavanagh, et el., 2011; Tiggemann & Kemps, 2005).

Interference with imagery in the laboratory, by the construction of competing but emotionally neutral visual images, reduces craving for chocolate (Kemps & Tiggemann, 2007), food (Harvey, Kemps & Tiggemann, 2005; Kemps & Tiggemann, 2007), coffee (Kemps & Tiggemann, 2009), and cigarettes (May, Andrade, Panabokke & Kavanagh, 2010; Versland & Rosenberg, 2007). This neutral imagery task has limited use outside the laboratory because participants learn the set of images through repeated use, reducing the task from effortful generation of a novel image to less demanding retrieval of a previous image (Panabokke, 2004).

Craving is also reduced by non-imagery tasks that selectively target appropriate components of working memory. Working memory is the set of mental processes by which we temporarily retain and transform information in memory to allow performance of tasks such as adding up a column of figures, following a conversation, planning a route etc. Temporary retention is achieved by the phonological loop, for auditory and verbal information, and the visuospatial sketchpad for visual and spatial information. These two short-term memory systems are controlled by a central executive, while information from long-term memory is fed into the system, and temporarily stored, by an episodic buffer (Baddeley, 2000). According to EI theory, the visuospatial sketchpad is a key component in craving because it is essential for vivid visual imagery (Baddeley & Andrade, 2000), and the research described above shows visual imagery to be a feature of craving for a range of substances. Imagery of smell, taste and bodily sensations (e.g., swallowing) are also important in food and substance craving, but auditory imagery tends not to be because the activities themselves are not characterized by how they sound (e.g., Kavanagh et al, 2009; May et al, 2008). The visuospatial sketchpad and other components of working memory have limited capacity, therefore loading the visuospatial sketchpad with a task requiring visual or spatial processing prevents that component simultaneously being used to construct vivid visual images (Baddeley & Andrade, 2000). Consistent with EI theory, visuospatial loads have been found to reduce craving. For example, dynamic visual noise (Quinn & McConnell, 1996) reduces craving for chocolate and other foods (Kemps, Tiggemann & Hart, 2005; Kemps, Tiggemann, Woods & Soekov, 2004; Steel, Kemps & Tiggemann, 2006), as do side-to-side eye movements (Kemps et al, 2004). McClelland, Kemps and Tiggemann (2006) found that the novel task of watching one's forefinger moving in 1cm jumps across one's forehead also reduced food craving. Tasks that load the phonological loop of working memory, such as auditory imagery of sounds, do not reduce substance or food craving (Kemps & Tiggemann, 2007; May et al, 2010), though they may reduce craving for sports (May et al, 2008) and other noisy activities such as racetrack gambling.

If cravings are an important factor in relapse from abstention, and visual imagery is a key component of craving, then these laboratory findings suggest that visuospatial tasks might be useful to help people resist everyday cravings and so support abstention attempts. However, none of the research tasks described above have been tested outside the laboratory and all have limited suitability for take-home use, either because they are too intrusive or embarrassing to perform in public (eye movements, forehead tracking), or because they require custom-made software (dynamic visual noise). Stuart, Holmes and Brewin (2006) used a novel visuospatial grounding task that potentially solves these problems. The task involved making cubes and pyramids from modeling clay (plasticine), with one's hands and the clay out of sight. Performing this task while watching a trauma film reduced the incidence of subsequent intrusive images from that part of the film relative to intrusions from parts of the film viewed without a concurrent task, a finding that Stuart et al attributed to the visuospatial nature of the modeling task. A previous study had shown that a concurrent and demanding verbal task, counting backwards by threes, increased the number of intrusions (Holmes, Brewin & Hennessy, 2004), suggesting that the effect of clay modeling was via selective competition for visuospatial resources rather than general distraction. We recently showed that clay modeling reduces cigarette craving relative to a verbal control condition (May et al, 2010) but the task has not to our knowledge been tested in other craving domains. The present study tested the effects on chocolate craving of clay modeling compared with verbal interference, with a view to developing a theoretically driven self-help intervention for food craving.

Experiment 1A: Effect of clay modeling and counting backwards by threes on craving

This experiment compared the effects on craving of the clay-modeling task used by Stuart et al (2006) to reduce trauma imagery. Following Holmes et al (2004), we chose counting backwards by threes as a comparison task, as well as a do-nothing control condition, to load phonological working memory and to try and match the general resource loads of the clay-modeling task. Craving was induced through abstinence followed by an induction procedure in which participants rated the sensory qualities of different chocolates, without tasting them.

Method

Participants and Design

Participants were 63 people (19 male, 44 female; mean age 30 years, age range 18-70 years) who had responded to an email sent to all staff and student members of the University of Sheffield calling for 'chocolate lovers'. They received £2 and a small amount of chocolate for taking part. Participants were asked to refrain from ingesting any chocolate, chocolate drinks or other chocolate flavored products from midnight the night before the day of testing, and to refrain from ingesting any food or drink except water for two hours before the experiment. Participants were quasi-randomly assigned to one of three conditions: control, counting backwards, modeling, attempting to match for pre-induction chocolate craving scores.

Materials

Chocolate cravings were measured using the following three questions:

1. "I would enjoy eating chocolate right now"

2. "I have no desire to eat chocolate right now"

3. "Eating chocolate would be very satisfying right now"

Participants rated how much they agreed with each statement by making a mark on a 100mm visual analogue scale anchored by "strongly disagree" (0) and "strongly agree" (100). Responses to question 2 were reverse-scored.

Procedure

The University of Sheffield Department of Psychology research ethics committee approved the study. Participants gave written consent and were tested individually. The full experimental session began with measurement of craving using the three-item craving questionnaire, followed by the craving induction and the experimental phase. It lasted approximately 20 minutes.

Craving Induction

The craving induction procedure did not explicitly ask participants to imagine chocolate. First, participants were asked what type of chocolate they preferred – white, milk or dark/black. They were shown two bars of different brands of chocolate of their chosen type and asked the first six questions listed in Table 1. The bars were partially unwrapped, with the wrappers still visible.

[Table 1 about here].

A line of squares from the chocolate bar chosen in question six was put on a plate in front of the participant, and the participant was asked to wait until they were outside the laboratory before eating it. Next participants were shown two boxes of chocolates and asked questions 7 to 12 from Table 1. They then completed the craving questionnaire for a second time. The closed boxes of chocolates, the chocolate bars, and the chocolate squares given to the participant, were left on the desk in front of the participant during the experimental phase.

Experimental phase

Participants were left alone for 10 minutes in one of three conditions. In the *control* condition, participants were informed that for the next 10 minutes they would be left alone in the experimental cubicle and that during this time they were to 'sit still and allow your mind to wander'. In the *counting backwards* condition, participants were told that for the next 10 minutes they would be left alone in the experimental cubicle and that during this time they were to 'sit still and count backwards in threes, in their head, starting from 958'. To ensure compliance with the task, they were told that during the 10-minute period five tones would sound, and that on hearing each tone they were to write down the number that they had reached on a sheet of paper before continuing to count backwards from that number. In the *modeling* condition, participants were told that for the next 10 minutes they would be left alone in the experimental cubicle and that during this time they were to continually make small pyramids and cubes (in alternation) out of clay using both hands and were to place these on corresponding sides of the workspace. Participants were shown how to mould the material and manipulate it out of sight, their hands being concealed from view, and were given a practice trial. They were told to make as many shapes as possible and that the experimenter would count them and rate the shapes made. At the end of the 10-minute experimental phase, participants completed the chocolate craving questionnaire for a third time.

As an afterthought, we contacted participants by email and asked them to rate the pleasantness of the task that they had performed during the study, using a scale of 1: not at all pleasant, to 5: neither pleasant nor unpleasant, to 10: extremely pleasant. This happened approximately three months after the initial testing phase.

Results

Pre-intervention (i.e., post-induction) and post-intervention chocolate craving scores were calculated for each participant by averaging their responses to the three questions on the craving questionnaire (Figure 1).

[figure 1 about here].

Participants in the three conditions craved chocolate to a similar extent pre-intervention, $F(2,60) = 0.56$, p = .58, $\eta_p^2 = .018$). An omnibus ANOVA showed main effects for time ($F(1,60) = 5.09$, $p = .028$, η_p^2=.078) and an interaction of time x condition ($F(2,60) = 3.19$, $p = .048$,

η_p^2 = .096), but not of condition $F(2,60) < 1$. To test the effect of the interventions, craving change scores were calculated by subtracting post-intervention craving from pre-intervention craving scores and two tailed independent *t* tests showed significant differences between the control condition (M = -1.8, SD = 8.9) and clay modeling (M = 5.9, SD = 11.3; $t(40) = 2.14$, $p = .04$) and between control and counting backwards (M = 5.1, SD = 12.1; $t(40) = 2.44$, $p = .02$), but not between modeling and counting backwards ($t(40) = 0.21$, $p = .83$).

Retrospective ratings of pleasantness showed that participants liked the clay modeling task (N = 15, modal rating = 7, M = 6.9, SD = 1.4) more than the no-task control condition (N = 18, mode = 5, M = 5.9, SD = 2.0), and found the task of counting backward by threes somewhat unpleasant (N = 14, mode = 3, M = 4.6, SD = 1.3). Mann-Whitney tests confirmed the preference for clay modeling relative to counting backward, $Z = 3.50$, $p < .001$, or simple mind-wandering (control), $Z = 1.78$, $p = 0.07$.

Discussion

As predicted by Elaborated Intrusion (EI) theory (Kavanagh et al, 2005), the visuospatial task of clay modeling reduced craving for chocolate relative to a no-task control condition. A concurrent verbal task, counting backwards by threes, had similar effects. This verbal task was assumed to load verbal but not visuospatial working memory (Holmes et al, 2004). If this assumption is correct, then the findings suggest that general resource demands are sufficient to reduce craving. This finding would support Tiffany's (1990) view that craving is the result of applying effortful cognitive processes to inhibit automated substance-use schemas. It would not support the prediction from EI theory that craving depends on visual imagery and will be selectively inhibited by tasks that load visuospatial working memory.

Tiffany's (1990) theory predicts that tasks imposing equal task loads will have equal effects on craving, whereas EI theory predicts that, if general task loads are equal, tasks that load visuospatial working memory will reduce craving more than tasks that load verbal working memory. Experiment 1B therefore tested the prediction, from a general-load interpretation of the results from Experiment 1A, that counting backwards by threes and clay modeling impose equal loads,

Experiment 1B

Experiment 1B estimated the modality-specific and general resource loads imposed by clay modeling and counting backwards by threes by testing their effects on standard tests of visuospatial and verbal short-term memory.

Method

Participants and Design

A total of 12 participants were recruited from the University of Sheffield (7 female, 5 male; mean age of 31 years, age range 23-57), and were paid £4 for participating in the experiment. All participants had normal or fully corrected vision and none reported any auditory impairment.

The experiment used a fully within-participants design, with all participants completing visuospatial and verbal short-term memory tests under control (no competing task), modeling and counting backwards conditions. The experimental conditions were blocked according to memory test, with participants completing 42 verbal memory trials and 42 visuospatial memory trials. Six of the participants performed the verbal trials first, six the visuospatial trials first. Within each memory task, participants performed one block of 14 trials in each of the three conditions (two practice trials and 12 experimental trials per condition). The order in which participants completed the three conditions was fully counterbalanced using a Latin Square.

Materials

Stimuli for the verbal memory tests comprised 42 lists of six consonants, providing two practice lists and 12 test lists per condition. The consonant lists were generated from 12 possible consonants (f h k l n q r s t x y z), sampling pseudo-randomly but avoiding repeats. Consonants were recorded as sound files and presented auditorily to the participant at a rate of one per second. Stimuli for the visuospatial memory tests were 42, 16-square matrices printed on paper. The squares had 1.6cm sides and were arranged in a 4x4 array. Half of the matrices presented in each condition had six filled squares and the other half had seven filled squares. Squares were filled pseudo-randomly, avoiding obvious patterns (see for example, Andrade, Kemps, Wernier, May & Szmalec, 2001). Each matrix was presented to the participant for six seconds, after which participants indicated their response by marking squares on a blank matrix of the same dimensions.

Procedure

The University of Sheffield Department of Psychology research ethics committee approved the study. Participants gave written consent and were tested individually. The full experimental session lasted about an hour. On each trial participants were presented with the stimulus to be remembered (either a string of auditorily-presented consonants or a visual matrix). After six seconds of stimulus presentation, a beep sounded to indicate the start of the 10 second retention interval. At the end of the retention interval, a second beep signaled to the participant that they should stop performing the concurrent task, where appropriate, and try to recall the stimulus.

For each condition with each type of memory test, there were two practice memory tests and 12 experimental trials. In the *verbal memory* trials, participants recalled the consonants verbally and their responses were noted by the experimenter. In the *visuospatial memory* trials, participants attempted to reproduce the matrix by marking previously filled squares on a blank grid. In the *control* conditions, participants were instructed to concentrate on remembering the stimulus during the retention intervals. In the *counting backwards* conditions, they were instructed to count backwards in threes 'in their heads', as in Experiment 1A. On the first trial in the block participants started counting from the number 958, and on subsequent trials they started counting from the number they had reached by the end of the retention interval of the previous trial. In the *modeling* conditions, participants were instructed to make a shape out of clay using both hands, with their hands concealed from view as in Experiment 1A. The shape, cube or pyramid, alternated on each trial. At the beginning of these blocks, participants were shown how to mould the material and, to enhance task compliance, were told that the experimenter would count the number and rate the shape of the forms made.

Results

[Figure 2 about here].

The proportion of trials in which participants correctly recalled the stimulus was calculated for each memory test and each condition (Figure 2). For correct recall on a verbal memory trial, participants had to recall all six letters in the correct order. For correct recall on a visuospatial memory trial, participants had to recall all six or seven filled squares on the matrix, with no omissions or additions.

An overall ANOVA on the proportion of correct trials showed main effects of memory task, $F(1,11) = 18.53$, $p = .001$, $\eta_p^2 = .63$, and concurrent task, $F(2,22) = 36.96$, $p < .001$, $\eta_p^2 = .771$. The expected interaction was only marginal, $F(2,22) = 2.84$, $p = .08$, $\eta_p^2 = .205$.

To allow for the fact that baseline performance on the verbal memory test was somewhat lower than baseline performance on the visuospatial memory test, the effect of the modeling and counting backwards tasks on performance of each memory test was calculated by subtracting the proportion correct in the control condition from the proportion correct in each of the other two conditions. A 2x2 ANOVA was carried out on these task-effect scores with memory test (visuospatial or verbal) and condition (modeling or counting backwards) as within-subject factors. The ANOVA revealed a significant main effect of condition, with a greater effect of the counting backwards condition on memory overall, $F(1,11) = 5.95$, $p = .03$, $\eta_p^2 = .35$. Task effects were similar across the two memory tests, $F(1,1) = 1.22$, $p = .29$, $\eta_p^2 = .10$). The interaction between memory test and condition did not reach statistical significance, $F(1,11) = 4.35$, p = .06, $\eta_p^2 = .28$. Paired samples t tests revealed a larger effect of counting backwards compared with clay modeling on verbal memory, $t(11) = 3.12$ p = .01, $CI_{95} = 0.91$ to 5.26), as expected, but no difference in the effects of the two tasks on visuospatial memory, $t(11) = 0.27$, $p = .80$, $CI_{95} = -2.32$ to 1.82). Task-effects clearly exceeded zero for both conditions and both memory tests (one-sample *t* values 4.23 to 5.96, all *p* values < .001).

Discussion

The simplest interpretation of the findings is that clay modeling imposed a smaller general resource load than counting backwards by threes , but had a similar effect on visuospatial short-term memory because the smaller general load was offset by the visuospatial and motor components of the task. Task elements such as visualizing the target form, and making and controling the necessary hand movements would be expected to interfere selectively with visual short-term memory and spatiomotor rehearsal (e.g., Logie, Zucco & Baddeley, 1990; Quinn, 1994)

These findings help with interpretation of the results of Experiment 1A. Tasks that interfered equally with visuospatial short-term memory had equal effects on craving. Contrary to predictions from Tiffany's (1990) theory, increasing the overall resource demands did not further increase the effect on craving. As visuospatial short-term memory is needed for visual imagery (Baddeley &

Andrade, 2000), the results support the hypothesis from Elaborated Intrusion theory (Kavanagh et al, 2005) that visual imagery plays a role in food craving.

Experiment 2

Experiment 2 improved and extended Experiment 1A in several ways. First, it measured craving using an improved craving scale, the Craving Experience Questionnaire (CEQ). The CEQ allows measurement of craving factors predicted by EI theory, that is, imagery content and intrusiveness, as well as of overall craving strength. These factors emerged as separable components of alcohol craving in a version of the CEQ focusing on alcohol craving (the Alcohol Craving Experience questionnaire, Kavanagh et al, 2009; Statham et al, 2011). Second, thought probes were used to measure the frequency of thoughts about chocolate. EI theory predicts that apparently spontaneous thoughts about desirable substances serve as the gateway to craving, and also result from craving. Previous studies of interference effects on craving have not measured the effect upon task-irrelevant substance-related thoughts. We would expect manipulations of craving imagery to have concomitant effects on substance-related thoughts, because less vivid or less frequent images will trigger fewer associations. This element of the experiment therefore allows us to explore the impact of visuospatial interference on task-irrelevant thoughts about chocolate. Third, clay modeling was compared with a simpler counting task – counting aloud by ones – to provide a general and verbal resource load without loading visuospatial resources (e.g., Baddeley & Andrade, 2000; Teasdale, et al., 1995). We would expect counting to have similar effects on task irrelevant thoughts in general, as Teasdale et al (1995) found, but less effect on visual craving imagery and thoughts specifically triggered by that imagery.

Method

Participants and Design

Participants were 87 people (74 female, 13 male; mean age 22.7 years, age range 18-49 years) who signed up for an experiment on 'chocolate craving' in return for participation points in partial fulfillment of course requirements, or an honorarium of £3. Participants also received a wrapped chocolate for taking part. Participants were asked to abstain from chocolate before taking part, as in Experiment 1A. Participants were randomly assigned to a counting or modeling condition at the start of the study, with 45 in the modeling condition and 42 in the control condition. The dependent variables were self-rated chocolate craving before and during the 10-minute period experimental period, and the incidence of thoughts about chocolate during the 10-minute period.

Materials

Chocolate cravings were measured using three versions of the Craving Experience Questionnaire (Table 2). The CEQ-S_{now} asked about current chocolate craving experience and provided a measure of craving strength, craving imagery, and craving intrusiveness immediately before the 10-minute experimental period. The CEQ-S_{10m} and CEQ-F_{10m} were completed after the 10-minute experimental period and asked about craving during that period, with the aim of gaining a more sensitive measure of task effects than assessment of craving at one moment after task completion. The CEQ-S_{10m} items were the same as the CEQ-S_{now} except that questions referred to the previous ten-minute period, rather than the present moment, and the tense of the items was changed. The CEQ-F_{10m} contained similar items, rephrased to measure the frequency of craving, craving imagery and intrusive thoughts during that period.

[Table 2 about here].

Procedure

The University of Plymouth Faculty of Science and Technology human ethics committee approved the study. Participants gave written consent and were tested individually. The test session lasted approximately 20 minutes. Participants completed the craving induction procedure described for Experiment 1A, and then rated how much they were craving chocolate using the CEQ-S_{now}. For participants in the *modeling condition*, the 10-minute experimental phase proceeded as in Experiment 1A, with participants manipulating clay into cubes and pyramids, alternately and as quickly and accurately as possible, with their hands and the clay out of view under the table. Participants in the *verbal control condition* were told that for the next 10 minutes they would be left alone in the experimental cubicle and that during this time they were to sit still and count aloud, starting from one, at a rate of approximately one item per second. The experimenter demonstrated the desired counting speed.

Participants in both conditions were told that from time to time during the 10-minute period, a beep would sound as a cue to tell the experimenter 'what you are thinking about right at that moment. Just a short phrase will be sufficient, for example, 'going shopping', 'doing the task', 'eating chocolate', or 'something private'. We will not ask you to describe or remember your thoughts in detail or to tell us anything that you would prefer to keep private'. Participants were asked to return to modeling shapes, or counting upwards starting from one again, after responding to the thought probes. A total of 20 beeps sounded at random intervals of 20 to 40 seconds, played as an MP3 file through headphones (Majestic MJ-8 lightweight stereo headphones). The experimenter recorded the response to each beep. Participants completed the CEQ-S_{10m} and CEQ-F_{10m} at the end of the 10-minute period. The experimenter then went through the thought probe responses with the participant, to categorize them as chocolate-related, task-related or other (unrelated to chocolate or the task).

Results

Properties of the CEQ scales

Overall, the scales had high Cronbach's alpha ratings of .93 for the CEQ-S_{now}, .97 for the CEQ-S_{10m}, and .97 for the CEQ-F_{10m}. The strength, imagery and intrusiveness subscales of the three measures were also highly reliable, with Cronbach's alpha ratings between .89 and .96 with the exception of the intrusiveness subscale of the CEQ-S_{now} for which Cronbach's alpha was .78.

[Figure 3 about here].

Effects of clay modeling on craving

Figure 3 shows the mean craving scores before and during the experimental period, and scores on the strength, imagery and intrusiveness subscales. An independent samples *t* test on mean craving scores prior to the intervention showed no differences between the modeling and verbal control conditions, $t(85) = 1.02$, $p = .31$, $CI_{95} = -0.42$ to 1.29. Mean craving scores after the intervention showed weaker and less frequent craving during the intervention in the modeling condition than in the verbal control condition, $t(85) = 2.68$, $p = .009$, $CI_{95} = 0.41$ to 2.75 for CEQ-S_{10m} and $t(85) = 2.62$, $p = .01$, $CI_{95} = 0.34$ to 2.50 for the CEQ-F_{10m}

Univariate ANOVAs were also conducted on each subscale. Craving strength and imagery both showed an interaction between time and condition(Strength: $F(1,85) = 4.24$, $p = .043$, $\eta_p^2 = .05$; Imagery: $F(1,85) = 5.13$, $p = .026$, $\eta_p^2 = .06$), reflecting a greater reduction in craving strength and imagery over time in the modeling condition than in the verbal condition (there were also main effects of condition and time for both subscales). Responses on the intrusiveness subscale did not vary.

After the intervention, the craving frequency subscales showed less frequent craving in the modeling condition than the counting condition, $F(1,85) = 5.25$, $p = .024$, $\eta_p^2 = .06$, less frequent craving imagery, $F(1,85) = 6.75$, $p = .011$, $\eta_p^2 = .07$, and less frequent intrusive thoughts, $F(1,85) = 6.50$, $p = .013$, $\eta_p^2 = .07$.

Effects of clay modeling on vividness of imagery in different modalities

The five craving imagery items were subjected to 2 (time: before, after) by 2 (condition: modeling, counting) multivariate ANOVA. Before the intervention, mean vividness for each was around the midpoint on the scale of 'not at all' to 'extremely'; all decreased in vividness following the intervention (Table 3) $MultF(5,81) = 11.33$, $p <.001$, $\eta_p^2 = .41$. The effect of condition, $MultF<1$, and the interaction, $MultF(5,81) = 1.32$, $p = .266$, $\eta_p^2 = .075$, were not significant. Separate univariate ANOVAs for the each modality showed significant time by condition interactions for visual imagery ('picture'), $F(1,85) = 4.52$, $p = .036$, $\eta_p^2 = .05$, smell, $F(1,85) =5.64$, $p = .020$, $\eta_p^2 = .06$, and feel ('imagine what it would feel like in your mouth or throat?'), $F(1,85) = 5.23$, $p = .025$, $\eta_p^2 = .06$; but not for body ('imagine how your body would feel…') $F(1,85) = 1.79$, $p = .19$, $\eta_p^2 = .02$ or taste imagery $F(1,85) = 3.58$, $p = .062$ $\eta_p^2 = .04$.

[Table 3 about here]

Responses to thought probes

Responses to the 20 thought probes during the experimental period showed that participants in the modeling condition thought more about the task they were doing (number of thoughts M = 8.24, SD = 4.87) than did participants in the verbal control condition (M= 3.69, SD = 4.19; $t(85) = 4.66$, $p < .001$, $CI_{95} = 2.61$ to 6.50). There were fewer thoughts about chocolate in the modeling condition (M= 2.38, SD = 3.97) compared with the control condition (M= 4.29, SD = 4.23; $t(85) = 2.17$, $p = .03$, $CI_{95} = 0.16$ to 3.66).

Discussion

The results of Experiment 2 replicated those of Experiment 1a, showing that the clay-modeling task reduced craving strength relative to a control condition. This time the control condition was a simple counting task rather than a no-task condition, providing control for general dual task and phonological loop (verbal rehearsal and storage) effects. Strength measures from the Craving Experience Questionnaire administered before (CEQ-S_{now}) and after (CEQ-S_{10m}) the task showed that clay modeling reduced the strength of craving and the vividness of craving imagery, though not the intrusiveness of craving. We note though that the intrusiveness factor comprises only two items and may be less reliable than the craving and imagery factors (see Statham et al, 2011). It is also worth noting that, in line with previous research (May et al, 2004; 2008), participants endorsed the imagery items at baseline, supporting the assumption of EI theory that imagery is part of the phenomenology of craving.

The CEQ-F_{10m} scale showed that craving occurred less often during clay modeling than during counting, as did craving images and intrusive thoughts about chocolate. Converging evidence on frequency came from responses to thought probes during the tasks. Participants in the modeling condition thought less about chocolate, and more about the task they were doing, than participants in the control condition. Note that thoughts about chocolate or about the task only comprised about half the responses to the thought probes in each condition, so it is not the case that the additional task-thoughts in the clay-modeling condition left no opportunity for thoughts about chocolate to occur.

General Discussion

A clay-modeling task shown to impede visuospatial short-term memory reduced craving for chocolate compared with a simple counting task assumed to load the phonological loop. A more complex counting backwards task, which also impaired visuospatial short-term memory, also reduced craving. This counting backwards task loaded the phonological loop more heavily than did the modeling task, indexed by reductions in performance on a verbal short-term memory task in Experiment 1B. This heavier verbal load did not increase the impact of the counting task on craving relative to the clay-modeling task. These findings are therefore consistent with previous research showing that visuospatial tasks reduce craving for chocolate (Kemps et al, 2004; 2005; 2006; McClelland et al, 2006; Steel et al, 2006) and other substances (May et al, 2010) compared with auditory or verbal tasks. The results support the prediction from Elaborated Intrusion theory (EI theory; Kavanagh et al, 2005) that blocking the visuospatial working memory processes needed for visual imagery will reduce craving. This study thus adds to the growing body of literature supporting the central tenet of EI theory that sensory imagery, and particularly visual imagery, drives craving and gives it its emotional bite. It gives less support to Tiffany's (1990) theory that craving reflects the operation of controlled cognitive processes and that general resource loads will impede craving by impeding those processes; counting backwards by threes imposed a greater resource load than clay modeling but did not have a greater effect on craving. However, a definitive future study would need to match the verbal and visuospatial tasks more closely for general resource load than we have been able to do here.

The CEQ-S questionnaires assessing craving before and during the 10-minute experimental period in Experiment 2 showed effects of clay modeling on craving imagery as well as overall craving strength. Clay modeling also reduced the frequency of intrusive craving-related thoughts, as shown by responses to thought probes during the tasks as well as post-task ratings on the CEQ-F_{10m}

scale. In EI theory, intrusive thoughts and sensory imagery are closely related, so that intrusive thoughts trigger imagery and then that imagery leads to further substance-related thoughts. The counting task controlled for general task effects on task-irrelevant thoughts (Teasdale et al, 1995), so additional effects of clay modeling on intrusive thoughts about chocolate may have resulted from a primary effect of clay modeling on craving imagery. Future research might use thought-based interventions, such as mindfulness or thought acceptance techniques, to explore this hypothesised relationship between seemingly spontaneous craving-related thoughts and elaborated craving images (e.g., May, Andrade, Batey, Berry & Kavanagh, 2010; May, Andrade, Willoughby & Brown, 2011).

It could be argued that the observed effects are due to general distraction rather than selective interference with imagery. A distraction interpretation is consistent with EI theory, where general or central executive resources are involved in retrieval of sensory and goal-related information from long-term memory and binding of that information into multimodal images (e.g., Baddeley, 2000; Baddeley & Andrade, 2000), but is also consistent with Tiffany's (1990) model, in which craving is the feeling associated with the exertion of effortful cognitive processes to inhibit automated consumption behaviors. In Tiffany's model, depleting general cognitive resources would reduce craving, by weakening attempts at inhibition, and increase the likelihood of giving into the temptation to eat chocolate, though we note that participants in this study did not spontaneously eat the chocolates left in view in the laboratory. Indeed, interventions that reduce craving tend also to reduce selection and consumption of chocolate, not increase it (van Dillen, Papies & Hofmann, 2012). Another possible effect of task load is that participants are more likely to avert their gaze from distracting stimuli when attempting more difficult tasks (Doherty-Sneddon, Bruce, Bonner, Longbotham, & Doyle 2002; Glenberg, Shroeder, & Robertson, 1998; Meskin & Singer, 1974). In our experimental set-up, gaze aversion during a more demanding task might make participants less likely to look at the boxes of chocolate on the desk in front of them, reducing the chance of the sight of the chocolates provoking craving.

These distraction explanations potentially hold for Experiment 2 if the clay-modeling task is more demanding than counting aloud. We did not test the relative general task loads of clay modeling and counting aloud by ones, because we had taken counting aloud as a standard load on the phonological loop (e.g., Baddeley & Andrade, 2000) to rule out verbal or auditory imagery effects, to control for the general load of having something to do, and to control for general task effects on daydreaming (Teasdale et al, 1995). Taken alone, the results of Experiment 2 could be attributed to general load effects, but a general distraction explanation does not hold for Experiment 1, where the clay modeling task was less demanding than the counting backwards task yet had as large an effect on craving. A general load explanation is also inconsistent with other studies in the literature. For example, Versland and Rosenberg (2007) found that simply imagining visual scenes reduced cigarette craving relative to the demanding task of counting backwards by sevens. In our own previous research, clay modeling reduced cigarette craving relative to a counting task of intermediate difficulty, counting backwards by ones (May et al, 2010).

The present finding, of selective effects of clay modeling relative to counting, is consistent with research showing selective effects on craving of visual or olfactory imagery compared with auditory imagery (Harvey, Kemps & Tiggemann, 2005; Kemps & Tiggemann, 2007; 2009; May et al, 2010) or counting backwards by sevens (Versland & Rosenberg, 2007) and with research showing selective effects of non-imagery visuospatial tasks compared with verbal tasks (e.g., May et al, 2010). A recent study shows that the selective interference effects observed here are bidirectional, thus Tiggemann, Kemps and Parnell (2010) reported stronger effects of craving on visuospatial short-term memory performance than on verbal short-term memory. Taken together, this body of research supports the central tenet of Elaborated Intrusion theory (Kavanagh et al, 2005), that sensory imagery is a central component of the conscious state we call craving.

Analysis of imagery vividness in different modalities showed that effects of clay modeling were not restricted to visual imagery of chocolate. Modeling also reduced how vividly participants imagined the smell of chocolate and how it would feel in their mouth, though effects on imagery of taste and bodily feel were not statistically significant. We speculate that visual imagery consistently appears in people's reports of food craving experiences (May et al, 2004; Tiggemann & Kemps, 2005) because it serves as a framework or anchor for integrating information from other sensory modalities into a vivid, multimodal image. Thus, we might visualize different sorts of chocolates in order to mentally compare their different odors. Imagery in non-visual modalities may be rendered less vivid by interventions that remove this visual framework. The tactile nature of the clay-modeling task may additionally have impeded imagery of how chocolate would feel in the mouth. Effects on the different image modalities may be attributable to general resource loads, but this explanation also begs the question of why the effects did not extend to taste and body imagery.

Taken together, the findings are consistent with Kavanagh et al's (2005) model of craving in which sensory imagery plays a central role, although they do not entirely rule a model of craving as the effect of exerting generally effortful control processes (Tiffany, 1990). Thus participants in Experiment 2 endorsed imagery items on the CEQ-S at baseline, and did so less strongly after ten minutes of clay modeling designed to impede visual imagery than after ten minutes of a verbal counting task. Increasing the general resource load in Experiment 1A did not increase effects on craving. We note that clay modeling weakened craving but did not abolish it. However, we predict that such an effect will be sufficient to reduce consumption of craved foods if craving is weakened to a degree that can be tolerated. The present findings also suggest that episodes of weaker craving are likely to be shorter-lived as weaker imagery triggers fewer intrusive thoughts, breaking the cycle of elaboration and intrusion. Finally, although it was an incidental finding, the greater enjoyability of the clay modeling task reported by participants in Experiment 1a is potentially important for its use as a craving suppressant in the field, for two reasons: 1) Improved mood will help weaken the cycle of craving by making people less likely to act on any cravings that remain (Kavanagh et al, 2005); 2) We assume that people are more likely to use a self-help tool that is intrinsically enjoyable rather than one that is equally effective but less enjoyable to use. Clay modeling thus seems a promising intervention for tackling craving in the field, as it is a discreet and relatively enjoyable task using a cheap, portable material that can be deployed whenever strong cravings are experienced.

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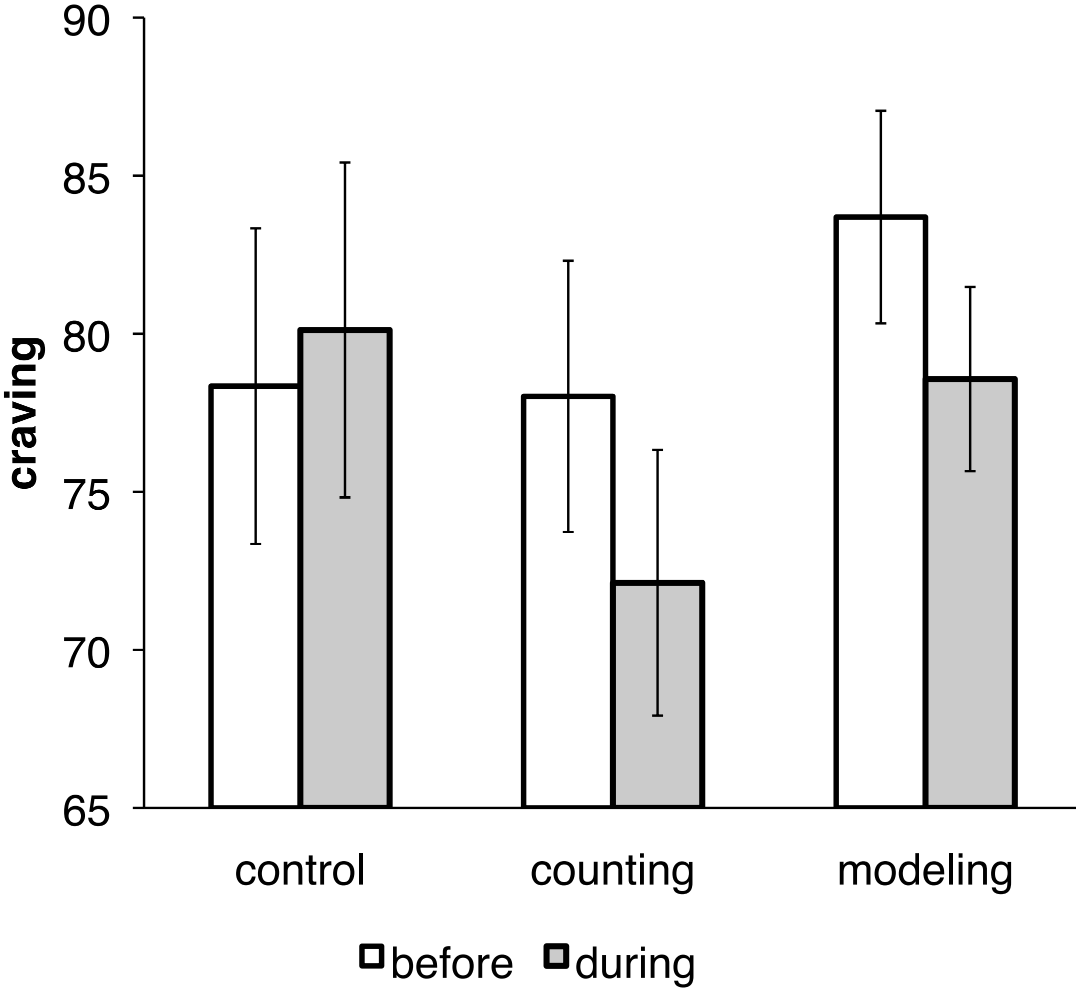

Figure 1: Chocolate craving scores (0-100) before the control, counting and modeling tasks (open columns) and during the tasks (filled columns) in Experiment 1a (standard error bars).

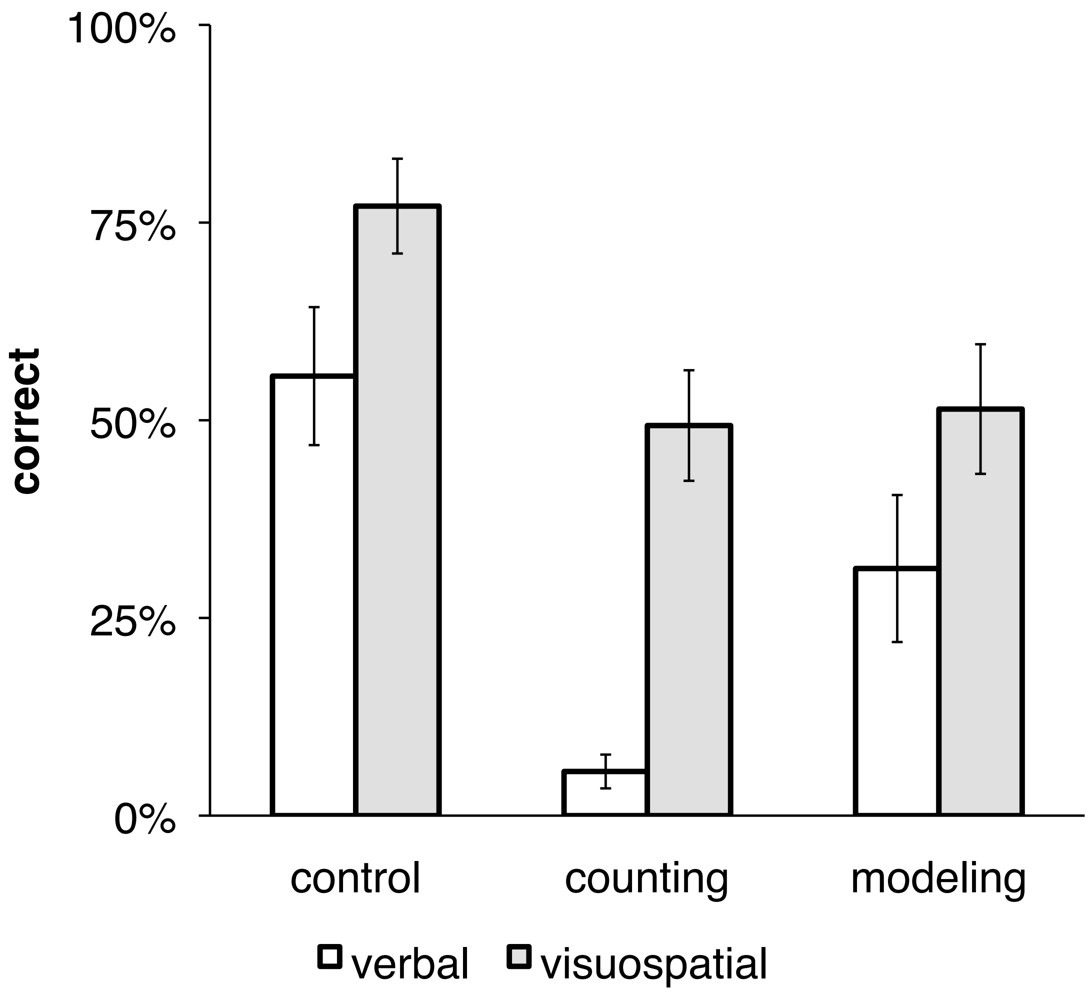

Figure 2. Percentage of trials (12) correct in Experiment 1b (standard error bars). Both tasks interfered with visuospatial memory (filled columns), but the verbal task had a greater effect upon verbal memory (open columns) than did clay modeling.

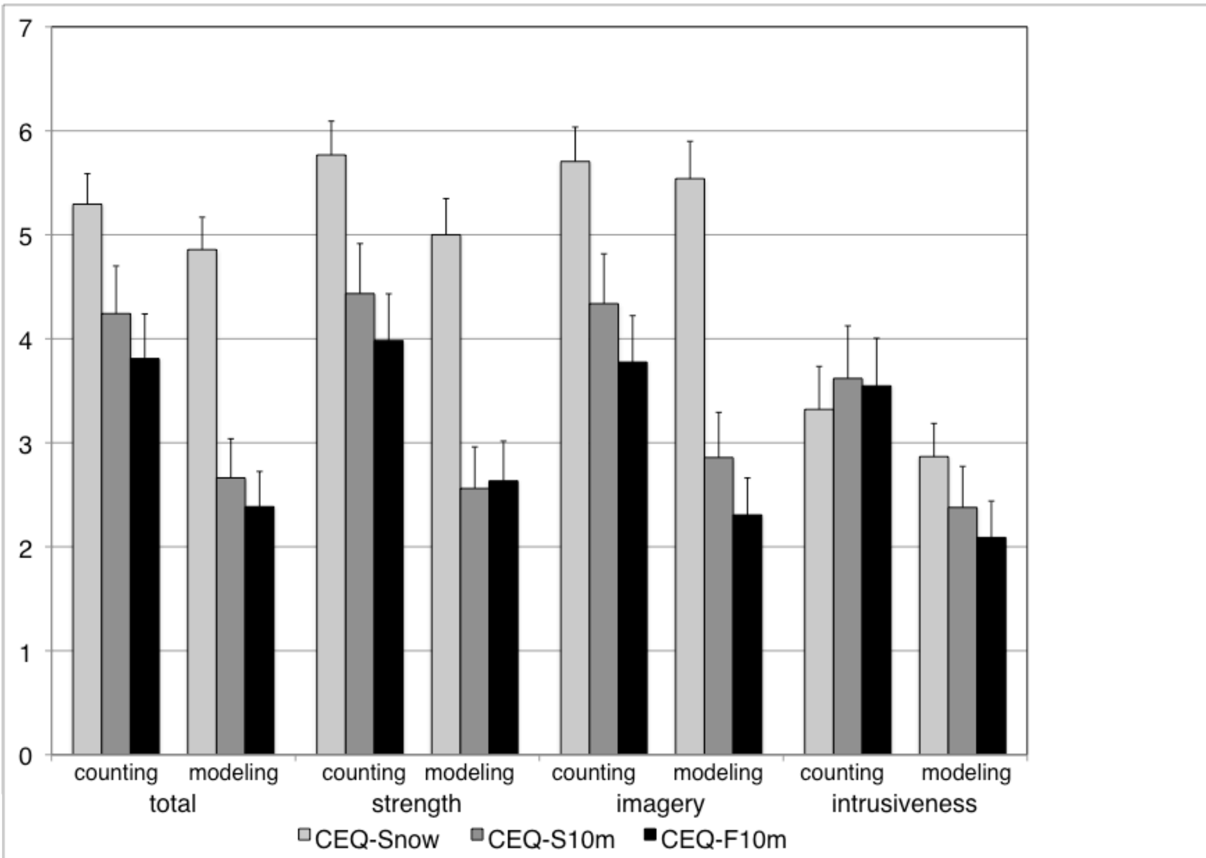
7
6
5
4
3
2
1
0
counting
modeling
counting
modeling
counting
modeling
counting
modeling
total
strength
imagery
intrusiveness
CEQ-Snow
CEQ-S10m
CEQ-F10m

Figure 3: CEQ total scores before and during the experimental tasks in Experiment 2, and scores on the craving, imagery and intrusiveness subscales. Scores shown as mean rating per item (0-10) with standard error bars. Within each task, the bars represent CEQ-S_{now}, CEQ-S_{10m} and CEQ-F_{10m}.

Table 1. Craving induction questions for Experiment 1a.

1. Which chocolate bar looks the most attractive?

2. Which chocolate bar do you think smells best?

3. Which chocolate bar do you think would taste the best?

4. Which chocolate bar do you think cost more?

5. Which chocolate bar are you most tempted to sample now?

6. Which chocolate bar will you try first at the end of the experiment?

7. Which box of chocolates looks the most attractive?

8. Which box of chocolates has the best variety?

9. Which box of chocolates do you think smells best?

10. Which box of chocolates do you think would taste the best?

11. Which box of chocolates do you think cost more?

12. Which box of chocolates would you be tempted to sample now?

Table 2. Craving Experience Questionnaires: CEQ-S_{now}[CEQ-S_{10m}] and CEQ-F_{10m}

CEQ-S_{now}[CEQ-S_{10m}]	**CEQ-F_{10m}**
Right now [During the last ten minutes]	*Over the last ten minutes, HOW OFTEN did you*
…how strongly do [did] you want some chocolate?	…want chocolate?
…how much do [did] you feel like you need[ed] to eat chocolate?	…think about needing chocolate?
…how strong is [was] the urge to eat chocolate?	…have a strong urge to eat chocolate?
…how hard is [was] it to think about anything else?	…find it hard to think about anything else?
Right now [Over the last ten minutes] how vividly are [were] you	*Over the last ten minutes, how often did you*
…picturing chocolate?	…picture eating chocolate?
…imagining its taste?	…imagine what it would taste like?
…imagining its smell?	…imagine what it would smell like?
…imagining what it feels [would feel] like in your mouth?	…imagine what it would feel like in your mouth or throat?
…imagining how your body would feel if you had some chocolate?	…imagine how your body would feel if you had some chocolate?
Right now [Over the last 10 minutes] when you are [were] thinking about chocolate	*Over the last ten minutes, how often*
…how hard are [were] you trying not to think about chocolate?	…were you trying not to think about chocolate?

…how intrusive are [were] the thoughts? …were the thoughts intrusive?

Note: The CEQ-S_{now} is prefaced by the instruction: “Think about your feelings towards chocolate NOW”. The CEQ-S_{10m} is prefaced by the instruction: “Think about the time you MOST WANTED chocolate during the last TEN MINUTES”.

Table 3. Image vividness ratings before and during the experimental tasks in Experiment 2, by sensory modality

Modality	Condition	CEQ-S_{now}	CEQ-S_{10m}S
How vividly are you… (wording from CEQ-S_{now})			
picturing chocolate	counting	5.95 (2.46)	4.36 (3.28)
	modeling	5.99 (2.64)	3.02 (3.15)*
imagining its taste	counting	6.24 (2.61)	4.91 (3.57)
	modeling	5.94 (2.61)	3.29 (3.30)
imagining its smell	counting	5.91 (2.26)	4.17 (3.22)
	modeling	5.94 (2.88)	2.56 (3.00)*
imagining what it feels like in your mouth?	counting	5.57 (2.67)	4.38 (3.47)
	modeling	5.41 (2.70)	2.78 (3.11)*
imagining how your body would feel if you had some chocolate?	counting	4.86 (2.69)	3.88 (3.37)
	modeling	4.41 (2.77)	2.64 (3.03)

Note: vividness is shown as mean (± standard deviation in parenthesis); * indicates significant time x condition interaction, $p < 0.05$.